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The contributions in this volume are derived from assignments prepared and submitted by final-year students studying module 77-602799 Natural Hazards for credit towards undergraduate degrees in either BSc Geography or BSc Environmental Science at Sheffield Hallam University.

Assignments have been reformatted for inclusion as individual chapters in this volume. This process has involved amendment of typographic style and formatting, removal of figures other than a single illustrative figure, and a light-touch proof read for major errors in text. Otherwise, the material in each chapter is entirely the original contribution of each author, with reference to previous work and source material as cited.

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Preface

This volume, which is intended to be the first in an annual series, was conceived as part of a review of assessment for a final-year module in natural hazards which sought to enable students to engage critically and reflectively, not only with the subject in hand but with the process of collating and writing about it. Too often in the student experience the process of writing a report is seen as secondary to the content. The finished article itself, the substantial product of a creative process taking (at least in theory) many tens of hours of scholarship, is an ephemeral thing – prepared, submitted and graded digitally, reduced to a mark and a few lines of feedback.

Such a situation has several negative consequences both for the student and for the teacher. The effort and the outcome, both in preparation and teaching of course material and in the study of it, are diminished to the single, often time-limited, act of grading and scrutiny. There is little opportunity to stand back, reflect and, yes, *enjoy* the fruits of everyone's labours. Furthermore, and more importantly, such a reductionist approach detracts from the experience of studying towards the assignment. 'Just another essay'; where is the motivation to craft, to refine? To think not just about whether the basic parameters of the assessment have been met but how they are being met, the message or philosophy being communicated alongside the information, and the value of creating an object of substance and longevity. This creative process is often lost in 'non-creative' disciplines, yet in fact is crucial to learning, motivation and representation of oneself and one's work in any sphere of society.

An important part of this process, and one that is central to academic practice, is peer-review. Scrutiny of ideas by collaborators or peers, acceptance and provision of constructive criticism, and iterative revision of work as a result is a critical part of the learning process. Without timely criticism, weaknesses or omissions in a piece of work can be left unchallenged until it is too late. The process of iterative review stimulates deeper inquiry, better and more considered learning, and results in higher-quality outcomes by every measure. Collaborative peer review exercises social and communication skills, building confidence in one's own work through a better appreciation of the strengths and weaknesses present in the work of others and reflection on ways in which these can be overcome.

This volume, then, represents a lasting output of this process of scholarship by the Class of 2020; an opportunity for their research and learning to be used and enjoyed in its own right, rather than as a means to an end. More generally, however, the 'Annual Review…' series is intended to act as a serious resource in its own right. The world is a large and complex place. Hazards to human health, wellbeing and economy come in many shapes and forms – more than 300 distinct types of hazards were identified recently by a UNDRR report (https://www.undrr.org/publication/hazard-definition-and-classification-review) – and there are surprisingly few attempts to catalogue these in a concise and consistent form at a global scale. While this volume does not pretend to be entirely comprehensive – limited by class size, personal preference and availability of data – it does aim to present an overview of major events, across all natural hazard typologies, at global scale for the preceding year and thus to give a regular snapshot of both threats and responses to human society in a world that is rapidly changing. The format of chapters is, as far as possible, consistent – focusing normally on a single 'event', an account of the hazard context, occurrence and aftermath based on a careful analysis of contemporary sources; a technical review in the context of current understanding of the hazard and the social dimensions of its impacts; and a conclusion which assesses the significance and wider impacts of the event and response in light of its likely future repetition. It should, I hope, become a useful resource for future cohorts of students faced with the task of preparing their own case studies and also for a wider audience.

Dr Jon Bridge

Sheffield, August 2020.

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Europe, the Middle East and North Africa

Stromboli’s volcanic eruptions, summer 2019

Amy Bracegirdle

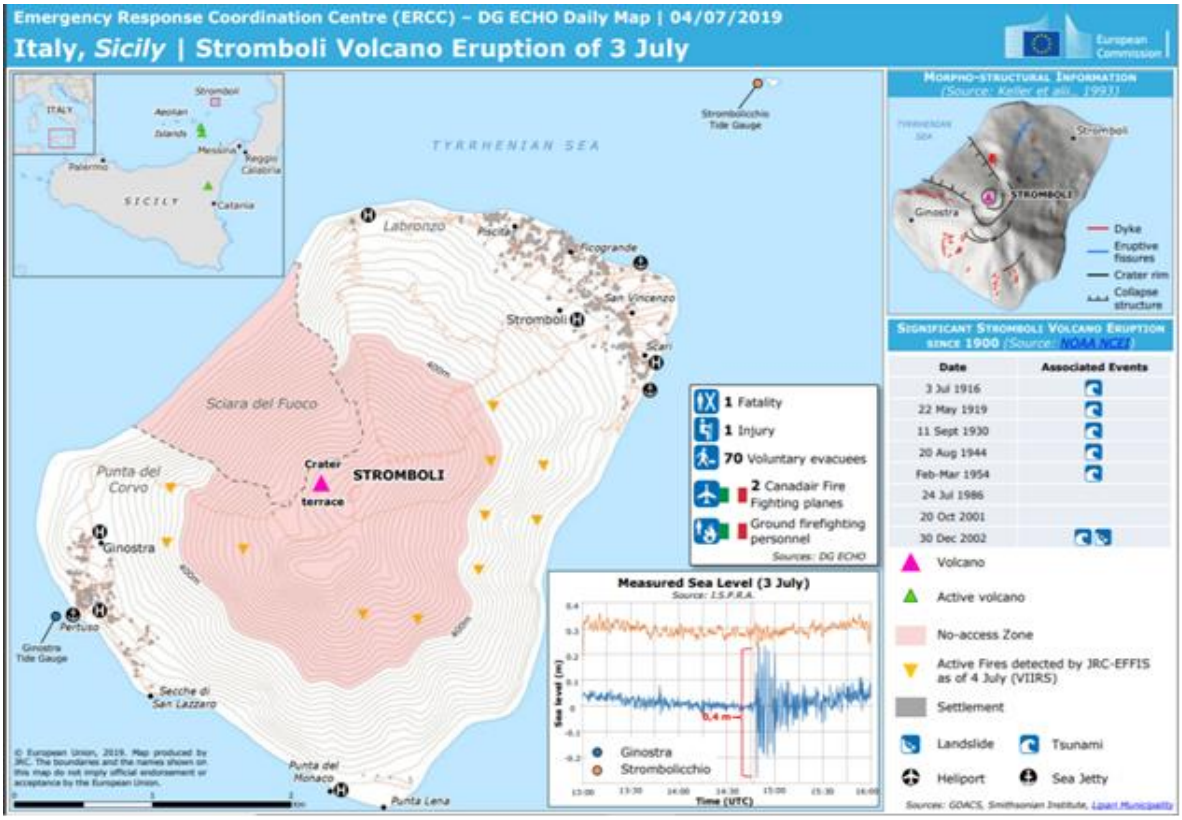


Figure 1 - Map of Stromboli indicating the wildlife’s following the July 3rd Eruption, and a tide gauge graph (Global Disaster alert and coordination system, 2019).

Account of the event

Stromboli is a volcanic island which lies off the North coast of Sicily, Italy in the Tyrrhenian Sea, as seen in Figure 1, it’s been in a continuous state of eruption for over 2,000 years. Stromboli has 400 permanent residents therefore the vulnerability to impacts are low, however during summer the impact risk can be considerably higher, when the population can rise to approximately 2,000 due to the influx of tourists (Bertolaso et al., 2009). The volcano lies above a subduction zone, where the African plate subducts under the Eurasian plate (Ball, 2019).

As Stromboli lies above a subduction zone, small eruptions occur on a daily basis sometimes every 10-20 minutes, whilst large paroxysms only occur, on average, once every decade (Bertolaso et al., 2009). However, unusual activity developed during the summer of 2019, as two large eruptions occurred on the 3rd July and 28th August. The impacts to life were minimal with one fatality recorded after the first eruption and no fatalities following the second eruption (Webster, 2019). The most active crater located on Stromboli is the Sciara del Fuoco, as seen in Figure 2, which lies 100m below the highest point of the volcano, the three main craters lie in the North East, South West and centre of the Sciara del Fuoco (National Institute of Geophysics and Volcanology, 2019).

Disaster

Prior to the 3rd July eruption activity levels at Stromboli were moderate, however less than an hour before the eruption a new vent developed at 15:57 local time on the Sciara del Fuoco approximately 100m from the central crater. By 16:24 lava proceeded to flow out of the vent as seen in Figure 3, within minutes lava was pictured flowing from all vents. Seismic activity increased rapidly indicating an eruption was imminent (Volcano Discovery, 2019a). At 16:46 two gas explosions occurred laterally, 10 seconds apart, which produced a major eruption (Global Volcanism Programme, 2019).

The eruption produced ash clouds which reached over 3km high, whilst two pyroclastic flows reached the sea (Forbes, 2019; Tondo, 2019). As a result of the pyroclastic flow, fires broke out across the mountain, many news reports said these were near Ginostra. However, most of the fires broke out on the East side of the volcano where there are no settlements, as seen

in Figure 4. A minor tsunami occurred due to crater failure, it reached a height of 40cm which was recorded by the Ginostra tide gauge which can also be seen in Figure 4 (Global disaster alert and co-ordination system, 2019).

Less than 2 months later another eruption occurred on the 28th August, the eruption occurred at 12:18 local time, there were four individual eruptions within minutes of each other which produced a large paroxysm (Volcano Discovery, 2019b). The eruption wasn't predicted, however as the volcanic activity levels failed to decline following the July eruption scientists were prepared for another eruption, hence all human activity near the crater was still prohibited (Webster, 2019). Prior to the eruption a small eruption occurred in the North East vent of the crater at 11:55 local time on the Sciara del Fuoco, however this wasn't deemed abnormal, as it was of a similar magnitude to daily eruptions (Volcano Discovery, 2019b).

Ash clouds were seen to reach over 6000ft high immediately after the eruption, however some reports do vary, as others say the ash reached over 1 mile high. The reports aren't likely to be precise due to the fast nature of the ash rising and dispersing (Webster, 2019; Phys.org, 2019). There were two large pyroclastic flows which merged when travelling down the Sciara del Fuoco, as these entered the sea they produced a small tsunami which reached a maximum of 70cm high (Global disaster alert and co-ordination system, 2019). Lava bombs were ejected from the crater towards Stromboli village, which caused multiple fires to break out on the north side of the island, as well as down the Sciara del Fuoco as a result of the pyroclastic flow (CBS, 2019; Volcano Discovery, 2019).

Aftermath:

Following the July eruption, there was one fatality, a 35-year-old male from Sicily named Massimo Imbesi (Squires, 2019a; Tondo, 2019). There are multiple versions of his death, it is clear that he was walking around the 400m elevation zone of the volcano and attempted to retreat following the eruption. However, news reports state he died from impact after being hit by lapilli (BBC news, 2019; Squires, 2019b). But Italian reporters who interviewed Massimo's companion after the event claimed he died due to smoke inhalation (Lastampa, 2019, Volcano Discovery, 2019a). The only reported injury was Massimo's companion who was treated for shock and smoke inhalation.

Firefighters and Canadair water planes were sent from Sicily to control the wildfires and reduce the immediate damage (Tondo, 2019; Squires, 2019a). Various new reports claim that residents were forced to evacuate, the BBC (2019) claimed the navy were sent to evacuate 70 people, most of which were tourists, whilst Tondo (2019) claimed Ginostra residents were evacuated via hydrofoil boats. However, the Civil Protection Authority stated there was no evacuation order as they predicted the eruption was an isolated event (Volcano discovery, 2019a). Stromboli faced a reduction in their tourism revenue as many are reluctant to visit the island due to higher perceived risks.

The August eruption had fewer direct impacts than the July eruption, with no fatalities or injuries reported (Squires, 2019b; Phys.org, 2019). The Civil Protection Authority implemented preventative measures, as they were still on high alert as the volcanic activity levels failed to decline following the first eruption. The access to the crater was prohibited prior to the eruption which led to less potential fatalities and injuries as people had more time to react (Phys.org, 2019). As with the first eruption wildfires spread rapidly due to the weather as the ground and bushes were extremely dry, so firefighters and water planes were sent to control them (Volcano Discovery, 2019a; CBS News, 2019). There was very little infrastructural damage, as the lapilli didn't reach the villages, however people were still advised to take shelter as a precaution.

Technical analysis of the eruptions

Research into Strombolian style eruptions indicate that typical paroxysmal eruptions occur due to large gas bubbles known as slugs bursting at the surface of the shallow conduit within the crater (Lautze and Houghton, 2007). Gas bubbles are formed when volatiles exsolve from crystalizing magma, the activity of the gas bubbles can in turn develop into gas slugs (Bachtell-Clarke, 2015). Research suggests that gas slugs can be formed in two circumstances, the first theory suggest they are developed when gas bubbles interact in magma of a low viscosity and velocity, this enables large gas bubbles to rise rapidly merging with smaller bubbles during their ascent which forms gas slugs. Whilst another theory suggests that individual gas bubbles develop on the roof of the magma reservoir and collapse forming a large gas bubble which develops as it ascends through the conduit (Patrick et al., 2007).

In order to produce a paroxysmal explosion gas slugs must develop between 250m and 3km below the crater, as seen in Figure 5 (Blackburn, Wilson and Sparks, 1976). Once in the shallow sector of the magma chamber the gas slug will rise rapidly forcing magma through the conduit at a faster rate, the slug will compress and expand horizontally to enable more magma to rise with it. As the gas slug rises rapidly, the pressure increases therefore when it reaches the surface of the crater it will burst generating a paroxysmal explosion (Taddeucc, Edmonds, Houghton, James and Vergniolle, 2015).

The collapse of a gas slug generates a loud explosive noise, eyewitnesses reported a large explosive sound

during the summer eruptions of 2019, tourists on Panarea, a neighbouring island, heard the explosion (Squires, 2019b). Reports from the 2002-2003 Stromboli eruptions also suggest that a loud explosion could be heard at the time of the eruption from neighbouring islands which is consistent with the theory of a gas slug bursting (Calvari et al., 2005).

Eruption relative to other Strombolian eruptions

The development of a new vent on the North West crater was the only indication of a possible eruption prior to the July 2019 eruption, as magma rises within the conduit and through developing feeder dykes it forces pressure upon the surface and laterally produces a new vent (Rosi et al., 2013). It is common for new vents to appear at Strombolian style volcanoes prior to an eruption due to the rapid rise of basaltic magma (Taddeucc et al., 2015). Prior to the 2002-2003 and 2007 eruptions new vents developed on the Sciara del Fuoco on the North East crater with lava flow eventually reaching the sea, similarly this was the initial indication of an imminent eruption (Bonaccorso, Calvari, Garfi, Lodato and Patane, 2003).

Strombolian eruptions have three main styles, as seen in Figure 6, type one are ballistic eruptions with no ash cloud, whilst type two(a) are ash columns with large ballistic eruptions, and type two(b) are ash columns with minimal ballistic eruptions (D'Oriano, Bertagnini, and Pompilio, 2011). Type two(a) eruptions are dominant at Stromboli, as all paroxysmal eruptions over the last decade have featured type two(a) eruptions (Landi et al., 2009). Type two(a) eruption styles eject large volumes of magma, which weakens the crater structure due to the rapid release of pressure which can potentially result in part of the crater collapsing (Rosi et al., 2013). Crater failure is common following Strombolian eruptions as after the 2002-2003 paroxysmal eruption crater failure caused a landslide generated tsunami reaching over 10m high (Bonaccorso et al., 2003).

Magma activity levels failed to decline following the July 2019 eruption which is slightly unusual, as previous large paroxysmal events have caused the volcano activity levels to decline quickly, suggesting that the July eruption was not an isolated event. The scientific awareness of high magma activity levels recognised another potential eruption, which reduced the potential impacts of the August 2019 eruption.

Assessment of vulnerability and preparedness

The summer eruptions were classified as low impact, as the vulnerability is relatively low as residents have access to information to prepare themselves for possible eruptions, whilst having access routes off the island in the event of a widespread disaster (Global Disaster alert and coordination systems, 2019). Stromboli has continuous monitoring services carried out by the Italian National Institute of Geophysics and Volcanology. As seen in Figure 7, the scientific monitoring has increased since 2002, with daily reports released to residents via news outlets to inform them of potential changes (Barberi, Civetta, Rosi and Scandone, 2009). However, despite advances in technology scientists were still unable to predict the July eruption as the 400m elevation zone was still open, had this been closed the fatality may not have occurred.

Residents are well prepared for eruptions however tourists are often unaware of the dangers, therefore the Civil Protection Authority limit excursions to the crater. Those travelling above 400m must do so with guides, and those travelling above 700m have to sign declaration forms demonstrating they understand the potential risks. Improved access routes to the crater ease evacuations and shelters built along the routes provide protection in the event of an unexpected eruption (Bertolaso et al., 2009). However, hazard maps produced to highlight different risk zones for tourists have created confusion as they're difficult to interpret (Nave, Isaia, Vilardo, and Barclay, 2010).

Potential future risks

Paroxysmal eruptions are hard to predict due to the active nature of the volcano, despite technological advances scientists were unable to predict the July 2019 eruption until less than two hours beforehand (Volcano Discovery, 2019a). Scientists need to determine the difference between normal activity and potential paroxysmal eruptions, as some eruptions may occur without the development of new vents and lava flow. During the summer season the risk to life is greater with the influx of 2,000 tourists, many of which are unaware of key warning signs and have little knowledge about evacuation plans, hence fatalities may be greater (Bertolaso et al., 2009).

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Wildfires in Italy 2019

Oscar Chapman

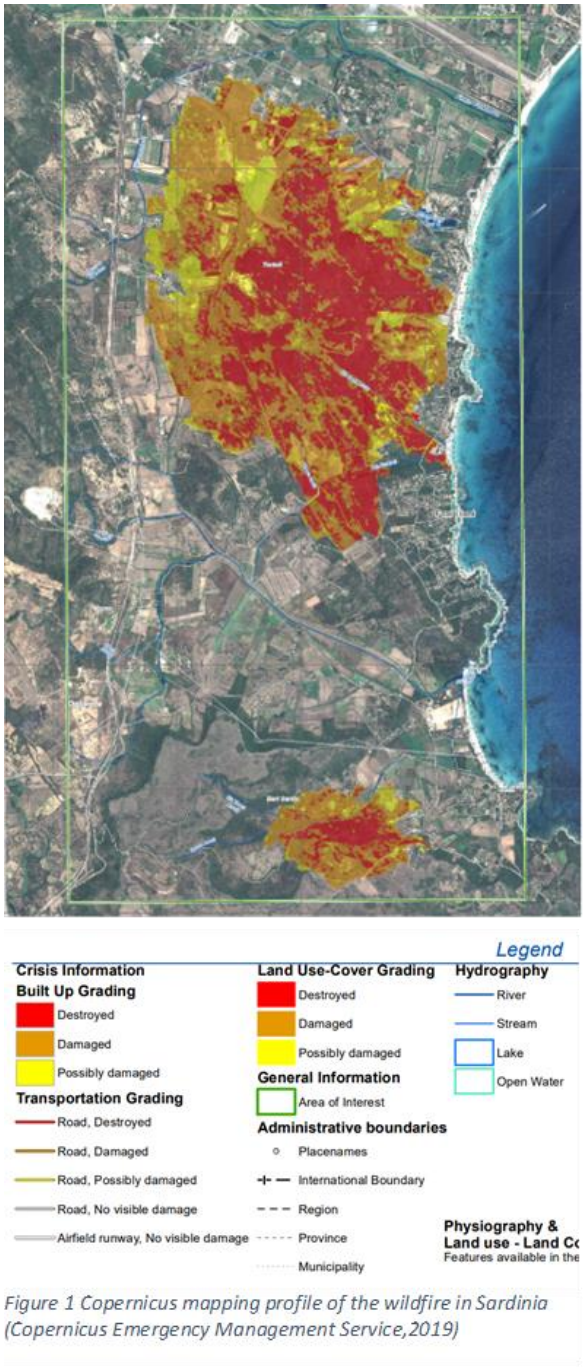


Figure 1 Copernicus mapping profile of the wildfire in Sardinia (Copernicus Emergency Management Service,2019)

Background

Italy is a European country with a long Mediterranean coastline with an estimated population of just over 60 million (http://worldpopulationreview.com/countries/italy/ ,2019). Figure 1 below shows that Italy is one of the southernmost countries in Europe and this influences its climate especially during high summer.

The summer of 2019 saw a large mass of hot air sweep over southern and central Europe from North Africa and the Sahara (https://www.thelocal.it ,2019) however it was also mentioned that the heatwave was also exacerbated by a storm stalling over the Atlantic and also a period of high pressure over most of central Europe (https://www.express.co.uk, 2019).

This prolonged period of intense heat had several severe impacts on the region of Italy which was left vulnerable due to its geographical location but also due to the amount of forestry and vegetation. According to the Telegraph (2014) in 2014 over 35% of Italy was forest and this is what provides the main fuel for fires combined with low precipitation also being a factor. An Italian newspaper (https://www.thelocal.it ,2019) made an account of the heatwave describing how 16 cities where placed on red alert, which is the highest weather warning level, after temperatures reached the high 30s and even low 40s in early July which matches the reports made in The Express (https://www.express.co.uk, 2019).

The main effects of a heatwave include effects to agriculture as crops which are not used to extreme temperatures fail to grow, there are also effects to wildlife and the human population both from heat stroke and wildfires. These can be caused by arson or by people not putting out cigarettes of barbecues in a safe manor, these fires can pose a significant threat to human life and lead to evacuations. They can also grow to be almost uncontrollable and require firefighters and specialist vehicles to contain them which can often take days.

Disaster

One significant wildfire was that on the isle of Sardinia near the city of Tortolì on the eastern part of the island. The fire started on the 13th of July 2019 and affected an 800-hectare area which led to the evacuation of between 69 and 84 people according to (Copernicus Emergency Management Service,2019) and (https://www.express.co.uk, 2019)

The information above comes from a European programme used to obtain information about natural hazards soon after they have happened using satellite imagery with the photo above being taken 4 days after the fire started which shows the extent at which a wildfire can travel and soon affect hundreds of people. The Wildfire in Sardinia had several tourist facilities nearby including two campsites and a hotel (https://www.express.co.uk, 2019) Which can be particularly dangerous as these tourists may not be aware of the proper evacuation plans or the correct protocol to follow.

This source is particularly useful as it uses 1st hand data to track the area of affect which means that the information obtained will be far more accurate than

that of a third hand report in a newspaper or on a website. Another source (http://www.xinhuanet.com, 2019) mentions that the fire front spread for over 3km as over 20 homes were evacuated.

Another example is that in December 2018 two Italian students where fined €13,500,000 each for starting a wildfire in northern Italy near Lake Como (https://wildfiretoday.com). The fire allegedly started after sparks from a barbecue set an area of particularly dry grass on fire and combined with uncharacteristically high winds of up to 63mph, meant that this fire spread and damaged over 1000 hectares of forest and led to the deaths of several animals including some horses. The fire was able to grow to such an extent because of the high winds which carried the fire and meant it took just over a week to control and put out the blaze. This story shows the importance of knowledge about these hazards. By being aware of the possible consequences and the impacts of you actions these events can be prevented. However, it is not necessarily correct to impose these huge fines, for example (https://www.euronews.com, 2019) mentions that it will be impossible for these students to pay off the fine and it will even go on to affect their ability to buy houses and affect their children.

The wildfires in Italy show the effects of these hazards when they happen near populated areas and even when they occur in the wilderness. It seems that these hazards are brought on by other hazards such as extreme temperature and drought. Some sources say that in Italy there was only one life lost as (https://www.usnews.com, 2019) mentions that a body was found in Puglia, Gallipoli however this is an American news source citing another paper and so it may be that there where more deaths around the country. Also, the article does not mention the number of animals that may have died or the number of people affected in total via evacuation of property damage.

(Ferrara, C, et al 2019) mentions how the effects of wildfires are influenced more by the socio-economic factors of an area than the geographical properties, especially as the changes in land use occur. They mention that the anthropogenic factors that affect land use present a key socio-economic challenge when it comes to tackling the fires, especially when there are a number of fires during the same time period, this is because many countries rely on others to lend them firefighting equipment such as planes and so therefore if there is a period of time when the demand is too high then some countries miss out on the necessary equipment which could further increase the consequences.

Technical Interpretation

It is important to see how these wildfires in Italy compare to other examples of typical wildfires as this will enable us to see if this is an extreme example of this type of disaster or if it is just an anomaly. One area that experiences many wildfires is the West coast of America due to its arid climate and high heat but also due to its high population density. High population density means that there are likely more instances of humans causing these fires. However, it is important to mention the differences in both Landscape and climate between Italy and the Western United States. Italy is much smaller and has a more varied climate with seasonal rainfall during the winter months whereas much of the west coast experiences drought for years at a time (Wildfires, 2017). In the book "Disasters in the United States: Frequency, costs, and compensation" It mentions that wildfires are an integral and natural part of forest ecosystems (Wildfires, 2017) and as mentioned earlier much of Italy is covered by this forest ecosystems and so this is evidence that the wildfires that occurred in 2019 where not random and in fact where designed to happen by the forest systems. However, the chapter then goes on to mention that there are two main factors which are changing these systems, being climate change and human development. In order to see if climate change and human development are having the same impact on wildfires in the US as they are in Italy, we need to firstly see the change in the United States.

Figure 3 above shows how over the past 50 years the number of wildfires has not increased in the United States and has in fact decreased. Annual National Interagency Fire Center (NIFC) data which began collecting in 1960 shows how in the 54 years since there have been 5.6million wildfires with the burned area totalling 235.8 million acres (Wildfires, 2017). And as the graph shows the number of wildfire incidences are not increasing however the number of acres burned is increasing as well as the number of acres per fire. This trend suggests that the wildfires are getting more intense with each year and are becoming more difficult to control which explains why the acres per fire is increasing. This is backed up by the fact that it would be expected that the number of acres burned, and acres burned per fire would decrease with improved detection and response time as well as firefighter's equipment getting better however this is not the case.

However, in the report "Decreasing Fires in Mediterranean" (Turco et al, 2016) it mentions that the trend in Italy is different to that of the United States, Firstly it is important to mention that these two areas are different in terms of Population and area and so it is likely that the total area burned will be far lower in Italy due to its size and also its lower population however we are looking to see if the fires have gotten more intense over the past decades. There has been data collected by the Corpo Forestale dello Stato (CFS) which was part of the forestry department in Italy however in 2015 the role of the CFS has been

reduced and now the responsibility of recording forest fire data is now on a Supranational institution such as those run by the EU for example the Emergency Management Service of the European Forest Fire Information System (Michetti, Pinar, 2019) .However, the issue with this is that these institutions only record fires that results in over 30 hectares burnt meaning that many forest fires may go unrecorded. In the report "Forest Fires Across Italian Regions and Implications for Climate Change: A Panel Data Analysis" (Michetti, Pinar, 2019) it mentions how in the whole of Italy there are on average 7077 fire events a year between 2000 and 2011 with around 76,350 hectares burnt annually on average. The problem with averaging this kind of data is that it does not indicate whether some years had more fires and a higher area burnt which means that it is hard to detect a trend, however the report then goes on to say that fires in 2017 have been the most intense in 30 year and if we look at the event in Como December 2018 mentioned earlier in the report, that one particular even burnt over 1000 hectares in one incidence and was one of the most destructive fires in Italy in recent history.

Conclusion

Overall it can be said that the wildfires that occurred in Italy in 2018-19 are a natural part of the ecosystem and where not anomalies, However the event in Como was a result of human involvement and as population increases it can be expected that fires as a result of human involvement become more common. Wildfires are also difficult to predict due to the nature of them, an earthquake often occurs along a fault line and a storm can be tracked before it turns into a hurricane whereas a wildfire can start in a matter of seconds and become uncontrollable in a few hours. The only thing that can be said is that there are certain times of the year when fires are more likely for example when variations in temperature and precipitation create an ideal weather system for a fire to start. Climate change will certainly have an effect on the number of fires, In the report mentioned earlier detailing predictions for wildfires (Michetti, Pinar, 2019) they used European scale predictions from regional and global climate models to estimate the effects of climate change and found that the number of fires are not likely to increase by a large amount however the area burnt area is expected to increase and this mirrors what happened in the United States over the past 50 years. The reason for this could be the increase in temperature and high heat events such as the one in 2003 or it could be that the soil patterns change leading to a more flammable vegetation.

So in conclusion the events in 2018-19 where not uncharacteristic however they do indicate that humans are having a significant impact on the number of large scale wildfires and also that these wildfires can have a serious economic consequence and increased numbers are expected to happen in the next 30 years.

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2018 Catalonia landslide

Pip Allen



Figure 1 – Image of the landslide that caused the train to derail. (The Guardian, 2018).

Background

The area of Catalonia, is located, when reading, Britannica (2018), in the region of North-Eastern Spain, and according to ITV (2018) it is about 28 miles North-West of Barcelona, which is situated in the same region as Catalonia (Figure 1). It has been said by BBC (2018), that Catalonia is one of the most highly industrialised regions in Spain, with most of the population living in the popular city destination of Barcelona. There is also a significant mountain range, called The Catalanides, which have historically separated the industrial towns, near the coast, from the somewhat agricultural settlements (Britannica, 2018) that are further inland.

The climate of the region and the country is well known for being warm, sunny and of high temperatures during the summer, throughout North-Eastern Spain and the majority of the region of Catalonia has a Mediterranean climate (Britannica, 2018). The Mediterranean climate is characterised, according to Global Security (2017), that they have hot summers and mild winters, with irregular rainfall However, it also mentions that torrential rain is likely to occur across the season of autumn and later months. It was also recorded by AccuWeather (2018), that the North of Spain had spells of heavy rain and wet weather, to the upcoming accident, as well as Barcelona having received nearly double the normal levels of rainfall for all of November. Which is significant towards the factors that would trigger a significant a landslide in this region, which then caused an accident with a passenger train and the landslide across the train tracks.

Disaster

During the morning, according to both Watchers News (2018) and Euro News (2018) at around the time of 6am local time, of 20th November 2018, where a landslide had occurred and the train had hit the landslide debris (see Figure 2) . The accident and derailing of the train had occurred between the towns of Manresa and Terrassa (Watchers News, 2018), which is a significant and popular route to get to Barcelona. As reported by El País (2018), the collision with the debris had caused the last two cars of the train to come off the tracks, resulting in a significant accident.

As mentioned by The Guardian (2018) and The Journal (2018), the train was carrying 131 passengers on board at the time of the accident, out of these passengers, 41 of them were injured with 5 of the passengers were sent to hospital with more serious injuries and had also confirmed that one passenger

had died (ITV, 2018). Some police officers had also commented that the person who had died in the accident, had likely died in the impact as it was reported that some doors of the train cars had been ripped off in the collision (El País, 2018), which is likely to imply that this passenger may have been thrown out of one of the two derailed cars from the impact. According to the Standard (2018), there was heavy rain over the past few days, leading up to the incident, which have caused the majority of the land and hillside to become unstable and more susceptible to movement. Therefore, the heavy rain would have been the most likely factor in causing the landslide to occur. There were certain measures already in place to avoid incidents like this happening, such as having the area fitted with netting to hold back any debris and larger rocks. However, during this hazard the netting did not hold the landslide (The Journal, 2018) or landslide debris back. There have also been similar incidents in the same area as this one, where Catalan News (2018), has commented that this derailing of the train has been the third one since 2009, but had less of an impact and caused significantly less mortality.

Aftermath

Only the 131 passengers (The Guardian, 2018 and The Journal, 2018) were directly affected from the accident. It was known that only one passenger had died, and a few were seriously injured. Another direct impact that was not reported, but could have potentially occurred, would have been the high risk of another landslide happening in the same location or nearby. In which may have compromised everyone's safety and might have paused any evacuation and rescue efforts for the accident. Luckily this didn't happen, and therefore made the evacuation of the passengers simpler and easier. In the immediate aftermath of this event there were emergency facilities put into place in nearby community areas, such as a local sports centre, where psychologists were offering counselling (The Guardian, 2018). This would have offered help to both the passengers who are likely to be in shock from the incident, as well as the workers and emergency services who helped to rescue and evacuate people from the derailed train. Although there were direct impacts of the landslide and accident, there was one main indirect impact from this. Which, GISMeteo News (2018), reported and announced that traffic between the cities of Terrassa and Manresa, all traffic was temporarily suspended, this was so all passengers can be evacuated safely, with no other trains or vehicles being a danger towards them. The traffic suspension allowed safe access to the disaster accident for the emergency services, helping to avoid any unnecessary accidents. As well as putting the suspension in place for the rail lines, the rail systems had also advised people and passengers on other trains to take alternative transport (Euro News, 2018). Although the rail line was closed and traffic was suspended, there have been no reports on how long it was closed for, but this would most likely have been due to be able to clear the accident scene and to fix the safety netting and tracks, to allow for normal service to continue again. Overall, there was only one fatality from the hazard caused accident, however there were little not no other major effects from this, other than traffic disruptions.

Technical analysis

Factors influencing the probability and frequency of landslides

The concept of a landslide is based on the mass movement of soil and/or rock down a slope, which is often, according to Smith (2012), triggered by an earthquake or rain storm, this was similar to what caused the landslide in Catalonia, where a period of heavy rain weakened the soil and rocks that were already being held back by netting, however the intensity still caused the slide onto the rail line. In addition to this, as noted by Hong, Adler, Negri, and Huffman (2007), there are also many variables that influence the land surface, such as topography, geological history and local land uses. The mentioned variables are significant when looking at the Catalonia landslide case study, where the local land use is solely rail way lines at the bottom of the slope, where it is attempted to be protected by the netting that was mentioned above. The Catalonia region has also seen a number of landslides occur in the past few years, however, it is now generally accepted that mass movements of sediment and rocks have increased and become more common over time (Smith, 2012). Therefore, with the fact that the case study area has already seen more serious landslides in previous years, they are more likely to see more occurring in the same area. On the other hand, it has been said, by Glade (2003) in Persichillo, Bordoni, and Meisina (2017), that the type of movement and occurrence of landslides are often strongly influenced by land use, and this factor is one of the most important that influence the occurrence of landslides. Despite land use being recognised as the most important factor, the case study of Catalonia suggests that land use would not be influenced by land use, as there is only the rail line nearby, with the significant heavy rainfall being the influencing factor in this case study. Although, the Catalonian region is known for having landslides occurring, as they have prepared for when another happens by protecting the rail line, but it has been mentioned by Persichillo, Bordoni, and Meisina (2017), where most major landslides take place that affect society, such as the train accident in Catalonia, Spain, are almost always unexpected. Therefore, causing the train accident as it could not be avoided, because it wasn't expected, as there are mitigation plans in place to be able to protect the region, to try and help avoid accidents like the one that has been studied.

Likelihood of landslides in the region of Catalonia, Spain

The region of Catalonia has experienced a number of landslides over the years, especially in the Coastal Mountain Ranges of Catalonia, the Eastern Pyrenees and the Iberian Range, where Corominas, Mateos, and Remondo (2016) found that most landslides occur during the months of October and November in these regions and when this landslide case study occurred. Where it has been reported by Remondo, et al (2003), where the main triggering factor was intense rainfall, along with the significant degree of the slope angle being 22° in general, across Northern Spain. This would clarify what happened before and the landslide train accident, as mentioned in the background section above, where they received a large amount rainfall in the days running up to the accident, which would have a significant impact on the slopes above the rail line. Similarly, it was also found that the main landslide-triggering mechanism for landslides in Spain, is rainfall, and it has been predicted by models that there will be an increase of intense precipitation events (Corominas, Mateos, and Remondo,2016) throughout the country, where it will increase the triggering of landslides. This research provides the information that the landslide event in Catalonia, was triggered by the heavy rainfall and the significant slope above where the trains pass through, and without the mitigation plans that were already in place, the accident could have turned out a lot worse. It is most likely that events like this will happen again in the region, especially when it has been predicted that heavy rainfall events are likely to increase, therefore increasing the frequency of landslides occurring. The train accident was not an unusual event to take place, as there were similar incidents in the past in the same area, under the same circumstances.

Conclusion

Preparedness and responses to landslides

There are already measures in place to avoid any landslides affecting the area and region, where they have netting nailed or attached to the slope (The Journal, 2018), to try avoid any landslides or rockfall hitting the rail line. Therefore, this will help to avoid causing any serious damage to the tracks and any more serious accidents in the Catalonia region. However, the netting didn't work too well, as the slide still occurred and caused the train to derail and kill a passenger, meaning improvements do need to be made. There are other measures that can be put into place to help provide information towards the possible occurrence of a landslide, such as using and creating a landslide susceptibility map, which is mentioned by Davies (2014), who believes that one of these maps, that includes an event scenario. In which will help to provide local people and local governments with realistic information about what may happen at any time, and what to prepare for, for when a landslide does occur. Another mitigation project comes from research from Choi, Cui and Zhou (2018), who found that scientists will collect data from relying on smartphones, for early-warning and post-disaster management systems. Plans and resources like these will help to allow data to become more readily available, to better manage and mitigate landslides and rockfalls, especially in the Catalonia region, where landslides are more frequently occurring.

There are always potential future risks that will come about, when involving landslides, however these risks can be reduced by having more plans in place to help avoid landslides falling on the tracks again. As well as improving the measures that are already in place, by making the netting stronger or putting more up to help hold back any larger rocks or movement.

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Mount Etna, 24th December 2018

Jamie Hazledine

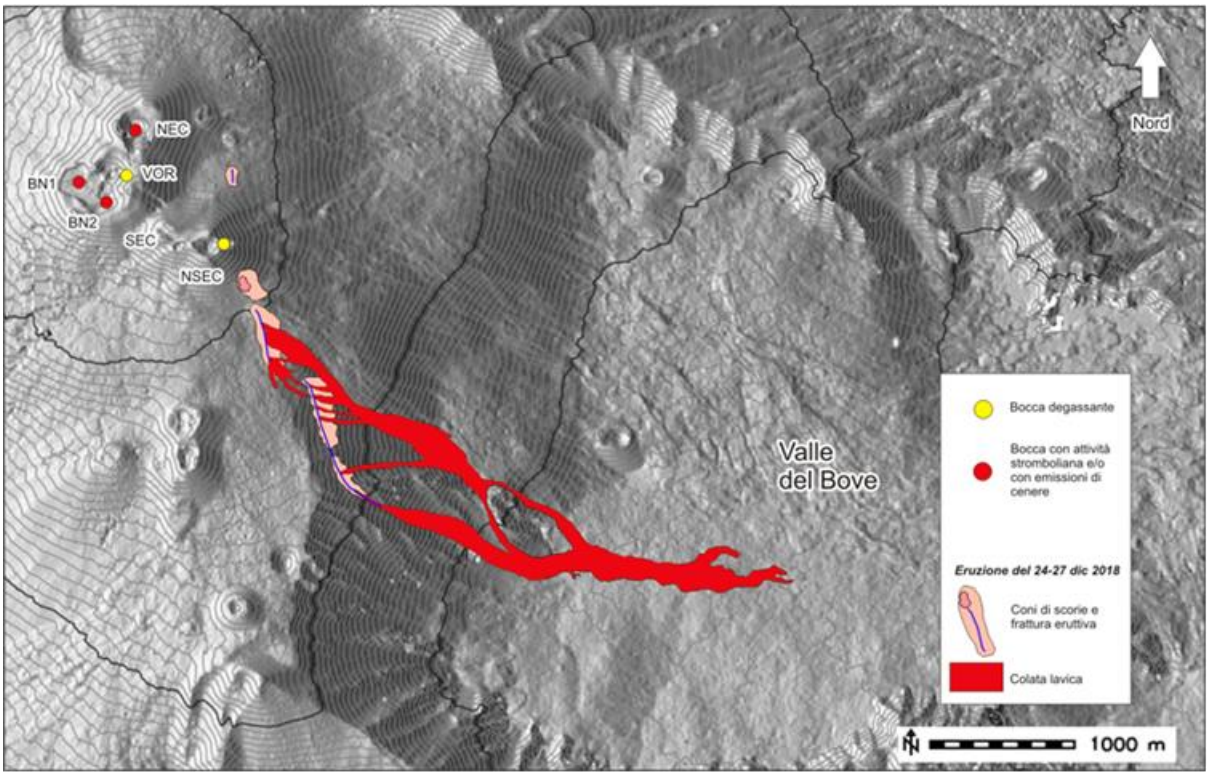


Figure 1.3 – Topographic map showing the extent of the lava flows coming from the new south-east crater over the course of three days after the eruption on the 24th December 2018 (Crafford & Venzke, 2019).

Authoritative account

Introduction

On the east coast of the Island of Sicily, Italy, Mount Etna (figure 1.1) stands at 3,326m making it the largest volcano in Europe by over 1,000m (Omondi, 2019). Located on a conservative plate boundary between the African and Eurasian tectonic plates. It is a stratovolcano meaning that it's made up of layers of debris from previous eruptions including pumice, ash and solidified lava. Mt Etna is almost always in a constant state of activity and is one of the most active volcanoes in the world.

Timeline of events

On 24th December 2018 after a series of volcanic and seismic events a lateral eruption took place at Mt Etna for the first time in over a decade. As previously mentioned, the volcano is almost always in a constant state of activity and had been erupting since September 2013 through to May 2019 with various volcanic and seismic paroxysms happening during this period, including the main eruption on 24th December 2018. The events leading up to this eruption included the release of ash and gas from volcanic vents as well as flows of lava and lava effusions. According to the Smithsonian Institution's Global Volcanism Program continuous small lava flows were recorded coming out of the new south-east crater of the volcano on 4th December. Intermittent strombolian events that lasted around five to ten minutes were also recorded (Crafford & Venzke, 2019). On the 9th December the Mt Etna eruption update blog by Volcano Discovery stated that, strombolian activity at the eastern vent of the new south-east crater could be heard from several kilometres away with low-rise lava fountains protruding out of the crater. This activity decreased in the next few days and by the 13th the strombolian eruptions were less frequent and explosive but still occurring (Volcano Discovery, 2018). Activity in the volcano was then said to have increased on the 16th with nearly continuous lava effusion seen coming from the new south-east crater (Crafford & Venzke, 2019).

The BBC reported that at 08:50 on 24th December a swarm of seismic tremors thought to have been caused by magma travelling up through the rock were recorded for around three hours at the Mount Etna Observatory; part of Italy's National Institute of Geophysics and Volcanology (INGV). The largest of

these tremors was equivalent to a magnitude 4.0 earthquake (BBC, 2018). Going back to the Mt Etna eruption update blog, during the swarm a new fissure in the new south-east crater caused Etnas first lateral eruption in over a decade as magma made its way to the surface. At 12:05 lava flows protruded from the fissure releasing large amounts of debris into the atmosphere and a large ash cloud to loom over the surrounding area; seen in figure 1.2. This figure captures the lateral aspect of the eruption and clearly shows how the ash plume is travelling to the side of the volcano and not directly upwards. The lava flows in figure 1.3 were larger than those on the 4th and they travelled over a kilometre down to the Valle del Bove at an altitude of 2,400m (Crafford & Venzke, 2019).

Information from a news article released by the excursion group 'Etna Experience' said between the 24th and the 27th in the following days after the eruption there was a sporadic release of ash with occasional larger plumes which could be seen from several kilometres away (Etna Experience, 2019). Ash was also released by the collapse of small portions of solidified lava fields at the top of Etna as well as the interaction between snow and lava causing vaporised water to be added to the plumes in a sublimation reaction according to a news article released by Discover Magazine (Klemetti, 2018). Abundant amounts of sulphur dioxide were also emitted from the fissure in the new south-east crater on the volcano between the 25th and the 30th (Crafford & Venzke, 2019). Over the next few days after the eruption magma movement in the crust likely caused approximately 2,000 seismic events around Etna with the largest being equivalent to a 4.8 magnitude earthquake (Volcano Discovery, 2018).

Though the eruption was not the largest Mount Etna has produced it still had impacts on the surrounding area. Seismic activity caused by the movement of magma through rock meant that minor earthquakes were felt across Sicily. A Quartz news article mentioned that social impacts caused from this included 28 people being injured as well as structural damage to buildings such as houses and businesses in the city of Catania and villages like Fleri (Bain, 2018). Hikers at high elevations on the volcano were evacuated, however, these where the only people evacuated as the eruption was not considered to be a threat to any populated areas (Klemetti, 2018).

Above average amounts of sulphur dioxide were released into the surrounding area following the eruption through volcanic degassing and had an environmental impact on the surrounding area as the air quality was temporarily affected (Crafford & Venzke, 2019). Topographical impacts were also recorded as Robin Andrews states in his Forbes article Mount Etna Just Started Erupting from A New Fissure. Here's Everything You Need to Know, that there were 'conspicuous deformations of the summit area' (Andrews, 2018) according to a press release from the National Institute of Geophysics and Volcanology.

The most publicised impact of the eruption was the closure of Catania Airport as a result of the ash plumes in the sky. Bad visibility and the risk of volcanic glass forming in the engines of planes caused a restriction on the local airspace around the volcano and the surrounding area. Shortly after the airport reopened to allow four planes per hour to land and then eventually by 20:00 the same day it returned back to normal operations. This would have economically impacted airlines and passengers that could not land at the airport (Klemetti, 2018). Structural damage to the buildings in Catania and Fleri would have also had economic impacts on the people who owned them too.

Source credibility

To Gather the information for the authoritative account I used search terms such as 'Mt Etna eruption 24th December 2018' and 'Mt Etna 2018 News coverage' in Google. These came up with 201,000 and 327,000 search results respectively and allowed me to form a timeline of events from different articles by bringing them together into one. One particular source called 'Volcano Discovery' was a blog on eruption updates for Mt Etna. This showed me a timeline of updates leading up to the eruption as well as after. I then read other news articles to fill in the gaps such as the BBC, Discover and Quartz.

Technical Interpretation

Lateral eruption

The eruption on the 24th December 2018 was the first lateral eruption at Mt Etna since 2008. These types of eruptions are not uncommon for Etna; however, they do not occur as frequently as vertical summit eruptions. Volcanic debris was emitted from the new south-east crater on the volcano through a newly formed fissure which could have resulted from a seismic tremor caused by magma and gases migrating through the crust in a formation known as a dike. This is standard for Mount Etna as past activity suggests that dike intrusion in the shallow crust or upper volcanic pile happens after months or years of recharging (Sicali et al, 2015). Since it is almost always in a state of activity it is relatively easy for the volcano to recharge.

Dike formation

Dikes are columns of magma that can cool and solidify to build up the crust or they can act as conduits connecting the magma plume to the surface and provide material for eruptions in like lava flows. They form as a result of superheated magma rising upwards towards the Earths surface while following the path of least resistance and tensile strength

through the host rock. An easy way of explaining how dikes form is using a simple equation:

$P > \sigma h + T$

The equation states that if magma pressure (P) is greater than the perpendicular stress (σh) acting on a given dike plus the tensile strength of the rock it is inside then a dike will form. This means that the magma in a dike will spread through the rock where (σh + T) holds the minimum value (Gudmundsson, 1984).

Effect of dikes on lateral eruptions

As dikes grow, magma pressure can overwhelm the host rock and cause horizontal fractures in the dike walls allowing them to propagate outwards rather than upwards (Taisne et al, 2011). Therefore, the magma migrates horizontally through the rock towards the side of the volcano instead of upwards to the top. This is how dikes can cause lateral eruptions as pressure builds on the side of the volcano and not at the top. These dikes have been recognised at Mt Etna and are likely the cause of the semi-frequent lateral eruptions over the years (Urbani et al, 2018). With every pulse of moving magma in a dike it is suggested that the dike is split in two and branches out into the rock with the increased pressure. Therefore, it is thought that there is a relationship between dike intrusions in rock and the formation of fissures in said rock (Gudmundsson, 1984).

Fissure in the new south-east crater

The pressure inside the volcano caused by a dike was released during the eruption when the fissure in the new south-east crater opened. This fissure could have resulted from numerous things including the most likely being a volcanic tremor; caused by magma rising from depth towards the surface and going through significant stress changes resulting in seismic vibrations (USGS, 2016). Seismic tremors are very common at Mt Etna, especially during times of high volcanic activity. In July-August 2001 Mt Etna erupted after eight months of seismic activity totalling 683 different earthquakes (Sicali et al, 2015). At the end of this period of seismology the volcano erupted laterally which shows how the different eruptions at Mount Etna relate to the one on another as even though they were 17 years apart the volcano still behaves in a similar way.

Conclusion

Vulnerability

Due to the magnitude of the eruption there weren't a lot of people who were exposed to the full force of it, with the most exposed people being the hikers who were evacuated and taken to safety. The closest highly populated area was the city of Catania which authorities deemed far enough away to not need to evacuate (Bain, 2018). Overall, the response of the emergency services to evacuate the hikers and to close the airport to prevent any planes from flying into the ash cloud reduced the vulnerability of people in the vicinity. Combined with the actual hazard, this meant that the risk of the natural disaster was largely reduced. The most direct loss of tangible assets was through the seismic activity and not through any strombolian activity.

Potential future risk

Due to Mt Etna being almost constantly active it means that there is always going to be potential future risks that will arise from similar situations. Eruption risks are very likely, however, since being added to the decade volcano project by the International Association of Volcanology and Chemistry of the Earth's Interior (IAVCEI) more quantitative and qualitative data can be gathered from the volcano. Therefore, more information on the volcano can be provided meaning that populations close to the volcano are less at risk due to education and awareness (Klemetti, 2009).

The south-eastern flank of Mt Etna faces the Ionian Sea and slides further in by centimetres each year. For example, in May 2017 during an eight day long seismic event the flank was displaced by around 4cm. If a significant enough volcanic eruption or volcanic tremor were to happen then an extremely rare event could happen where a large section of the flank could slide into the sea, displacing massive amounts of water (Urlaub et al, 2018). Resulting from this would be a tsunami which would have devastating consequences on countries around the Mediterranean, mainly Malta (Doyle, 2019). Flank failures are one of the most notable causes of volcanic hazards for ocean-island volcanoes, especially for tall and active volcanoes like Mt Etna as there is greater risk of flank instability (Maccaferri et al, 2017). However, as unlikely an event this might seem, it could still become a reality due to the extreme conditions inside of Mt Etna.

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Trabzon Province landslides – 18th June 2019

Alexander Cramer-Smith



Figure 1.1 Location map of the landslide that took place on 18th June 2019 in Trabzon Province (EDINA, 2019)

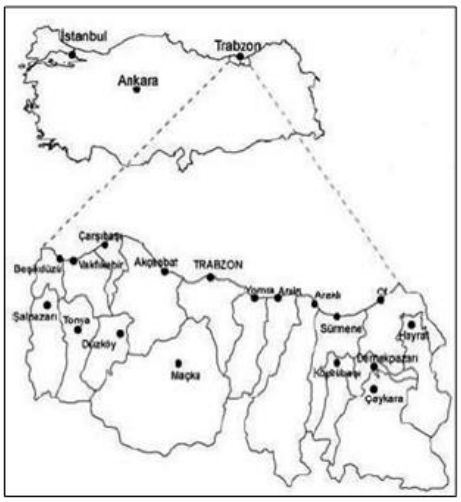


Figure 1.2 Location map of the Trabzon Province. Turkey. Çamlıktepe and Yeşilyurt neighbourhoods highlighted in red (Bayraket al., 2009)

Overview

Extreme events that involve high intensity rainfall have the potential to trigger landslides and induce significant morphological changes to a region, especially in mountainous terrain. (Martha, T. et al. , 2013). On the 18th of June 2019 in Trabzon Province of North-East Turkey (see Figures 1.1-1.2), the communities of Çamlıktepe and Yeşilyurt in Arakli were imperilled by Intense rainfall (Petley, 2019). News outlets stressed that the heavy rain triggered landslides and flash floods (FloodList, 2019) which devastated the towns, as buildings and vehicles were inundated and destroyed (Daily Sabah, 2019).

The disaster claimed the lives of 8 (Guncelfiyat, 2019)and injured 3((FloodList, 2019) (Blašković, 2019)). However, some reports from media and locals suggest that the intense rainfall may not have been the root cause of the disaster but that a faulty pipe at a hydroelectric power plant nearby exploded, causing large floods in the area (BIA News Desk, 2019). A shopkeeper, an imam and a municipality worker were some of the victim's professions. The municipality worker was clearing up after the town was hit by floods the previous week when heavy rain rocked the Black Sea province once again causing landslides and flash floods (Daily Sabah, 2019).

Immediate Rescue Attempts

When the event struck, locals made an attempt to save lives by moving others to areas of safety such as higher ground (Daily Sabah, 2019) .Firefighters made the first rescue attempt but were impeded at reaching areas affected due to debris brought by the landslides and floods blocking access by road. (Blašković, 2019).

Evacuation and Response

It is estimated that 70 people were evacuated (FloodList, 2019) from Çamlıktepe and Yeşilyurt when rescue finally arrived. Minister Suleyman Soylu set up an emergency desk (Daily Sabah, 2019)that lead to the deployment of 280 search and rescue members from outlets such as the state-run Disaster and Emergency Management Presidency (AFAD), Gendarmerie forces, Coast Guard and Turkish Red Cross (Guncelfiyat, 2019) (Hürriyet Daily News, 2019).

Governor Ismail Ustaoğlu of the Trabzon region warned the communities in Arakli that there was still the risk of landslide action due to more intense rain in the area following the disaster and advised locals to leave their neighbourhoods (IPA NEWS, 2019). Minister Suleyman Soylu stated that locals should stay away from the Çamlıktepe and Yeşilyurt neighbourhoods and that those whose assets had been destroyed would be compensated for their losses. (Daily Sabah, 2019)

Damage and Destruction

The extent of the event left the towns in wreckage as floods ripped through multiple buildings (Hürriyet Daily News, 2019) only leaving their foundations behind. Authorities declared that a school, three houses and two businesses had severe flood damage and that landslides in the region damaged these houses with mud and heavy rocks (Daily Sabah, 2019) (see Figures 2.1-2.2). Most of the houses affected were near to the riverbed leaving them completely

exposed when the landslides and floods hit. (Guncelfiyat, 2019)

Reasons for the flood. Natural Disaster or Human Disaster?

Turkish officials have disputed the cause of the landslides and flash flood. One official believes it was a natural disaster following heavy rainfall, and another blamed a hydroelectric power plant (HES) in the region for having a broken pipe. (IPA NEWS, 2019). A news outlet reported that a water pipe exploded at the power plant in the area causing floods (BIA News Desk, 2019). However, the Agriculture and Forest Minister Bekir Pakdemirli denied these accusations, stating that the flood was caused by a landslide which damaged the pipe. (Hürriyet Daily News, 2019).

One understanding of the incident points towards the intense rainfall and measures in place for it to happen under natural circumstances (Daily Sabah, 2019). The General Directorate of Meteorology (MGM) reported that 69mm of rain fell in 24 hours on the 18th of June in the Trabzon province (FloodList, 2019). The previous week a small-scale flood occurred (Daily Sabah, 2019) saturating the rough terrain. (Guncelfiyat, 2019). This small-scale flood made the ground less stable, increasing the chance of landslide behaviour and allowing more runoff down steep slopes. Minister Soylu informed news outlets that the epicentre of the disaster was on the steep slopes on which the neighbourhoods of Çamlıktepe and Yeşilyurt are located below. It was here that rock broke away from the slopes, prompting landslides. (Daily Sabah, 2019). Agriculture and Forestry Minister Bekir Pakdemirli visited Arakli following the disaster labelling it a 'completely natural phenomenon' and emphasised that the incident could not be because of the HES as it is further downstream. (IPA NEWS, 2019). Pakdemirli also claimed that the pipes of the HES exploded due to the floods and landslides (Blašković, 2019).

The Black Sea region has been criticised in the past for its use of Hydro Electric Power Stations (HES) as they pose a threat against the environment and increase the risk of incidents. In this case for instance, landslides and floods. It has also been known that the AKP government have constructed HES systems without cogitating the potential ecological factors. (IPA NEWS, 2019)

Recep Cebi, the district mayor of the Justice and Development Party (AKP) claimed that the broken pipe influenced the disaster and is equally at fault for the event as natural processes that took place, due to it being a flood prone area where events have occurred in the past. Haim Kose, a local resident evacuated by helicopter (Daily Sabah, 2019) emphasised that this was the sixth disaster experienced in his community and that no coping mechanisms have been put in place In order to avoid the disasters from happening again. Kose noted that officials had come in the past in order to assess the damaged pipe but could not carry out the necessary repairs (IPA NEWS, 2019).

Preparation for event

The communities of Çamlıktepe and Yeşilyurt had little warning in terms of preparation of the disaster. Bekir Pakdemirli said that the ministry's meteorology service warned locals of heavy rainfall. However , Halim Kose told of how his first sign of the event unfolding was when he noticed the river heading towards him like a tsunami, at this point he phoned his relatives to tell them to flee the neighbourhood. (Daily Sabah, 2019)

Technical Assessment

Rainfall Prone

The Trabzon province in Turkey is prone to large amounts of intense rainfall every season. (Bayramoglu et al., 2016) Seasonal rainfall in the region is the main meteorological factor that reduces soil stability, in turn accelerating the frequency and development of landslide occurrence. (Bayrak et al., 2009) The Trabzon Province receives 838mm of rain annually and in June there is an average of 50mm of precipitation expected for the month (ClimatesToTravel, 2019).

Landslides activated by intense rainfall are the main culprit for causing serious harm to humans in Turkey, as well as large-scale damage to the environment, property and infrastructure. Between 2005 and 2008 there were 178 landslides recorded that were triggered by rainfall alone (Bayrak et al., 2009).Between 1988 and 2008, 2000 landslides occurred in the Trabzon Province (Akcali et al, 2010)

Comparison to previous rainfall events/landslides

In a study by Akcali examining the initiation of landslides in the Trabzon province, landslides occurred on days with notably high amounts of rainfall in 24 hours e.g. 91.7mm, 73.6mm, 62.9mm, 47.2mm. In relation to the landslide event that occurred on the 18th of June where 69mm of rain (19mm more than what would fall in all of June (ClimatesToTravel, 2019)) fell in 24 hours in the Trabzon Province, high rainfall suggests that the area was extremely prone to landslides on this day. A flood hit Trabzon the previous week (Daily Sabah, 2019), indicating pressure on the soil stability from saturated ground contributed to the landslides. The study concluded that singular days of intense rainfall are correlated with the occurrence of rainfall induced landslides. (Akcali et al, 2010)

Landslide Susceptibility

Trabzon is prone to severe landslides from natural triggers such as steep and improperly cut topography which is subjected to heavy precipitation. Artificial

triggers include poor surface drainage and agricultural activities in the region (Akgün et al, 2007). Terracing for agriculture alters the natural drainage environment of the slopes by lowering surface runoff and increasing infiltration of precipitation. Additionally, the increase in soil water content decreases the slopes shear strength, creating landslide prone conditions. (Uyeturk, 2019)

Residual soils

Landslides in the Trabzon province take place on residual soils. 80% of landslides investigated in a study by Yalcin (2011) took place on soils with 14% average clay content. Clay has high void ratio and porosity due to its finer grain sizes (Akcali et al, 2010) (Uyeturk, 2019),which in high amounts slows drainage in the soils, promoting saturation. When saturated, the clay has a high pore pressure, disturbing the stability of the mass and promoting landslides. (Yalcin, 2011)

Slope Angle

The average natural slope angle for landslides in the Trabzon province is 44.7°. Slopes with a higher angle e.g. 60°, would allow more water to run off the surface instead of infiltrating the soil making landslides less of a risk. A low slope angle would pose less stress on the slope from gravity, reducing the risk of mass movement. (Akcali et al, 2010)

Forests and Landslides

Between 1987-2008 satellite imagery expressed an increase of vegetation in Trabzon. These areas are a result of increasing agriculture and forestry. (Sancar et al, 2009). In the Forests and Landslides RAP Publication (2011) it states that the maintenance of forest cover is crucial for areas of steep topography due to tree roots aiding the binding of soil particles, increasing stability and decreasing moisture content. Conversion of trees to crops or grazing means that soils are dried to a shallower depth due to the shallow rooting patterns and lower amounts of evapotranspiration from agricultural land use (Forbes & Broadhead, 2011). Akcali's (2010) study relating to what type of land use landslides occur on in the Trabzon province revealed that 5% were in forested areas showing the lowest levels of landslide occurrence whereas agricultural land made up 87% of the cases where landslides occurred.(see Figure 3.1)

These changes in the land use increase landslide susceptibility and are enhanced by agricultural factors such as terracing, reduced infiltration, low soil cover and tillage. (Forbes & Broadhead, 2011)

Flora type and agricultural product

The report highlighted how agricultural lands in Trabzon comprise mostly of tea and hazelnut cultivation which have shallow roots and a significantly lower rainfall threshold than forest and uncultivated land. Areas of forestry have a better soil structure due to the deep expansive root system increasing its cohesiveness that makes it more resilient to stress (Akcali et al, 2010) (see Figures 3.2-3.3).

Meteorological Vulnerability

The Trabzon Province receives 838mm of rain annually (ClimatesToTravel, 2019). Rains are abundant in all seasons on the Black Sea coastline and summer rains tend to be concentrated in periods that last a few days. On the 18th June 2019, 69mm of rainfall fell in 24 hours (Daily Sabah, 2019) which raises concern on the future of Trabzon. As global warming intensifies there will be more evaporation of water into the atmosphere, leading to more intense rainfall periods (Trenberth, 2011) in the region, increasing the potential of landslide activation in the Trabzon province.

Topographical Vulnerability

Steep slopes abundant of deep-rooted trees in the region are cleared for tea and hazelnut agriculture which are key contributors to the province's economy, putting pressure on the land. These practices reduce the binding stability of the soil and will make slope failure more numerous for those living at the bottom of slopes e.g. Çamlıktepe and Yeşilyurt. (Akcali et al, 2010)

Soil Vulnerability

Soils in the Trabzon province comprise on average of 14% clay in areas subjected to landslide susceptibility (Yalcin, 2011). It is these soils that have a small negative charge, meaning that they have a high affinity for the positive charge of water molecules (Davison, 2000). Clay has very low strength parameters when saturated with water. Due to the presence of fine grains in the soil, drainage is limited, increasing the pore pressure which disturbs the stability of the soil mass, promoting landslides.

Water Pipe Vulnerability

The vulnerability of Arakli to landslide events is high as the HES system nearby means pipes in the region carry large amounts of water at low depths under the steep slopes. During periods of intense rainfall, pipes can burst and saturate soils on steep slopes quickly, causing tension cracks that activate landslides leaving those living at the bottom of slopes e.g. Çamlıktepe and Yeşilyurt at high risk of danger.

Mitigation and Adaptation

Strategies to reduce the impact of landslides in the Trabzon Province could include the construction of retaining walls at the bottom of slopes. Retaining walls remove the risk of landslides by moving slope failure to a less critical depth, they also provide stability whilst remaining permeable and inexpensive. (USGS, 2008).

Policies encouraging land uses that retain high forest cover will help to reduce soil disturbance. It has been

proven that areas of forest indicate the lowest levels of land-sliding (Forbes & Broadhead, 2011).

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Urban flooding Case study: Aude region floods 15th October 2018

Natalie Amaro-Barnard



Figure 1 - Map showing extent of flooding in Lespignan using Sentinel-1 imagery (Copernicus EMS 2018)

Introduction

On the 15th of October 2018, multiple municipalities within the Aude region of south west France were hit with devastating floods, leaving people injured, displaced and even losing their lives. The map below shows the main regions affected by these floods. This report will aim to cover the events of that day and unfold the devastation that occurred in the aftermath.

An account of the events leading up to, during and after the flooding event

Tropical Storm Leslie's contribution

Hurricane Leslie formed over the Atlantic Ocean on September 23rd and fluctuated in size and location over the next 19 days, before making landfall in Portugal and being downgraded to a tropical storm (G. Laud, The Express, 2018). Upon making landfall, it brought in warmer air over the Atlantic and across Portugal and Spain, before moving up towards Southern France. This caused disruption to the weather systems for Southern France as it hit an area of colder air around the Massif Central Mountain Range (Egypt today, 2018) This increase in rain from warmer air occurs roughly three to six times a year so in this region and so it is expected by the areas affected that they will need to prepare for heavier rain than normal, and flood defences are already built up with regards to this.

An abnormality in periodic rainfall patterns

Normally this sort of heavy rain in the region is a formality and something they are used to. However, this time the rain was blocked in by converging winds from both the east and the west, causing the storm to be blocked in over the Aude region and remaining static for a longer period of time. According to local authorities the storm then "poured out between 160-180mm of water around Carcossonne" – one of the towns within the Aude region. This was also reported

by Sky News (15/10/18) and French news magazine The Connexion (10/10/2018).

The heaviest of the downpour began on the night of the 14th of October 2018, leading to multiple alerts being given and at 6 a.m. on the 15th of October the highest possible red alert was given by local authorities, after the worst of the rain had already poured down and rivers had already been bursting their banks (PRESSTV, 2018). By 7:30 a.m. on the 15th of October, and after three months' worth of rainfall fell in just six hours, water levels in the town of Trèbes had risen to 7.68m. To put that into perspective the record at the town is 7.95 and was set in 1891. According to French news tabloid 'Connecionfrance.com', and Sky News, around 600 - 700 firefighters, 200 gendarmes and nine helicopters were deployed overnight to help residents escape as part of the Copernicus Emergency Management Service, which was deployed at 13:32 on the 15th. However, it was confirmed in a news release on twitter by the French President, Edouard Philipp, that 350 firefighters were deployed, with the possibility of another 350 being drafted in along with rescue teams for the region as of the 15th of October. Due to the violent and powerful nature of the flooding, many settlements were inaccessible by boat due to unsafe conditions. Therefore, several helicopters were scrambled, with residents being rescued from the top of their homes.

Despite it being left too late for the 14 people who lost their lives, over 1,000 people were evacuated on the 15th of October from flooded areas, and areas at further risk of flooding. This includes Pezens, Trèbes, Villemoustaussou and Villegailhenc. As well as the 14 fatalities, there were reports of between 70 and 100 people being injured by the event. (Richard Davies, Floodlist, 2018) (Tariq Tahir, Peter Allen, Jon Lockett, The Sun, 2018)

The aftermath

The Copernicus Emergency Management Service (EMS) have published maps showing the extent of the flooding as part of their report on the flooding, using imagery form the Sentinel-1 satellite. This report showed that the extent of the flood water as it had spread across the region around the river Aude. A region called Lespignan, at the river mouth, experienced the largest area of flooding, with there being 1,396.4 ha on the 16th October just after the initial downpour ended, before rising to 2,196.6 ha that evening on the 16th October, and then decreasing down to 1985.2 by the 17th of October.

French reporter Benjamin Peter gave an account of the damage in the aftermath of the main water level rise overnight, tweeting about the damage in the village of Villegailhenc. His tweets showed images of ripped up/ destroyed roads and large bridges, cars stacked on top of each other and said that water rose at some points to the first floor of the houses, leaving people stranded on roofs. Two people were confirmed to have been killed in this village alone, also leaving hundreds displaced with houses uninhabitable on any floor and treasured possessions being lost to the flood. The heavy flooding obviously had a massive impact on infrastructure and transport networks, with roads and trainlines being blocked between Narbonne and Carcassonne. Schools have also been closed with residents being advised to stay at home where possible in areas that are not being evacuated. In addition to people becoming stranded in their homes by the flooding, the authorities also strongly advised that the tap water was temporarily unsafe to drink due to the flooding of water management systems and mixing of muddy flood water/sewage with the drinking water.

Technical assessment

Why do these abnormalities occur?

According to Blanchet et al. (2018), extreme daily rainfall has been increasing in the South of France for the past 35 years. This is mostly down to climate change as a result of human impact. Furthermore, Ribes et al, (2019) have estimated that there has been an increase twenty two percent over a period of time from 1961-2015. This equates to the significantly extreme events of 200 mm in a day having almost doubled in frequency.

Events of this scale are expected to continue into the future in the Mediterranean and increase in frequency. The main cause of this is climate change, with the Mediterranean being viewed as a hot spot for increasing flood events. Tramblay and Somot (2018) state that there are a number of potential factors for this, with multiple authors citing temporal instability at low levels due to the difference in temperature and temperature changes between the sea surface and low lying land along the coast.

There is, however, lots of papers showing patterns which suggest an increase in temperature is causing a decrease in precipitation levels as a direct impact. Whilst this is true that precipitation will continue to decrease over the course of the year, it has also been suggested that increasing dry spells will and have been responsible for increased intensity of rainfall when it does occur, resulting in a greater number of extreme weather and flooding instances.

Historic case studies

In the Aude region, there is a very well documented and well-known flooding event that took place in 1999, with very similar levels in precipitation being seen and coming only a month later in the calendar than the recent 2018 flood.

A paper by looks into the rainfall patterns from that period, and also the response of the local watershed for the Aude region. In this event, the same thing happened, where the storm became blocked in by

converging weather fronts, leading to it being fairly stationary of the region for nine hours. In 2018, Macron said that the speed and sudden impact of the flooding from the rainfall added to the unpredictability and impact of the flooding. This was also evident in 1999, with a very small lag time between the peak precipitation levels and the peak discharge. This led to a similar result, where high volumes of water very rapidly flooded the region. (E. Guame, M. Livet, M. Desbordes, J-P. Villeneuve, 2004)

Conclusion

Vulnerability of communities in the Aude region

As stated earlier in the report, the Aude region is used to seasonal flooding, and so has some flood defences in place such as flood walls to contain the river. However, these were designed to protect the area from much smaller flood risks and did not stand up well against the recent onslaught of rain.

Whilst this level of rain proved difficult to predict due to the unique circumstances in the local weather systems, there has been a lot of anger and criticism towards the time it took to realise the scale of the impact the flooding would have (Presstv.com, 2018). For example, despite the huge amount of rainfall falling overnight on the 14th/15th October, the weather warning system still stayed at orange (mid-level). This level is often said to be overlooked as in the past there has generally been little to no long lasting or high-risk consequences to this type of warning. As a result of this, many of the communities were not prepared sufficiently and in one case, an elderly nun was killed as she thought she would be safe behind the doors and windows of her house before the water burst through and swept her away.

French president Emmanuel Macron stated that whilst the late response was regrettable, the scale and speed at which the flooding occurred meant that it was impossible to predict. This comes with the information from the French meteorological office that the unusually extreme weather experienced in 2018 is likely to “continue to increase” over the coming years as climate change continues to change weather patterns and draw in new weather systems to meet at places we have not seen very frequently in the past.

It is clear from this assessment and from the literature, that regions such as this, which have already adapted to cope with flood risks, now need to improve flood defences and response systems further to ensure that when the increasing number of historic event floods come back more frequently, they are able to reduce the impact and reduce casualties.

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Venice Flooding (29th October 2018)

Dan Brodniewski



Figure 5. The locations of the three MOSE sites (MOSE, 2018).

Flooding Case Study

The most recent Venetian flooding of note occurred in 2018. On the 29th of October 2018, a combination of high tides and strong winds gusting up to 118mph caused the worst flooding in years and reached a death toll of 17 (Andone, Mezzofiore & Smith-Spark, 2018). Multiple communal squares and pavements were submerged in the highest floods the city had seen in a decade (Povoledo, 2018) as more than 75% of the city was inundated by high tides (Shoot, 2018). Throughout the case study, statistics from less credible outlets are cross-referenced by consulting multiple sources to gather accurate information.

Account of the Event

Background on Venice and Flooding in the City

Situated in north-eastern Italy, Venice can be found along the Adriatic part of the Mediterranean Sea and is situated on the Venetian Lagoon. The city is built on top of 118 islands, separated by canals and connected by utilising boats and bridges. A

phenomenon known as "acqua alta" or "high water" is experienced in the area due to the abnormal tidal peaks in the Adriatic Sea (Higgins, 2018) paired with an elevation of 1 M.A.S.L. makes Venice especially prone to flooding events. The centrepiece of the City, St. Mark's Square floods more than 60 times per year and the city finds itself inundated by minor flooding four times per year (Amos & Umgiesser, 2018; Higgins, 2018). October to January is the "acqua alta" is most likely to occur (Renzulli, 2019) as the city must also battle high precipitation rates contributing to the flooding, see figure 2.

The Disaster

Storm Patterns Over Europe

Although flooding is common for this time in the year, the "acqua alta" event in 2018 was triggered by a low-pressure storm. The catalyst for a string of extreme weather events across Europe – which included record high temperatures on one side of Switzerland followed by record October snowfall on the other – was a distinct dip in the polar jet stream, extending from across Spain into north-western Africa (Henson, 2018). The storm travelled from south to north, bringing in strong winds that pushed the water into Venice – as well as torrential rainfall (Simpson, 2018). The event meant that tourists and locals were evacuated from St. Mark's Square and the elevated wooden platforms used on main passageways were not high enough to ensure a safe passage through the low-lying square. Following the flooding event, the "acqua alta" (high water) peaked at 156cm (5'1"), The high-water mark in Venice had previously topped 150cm five times in recorded history.

The Sinking City

The event was worsened by natural processes in the area, such as the land masses sinking. By using a combination of GPS and interferometric synthetic aperture radar (InSAR), it was concluded that Venice was subsiding on average around 1 to 2 millimetres per year (Planet Earth, 2018). It has been found that Venice has sunk by ~9 inches since the 1970s (Steves & Openshaw, n.d.). This is caused by a lack of subsidence. The city is built atop of a muddy lagoon, which proves inadequate in supporting long-term cities. As a result of this, the city becomes prone to more severe events – such as the 1966 record high of 6'5", which left 5,000 residents homeless. The impact sinking had on the flooding event is difficult to gauge, but when compared to previous events it serves as a benchmark. Had the event replaced the 1966 flood, it would not be as detrimental.

Aftermath

Loss of Life and Displacement

As a result of the storm surge near across the Italian coast that caused the flood, 17 were killed (Andone, Mezzofiore & Smith-Spark, 2018), the mayor gave orders to evacuate the area and then stated "all of Veneto is in code red alarm for this wave of bad weather" (Vogt, 2018) and vaporetto (Venetian public water bus) services were cancelled. This was done as a result of the elevated platforms usually used at the main tourism attractions, as they were deemed as being too unsafe for pedestrian traffic. As a result, adults were forced to walk through the city in knee to hip high water – especially dangerous for those who cannot swim (Kosowan, 2018). However, the evacuation and management of people was significantly better than that of the 1966 flood. In the months following the record-breaking event, 5,000 Venetians were left homeless and without support (Leibenluft, 2008).

Historic Artefacts and Landmarks Deteriorated

Venice is a city decorated with historic architecture and is home to a host of high-end artwork. After the city was inundated, the 1,000-year-old marble floors within St. Marks Basilica in front of holy altars were turned into temporary lake beds. It is estimated that for one day of flooding, it aged the historic attraction 20 years (Smith-Spark, 2018). Additionally, two Joan Miró paintings at the Palazzo Zaguri museum were saturated and lost all value and any artistic nature to them – they were said to be worth a combined total of €1 million (Sutton, 2018). Whilst artwork pales in comparison to human life, it is important to remember and understand that it is a work of art and a relic of the past.

Response

More than 5,800 firefighters have been utilised to respond to over 7,000 emergency rescue calls across Italy during the storm period (Shoot, 2018). In Venice specifically, there is a water level detection system that forecasts storm surges and the possible damage (Didonato, 2018). As the situation developed, those within the impacted areas were told to stay put and seek shelter unless they could evacuate the area, as well as cancelling the 'vaporetto' water bus services due to strong winds (The Local, 2018; ABC News, 2018). Evacuation in developed urban areas has proved efficient when there is a clear understanding for the population of the received information, making it easier for them to consider the choices when confronted with a disaster (Thomas & Tsujimoto, 2014).

In addition to the limited travel options out of the city, the emergency walkways normally introduced during times of flooding would have been submerged, making it more dangerous to walk through the city (Chronicle Live, 2018). The flooding is a regular occurrence in Venice, with water reaching 110cm happening around four times a year and the "acqua alta events" occur typically once every four years, when the water level in the lagoon is above 140 cm (Walks of Italy, n. d.). With this, Venetians have

become accustomed to flooding events and usually continue as usual. However, the addition of the MOSE project may change this mindset in the coming years.

Technical Interpretation and Future Management

Storm Formation

Figure 4 shows the storm event on the day of the flooding, demonstrating why it was difficult for even a developed nation to mitigate the impacts. High winds along the western seaboard of Italy reached up to 180 kilometres per hour (Blašković, 2018; New Straits Times, 2018). However, the month of October in Italy featured above average temperatures and little rain, then an abrupt storm – a tropical cyclone – which can also be classed as a 3rd category hurricane on the Saffir-Simpson Scale, battered the coast (GeoSocial, 2018). As a result, the storm caught most residents by surprise.

The root cause of the flooding in Venice is attributed to strong gusting winds that were caused by a dip in the polar jet stream, extending across Spain and into northwest Africa (Henson, 2018). The polar jet stream varies daily, as aspects such as sea-ice extent and sea-surface temperatures ultimately determine the pattern produced and subsequent storms (Screen, 2014). North Atlantic Oscillation (NAO) is the result of varied stratospheric circulation and is usually most significant to western Europe in tracking storms through atmospheric pressures (Hall, Erdélyi, Hanna, Jones & Scaife, 2015). Henson, (2018) reported that a flow of warm air extended from northeast Africa to Scandinavia, with an intense area of low pressure at surface level stuck between the contrasting air masses and resulted in extreme winds, shown in figure 4.

Climate Change and Increasing "Acqua Alta" Events

The increased frequency of these events means that more effective counter measures must be considered. However, with climate change becoming a bigger issue – the investment could be futile. Venice's location on Italy's north-eastern coast leaves it vulnerable to sea-level rise as a result of climactic change and ice melt – as the average water height has increased by nine inches since 1897. Forty percent of that is attributed to polar ice melt (Pitofsky, 2018). When combined with the sinking of the city, flooding may no longer be an event more than it being a fact of life as the Mediterranean Sea is forecast to rise by 140cm before 2100 (Walker, 2017). However, it has been concluded that the frequency of storm surges and "acqua alta" events could decrease by 30%, but the magnitude of the surges will increase (Jorda, Gomis & Marcos, 2011) - offsetting the reduction in frequency. However, whether climate change could be attributed to the 2018 flooding is something that researchers have been unable to prove or disprove – as the evidence lends itself to multiple theories.

New Flood Defenses and Corruption

Venice will become more efficient at dealing with acqua alta events in the future after the completion of MOSE, the 'Modulo Sperimentale Elettromeccanico' or Experimental Electromechanical Module project. The MOSE system is located at the Lido, Malamocco and Chioggia inlets (see figure 5) and separate the lagoon from the Adriatic Sea in the event of a high tide (MOSE, 2018).

It is estimated that when the project is completed and operational that the flood defences will protect against floods such as the 1966 record high water levels for the next three decades – but won't stop low-lying sites such as St. Mark's Square from flooding, as it only requires 32 inches to flood the low-lying area (Rossi, 2018). The construction is expected to cost over €5.5 billion and be completed by 2022, with the management and maintenance costing an additional €30 million per year (Gambolati & Teatini, 2014). For Venetians, this is a temporary solution as the project has been quoted by Luigi D'Alpaos (cited in Harlan & Pitrelli, 2019) as being "obsolete and philosophically wrong" and that "MOSE might work tranquilly and without issues for 10 to 20 years. But then problems will arise, and it will be necessary to take other actions".

Furthermore, the construction of has been slowed down due to the corruption within the projects team. Thirty-five people were arrested and more than 100 people including entrepreneurs, managers, officials and politicians, were under investigation for tax fraud, corruption, misuse of public funds and illicit financing. Investigations into this found at least €25 million were channelled into fraudulent accounts (Porta, Sberna & Vannucci, 2015; Monella, 2019). The impact that this has had on the project has not been quantified temporally, but the financial disruption has delayed it completion date – possibly risking another severe flooding event within this timeframe.

Conclusion

Venice is a naturally vulnerable place as a result of its foundations and location in regard to the Adriatic Sea. Through investment and the correct countermeasures being implemented in Venice, the impacts caused by flooding events could be significantly reduced – if not eradicated.

The attempts to preserve works of art, such as St. Mark's Basilica is important to consider, as this is synonymous with Venice and the finest craftsmanship from a forgotten world. Juxtaposing this is the attitude taken by governments both before the event in corruption and during the event with little published material on how they mitigated the impacts once the storm hit.

In future, the importance placed on having reliable procedures in place will be key in reducing the death toll from 17 to 0. With the MOSE project set to be completed in 2022, the implementation of this will be crucial in reducing the damage future floods have. Despite this, if the flooding is triggered by a similarly unpredictable and unexpected storm, then the MOSE may be ineffective – especially when the impact that climate change could possibly have is factored into this.

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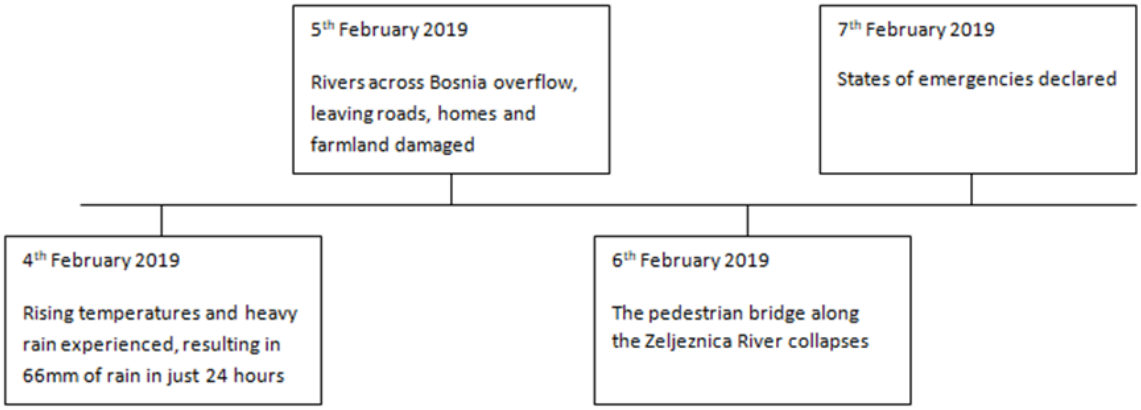
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2019 Zeljeznica River Flood, Bosnia

Amy Ellis



The Zeljeznica river flood was a natural disaster that occurred between the 4th and 7th February 2019. On the 4th February, snow melt and heavy rain caused several areas throughout Bosnia to experience flash floods. The floods led to evacuations, school closures, a bridge collapse as a result of the Zeljeznica River overflowing, and state of emergencies being declared through the worst affected areas. The bridge collapse was the largest amount of damage caused by the floods.

Background

Located in south eastern Bosnia, the Zeljeznica River joins the Mala Bosna River, a stretch of the Bosna River, near the town of Ilidza in Sarajevo, and is one of the chief geographic features of the western Sarajevo field (Revolvy, 2019).

Days before the disaster, the end of January brought large amounts of snow in Bosnia; weather that, given the time of year and the climate of the country, was to be expected. However, temperatures in the beginning of February were higher than average – in the space of 24 hours, temperatures soared from 0oC to 15oC (Aljazeera, 2019) – and the snow that had fallen started to melt, particularly in areas such as the Western Balkans (Reuters, 2019), adding to the flow and momentum of the river (Independent Balkan News Agency, 2019). This, along with 66mm of rainfall rapidly triggered the onset of floods, which led to a chain of events, as shown in Figure 1 (Floodlist, 2019).

However, this is not the only river flooding event to have affected Bosnia. In May 2014, thousands of people had to flee their homes after record amounts of rainfall turned the Sava River, located along the northern border of Bosnia, into what was described by locals as a ‘deadly torrent’, resulting in the worst floods in the country for more than a century, mainly affecting Bosnia, as well as some areas of its neighbouring country of Serbia. Over a million people were affected by the flooding, and 144 people were killed (The Guardian, 2019), but the flooding caused long term extensive damage to livelihoods, health and water and sanitation facilities (Relief Web, 2019).

Disaster

The combination of snow melt and rainfall caused flooding in residential areas within central Bosnia when tributaries of the Bosna River burst their banks, which led to the Bosnian rescue services raising security alerts and needing to evacuate hundreds of elderly residents from their homes (Associated Press, 2019). The most damage was in Ilidza, a municipality of the Bosnian capital of Sarajevo, where the overflowing Zeljeznica River burst its banks and caused a newly built pedestrian bridge to collapse, as demonstrated in Figure 2.

The new bridge connected the two settlements of Luzani and Pejton, and the entirety of the bridge was expected to collapse due to the force of the flood water and the lack of strength in the structure. Fortunately, during the bridge collapse, there were no injured persons (Associated Press, 2019). However, numerous residents expressed their concern if the Zeljeznica River breaks through the protective fence and floods the nearby settlements (Sarajevo Times, 2019).

Aftermath

As a result of the floods, states of emergencies were declared in the cities of Zenica and Kakanj, as some neighbourhoods were being compared to rivers and rescue services had to evacuate people from their houses in rubber boats. In addition, schools in the most affected areas of central Bosnia had to close for several days as a result of the threat to health and

safety caused by the excessive amounts of water (Reuters, 2019). The Chief of the Federation BiH Civil Protection Administration said that several teams consisting of 50 to 60 persons were deployed to the affected areas. In just a few hours after the flooding began, within the affected areas, and across the entire country, people experienced a "flash back" to the devastating floods of 2014, and the public began to question how much those responsible for a prompt intervention in similar situations had learnt from the floods five years prior.

Officials argued that the help to people in need was late and insufficient, with some people having to fight the raging flood water themselves until aid and rescue teams arrived. In some settlements, there were no sandbags and no machinery available to fight against the flood water. Additionally, a political quarrel in the Federation BiH Parliament had resulted in MPs not being able to agree on what had been described as an 'entity budget', which made it difficult for those who need help to receive any kind of financial aid (Independent Balkan News Agency, 2019).

Technical Assessment

Mechanisms and Causes of River Flooding

A key objective for geographers, environmentalists and meteorologists is to understand how and why river flooding occurs. From this, initiatives to mitigate the effects of river floods and plans to prevent it can then be put into action, but the first step is to question what actually causes a river to flood.

Studies that have taken place over the past 50 years have been conducted to analyse the timings of river floods across Europe, including Bosnia, and these studies have found clear patterns of changes in flood timing that can be ascribed to the effects of climate change, for example, rainfall patterns and intensities at peak times across the year that can influence and exacerbate a flood hazard (Jongman, Winsemius, Aerts & Chorus, 2015). As well as rainfall, other variations include delayed winter floods and winter storms and, in the case of the river floods in Bosnia, earlier spring snowmelt caused by unusually high temperatures (Smith, 2017).

As the global climate changes and as greenhouse gas concentrations increase also, the frequency of extreme weather events is likely to be raised (Booij, 2005). On top of this, trends in global floods have been increasingly attributed to increasing exposure due to high population growth and economic development in flood-prone areas (Jongman, Winsemius, Aerts & Chorus, 2015). With a growing population comes an increased need for residential and transport infrastructure, increasing the amount of impermeable surfaces within a settlement, resulting in increased surface runoff and decreased absorption by surface material.

Impacts of River Flooding

While global climate changes can raise the intensity and frequency of extreme natural disasters, these changes can also have serious impacts on society, and can cause enormous economic, social and environmental impacts (Booij, 2005). A significant primary impact of river flooding is the threat to personal safety given the incursion of water to normally dry areas, where escape from buildings via boats, helicopters, or other emergency vehicles is often necessary; after the Zeljeznica River floods, residents from flooded areas had to be rescued using rubber boats by rescue services.

As well as threats to personal safety, physical damage is another major impact of river flooding including damage to buildings and transport infrastructure. Repairing the damages to buildings such as houses, offices and retail spaces to a habitable standard can be a major undertaking and can take years to complete. Floodwaters can also obstruct transport systems, covering roads during flooding and causing long-term and extensive damage. In the case of the flood of the Zeljeznica River, the pedestrian bridge collapse caused disruption to the walkway along the bridge, disrupting the domestic and everyday lives of the residents who rely on it (Proverbs, 2012).

Essential services, such as electricity and water supplies can be contaminated, or even cut off, causing discomfort in addition to threats to health and safety to those affected; such threats include flooded cables and wires from appliances and possible injuries resulting from electrocution. However, in the months and years following a significant flood event, there can be longer-term impacts of flooding. These include financial hardship as a result of paying for damages or replacement of belongings if residents do not have insurance or stress-related problems such as Post Traumatic Stress Disorder (Proverbs, 2012).

The causes and mechanisms of river flooding necessitate the application of robust and accurate flood estimation systems to provide a strong basis for investments in flood protection measures to investigate the likelihood of flood events and implement mitigation and protection strategies to better manage with future flood events (Booij, 2005).

Conclusions

Preparation and Mitigation for Future River Flood Events

The role of flood defences is to reduce the risk of flooding, to protect property and to safeguard life (National Audit Office, 2001), and such defences can be permanent, for example, levees or flood walls, but they can also be temporary barriers, erected only when a flooding event is imminent (Proverbs, 2012). While it might be thought that the construction of flood defences would always reduce the losses due to

flooding this is not always the case (Smith & Tobin, 1979). Often the construction of defences allows development in what are now regarded as 'safe' areas. The result of a disastrous flood will consequently affect more property and can more than counteract the gains made by protecting the original settlement. This effect, known as the 'levee effect', means that flood defences reduce the costs due to regular anticipated flooding, but increase the flood loss burden overall unless development is prevented behind the defence (Proverbs, 2012).

In the case of the Zeljeznica River flood, the pedestrian bridge collapse caused the most damage and disruption to residents affected by the flood and the rescue services. The bridge could not withstand the force of the flood water impacting it. This, combined with flood-induced soil erosion, known as scour, and saturation caused a loss of lateral support at the bridges foundations, which resulted in its collapse (Banerjee & Ganesh Prasad, 2013).

The municipality of the Ilidza, where the Zeljeznica River is situated, is an area with a low overall flood risk (Prevention Web, 2016), and so building a flood defence, which would take a significant amount of time and money to complete, would not be the most worthwhile approach to adopt to mitigate future flood damage in the area. A suitable approach to implement would be the construction of a flood-resistant bridge that would withstand collapse should a considerable flood event occur again. Engineers in Bosnia can develop a flood-resistant bridge similar to the bridge displayed in Figure 3.

The concept for the flood-resistant bridge along the Zeljeznica River, inspired by the bridge along the River Usk in South Wales, will provide a safe route for cyclists and pedestrians, allowing easy access between the settlements either side of the river, and preserving the bridge's original use; a pedestrian bridge. The structure will mainly be comprised of timber and stainless steel, with side beams to act as a parapet, and are protected by geometric timber cladding. A hydrodynamic concrete support pier with four stainless steel arms will act as a cutwater to any flood water (Building Design, 2018), protecting the bridge itself, and the areas adjacent to it.

Will Bosnia Flood Again?

Despite the Bosnia floods of February 2019 being a relatively minor disaster compared to the floods that hit the nation five years previously in 2014, there are still sound reasons to expect that powerful floods will continue to occur in the future. More intense rainfall is likely to increase the cost of existing flood protection strategies, as well as infrastructure such as roads and drains. As important as the size and intensity of extreme events is how often they are predicted to occur, and in Bosnia, flood events are expected to occur more often; floods that were previously expected to occur once in a lifetime are now anticipated to occur every five or ten years. The condition of flood control facilities is very poor as the result of war damage, lack of regular maintenance and minefields situated close to some facilities, but one fact remains clear – if a serious flooding event were to occur in Bosnia again, the impacts and consequences would be immeasurable (Climate Change Post, 2019).

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Technical Review into Flooding in South Wales – Storm Callum

Tom Appleyard



Figure 1.0 Commercial and residential propertieswere both affected by the floodwaters (Retrieved from https://www.walesonline.co.uk/news/wales-news/storm-callum-one-week-on-15304323)

Background

The third storm to be named of the 2018/19 winter season, Storm Callum across the period of 11-13th October solicited widespread impacts across westerly regions of the UK due to resulting strong winds and heavy rainfall (Met Office, 2018).

South Wales suffered the brunt of the impact; the Brecon Beacons National Park received 100 – 150mm over the course of 48 hours and the Met Office (2018) thus determined the rain that fell over 11th-12th October was amongst the most significant and extreme rainfall / flood events to have occurred in the last 50 years specific to the region of South Wales.

Storm Callum

Forecasting and Prediction

The storm established as an Atlantic depression forced eastwards towards Ireland by a powerful jet stream and first came to the attention of the UK on 8th October when the Met Office presented a rainfall scenario map evidencing a potential of 50mm rainfall within 12 hours for areas of West Wales. Shortly after at 11:20 on the 9th October, the Met Office declared its first official warnings for the impending storm with a yellow warning for 60mm of rain due Friday 12th October between the hours of 06:00 and 23:59 (CCC, 2019)

By 10:25 on Thursday 11th October, the Met Office announced an amber warning (see Figure 1.0) for rain extended until 18:00 on Saturday 13th October.

During this period, 40-80mm of rain were forecast with a potential for 120-160mm at higher elevations. In conjunction to the rainfall predictions, a high likelihood of medium impacts was implied through the likelihood/severity chart seen in Figure 2.0.

Impacts of Storm Callum

Storm Callum had devastating impact across the UK playing a role in three separate tragedies involving an incident of a man falling into rough waters at Penarth Marina (BBC, 2018), a similar incident of another man having been swept away by turbulent seas in Brighton (Sky, 2018) and an unfortunate circumstance of a 21 year old man who died in his car when a landslide hit a road near Cwmduad, west Wales (Sky, 2018; WalesOnline, 2018). Travel disruption occurred through flooding with the severe weather affecting rail services across Wales and North and South West England with a landslip occurring on the Preston-Carlisle line bringing all Virgin trains to a halt (Express, 2018).

Localised to Wales, the amber rain warning in place until 18:00 Saturday 13th October warned of danger to life from fast-flowing or deep floodwater, flood damage to homes/businesses (see Figure 3.0), power cuts and the possibility of communities being cut-off (see Figure 1.0). The warnings actualized with the most severe impacts felt across the County of Carmarthenshire, South Wales in communities such as Johnstown and on that basis, it remains a focus of this review.

Case study of Johnstown, South Wales

Prior to the event that occurred Saturday 13th October in Johnstown involving over 19 residential dwellings inundated with floodwater, it is worth noting that Natural Resources Wales (NRW) recognise 49 flood risk assets in the area ranging from embankments or simply areas of high ground that act as flood defences (CCC, 2019). It appears that the flooding that occurred was not solely a result of the extreme rainfall event, but a malfunction of a flood defence structure.

Figure 4.0 above depicts the adverse effects from the malfunction of the embankment by highlighting the course of the floodwater. As the water left Tawelan Brook, it flowed northwards towards the road network nut most importantly commercial and residential property. An investigation has revealed that contractors for Carmenthenshire County Council (CCC) detached parts of the embankment whilst engaged in unrelated work, unbeknown to CCC (CCC, 2019). Ultimately, this modification was responsible for the flooding of the commercial and residential property along Llansteffan Road since it allowed water flow to escape the river.

A second area of Johnstown, Maes Y Dderwen, was hit by flooding as water overtopped an embankment next to the floodplain guarding residential properties. Initially, this was thought to have been caused by the rivers excessive flow however CCC (2019) suggest surface water flowing downhill could get trapped on the landward side of the defence, thus contributing towards the flooding of residential properties. In addition to that, groundwater flooding occurred throughout Johnstown due to local geology and the rivers excessive flow.

Technical Interpretation

Why was the rainfall so high?

Looking at Figure 2.0 down below which depicts total rainfall over a 48 hour period between the 11th October to the 13th October, it is clear to see the Brecon Beacons recorded the highest accumulation of rainfall with one weather station recording in excess of 200mm however 150 to 200mm was more common for that area. Areas adjacent to the Brecon Beacons such as the Black Mountains interestingly recorded 3 to 4 times less rainfall however, and this noticeable differentiation in the spatial pattern of rainfall is a result of the process orographic enhancement (Met Office, 2018).

Orographic rain enhancement occurs when flow over a mountain in humid conditions causes condensation in the form of a new cloud or can add to an already existing cloud. Because an air parcel takes longer to advect across a wider mountain this means that air parcels are more likely to remain saturated for a longer time. Consequently, this allows for more time for cloud droplets to transition into rain drops and thus fall to the earths surface. In the case of a pre-existing cloud, the process where rain accretes cloud liquid water droplets produced by orographic ascent is otherwise known as the seeder-feeder effect. This particular effect was uncovered as the mechanism behind orographic rain enhancement in the hills of South Wales in the late 1970s (Browning et al., 1975) and gives reason to the 150 – 200mm rainfall accumulations seen recorded in the Brecon Beacons during Storm Callum.

The decreased rate of rainfall experienced in neighbouring areas such as the Black Mountains can be explained by such that more precipitation falls more on windward slopes compared to leeward slopes (Ward and Robinson, 1990). In the event that leeward slopes occupy consistent prevailing winds, a ‘rain-shadow’ can be observed (Smith, 1979) which is why this area experienced 3 to 4 times as less rainfall, despite being in close proximity.

Why did flooding occur in Johnstown?

Of course, the overriding factor as to why flooding occurred in Johnstown is the prolonged period of heavy rainfall the town suffered between the 11th October to the 13th October which made its way into local watercourses. Initially, CCC thought that Johnstown was primarily affected by fluvial flooding, but the report suggests that the affect of groundwater flooding was underrepresented. Macdonald et al.,

(2008) states groundwater flooding is the emergence of groundwater at the ground surface away from perennial river channels and can also include the rising of groundwater into man-made ground infrastructure.

Figure 4.0 above highlights the area of Maes Y Dderweb, Johnstown and it is clear to see a floodplain separates the residential settlements from the river channel. Groundwater flooding was reported in this section of Johnstown (CCC, 2019) before the riverbanks were exceeded. During periods of heavy rainfall and in turn increased flow, water can still be contained within its banks whilst the low-lying ground adjacent can be flooded because of rising groundwater. This is due to the deposits of floodplains generally being permeable and therefore hydraulically well connected to the river which in turn means the groundwater level remains high and can sometimes protrude above ground surface (Macdonald et al., 2012). In the event of Johnstown, groundwater flooding occurred due to the sheer weight and volume of water in the river in combination with the local geology.

In summary, the flooding that occurred in Johnstown was a result of a number of factors but it is clear to say that the prolonged 48 hour period of rainfall between the 11th and the 13th October brought devastating impacts not just in Johnstown but across the whole of South Wales.

Vulnerability of an affected community, Johnstown, South Wales

In this section the vulnerability of Johnstown, a small community in Carmarthenshire, will be assessed by looking at the existing flood risk/warning approaches in the area. Johnstown was one of the worst areas to be affected by Storm Callum with 19 residential dwellings flooded internally with many more businesses and dwellings affected externally. Road systems in the area were also significantly affected (CCC, 2019)

A 'Flood Alert' is declared by Natural Resources Wales (NRW) prior to any flooding and indicates businesses and residents to start preparing as flooding is a possibility. This was declared at 13:56 Friday 12th October 2018 followed by a 'Flood Warning' at 15:22 on Saturday 13th October suggesting immediate action is required as flooding is impending (CCC, 2019). NRW have four flood codes to use appropriately and can be seen in Figure 3.0 down below. In terms of assessing the vulnerability of the community, 134 properties are eligible to receive warnings identified within the Johnston flood warning area, however only 75% of properties are fully registered to receive such warnings. This not only highlights vulnerable properties but brings to surface rooms for improvement.

As previously mentioned, the tampering of the flood bank by CCC contractors was a critical determinant when it came to residential and commercial properties in the Johnstown recreation area being affected by the extreme weather event and the flood bank has since been repaired. However, questions can be raised in any urban area on a floodplain, where a cycle can develop in which attempts to protect property through flood defences, actually increases further risk of flooding through removing storage areas and thus rising flood levels, which in turn demands more functional flood defences (Macdonald et al., 2012). A shift from trying to remove flooding towards working more with natural processes to minimize the risk of flooding is worth thinking about in the case of Johnstown (Fleming, 2002).

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Luxembourg Storm – August 2019

Emilia Arden



Figure 1, Photograph of damage in Luxembourg (Image: PIERRICK BOURGEOIS via REUTERS) (Mirror, 2019)

The Event

Introduction

The Luxembourg storm took place on the 9th August 2019 at 3:35pm, mainly affecting the South West of the country (European Severe Weather Database, 2019). It left 19 people injured, with 2 of them enduring more significant injuries (The Telegraph, 2019: Deutsche Welle, 2019). Strong winds and heavy rain affected not only Luxembourg, but also parts of The Netherlands, Germany and France (The Telegraph, 2019: Aljazeera, 2019). The police in Luxembourg described the storm as a "swath of desolation" which reached up to around 6 kilometres in height (Aljazeera, 2019).

Background

Luxembourg is a small landlocked country in the middle of Europe with a population of 600,000, neighbouring Germany, Belgium and France, making it quite unusual for such a damaging storm to occur

(Wesner Childs, 2019). Figure 1 shows where Luxembourg is situated within Europe with the surrounding countries that were also affected.

The climate in Luxembourg is temperate, resulting in seasonal changes throughout the year. The months of April to September in Luxembourg are the months which have the least rainfall, with an annual average precipitation of 800mm (Weather Online, 2019). The drainage infrastructure in Luxembourg is built to withstand high amounts of precipitation. However, the storm in August carried so much rain to Northern Luxembourg that the streets flooded from the drain covers bursting out of place (RTL Today (a), 2019).

Disaster

The European storm that occurred on the afternoon of 9th August 2019 had major effects on Luxembourg, where nineteen people were injured, two of them sustaining serious injuries (The Telegraph, 2019: Deutsche Welle, 2019). The areas in Luxembourg which experienced the most damage, were in the South West of the country (RTL Today (a), 2019), as shown in Figure 2. The initial Government press release said Kaerjeng was the province with the most reported damage, where seven people were injured in the collapse of a supermarket in Bascharage, seen in the highlighted area of Figure 2 (RTL Today (a), 2019).

The Telegraph, (2019) reported the day after the storm on August 10th that around 100 homes in Kaerjeng have been damaged and left unhabitable. A more recent and reliable update (August 12th) from two news reports in 'RTL Today (a)' (2019) and 'Deutsche Welle', (2019) claim that around 160 homes had been damaged across the Kaerjeng province, with severe damage in the towns of Bascharage and Pétang where 30 houses have had their roofs blown off by extremely strong winds. The meteorological office reported that the fierce winds reached up 80 miles per hour (mph) (The Telegraph, 2019: Deutsche Welle, 2019). Eastern France saw similar impacts from the storm with roofs being destroyed and blown from houses, as well as multiple cars getting damaged from being hurled by the strong gales (The Telegraph, 2019). Figure 3 shows a photograph taken in Luxembourg of the damage on cars, houses missing roofs and debris on the street, providing an insight into how powerful the storm was and suggests how unprepared Luxembourg are for such high impact storms.

The 80mph wind tore down 4 power poles, meaning there was an electricity power failure (The Telegraph, 2019: RTL Today (b), 2019). To prevent any fires occurring from exposed damaged power lines, the fire service turned off the electricity in certain areas to keep people safe. If any fires had occurred due to the bare power lines, it may have caused a lot more devastation in the towns where this storm had the largest effects (The Telegraph, 2019).

Aftermath

On Friday 9th August, a yellow weather alert was originally announced by Meteolux at 5pm when the storm was predicted, to give an indication about the storm approaching. However, this warning was raised to an orange alert shortly after to warn the population of the impending storm (RTL Today (a), 2019). This weather alert may have prompted a number of residents to evacuate their homes and move into a safer area. The night that the storm occurred, a report from a national newspaper claims that over 200 firefighters and 40 police officers were deployed to help rescue the trapped or injured locals, and to begin the clear up (RTL Today (b), 2019).

Luxembourg's rescue centre said that the clean-up of the event would take days (Aljazeera, 2019: RTL Today (b), 2019). The local authorities declared that the clean-up of the event would prioritise certain areas first, including important roads and larger streets, to ensure there were easy access routes to the areas that may have needed it the most (RTL Today (b), 2019).

In response to the storm, the Government set up a crisis unit which included the fire service, the army and the police, to help begin with the clear up of the damage, and to assist people to safety if they were still in danger (The Telegraph, 2019: RTL Today (a), 2019).

Emergency shelters were set up to provide a safe, dry space for people whose houses were damaged and could not be lived in or returned to (Deutsche Welle, 2019). The main responses were focused around the two most damaged provinces, Bascharage and Pétange. Information provided at a press conference discussing the storm claimed that the government were going to organise a meeting for the residents of both of these places so that they could be provided with the information they require about their homes and the clear-up of their towns. The meeting took place in Pétange and residents were provided a bus from Bascharage to ensure they could all go, due to unstable and damaged roads (RTL Today (b), 2019).

Technical Analysis

As storms are mainly detected by satellite images, it has recently become a lot simpler to predict where storms may hit more accurately. Nevertheless, there are still issues with satellite tracking because it does not provide information on the intensity of the winds or rain (Elsberry, 2014).

Thunderstorms are fuelled when warm, moist air rises from the sea and reacts with cooler air higher in the atmosphere (Rahmstorf et al, 2018). The moisture condenses into clouds which is how precipitation is formed and released. The cooler air sinks towards the Earth's surface, resulting in strong winds being formed, creating a potentially fatal storm (Krider, 2016). Ocean temperatures play a key part in defining

the strength of a hurricane, as well as the vertical wind shear (VWS), which is important in keeping hurricanes from attaining or maintaining their potential strength (Shultz et al, 2018). One report says that the smooth surface of the water may have helped intensify the Luxembourg storm's rotation, therefore allowing it to build up most of its strength (The Washington Post, 2019).

The wind speed of a thunderstorm can typically range from 0-70mph (Davies-Jones, 2014). Once a thunderstorm generates winds that are faster than 58mph, the storm is considered a tornado (Davies-Jones, 2014). Therefore, as the winds in this storm reached up to 80mph, it was classed as a tornado. Davies-Jones, (2014), claims that in temperate climates, such as Luxembourg, any thunderstorms that occur will bring the same amount of rainfall that the country usually sees annually.

The Luxembourg storm in 2019 was formed from a cold front which moved across Europe as a thunderstorm, which then generated the tornado over land (Wesner Childs, 2019). According to accounts reported in The Washington Post (2019), the funnel of the tornado seemed to diffuse as it moved onto the land, compared to the size of it while above the water. Typically, this is usual for a storm which suggests the Luxembourg storm formation was conventional to other storms.

Tornados and storms in Europe are not very frequent; according to Aljazeera (2019), around 200 to 400 storms in the continent are reported annually. Wesner Childs (2019), claims that August is the second most frequent month for Europe to experience tornadoes, however this information may not be fully accurate because some information from this source is not backed up with a valid reference.

According to a study conducted by Rahmstorf et al, (2018), it is still highly debated whether climate change will alter the number of tornadoes and storms in the future. However, there seems to be more evidence to suggest that tornadoes will increase. A meteorologist that works for 'Weather Underground', claimed that European tornado observations have become more frequent and consistent in recent years (Wesner-Childs, 2019). The European Severe Weather Database carried out a study in 2014 that showed an average of 300-400 tornadoes per annum since dependable records began in 2006 (Wesner Childs, 2019). However, a more recent separate study in 2015 was conducted which suggested the opposite and unexpected, that over the last 10 years, climate model findings indicate that a warming climate will not increase the number of tornadoes (Walsh, 2015, within Tory et al, 2018).

Figure 4 shows the amount of economic damage caused by climate-related and extreme weather events in Europe from 1980 to 2017. As seen in the figure, European meteorological events in 2017 built up an extreme bill of over €5 billion. This graph does not provide any clear patterns across the many years that shows that climate change may be increasing or decreasing the number of meteorological events that are occurring. However, this may be due to countries becoming more aware of these events and therefore plan accordingly to mitigate the impacts. Early-warning systems are a key involvement in reducing economical damage as countries know when to expect a meteorological event and therefore can evacuate and make sufficient plans. For example, in the Netherlands, after they were affected by a storm in 1990, they made changes to building codes (Dorland et al, 1999). This may be an explanation as to why they did not suffer as much when the Luxembourg tornado hit Amsterdam.

Vulnerability, response and impact

Preparedness is an important factor when assessing vulnerability, response and impacts. Considering Luxembourg has a low vulnerability and risk of tornadoes, the government response seemed practical to ensure the safety of their citizens. The economic, social and environmental impact from this storm will have been high, but no data has yet been provided to show the scale of damage. As a fairly wealthy European country, Luxembourg had precautionary measures in place such as early-warning systems which helps with the preparation of facing a storm (Dorland et al, 1999). The early-warning system should have prompted the government to evacuate as many residents as possible in the most effected predicted areas. On the other hand, the early-warning system worked well as residents were made aware and told to remain inside, which reduces death and injury rates (Shultz et al, 2018).

Luxembourg have a low number of reported tornadoes per year and therefore have a low potential for future risk. Nevertheless, with temperatures increasing due to climate change, tornadoes are likely to increase as the ocean is warming and rising, meaning that future risk is uncertain, but likely to be higher than it currently stands.

To conclude, Luxembourg responded well after the disaster hit by moving people to safety in emergency accommodation and by deploying the army and police to help rescue and begin the clear-up. The impacts felt within the community were high, with injuries, damaged homes and cars. These could have been reduced if Luxembourg were more prepared for such an event to happen by improving building regulations and upgrading drainage systems to cope with the high level of rainfall. To prepare for the next time, Luxembourg should look at current and future predicted climate trends to address the necessary changes that would need to be made to lessen the impact the next tornado.

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Flooding in Italy- October 2018

Amber Bentley

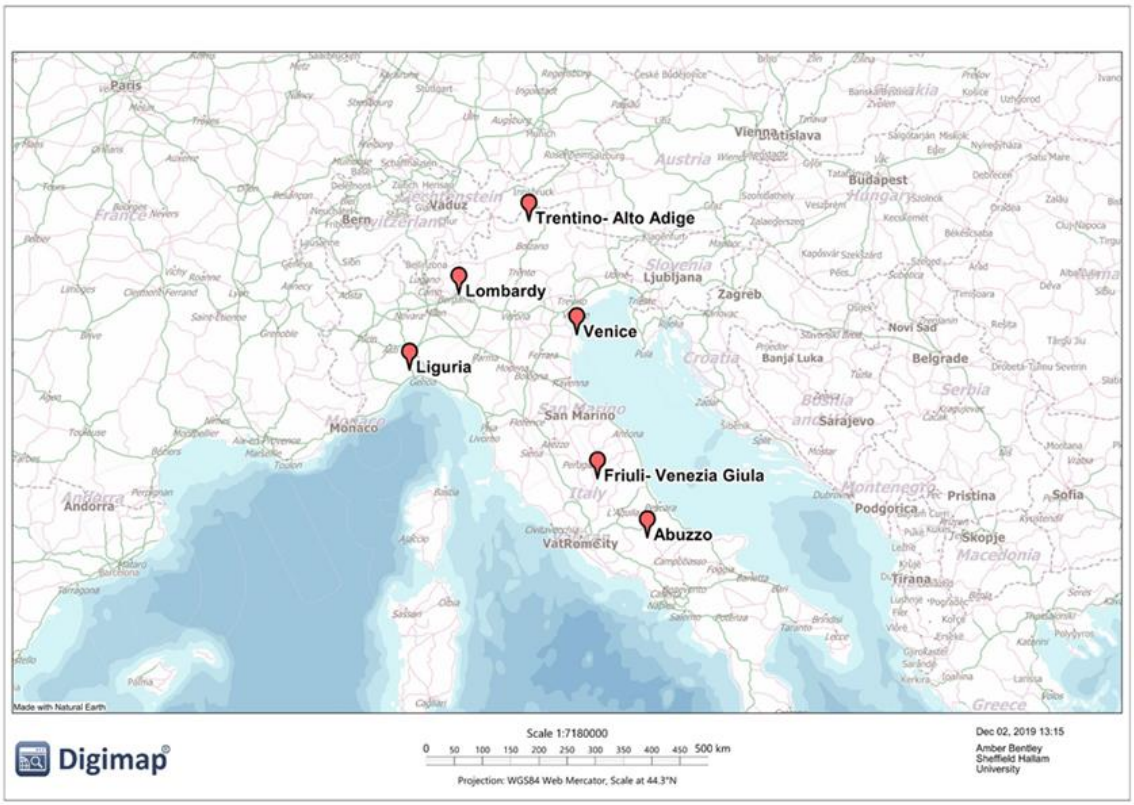


Figure 1- Map showing the areas worst effected by flooding following the storm (Digimap, 2019)

Authoritative Account-

Background-

Floods pose a significant risk to society and have severe economic impacts, 70 million people are exposed to flooding worldwide each year (UNDP, 2004; UN, 2011). Italy shares the Mediterranean basin with France and Spain which are frequently subjected to flooding (Llasat, 2010). Flooding in the Mediterranean basin is associated with warm humid air coming in at low levels from the sea during autumn, in many cases a low cyclonic pressure system is involved (Fioriet et al., 2014).

The complex topography of Italy acts as a catalyst to severe weather events as it favours instability and the formation of mesoscale structures such as orographic dipoles which intensify cyclogenesis processes (Cabaleri et al., 2019). Mediterranean river hydrology is influenced by seasonal variation of precipitation (Thrones et al., 2009), the river regime is characterised by maximum discharge in autumn and winter (Parde, 1950). Within this particular case of an extreme hydrological event, the magnitude of the hydrological cycle was significantly above mean average which resulted in flooding across Italy.

The Event-

The storm that began on the 29th of October 2018 was an explosive cyclogenesis, which resulted in Italy being disrupted by flooding through to the 1st of November. The nation saw winds speeds up to 112mph (BBC ,2018; Guardian, 2018; Floodlist, 2018) which disrupted social, economic and environmental systems. Six regions of Italy were put on red alert as torrential rain and strong winds increased river levels, storm surges and risks of landslides (Floodlist, 2018). These areas include Lombardy, Venice, Friuli- Venezia Giula, Liguria, Trentino- Alto Adige and Abruzzo which are located in figure 1.

Social Impacts-

This exceptional flood event killed 11 people (BBC, 2018; Guardian, 2018) however it has been reported up to 30 people died from additional implications (CNN, 2018). Land sliding caused a man's body to be found 8km away from his car without limbs and clothes (Palermo, 2018) suggesting he was thrown about drastically within the mud highlighting the severity and extent of the landslide. Schools in all regions that were put on red alert were forced to close (Floodlist, 2018; Sky News,2018) therefore many

children missed out on education. Road and transport infrastructure collapsed which disrupted daily lives due to roads being closed or inaccessible, therefore many people were not able to work during the flood event. However, rescue attempts were not affected due to drones and forces specialising in topography and disaster events (Lastampa, 2018; Palermo, 2018). This resulted in death toll being low compared to the severity of the events. Power disruptions occurred as 200 diesel generators were activated (BBC, 2018) but were not always constant leaving some people without power. Italy is behind other developed countries, as the insurance penetration for non-life insurance in 2016 is approximately 1.9% of GDP for Italy, lower than both France (3.4%), Germany (3.3%) and Belgium (2.8%) (ANIA, 2017). Most insurance for natural hazards only covers industrial and commercial buildings with less than 0.5% of houses have insurance (Flood services, 2018). Therefore, many people who were evacuated due to their homes being at risk must repair and restore their homes from personal finances. It is important to highlight due to lack of insurance and disproportional adaptive capacity not everyone effected will be able to return to their home.

In the town of Casteldaccia a family of 9 lost their lives as the Milicia river engulfed their home (Guardian, 2018). This fatality highlights the issue of illegal housing in Italy as the home was ordered to be demolished two year prior to the flooding event (Guardian, 2018) due to being in a high-risk zone. There are 1.2 million illegal homes in Italy which are built close to riverbanks and foothills which exposes them to flooding and landslides (Guardian,2018). There is a need for the illegal housing crisis to be dealt with as these people are the most vulnerable to the effects of flooding which will only become more frequent with climate change (Arnell & Gosling, 2016). Despite this, only 20% of demolition orders were carried out between 2004-2018 (Guardian, 2018).

Economic Impacts-

Many properties were damaged and are in critical condition. 20 million buildings were affected, and the great emergency fund will be used to repair conditions (BBC, 2018). However, the buildings that will be repaired will be critical infrastructure, commercial and industrial buildings leaving residential repair up to the homeowner. The worst damage was seen in the northern regions of Italy, where damage is estimated to be 20 million euros alone (CNN, 2018). Along the Ligurian coast waves up to 10m hit the marina destroying private yachts (BBC, 2018; ANSA, 2018; Wunderground, 2018) which is shown in figure 2. The previous sea wall protecting the yachts was destroyed during flooding in 2000 (Wunderground,2018) highlighting the frequency of flooding in Italy. Landslides blocked roads (BBC,2019) which disrupted the flow of goods and people therefore reducing economic activity throughout the duration of the flood. The largest association of farmers, Coldiretti, said farming fields were severely damaged considerably in the northern regions (EFE,2018); this may have led to short increases in food prices and increasing import.

Venice saw significant damage during the flooding episode. 75% of Venice was underwater and sea level was 156cm which is the 4th highest ever recorded (BBC, 2018; Guardian, 2018; CNN, 2018; Sky news, 2018) which is highlighted in figure 3. Many of the main squares in Venice were underwater and this disrupted tourism which is a significant economic income in the city which receives 25 million tourists annually (Guardian, 2019; BBC,2018; Guardian, 2018). The extent of the disruption is evident in figure 4. The basilica's mosaic floors were covered in 90cm of water, (Guardian, 2018). The historic and iconic landmark aged 20 years in just two days which is a significant loss of cultural history and tourism in Italy (BBC, 2018). The damage to Venice could have been avoided as the project MOSES involves the construction of flood gates which will protect the city up to a 200cm high surge was meant to finish in 2011 (la stampa, 2018; Wunderground, 2018). However, the project has been hindered due to corruption, completion is now intended for 2022 (Wunderground,2018; Fortune, 2018). The gates will lie flat on the seafloor and will be raised when tide is above 110cm in a thirty-minute process so will protect the city from future surges (Wunderground, 2018).

Environmental Impacts-

Some environmental impacts were seen across Italy. As 350m³ of water was discharged into lake Garda as a prevention method to stop the city of Verona from flooding (BBC, 2018). However, mud and river debris entered the river therefore the water quality is now questionable which has the potential to effect river ecology. Due to winds up to 112mph, (BBC ,2018; Guardian, 2018; Floodlist, 2018) 14 million pine trees and red spruces in the Dolomites were uprooted during the high winds (Italy magazine, 2018; flood services, 2018). 50,000 hectares of forests in Veneto, Trentino and Friuli Venezia Giulia were destroyed in one night (Italy magazine, 2018) which will take a century to return to the original state. This is fatal to the ecosystems that the forests were supporting, biodiversity will decrease, and hydrological systems will be affected which may further increase the risk of landslides and flooding. The flooding and saturation of the ground aided many landslides across the nation which caused fatalities.

Technical Interpretation-

Characterisation of The Area-

The Adriatic Sea is a long and narrow basin. Within the basin two strong winds are present: Bora and Sirocco which both have the potential to be strong but

are limited by fetch (Cabaleri et al, 2019). The sirocco wind is responsible for the surges that Venice faced in October 2018, which is associated with warm air and low pressure (Cabaleri et al., 2019). The astronomical tide is at the front of Venice where two seiches dominates the basin. There is an 11-hour seiche within the centre of the basin and a 22-hour seiche in the south of the basin (Bajo et al., 2019). The shallow bathymetry which reaches as low as 20m near the coast of Venice (Figure 7), astronomical tides and the sirocco winds led to the strong enhancement of the storm surge that hit Venice which is represented in figure 8.

Meteorological Evolution of The Storm-

The storm that brought intense flooding and strong winds across Italy in October 2018 was an explosive cyclogenesis following a cold input from the gulf of lion (Cabaleri et al., 2019). It was this interaction of the cold inflow of air with the warm moist marine boundary that trigged an explosive cyclogenesis with a central pressure of 985pa. The events are demonstrated in figure 7 that led to flooding across Italy in October 2018. The cyclone, which is represent as A in figure 7, rapidly moved northwards. The low south easterly winds within the Tyrrhenian Sea (B) were compressed within the Apennines mountain range which combined with winds within the Adriatic Sea (C). This led to strong winds in both the Adriatic Sea and Ligurian sea. This was followed by a violent cold air (D) which forced winds over the eastern Alps. The combined effects of the weather led to strong surges, heavy precipitation across Italy and wind speeds up to 112mph in the Alps (Cabaleri et al., 2019).

Land Subsistence-

The Adriatic coastline has notably seen land subsistence due to an integration of anthropogenic causes and sea level rise (Carbognin & Tosi, 2005). Land subsistence is linked to long term vertical movement in land elevation. The most concerning effect from land subsidence is the change in coastal morpho-dynamics leading to increased intensity of storm surges. A century long study was conducted which concluded that, excluding land subsistence, sea level increased by 1.13mm per year between 1896-1993 (Carbogina & Taroni, 1996). This will only be intensified due to rising climatic temperatures causing the retreat of ice sheets and thermal expansion, causing variations in mass and volume of the ocean (Bamber & Aspinall, 2013; Bindoff et al., 2007). Anthropogenic causes of land subsidence derived from the removal of water from subsurface aquifers (Carbognin & Tosi, 2005). The maximum fluid extraction was during the 1970's, when there was a huge demand for agriculture and industry. Extraction has significantly decreased due to controls; however, the change in land is irreversible (Carbognin & Tosi, 2005). This increases the Adriatic coastlines subjectivity to storm surges like the October 2018 event.

Conclusion-

It is evident through the analysis of the events during October 2018 that vulnerability to extreme weather events and flooding in Italy is not uniform. The illegal housing crisis forces people to live in marginal condition, such as flood plains and foothills, making them more vulnerable to flooding and landslides by increasing their exposure. It is evident that the Italian government could be implementing housing legislation more thoroughly, as only 20% of demolishment orders of illegal housing took place between 2004-2018 (Guardian, 2018).This may would have had the potential to reduce deaths and loss of livelihood to citizens with limited adaptive capacity during the event in October 2018. Overall emergency responses were good due to task forces specialising in disaster relief (Lastampa, 2018; Palermo, 2018), therefore impacts and death tolls were low considering the severity of the event. However, secondary responses could be improved due lack of insurance provided for residential buildings which only consists of 1.9% of Italian GDP (ANIA, 2017). This further separate those who are vulnerable from those who are not due to financial adaptive capacity to relocate or restore houses that are damaged through events like the one seen in October 2018. Insurance should be reconsidered in the future as floods and extreme weather events will only increase due to climate change through changes in precipitation patterns, melting of alpine glaciers and sea level rise (Bindoff et al., 2007; Arnell & Gosling, 2016; Zemp et al, 2006). Therefore, an increase in the Italian population effected by these events will occur.

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Greek wildfires in the period 1st October 2018 to 30th September 3019

Samuel Chorley



Figure 1 – Satellite imagery (Sentinel Hub, 2019) of southern mainland Greece displaying the smoke cloud created from the wildfire on the island of Evia. Taken 13/08/2019.

Introduction

Greece as a country is situated in south eastern Europe on the northern coast of the Mediterranean (Figure 1). The county is comprised of over 200 inhabited islands, with the largest island being Create to the south (Wikipedia, 2019). The country comprises of an area of about 130.875km2, with that land being designated as 50% forests and 80% as mountains (Kassomenos, 2010). The population of Greece is around 10.7 million people with the largest city, and the capital, being Athens (Wikipedia, 2019). The climate within Greece is like many other Mediterranean countries, whereby there are mild damp winters, and hot dry summers (Kassomenos, 2010).

Wildfire Events

Wildfire events that took place in Greece during the defined period (1st October 2018 - 30th September 2019), were mainly concentrated to the summer months of 2019. Notably August. The largest wildfires to take place during the summer occurred on the islands of Evia, Samos, and Thassos (BBC News, 2019). Other smaller fires were also reported on the islands of Zakynthos, and Corfu (Hadoulis, 2019) (Figure 1). The main cause of the wildfires was due to the climatic conditions, arsonists, and human negligence such as not discarding of cigarette ends properly (Bresler, 2019). As a result, at the height of the wildfires over 700 firefighters were deployed in one 24-hour period (Jackson, 2019). Due to the wildfires many people, which included locals and tourists, were evacuated from their homes and hotels.

The main cause of the wildfires in Greece was due to the climatic conditions at the time. Leading up to the events, Greece had experienced consistently dry conditions. With temperatures often reaching 40°c. This coupled with gale-force winds, created near perfect conditions for wildfires to take hold (Hadoulis, 2019).

However, it is not unusual for wildfires to occur in the summer months. As a result, there is a nation-wide ban on the creation of fire during these months. Due to the high chance of wildfires occurring, the British Government issued a statement to tourists in the area

to be aware of the dangers, and to follow any advice issued by the Greek government (Smithers, 2019).

Evia Wildfire

One of the largest wildfires to affect Greece during the summer months took place on the island of Evia. The wildfire began on the 13th August 2019 and was located at the 550-hectare Agrilitsa wildlife sanctuary, and surrounding pine tree forests (Hadoulis, 2019). The reserve is listed as part of the "Natura 2000". A European network that protects areas and habits of high interest (European Commission, 2019) . The fire was described by acting regional governor Kostas Bakoyannis as "a huge ecological disaster" (BBC News, 2019).

The fire was reportedly to have begun at around 3am local time on Tuesday 13th August (Al Jazeera, 2019). Al Jazeera (2019) reports that the fire began at the side of a road, raising the prospect that arsonists were involved. Due to weather conditions, the fire quickly spread into the nature reserve and surrounding pine forests (Wired Services, 2019). At the wildfires peak, flames were reported by a volunteer firefighter to be "20-30 meters high" and the heat could be felt from "250 meters away" (Wired Services, 2019). The extreme heat and smoke from the wildfire were captured via satellite from space (Figures 1 and 2). As a result of the wind direction, smoke eventually reached the capital Athens(Wired Services, 2019). Some 110 kilometres to the West (Maltezou, Papadimas, Georgiopoulos, & Kambas, 2019). By Wednesday the wildfire was contained to a gorge near the town of Platania (Ismailai, 2019). With the fire eventually extinguished on Thursday evening (Prensa Latina, 2019).

Response

Greek Prime Minister Kyriakos Mitsotakis, who was on holiday at the time, flew back to coordinate response efforts with the European Union (Ismailai, 2019). In response to the wildfire, more than 200 firefighters attended the scene (Al Jazeera, 2019). Along with 12 waterbombing planes, 9 helicopters and almost 100 fire vehicles were also involved (Hadoulis, 2019). A request was also submitted to the EU Civil Protection Organisation by The Greek Civil Protection Force for further assistance, with Italy then sending two aircraft and Spain sending one to aid efforts (Ismailai, 2019).

A state of emergency was declared on the island, with the four villages being evacuated as a precaution. (Maltezou et al., 2019). Over 500 people were evacuated from the villages as well as the local monastery (Al Jazeera, 2019). Efforts to extinguish were hampered due to the difficult terrain, poor air quality at the time and gale force winds (Wired Services, 2019). The fire was prevented from reaching a fourth town, Platania. People in Athens were told to stay indoors and to keep air conditioning to use internal air only, with the elderly, young, and people with breathing difficulties to take extra care (Wired Services, 2019).

Damage

As a result of the wildfire, state television in Greece stated that over 28,000 hectares of forest had been burnt down (Ismailai, 2019), with figure 4 and 5 displaying the extent of the fire. Caught up in the wildfire was a local resident who told state tv, TV ERT, that his shed had burnt down (Hadoulis, 2019). Other than one firefighter sustaining burns, there had been no reports of other injuries that required hospital treatment (Hadoulis, 2019). There is also a huge ecological impact as well as regional governor Kostas Bakoyannis stated (BBC News, 2019).

Samos Wildfire

The island of Samos was also severely affected by a wildfire that began over the weekend of the 24th August 2019 (Sakelaris, 2019). Jackson (2019) notes that Samos was one of the worst islands affect during the summer months of 2019. Around 1000 people had to be evacuated from hotels and homes in the town of Pythagoreio (Sakelaris, 2019). With those that were evacuated to a nearby stadium (Associated Press, 2019) . Around 56 firefighters and 25 vehicles were sent to control the fire (Ekathimerini, 2019). By the 26th August the fire had been brought under control, with the evacuated being able to return to their homes and hotels (Sakelaris, 2019).

Technical Interpretations

Like many other Mediterranean countries, Greece experiences numerous wildfires during the summer months. Historically, wildfires are part of a natural cycle within the environment that are caused by other natural phenomenon such as lightning strikes or volcanic eruptions (Keller, DeVecchio, Duane E. (Duane Edward), & Blodgett, 2016). They are often also attributed to anomalous high surface temperatures, low humidity, strong winds and extreme droughts (Papadopoulos, Paschalidou, Kassomenos, & McGregor, 2013).

The occurrence of wildfires is an integral part of the ecosystem as it allows rapid decomposition of vegetation. This rapid decomposition of vegetation enriches the soil which allows surviving and new species to thrive, along with the attraction of new animal populations (Keller et al., 2016). Keller et al. (2016) points out that many plant species, such as aspen, are adapted to cope with the prospect of wildfires and have evolved to take advantage of them. With many species requiring wildfires for reproduction. However, over the last century, wildfires are becoming increasingly common due to climate change and anthropogenic encroachment on the environment (Ríos-Pena, Kneib, Cadarso-Suárez, & Marey-Pérez, 2017). Kassomenos (2010) notes that

Greece from the 1970s onwards has been experiencing more intense and frequent wildfires.

Climate and Weather

It could be argued that climate change is the biggest contributor to the increase of wildfire events around the world and in Greece. SCHOENNAGEL, VEBLEN, & ROMME, (2004) points out that sustained dryer climatic conditions, with some precipitation, is having a greater impact on the likelihood of wildfires compared to shorter intense weather that may only last several days. This longer period of hot, dry weather creates conditions where the moisture content within the vegetation is sustained at low enough levels to allow for easy combustion (Keller et al., 2016). Schoennagel et al. (2004) notes that a sustained period without precipitation of 40 days or longer produces conditions that enables intense wildfires. With these longer periods becoming more apparent due to climate change. Within Schoennagel et al. (2004) section "high-severity fire regimes" it is noted that once vegetation moisture levels reached a critical level, wildfires were controlled by weather conditions such as wind direction and velocity, not the availability of fuel sources.

Strong winds have a considerable impact in the intensity of wildfires as it allows embers from the wildfire to be carried a greater distance, with it also preheating surrounding vegetation (Keller et al., 2016). Within Greece, Kassomenos (2010) discusses that 70%-90% of wildfires are caused by three main weather patterns. The first of these weather patterns being an increase in pressure gradient in the Aegean Sea and a low-pressure system over Greece. The second, low pressure being replaced by high pressure.

With the third weather conditions being anticyclonic, involving high temperatures, low humidity and a persistent wind. With the wildfires on the island of Evia and Samos being fuelled by the third weather pattern.

Human fire suppression

One of the main issues with human encroachment on the environment is the suppression of naturally occurring wildfires, and build-up of unnatural amounts of fuel sources (SCHOENNAGEL et al., 2004). A wildfire taking its natural course allows the destruction of vegetation which in turn keeps a check and balance on the availability of vegetation that can therefore be used as fuel. Schoennagel et al. (2004) discusses how fire suppression results fire-intolerant trees establishing during long periods without wildfires. These flammable trees then allow the wildfire to spread into the canopy of the taller indigenous fire-resistant trees by a "ladder" effect. Essentially this is where the wildfire uses the smaller trees to "climb" up into the canopy. These smaller trees also make the forest denser allowing the wildfire to spread more easily (SCHOENNAGEL et al., 2004). Taller indigenous trees are adapted well to resist wildfire at ground level as they often have thick bark to protect them.

Conclusion

Response of impacted communities

The main response to the wildfires that took place was with the use of firefighters, water and water bombing aircraft. As wildfires are a regular occurrence, Greece was able to act fast with over 700 firefighters being deployed during the wildfires (Jackson, 2019). There were also evacuations of towns and villages made when necessary which in turn resulted in no reported deaths. Only minor burns and injuries were sustained by firefighters (Hadoulis, 2019). The government also requested assistance from the European Union (Ismailai, 2019) when they decided that more assistance was required. As a result, this then shows that Greece has strong procedures and plans well thought out to cope with the wildfires that took place.

Potential future Risks

As population centres within Greece expand, they are increasingly likely to encounter areas that are prone to wildfires. Mitsopoulos, Mallinis, & Arianoutsou (2015) notes that as early as early as 1981 the risks surrounding rural and urban overlap became apparent, when a wildfire destroyed houses in northern Athens. Human activity within these areas increases the risk further with easily combustible materials readily available. If conditions are favourable it could see wildfires spreading from rural areas and devastating large urban centres such as Athens. Large wildfires such as on the island of Evia also pose a risk to populations that are located far away from the actual event. If the correct conditions occur, smoke can travel long distances downwind. With wildfires becoming more prominent due to climate change these population centres could regularly see smoke blanketing them. With wildfires seeming to become more prominent and aggressive within Greece it is only a matter of time before a major incident takes place. Greece may have well thought out procedures currently, but they may become less effective as wildfires increase in intensity. As Greece is largely made up of islands, it may become apparent in the future where resources from the mainland may take a long time to reach them. Delaying the response to tackle the wildfire and result in higher deaths.

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Extreme rainfall in South East Spain

Jon Fell



Figure 3 shows the flooded Rio Almanzora on 13/09/2019 (left image). The river channel is estimated at 30 metres wide. This channel is normally dry but extreme, rapid rainfall has quickly forced the channel to exceed its banks at various locations. Long periods of little rainfall over the summer period enabled the riverbed to be extremely dry and therefore the ground was impermeable due to decreased porosity (Photo – Authors own).

Introduction

This report discusses a variety of issues relating to the flooding across South East Spain in September 2019. During dramatic levels of rainfall, several regions of Spain (figure 1) were heavily affected by significant flooding. Through this, several people lost their lives, many people were injured and substantial damage to property and infrastructure occurred, costing a considerable amount of financial need (Proverbs et al., 2011).

The report will firstly introduce geography of the area affected itself before moving on to explain the natural hazard that occurred, explaining the conditions that caused the level of flooding recorded. From this, a discussion on the various impacts of the hazard will be considered and research into the preparedness of the places and people affected for this level of dislodgement will be undertaken. This will be from a macro to micro level, considering the state, city, rural community and individual preparations made by the groups affected, of which a focus will relate to a localised case study of the small town of Purchena, Almeria (Bodoque, et al., 2016).

Overall a summation of why the natural hazard occurred and created so much damage will be undertaken. Examining the level of preparation and response taken by local officials and the wider civilian population will assist in understanding the full effects of the natural hazard.

Geography of the region

South East Spain constitutes of the following regions – Andalusia (South-Most), Valencia (East-Most) and Murcia (Between these regions). Known as Autonomous communities, these regions have several key cities within such as Seville, Valencia and Murcia (figure 1). These regions have a range of climates, relating to their locality; coastal locations have increased variety in the weather experienced due to their closeness to the Mediterranean (Lloyd, n.d.). Many coastal locations remain cooler than their inland counterparts due to the cooling of the sea. This changes from August, where an increase in

temperature of the Mediterranean assists in warming coastal locations.

Locations within the mountain and desert regions experience a much smaller range of weather. Typically, the south of Spain has dry, hot summers. Little rain occurs in this time and therefore the land becomes hard and impenetrable to any precipitation. At the time of the torrential rainfall, the soil was dry and therefore precipitation was unable to easily infiltrate the soil. Most of South East Spain is considered a semi-arid climate (Climate Data, 2019; Grotzinger & Jordan, 2014; figure 2). These are areas defined as having precipitation over precipitation evapotranspiration (P/PET) between 0.2–0.5 (UNEP, 2019).

Account of the event

After a long period of warm, dry weather, the regions of Valencia, Murcia and Andalusia, all situated in the South East of Spain were affected by high pressure, resulting in heavy rain during September (Muriset, 2019). On the 11th, dramatic rainfall occurred, mostly between the cities of Murcia and Valencia (FloodList, 2019a). The State Meteorological Agency of Spain issued several warnings for these regions (FloodList, 2019b; AEMET, 2019). Already some deaths had been recorded, with three people losing their lives (FloodList, 2019a). In response to this, beyond the standard preparations made, the Spanish Government issued the Spanish Army to assist in the emergency.

Reported by FloodList (2019a), over 1000 military personel were brought in to affected regions. The response included evacuating several areas and over 3500 people, while many facilities and businesses were closed during the crisis. As of the 13th of September 2019, a variety of news reports summarised the impact of the extreme flooding (The National Es, 2019). A total of six people lost their lives as a result of the flooding (Jones, 2019; BBC News, 2019; Nazca & Trujillo, 2019). FloodList (2019a) reports (alongside other media; The Local Es, 2019) the "Spanish Prime Minister Pedro Sanchez visited some of the affected areas on 14 September", giving an impression of the scale and severity of the natural hazard in question and how the issue now had a significant political dimension.

Purchena – On the ground experience

A specific, in the field example can be taken from Purchena, a small town in South-East Spain. With the Almanzora River passing through the outskirts of the town, an overflow provision had been established to protect the town from dramatic rainfall, if it occurred. The level of rainfall that occurred during the incident in question was far greater than the potential volume the river channel could handle (figure 3).

As a precipitation event, the rainfall covered the entire town and therefore dramatic flows passed through the various streets and passage ways. Buildings and vehicles were visibly damaged from the levels of precipitation occurring, including the content of the water flows, with rocks and objects gathered within it. Small but significant landslides occurred on cliff paths and mud covered roads, making them unpassable without four wheel drive options.

Literature on urban flood response

Much of the research on flood response suggests the importance of flood defences and flood management in this situation (Proverbs et al., 2011). Having significant amounts of data about historical flooding of an area is vital in guiding future approaches (Zhou, et al., 2017). Bodoque et al. (2016) point to an understanding relating to a larger, holistic theory where alongside traditional empirical science relating to data of flood levels, an impression of the social vulnerability is gathered, informing a better sense of the issues faced.

The timeframes available in dealing with a flash flood event are small, and therefore having individuals know the correct procedure to mitigate risk of loss of life is important. Contrastingly, river floods can take longer to occur, but when a river bursts its banks, it generally affects a large area (Jonkman & Vrijling, 2008). Knowing how to react in both circumstances is vital.

Technical interpretation

Ostensibly, the authorities of Spain are well equipped and experienced at dealing with flash flood incidents. The various arrangements of overflow river channels and drainage networks enable excess water to pass through various settlements with little affected. On this occasion, the torrential rain did not enable the preparations to be as effective as they might normally have been. The runoff of the precipitation increased the water levels in various streams and rivers (Grotzinger & Jordan, 2014). While the soil was mostly impenetrable, once the volume of water had exceeded these river and channel paths, the excess water sat on impermeable or already saturated ground from the significant volume of floodwater. This created the dangerous conditions experienced on the ground.

The weather conditions also impacted the flood controls; from a long, hot summer the ground across the South of Spain was dry and hard, which did not allow it to be permeable to water. This meant vast flows of water gathered at the various, lowest points. In turn, the quantity of water and the force it travelled at meant it had significant means of transporting sediment and debris within. This created a damaging environment both for people and objects like vehicles and infrastructure as new downstream flooding occurred (Grotzinger & Jordan, 2014). The conditions created by the seasonal warm, dry weather had made an environment that was more vulnerable to flood risk

than at other times of the year. This exacerbated the issues.

Conclusion

The response by the relevant authorities helped to mitigate some of the issues but the scale of the hazard meant any response would have been inadequate at dealing with the damage faced (figure 4). The planned evacuation of several locations meant people were at less risk of injury even if they had to cope with the significant disruption of moving away from their homes. Similar natural hazards in the past have come to impact particular communities and people more severely than others – the elderly and people with accessibility issues would likely struggle to leave their accommodation quickly without support (Proverbs et al., 2011). Children are at a high risk of injury and need additional support from relevant adults.

More information about procedure before any weather or natural hazard event could help in assisted people to safety in a future crisis. Of those who lost their lives, many died when trying to drive through or away from the flooding. The sheer power of flow of floodwater meant their transportation could not assist them in the intended means. Public information made available by the relevant authorities of how to act and respond to major crisis could help mitigate future risks.

To summarise, the floods that occurred in South East Spain in September 2019 were incredibly damaging and impactful in various ways. From the catastrophic loss of life and injuries, to the damage of infrastructure and facilities, lessons can be learned and a stronger urban flood response method can be organised for the future in order to mitigate further damage. Natural hazards like the Spanish floods cannot be entirely mitigated but, through the various ways discussed, plans can be organised and put in place to reduce the chances of negatively impactful actions occurring.

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2019 Evia Wildfire

Kate Ballance

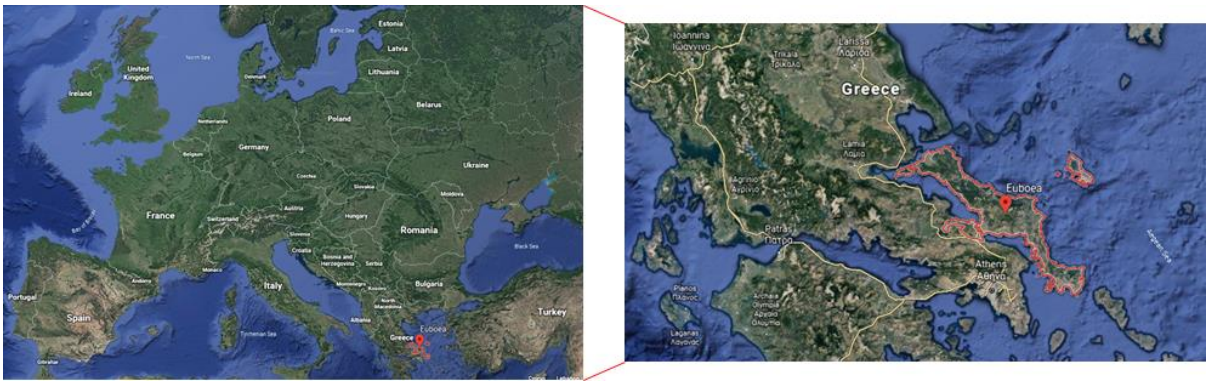


Figure 1 Map showing location of Evia (Google Earth 2019)

Wildfires can occur both naturally and as a result of human activity. More recently, the occurrence and intensity of wildfires has increased as a result of global warming providing conditions suitable for a fire to ignite. Analysis of natural hazards and responses to them are essential in order to protect global communities from the harsh reality of climate change. This report will consider the Evian wildfire and the impacts and responses to this natural disaster.

Background

Evia (also known as Euboea) is Greece's second largest island located to the southeast of mainland Greece, as shown in Figure 1. Evia became engulfed by wildfire flames on Tuesday 13th August 2019. It is a popular destination for the people of Athens to visit as well as international tourists due to its proximity to mainland Greece (connected by two bridges) and its historical architecture. Evia has a European Natura 2000 forest running through the centre of the island containing trees such as European Chestnut, Cephalonian Firs, Oaks, and Eastern Plane Trees. Natura 2000 was established in 1992 and the aim of the project is to encourage member states to care and protect areas that are listed under the Habitats Directive (Special Areas of Conservation) and the Birds Directive (Special Protected Areas) (Ostermann, 1998).

Evia's forests are also protected by the Natura 2000 as they are home to wildflowers such as peony and primulas, and rare birds such as peregrines and snake eagles. These species are protected as they are vulnerable to extinction or native to that specific area (Greek Reporter, 2019 (B)). This information is important to consider when assessing the impact natural hazards have on an area holistically rather than just focusing on environmental and social impacts. Wildfires are especially common in Europe during hot summer months (BBC, 2019; Euronews, 2019) as dry grounds and vegetation make it easier for a fire to spread. Greece is therefore often vulnerable to this type of disaster during the summer season.

Disaster

Reports state that the fire began at 3am (local time) on Tuesday 13th August 2019 (Aljazeera, 2019; BBC, 2019; Greek Reporter, 2019 (A)). This was a result of weekend temperatures nearing 40°C (BBC, 2019). The fire moved rapidly through the island because of the strong winds and densely packed, dry pine forest (The Telegraph, 2019; Greek Reporter, 2019(A)). Access by land to the forest is difficult which made it harder to control the fire, with reports stating the flames reached a height of 20-30m (Aljazeera, 2019). The fire continued for 3 days until it was eventually contained in a ravine near the village of Platana (Euronews, 2019).

The public were warned to stay away from vulnerable areas such as surrounding parks and abstain from outdoor activities that could cause fires (The Telegraph, 2019). Parks and forests were also closed to the public during the times of high fire risks. Around 3-4 villages were evacuated in central Evia including Stavros, Markrymalli, and Kondodespoti to prepare for the potential spread of the fire to residential areas (Greek Reporter, 2019 (A); Aljazeera, 2019). Greece's civil protection issued warnings to the public especially those vulnerable such as children and the elderly to stay indoors away from the smoke. In total over 200 firefighters were required to help combat the fire alongside 75 helicopters and air support including water bombing helicopters and planes (BBC News, 2019; Aljazeera, 2019; Greek Reporter, 2019 (A)).

Aftermath

No injuries or deaths occurred as a result of the wildfire, however instead the island suffered a

substantial ecological loss. The fire spread rapidly throughout the main pine forest running through central Evia which is protected under the European Natura 2000. This has therefore posed a significant risk to the vulnerable flora and fauna found within the protected area. Moreover, substantial damage was also reported to the mountain wildlife sanctuary of Agrilitsa (Euronews 2019). This highlights the damage caused to vulnerable animals within the area and the ecological loss this event caused. This is especially significant as Evia is home to rare and protected species of fauna and flora. Currently, no reports have stated the extent to which the species have suffered as a result of the wildfire.

The fire caused huge amounts of smoke that not only covered Evia but spread to cover the capital city of Athens 70 miles (112km) away (BBC 2019; Aljazeera 2019). In this particular case there were no reporting's of the smoke causing any inhalation issues which can often happen as a result- this is likely a result of the early warning systems. Unlike many other wildfires, the fire wasn't reported to have impacted any buildings throughout the island. Therefore, compared to the potential effects of the wildfire, Evia has not suffered significantly from social impacts when compared to other wildfires as there were no deaths or injuries. However, the island has suffered more environmentally.

Technical Analysis

Wildfires are one of the oldest natural hazards which have intensified since the beginning of the Holocene period as a result of anthropogenic activities (Keller and DeVecchio, 2014). Wildfires are common during conditions of high temperatures, droughts, and oxygen-high winds. Although human error is thought to be the most likely cause, wildfires can also occur naturally. Anthropogenic causes include arson and prescribed burning where the fires then become uncontrolled. Naturally, wildfires can begin when parched timber hits flashpoint and releases a volatile gas that combusts when mixed with oxygen causing the fire to begin (Palliser, 2012). It can also occur naturally as a result of lightning strikes. As no reports suggest that the fire started as a result as anthropogenic activities, it is therefore reasonable to presume that the fire started as a result of the high temperatures experienced by Evia the weekend before the fire began.

The heat (also known as fire) triangle is essential to fuel a fire which makes wildfires hard to manage in densely forested areas where fuel (in the form of leaf litter), oxygen, and heat (in warmer countries such as Greece) are abundant- Evia was therefore vulnerable to this type of hazard. There are 3 main types of fires that can occur- crown fires, surface fires, and ground fires. Crown fires are the hardest to manage as they burn to the top of the trees making them more intense. Surface fires are easier to manage as they burn through the litter on the forest floor and are therefore smaller. Ground fires take place in a deep amount of hummus or other dry vegetation such as peat and are also hard to extinguish (Natural Resources Canada, 2019). Although no specific reports have come as a result of the fire in Evia, from analysing photographic evidence and the intensity of the fire, it is indicated that the event was a crown fire. Wildfires can spread at different speeds depending on conditions such as topography, antecedent conditions, and fuel (litter) type. The fire can spread easier in areas that have a steep topography as the heat from the fire dries the vegetation higher on the slope which makes it easier for the fire to spread. The litter type is also important as vegetations such as grass ignite more easily meaning the fire can spread much faster making it hard to control.

Occurrence of Wildfires in Europe

Globally, the occurrence of wildfires is increasing as a result of global warming. Increasing temperatures mean that areas are more vulnerable to wildfires starting whilst vegetation and litter is generally drier making it easier and quicker for the fire to spread. This is especially evident in Europe, where more countries are affected by wildfires every year. Figure 2 maps fires that have occurred between 1st January 2019 and 30th September 2019 using MODIS technology. The European Commission Report 2018 (2019) stated that wildfires destroyed nearly 178,000 hectares of forest and land in Europe throughout 2018. Despite this equalling to less area burnt and a less long-term average than 2017, more countries were tackling wildfires. This suggests that strategies to stop the wildfires and reduce the area affected have improved, but more must be done to make forests more resilient to a warmer and drier climate. It is therefore no surprise that the wildfire took place in Evia after experiencing a summer of high temperatures and a dry climate. In March 2018, the 'rescEU' programme was launched to improve the protection of citizens not just in Europe but also globally against the growing number of disasters and risks. This type of strategy is essential to protect vulnerable communities from the increasing impacts of wildfires.

Assessment of Response and Preparedness

It is typical of a wildfire to cause a wide variety of economic, social, and environmental issues to the country. Negative impacts of wildfires include the cost to repair damaged property, injuries and fatalities, and loss of species (Palliser, 2012). More than 200 firefighters and 75 fire trucks were used to battle the blaze (Greek Reporter, 2019 (A); AlJazeera, 2019; BBC News, 2019). Specialist helicopters and water bombing aircraft were also used with initial reports suggesting 11 total aircraft (The Telegraph 2019; AlJazeera, 2019) which rose to 9 helicopters and 12 planes in later reports (Euronews, 2019). Some of the

firefighting aircraft was sent from nearby countries Italy and Spain (Euronews, 2019) which is likely a result of the EU transition fleet of firefighting aircraft that was created in the summer of 2019 (European Commission, 2019). The support from other countries within the EU meant that Evia had the resources required to react effectively in order to control the spread of the wildfire. Greece's civil protection authority were also quick to respond by evacuating villages and banning activities in vulnerable areas such as parks and parts of the forest. As a result, the local community had sufficient warning and were able to act appropriately to protect themselves and their possessions.

When compared with other wildfires such as the Mati wildfire in 2018, Evia arguably didn't suffer as significantly which suggests a better response and preparedness within the Greek islands compared to previous years. In July 2018 (13 months prior to the Evian wildfire) a small village in Greece called Mati lost 102 people as a result of a local wildfire. Similarly, to the Evian wildfire, the fire started naturally as a result of gale force winds and high temperatures in a pine forest similar to Evia. Due to a lack of preparation many locals and tourists were caught off guard which alongside a poorly planned town cause people to become trapped and unable to escape the flames (Aljazeera 2018). Unlike the Mati wildfire, the authorities reacted faster which enabled time to warn the public, especially the most vulnerable (elderly and children) which allowed for a staggered evacuation that reduced congestion. It is therefore vital that countries continue to learn from one another and have precise early warning systems and evacuation plans in place.

Future Suggestions

As increasing global temperatures appear unlikely to stop, the increase of natural wildfires across the world pose a significant threat to not just local communities and local economies, but also natural habitats and species that rely on densely vegetated areas. It is therefore vital that countries are able to prepare for the likely event of a wildfire in order to minimise damage. Countries can reduce the likelihood of a fire starting by using prescribed fires to burn any litter within vulnerable areas. By doing this, the fuel element of the heat triangle is eliminated thus preventing the start of a wildfire (Teeter, 2008). Countries can also consider building regulations in order to protect damage of property during the disaster. This can include refraining from building close to densely forested areas which usually happens as a result of a growing population. However, in smaller countries such as Evia this may not be possible. Instead, they should look to preventing the spread of fires through having gaps between different tree lines and close to houses. This would make it harder for a fire to spread and is more likely to contain it into one specific area.

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Sub-Saharan Africa

Drought, Zimbabwe

James Bennion

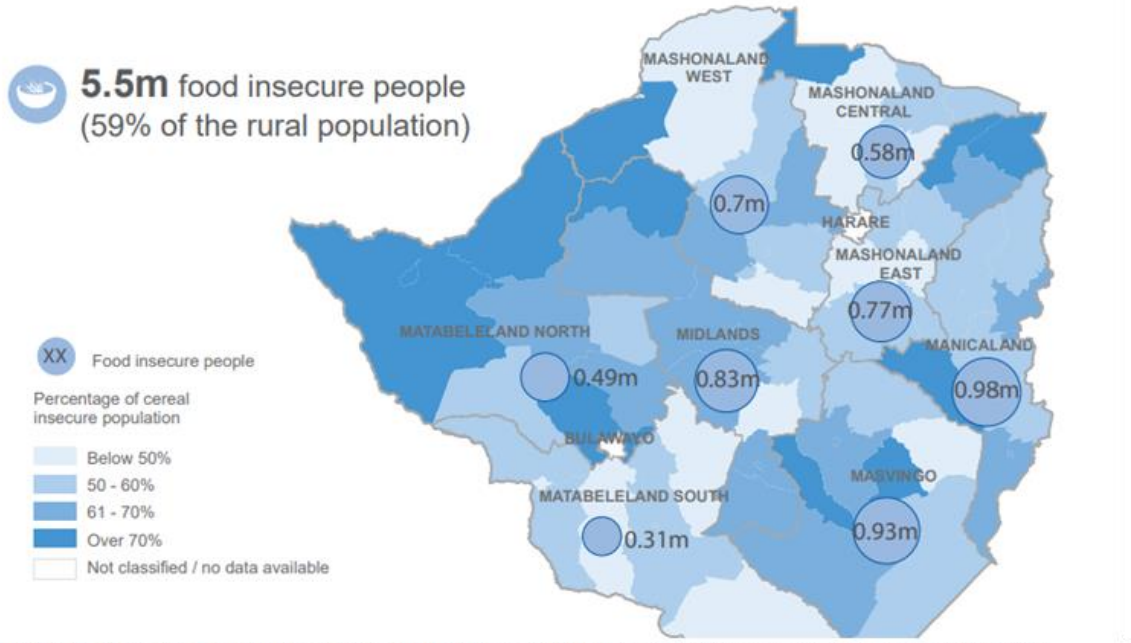


Figure 2. Percentage of cereal insecure population ("Zimbabwe: Vulnerability Assessment Committee Results 2019 - Zimbabwe", 2019)

Background and Authoritative Account

From October 2018 to May 2019 Zimbabwe experienced severe poor rains and "the government declared the () drought and cropping season `a State of National Disaster`" ("Zimbabwe: Drought Emergency 19 September 2019 - Zimbabwe", 2019). This was a result of the weather phenomenon El Nino. The effects of this have devastated crops and it is estimated to have left over five million people, about a third of the population, in need of food aid (Independent, 2019). Zimbabwe is a land locked country, as shown in fig 1, located in southern Africa which is impoverish and poorly developed in many areas therefore struggles to react with large scale natural disasters. It often requires aid from other countries in extreme cases such as this. The drought was particularly destructive as it came in the rainy season which is when the crops are supposed to flourish. This was the lowest rainfall since 1981 leaving people incapable of growing anything.

During the drought food security was a major concern in the country as many households produce their own crops and livestock. The agricultural industry contributes to 19% of the country's GDP. Around 80% of Zimbabweans depend on the rain fed agriculture for their livelihoods (Nangombe, S.). 2.5 million people were said to be on the cusp of starvation. This forced people to purchase food from markets, as it was a limited resource prices rose, the price of staple food (maize) increased by 31% compared to the same time last year ("Zimbabwe: Drought Emergency 19 September 2019 - Zimbabwe", 2019). Figure 2 shows the percentage of cereal insecure population. This means they do not have access to regular food and are likely to be malnourished. Below-average and erratic rainfall negatively impacted the maize crop development which accounts for nearly 65 percent of the region's cereal production. The UN's World Food Programme (WFP) head David Beasley said "(W)e are facing a drought unlike any that we have seen in a long time" (BBC News, 2019). The rainy season in Zimbabwe started 30-60 days late with areas experiencing 30 percent less rainfall or more below average, this coupled with above-average temperatures resulted in moisture deficits. A dry spell in mid-December caused many household's crops to wilt. People were forced to replant which cost farmers as they do not have the money to replenish their stocks but this is their only form of income.

Aid and Response

Drought monitoring in Zimbabwe is carried out by two main ministries, the ministry of Environment, Water and Climate through the Meteorological Services Department (MSD) and ministry of Agriculture through Agricultural Research and Extension Services (AGRITEX). They are responsible to observe, measure and monitor hydro-meteorological parameters. However, the early warning system from drought is relatively ineffective. Until there is effective monitoring and forecasting management programs will continue to be reactive

instead of proactive. As a result of the lack of water and therefore loss of crops, the UN launched a $331m (£270) appeal for aid. Total cereal production this season was 852,000 tonnes, this compared to the national requirement of 1.8 million tonnes for human consumption is miniscule, as well as the 450,000 tonnes needed for livestock (Anyadike, 2019).

Impacts

There were several exacerbating factors which affected the people of Zimbabwe such as rolling power cuts as the water level of the country's largest hydropower plant dropped. These power outages could last up to 18 hours a day negatively impacting industries, and even phone operators ("Charity warns of food shortage in Zimbabwe", 2019). Figure 3 shows the level of water in the hydropower plant at Kariba. Due to the lack of rain there was an inadequate amount of water to turn the turbines therefore producing no electricity for urban areas in Zimbabwe. The dam supplies power to both Zambia and Zimbabwe, and generates 6,400 gigawatt-hours per year ("Kariba Dam", 2019).

As the water security issue worsened so did the drinking water quality. Many Harare residents were forced to line up at wells in the middle of the night for water. Some of these wells are shallow and unsafe.

Technical Interpretation

A drought is a period of abnormally dry weather caused by sever hydrologic imbalance. Air masses over the area are usually slow, prevailing and subsiding from continental source regions. It reduces the relative humidity and inhibit cloud formation in the affected area greatly decreasing the precipitation (Namias, J., 2018, July). Droughts in Indonesia, northern Australia, northeast Brazil, and southern Africa are often associated with El Nino. The drought in Zimbabwe was triggered by this phenomenon, "it represents an irregular periodic variation in winds and sea surface temperature" (Owusu, Emmanuel, Musah-Surugu & Yankson, 2019). The issue of climate change is going to exacerbate climate variability in the future which is likely to have serious consequences on food production. It occurs near the equator which is why Zimbabwe was affected heavily by this. The expanse of warm waters causes such a huge increase in evaporation from the ocean resulting in a natural mode of oscillation from unstable interactions between the tropical ocean and the atmosphere. The effects can be felt globally and is connected to fluctuating pressure, temperature and rainfall; the severest impacts are in the tropics.

Drought is such a difficult process to deal with as it is hard to predict and is never clear how detrimental the disaster will be, "they are composed of sets of elements and subsystems which interact on different temporal and spatial scales and which obey different functions and hierarchies (Vargas & Paneque, 2017). With Zimbabwe still being a developing nation the responses to drought are usually reactive instead of proactive, most of the time they adopt a crisis management approach. The concept of a drought is relatively new and remains one of the most misunderstood risks. The effect of drought can be cumulative over long periods, even years. Moreover, drought affects water bodies but rarely causes any damage to infrastructure, therefore it is hard to quantify the damage compared to other natural hazards. But the effects on croplands are clear as seen in figure 4. Little is known about the physical mechanisms in the expansion and persistence involved. There is evidence in some circumstances that there are numerous "feedback" processes that are set in motion which aggravate the situation.

"A theory supported by numerical modeling studies suggests that over very dry areas, particularly deserts, the loss of heat by radiation relative to the surroundings creates a slow descending motion. This results in compressional warming, lowered relative humidity in the descending air, and inhibition of rain" (Vargas & Paneque, 2017).

This is the reason for most of the sub-Saharan droughts. They last longer here than anywhere else on the planet. One of the possible solutions to this issue is through the Drought Tolerant Maize for Africa (DTMA) project which has developed different varieties of drought tolerant maize. Using national agricultural research systems and private seen systems these have been tested in experimental and farmers' fields. Yields of the new varieties are superior to the current set of commercial maize under both stress and optimum growing conditions (Fisher et al., 2015).

Zimbabwe Economic Crisis

The reason the drought impacted the country in such a negative way was due to the inconsistent policies, inefficient government-controlled markets and poor infrastructure. Had Zimbabwe been economically stable with efficient markets, policy and infrastructure the effects of lower agricultural output would have been buffered by imports and government assistance to some extent (Sihlobo, 2019). More than 60% of the population of a country once seen as the breadbasket of Africa is now considered food insecure. Due to the hyperinflation in the country most households are unable to obtain enough food to meet basic needs. The government blames the weather for the economic crisis. Cyclone Idai coupled with the drought contributing to a poor harvest have been cruel to Zimbabwe. The country is currently suffering from massive hyperinflation.

"Unlike in 2008-09, when Zimbabwe printed bank notes with ever more zeroes on them, this time the government used a keyboard. It credited banks' books with electronic "Real-Time Gross Settlement" (rtgs) dollars, which it said were equivalent to real dollars. But these electronic notes, or "zollars", had no

backing" ("Zimbabwe faces its worst economic crisis in a decade", 2019).

Withdrawing cash became progressively harder. The issue is worsened by the non-availability of foreign currency meaning imports from nearby counties is difficult. This caused the cost of maize and other commodities to inflate.

Conclusion

Due to its physical location Zimbabwe is prone and very vulnerable to droughts. This natural hazard is expected to continue to be prevalent as climate variability increases as well as global warming. The area is even more at risk than countries in Europe for example because it does not have the infrastructure or economic stability to prepare for such eventualities. The repercussions of this is felt not just with a lack of food for the majority of the country but also diminishing power from the main hydroelectric plant. Any form of economic development is stunted as factories and other businesses are forced to work night shifts and for only six hours as that is the only time electricity is available. The disaster was exacerbated by the economic crisis meaning aid from foreign countries was hard to obtain making Zimbabwe more vulnerable as they could not import food and water. This caused a chronic malnutrition endemic throughout the country, mainly for children. The absence of food means the majority of kids consume the minimal diet to survive.

There are measures that the Zimbabwe government can take to reduce the countries vulnerability to droughts. Improving the infrastructure for drainage systems and also reservoirs, because when it rains in Zimbabwe it is usually heavy storms so lots of water, that could be stored, goes to waste. However, many of the solutions involve investment from the government which is in an economic crisis so does not have the resources to do so. A cheaper preparation method that could be rolled out to the farmers is using drought tolerant crops. These are genetically modified to produce a higher yield in conditions with less water and also perform better in optimum conditions for years where there isn't a shortage of water. It is important that the measures are put in place to reduce the impacts of droughts as they are likely to happen regularly in the future.

Due to environmental change being so dynamic there will always be new challenges emerging. However, there are still areas that can be invested in to reduce the effects of natural hazards, especially droughts. Upgrading and modernising the hydro-meteorological observation networks, data management and forecasting systems so that there is an effective early warning system. Education and training on droughts would decrease the countries vulnerability. Implementing contingency plans to local and national levels to strengthen capabilities for preparedness and management. Lastly, and possibly most important would be to develop sustainable irrigation systems.

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Ghana Floods April 2019

Emily Guirdham

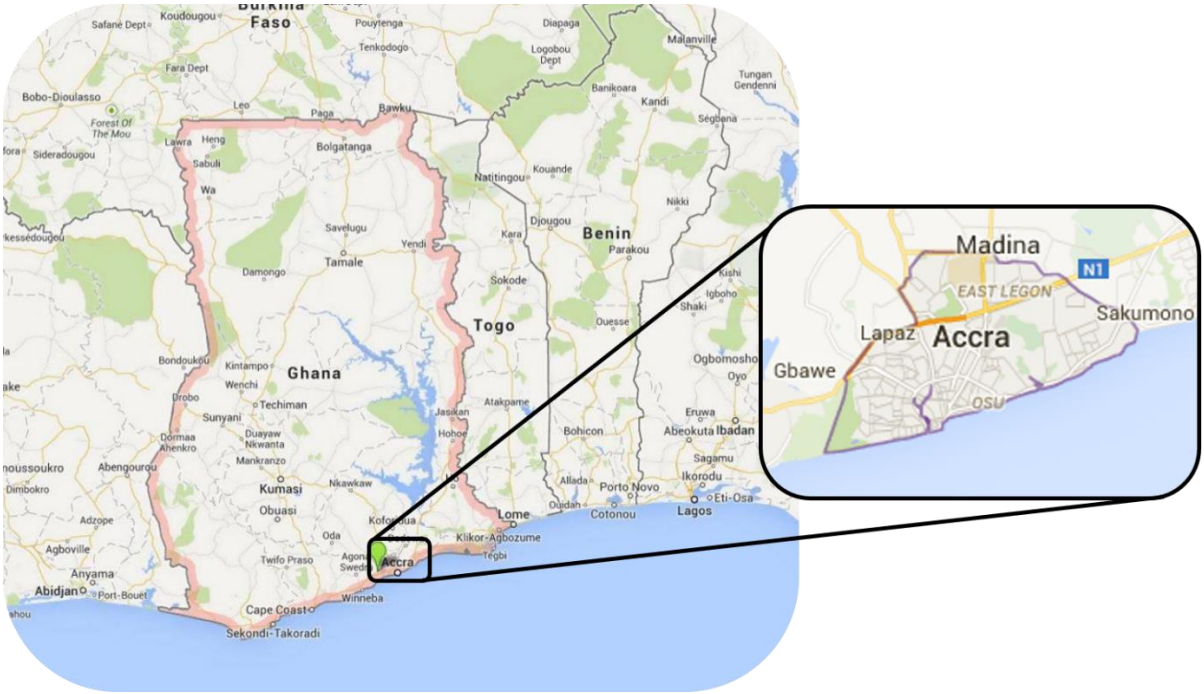


Figure 1- Map showing Ghana with a close up of the capital city of Accra

Abstract

Ghana has always struggled with a serious flooding problem. In the past 50 years, 4 million people have been affected by flooding within the country. over this time $780 million worth of damage has been caused by these frequent flooding events. The country experiences at least one major flood disaster annually and has done for the past decade; 2019 was no different. Throughout the rainy season the country of Ghana experienced many serious flooding events which affected hundreds of people, damaged buildings and took many lives.

One of these events included the flooding in the capital of Accra, on the 7th April the capital experience major flash flooding within the urban area after many days of heavy rain. The flood water damaged houses, trapped cars and caused disruption to the city and surrounding area. It was also thought that 7 lives where taken, 5 deaths and 2 people still missing. (Tasantab & Meding, 2018).

Event

Location

Ghana is located in the western region of Africa and lies just above the equator in the northern hemisphere. The climate of Ghana is tropical, meaning that the country experiences a wet season and a dry season. The south of Ghana, were the capital of Accra is located, experiences the rainy season during the months of March to mid-November. During these rainy months it can be expected for the area to experience heavy rains which often leads to flooding and flash flooding which usually leads to detrimental effects to many residents, their families, homes and businesses. (Oxford, 2008).

Disaster

On the 4th- 5th April, Kumasi experienced strong winds and torrential rain. This led to buildings collapsing leaving hundreds homeless. (Floodlist News, 2019). Following on from this on the 7th April 2019, the capital city of Ghana, Accra, was struck by flash flooding after heavy rain fell over the course of a few days. The flooding caused damaged to cars and homes. Many areas of the city were affected, including Abosseyokai, Awudome, Kwame Nkrumah Interchange, Kaneshie, Ashauman and Alajo. Along with Kwame Nkrumah Circle which was the worst affected area. Here running water gushed from blocked drains onto the roads at the interchange. Pedestrians had no choice but to walk through the knee-high water. The heavy rain also affected those areas mentioned previously also other wider areas were badly damaged. One of these areas specifically was Ho Municipality which is located 130km north east of the capital Accra. Here, 200 people were evacuated from their homes due to major damage

caused by the flood waters on Sunday 6th April 2019. Overall 38 houses were totally destroyed by the flood waters.

Cause

NADMO blame the residents of Accra, the capital of Ghana, for the flooding of the city and its surrounding areas. They suggest that some residents have turned some of the major drains into dump sites for litter. This has caused them to clog up meaning the rainwater has nowhere to go, eventually leading to flooding of the streets every time it rains. (Ghana web news, 2019).

Aftermath

According to NADMO (the greater Accra National Disaster Management Organisation) there was 5 deaths caused by the flooding and thought to still be 2 people missing. It was suggested by the NADMO that one of the deaths was caused by a resident being electrocuted when they came into contacted by a live wire hidden in the flood waters. The other deaths were caused by residents being perished by the rainwater, including a women and her baby. (The Watchers, 2019).

Ghana, specifically Accra, experienced a second downpour on the 14th April, which led to more flash flooding just a week after the first event. It was thought that 12 people had now died from the flash flooding in the month of April with 7 bodies being retrieved from the flood waters in the second event. The cause of this event was again due to the inadequate blocked drainage system in the city.

Throughout the rainy season of 2019 Ghana continued to be affected by flooding events in different regions throughout the country including: flash flooding in Ashanti during May, floods in Accra and the western region in June and a second flood in Accra towards the end June and flash flooding in the eastern region at the end of September. (Floodlist News, 2019).

Technical Assessment

Why floods occur there

Ghana's capital Accra along with the city of Kumasi are major urban areas. These areas are highly susceptible to flooding events caused by the seasonal rainfall. Other factors such as poor drainage systems, the discarding of waste into the water systems. The urban land use made up of impermeable roads, streets and buildings as well as the low elevation of the settlements. (Okyere, Tasantab, & Abunyewah, 2018).

Influences of humans

There is no doubt that informality, poverty and human vulnerability to floods have a relationship. Flood vulnerability within African areas such as Accra, can be put down to the urbanisation of the area, specifically, informal.

Informal urbanisation is usually the result of urban sprawl; the unrestricted growth of housing, development and roads over vast areas of land with little concern of urban planning. It occurs in poorer developing cities, whereby people from the rural areas want to live closer to the urban areas for economic reasons, in terms of money and job opportunities. Unable to afford urban housing, poorer quality cheaper settlements are built on the outskirts of the city. These settlements are known as slums and follow a shanty or favela style of housing. This style of housing does not follow any legal building regulations. These informal settlements show the urban inequalities within the citys development, in terms of access to sanitation, clean water, quality of housing, overcrowding and insecure residential status.

Informal settlements have played a key role in easing the urban housing crisis within Accra. However, have caused major impact in term of flooding vulnerability.

(Okyere, Tasantab, & Abunyewah, 2018).

Occurrence of floods in Ghana area

Floods are often triggered by seasonal rainfall and poor drains. Since the past decade flooding has been a yearly occurrence in Accra, causing the loss of several buildings and lives. The poor rural population most affected. The main reasons for these reoccurring tragedies is due to intense rainfall during wet seasons, but also human factors such as urbanisation, land use and poor drainage system. (Tengan & Aigbavboa, 2016).

Vulnerability

The capital of Ghana (Accra) is known for being incredible vulnerable of flooding events, its vulnerability can be put down to its coastal location as well as its urban characteristics which is predominantly the informal housing. The vulnerability to floods in Accra is set to increase due to the affects of climate change and sea level rise which will be significant on vulnerable coastal communities such as Accra. The sea level in Ghana is rising by 2mm per year. This many sound small, however with the coastline quickly eroding as well, Accra could see detrimental effects. In terms of worsening flood events causing losses in ecology and community livelihoods as well as challenges both socially and economically. (Amoako & Inkoom).

Response

Ghana is well organised and prepared in terms of having a plan of how to act in the event of a flood. The countries disaster management organisation jointed with the forces such as the military and police along with other emergency services are deployed to rescue residents and provide an emergency response to help those in need.

The government will then organise for repairs for damaged infrastructure to be carried out as well as clearing blocked waterways and demolishing

buildings situated close to the drainage channels. (Tasantab & Meding, 2018).

Currently the government of Ghana's response to these flooding event follows a coping strategy method. Unfortunately, these strategies are temporary when responding to the current flooding event at that time. They do not protect or prevent against the underlying risks or help with the key consideration, that floods will get worse. It is long term more expensive to follow this method, as they might not be effective strategy when another flood occurs and worsens.

The coping strategies could also become more expensive, due to the worsen of flood risks. This could be due to climate change causing rising sea levels. Due to the high temperatures there is an increased rate of evaporation causing more water vapour in the atmosphere. This means that there will be an increased amount of rainfall between 2010-2050, (Tasantab & Meding, 2018). Ghana will see wet seasons becoming wetter and dry season becoming drier during this time.

Potential future risks

In order to reduce future risks, the government of Ghana needs to enforce strategies in order to make the country more resilient to flooding events. Specific badly affected areas such as the capital Accra and other urban areas including that of Kumasi, need to be able to withstand the impacts caused by intense flooding. Currently there are strategy plans in place such as those of the resilient cities network and the African Adaptation Program. In which Ghana is a member. However, these strategies have not been put into action yet.

African Adaptation Program

Launched in 2008 the United Nations Development Programme in partnership with the United Nations Industrial Development Organisation, UNICEF and the World Food Programme, acquired the African Adaption Program. A program which has $92 million in order to help 20 countries within Africa, to integrate climate change risks and opportunities into their development plan. The program identified Ghana to be vulnerable to climate change and intense weather events such as flooding. The program helps the government and communication of Ghana to create adaptation plans to build resilience against disasters. (UNDP Ghana, n.d.).

Conclusion

Overall, it can be concluded that Ghana's government needs to put much more effort into the strategies and action plans in order to help to protect the cities and help to prevent these reoccurring annual devastating flooding events from occurring and worsening.

Investments are needed in order to put into place, mitigation strategies and infrastructure especially in coastal area such as the capital. These investments will save the government money in the future, as long term solutions can be carried out, which makes the country resilient and more able to withstand flooding events. Also help to prevent future risks, rather than adapting to the flooding at the time.

This investment money would be hugely beneficial to the country and will allow for many improvements to be carried out. Including ; the protection measures such as levees warning systems and monitoring systems to provide flood risk alerts. Housing improvements in order to move those in informal housing into a more stable, affordable social housing. The way houses are built so they are water resisted or can be built on stilts and adapting the natural environment by expanding flood plain areas.

One of the other biggest improvements would be the installation of a sufficient waste disposal system. This will help to reduce the blocking of drainage systems. This is a huge problem in Ghana and one of the main causes of flooding. Achieving better drainage systems will allow rain waters to flow through and reduce the risk of flooding.

It is difficult to determine the reason why Ghana, specifically Accra, experiences frequent flooding events. Much of the literature suggests that the causes of flooding in these poor urban areas is due to the severe rainfall, blocked drainage systems and the informal urbanisation where houses are built under no building regulation or planning, meaning they are built in vulnerable flooding areas. However, the literature also suggests there is no specific linkage between these factors or other factors will also play a part, such as climate change causing sea level rise and the low lying land of the area.

What is certain is that Accra needs to become resilient to these flooding events before they become worse due to sea level rise.

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Tibesti Landslide 24th September 2019

Phoebe Hoar

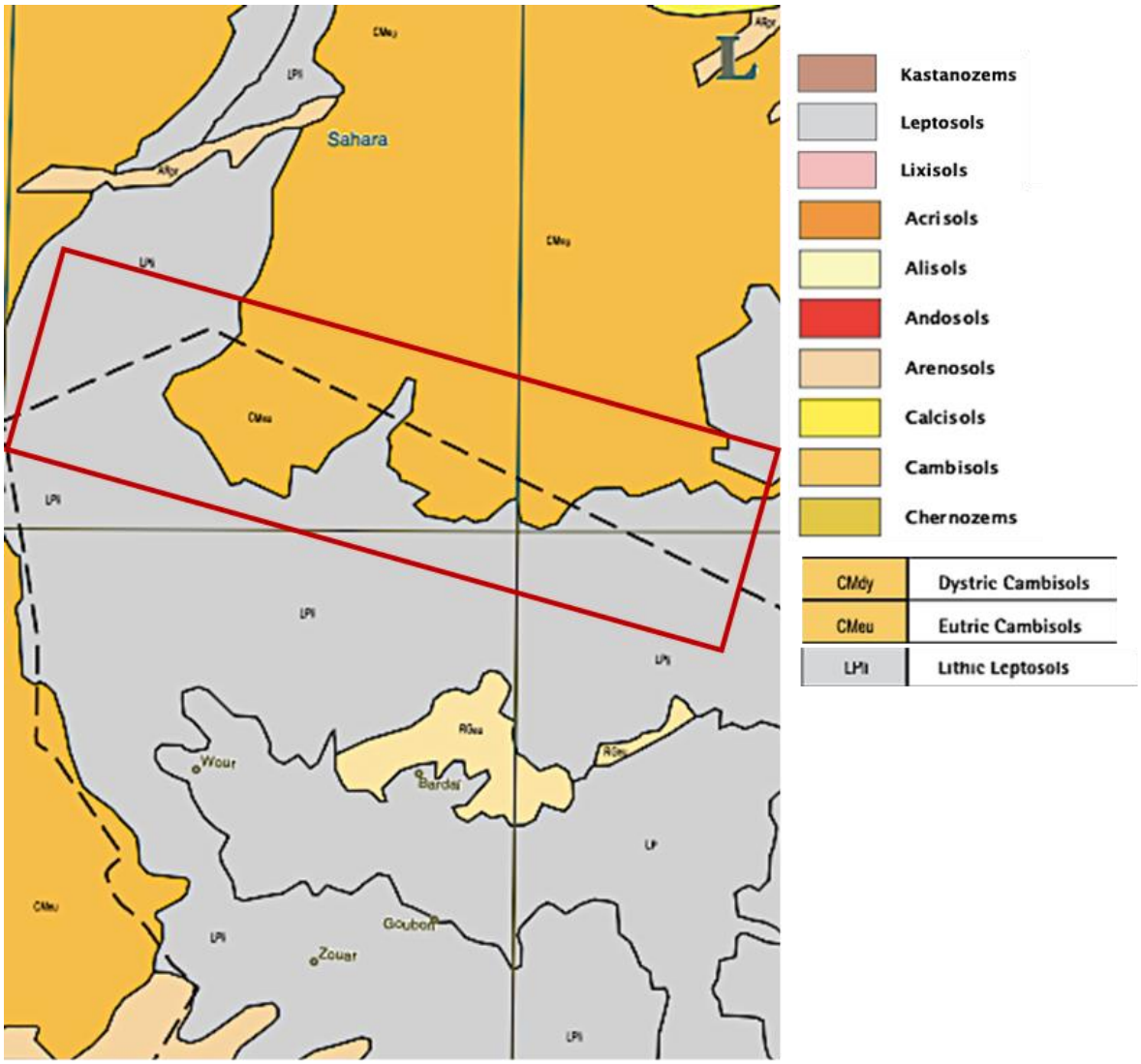


Figure 1: Soil morphology of the Libyan chad border, landslide area is outline by red box and legend shows that the soil in the area is made up of leptosols (LPl) and cambisols (CMdy & CMeu) (European commission, 2014)

Background

On September 24th, 2019, a landslide struck Kouri Bougoudi in the Northern Tibesti region of Chad, along the Libyan border (as shown on figure 1). The main impact of the disaster was the estimated death of 30 people, all of which were inside a goldmine at the time (BBC News, 2019). The defence minister for Chad, Mahamat Abali Sala, told news stations "I cannot say exactly how many fatalities there are but there are many people working in these mines, so there must be many deaths, for sure" (Mining technology, 2019).

The news of the landslide has been covered by many news reports, both Western and African, with six corroborating the death toll. Due to the large amount of mining in the area, it is highly possible that the landslide could have been a result of poor mine safety and oversight, rather than of natural events (Nako, 2019). Furthermore, news articles did not provide any coverage until the 26th September or later, indicating a delay in communication.

Conditions prior to hazard

Northern Chad has very little precipitation all year which gives plausibility to the idea that the landslide may not have been caused by rainfall. Exact weather forecasts for Tibesti are not available due to the remoteness of the area, according to the weather forecast site 'Weather.my' the closest weather station to the area is 'FAYA', shown in figure 2, located 426.6km south of Tibesti which recorded no major weather events for the whole of September (except a thunderstorm on September 29th), and recorded dry conditions with a high of 40 degrees and low of 28

degrees for the three days prior to the landslide (Weather.my, 2019).

By triangulating the weather of surrounding areas, a more precise estimate of the weather and climate conditions leading up to September 24th can be made. Weather stations in Libya and Niger recorded hot dry weather for the days prior to the event, however, Sudan's' Khartoum weather station recorded a thunderstorm and rain on September 23rd (Weather.my, 2019), partnered with a westerly wind on the morning of the 23rd (Weatherspark.com, 2019), meaning there is a small chance that this storm could have made its way west to Tibesti, however, from the data provided by surrounding stations it is best to assume the conditions prior to the 24th were hot and dry.

Remoteness and political tension

As mentioned previously, the remoteness of northern Chad can cause complications in communications and coverage of hazards. Chad is one of the least developed countries in Sahelian Africa, currently placed at 186 out of 189 on the World Banks' human development index (HDI), with an HDI score of 0.404 (UNDP, 2019). Over the past decades Chad has experienced many border conflicts with neighbouring countries due to the scale and remoteness of the borders. The Chadian-Libyan border conflict from 1978 to 1987 lead to Chad claiming the Aouzou strip in northern Tibesti shown in figure 3 , where Kouri Bougoudi is located, highlighting the political and social tensions in the area where the landslide occurred (Hodder, 1998).

The Aouzou strip and Tibesti region is now the base for many Chadian and Libyan rebels and terrorists who attempt to cross the border, although Chad legally closed its' border to Libya in May 2019 (Zaptia, 2019).The Tibesti region has a large gold mining trade which is often illegal, and is part of an ongoing dispute between the Chadian state and local ethnic groups and in May 2019 the Crisis Group highlighted the increasing tension in Kouri Bougoudi and the region over the management of gold mines (Crisis group, 2019). The region has attracted miners as well as Sudanese and Chad rebel groups, which has caused concern from the Chad government that mining could be funding the rebel activity and attacks on Libya, as a way of controlling this the state has been making the gold mine areas isolated and uninhabitable by restricting road access and supplies (Crisis group, 2019). Consequently all these factors create unsafe and poorly managed mines which have the potential of collapses and create landslides.

Technical Interpretation

Preconditioning factors of landslides

Landslides are part of the Earths geological cycle and can occur on a wide range of scales, from a small rock fall to whole slope collapse. There are numerous preconditioning and preparatory factors which can cause and unstable slope to collapse and could be triggered by both natural physical triggers and human triggers (McColl, 2015). Often, rapid mass movement can result in large loss of life while slower down slope movements can result in economic damage, however this depends on the remoteness, development and preparedness of an area and in the past landslides have been fairly overlooked in terms of disasters due to the often remote and mountainous setting (Smith, 2013). Mass movement hazards can be categorised into three types; rock fall, land slide and debris flow and can occur in five terrain categories; seismic, high relief, land degradation, high rainfall and fine-grained deposits (Smith, 2012) Furthermore, it is important to consider the soil structure as well, in relation to water holding capacity, pore pressure and strength. Figure 4 shows the soil structure for the Tibesti region, showing that the soils along the Aouzou strip are a mixture of lithic leptosols and eutric cambisols (European Commission, 2014).

Both cambisols and leptosols are fairly weak soils, with the latter being particularly weak due to the restricted pedogenic development (European commission, 2014). As the landslide happened in a mining area, it could be assumed to have occurred in any area of leptosols due to this type of soil being formed over hard rock, if this is the case then the soil structure would be a preconditioning factor to the landslide as it is already very weak (McColl, 2015). Due to the mining and soil structure it is most likely that the Tibesti landslide can be categorised as a rock fall, however the terrain is debatable.

Preparatory factors and triggers of slope instability

As well as the preconditioning factors of landslides it is also necessary to consider preparatory factors which reduce the stability over time and lead to triggers on an unstable slope (Glade and Crozier, 2005). The stress exerted on a slope can be both a preparatory factor and trigger of rock falls, driving and resistance stress are present on all slopes and can change over time, meaning that slope stability is a relative term depending on the balance between them (McColl, 2015). The Mohr-Coulomb failure criterion shown in figure 5 can be used to explain the response of brittle material (rock, soil, debris) to normal stress (perpendicular) and shear stress (parallel) (McColl, 2015).

In the case of the Tibesti landslide, it is possible that the was a decrease in resistance stress due to the excavation of material from mining as well as an increase in both normal and shear stress from building mining structures and machinery on an already unstable bedrock, all of which are preparatory factors to the subsequent rock fall (McColl, 2015; Smith, 2013).

Arguably it is possible for a slope to be in a state of instability for a long time after previous slope failure for it to then be affected by different triggers. Slopes can be classified into being stable, marginally stable and actively unstable depending on previous factors (Glade and Crozier, 2005). It is possible that the Tibesti mine had already experienced a landslide and was left in a marginally stable or unstable state, allowing for even a small rock fall or vibration to trigger a rock fall (McColl, 2015).

While many rockfalls are caused by physical triggers such as earthquakes, heavy rainfall and freeze thaw it is far more plausible that the Tibesti rockfall was triggered by human activity (Smith, 2012). The Tibesti region is volcanic, being home to the Tarso Toh volcano, however it has no recent recorded eruptions or seismic activity (Global volcanism program, 2013). Vibrations from machinery and explosive extraction techniques are likely to have triggered the Tibesti rock fall, possibly as a result of poor mining safety precautions or knowledge about the rockfall possibility (McColl, 2015; Davies, 2015).

Conclusion

A vulnerable population

The term vulnerability can be defined by Wisner (2004) as 'The characteristics of a person or group and their situation that influence their capacity to anticipate, cope with and recover from a natural hazard" (Wisner, 2004, p33). There are numerous social, political and environmental factors which contribute to the vulnerability of the Tibesti region. Being a less economically developed country (LEDC) makes Chad more vulnerable than other countries, almost half the population (46%) are living below the poverty line (Relief web, 2019) which means they are unlikely to have the economic means to cope with the aftermath of a landslide or to have insurance to cover losses (Wisner, 2004). As mentioned in section 1, the HDI in Chad is extremely low, meaning the average years of schooling is only 2.3 (UNDP, 2017), because of this many of the miners may have a lower awareness of the hazards caused by mining as well as other causes of hazards in the area.

Furthermore, the high proportion of illegal miners and refugees increases vulnerability, not being recorded as being in the country means death tolls are harder to know for certain and the collapsed mine has secondary effects in terms of no work for a period of time. It should also be noted that more than half the population is below the age of 18 (Relief web, 2019) indicating a high amount of dependent people within the population. Miners, for example, may have a large dependent family who will be left with no source of income if they are lost in a landslide or the mine is closed. This could also suggest that many of the miners are below the age of 18 and working to support older family members too. The remoteness of rural Tibesti also severely increases the vulnerability, communications are slow, taking 2 days to alert news stations of the landslide indicates there is likely a delay in emergency services help and aid if needed (Smith, 2013). As mentioned, the government is trying to isolate the Aouzou strip, meaning road access is poor, if machinery or vehicles were needed to excavate the rubble of the collapsed mine this could also be delayed which will lead to potentially more loss of life.

Planning and preparedness

There is a serious lack of disaster planning from major IGO's on all hazards in Chad. The GFDRR has no disaster risk profile for Chad as a whole and on the GFDRR 'think hazard' site landslide data is missing from Chads profile (GFDRR, 2019). Chad has received $3,000,000 from the world bank under the 'Hydromet assistance grant' (World Bank, 2019), but most of this is used for flood protection in the south of Chad, further excluding the Tibesti region and increasing vulnerability (GFDRR, 2019).

The absence of a democratic political body can also hinder preparedness, due to the state not trusting the area because of Chadian rebels and terrorists there is an obvious lack of government intervention in planning for natural hazards and taking the precautions to prepare for them. The political border conflict is taking priority over peoples safety and livelihoods and as the government is reluctant to intervene in the areas situation it may be up to more non-governmental organisations (NGO's) to help mitigate and impacts of future hazards, such as educating miners on the safety of mining and landslides (Smith, 2013).

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The 2019 Zimbabwe Drought “A National Disaster”

Matthew King

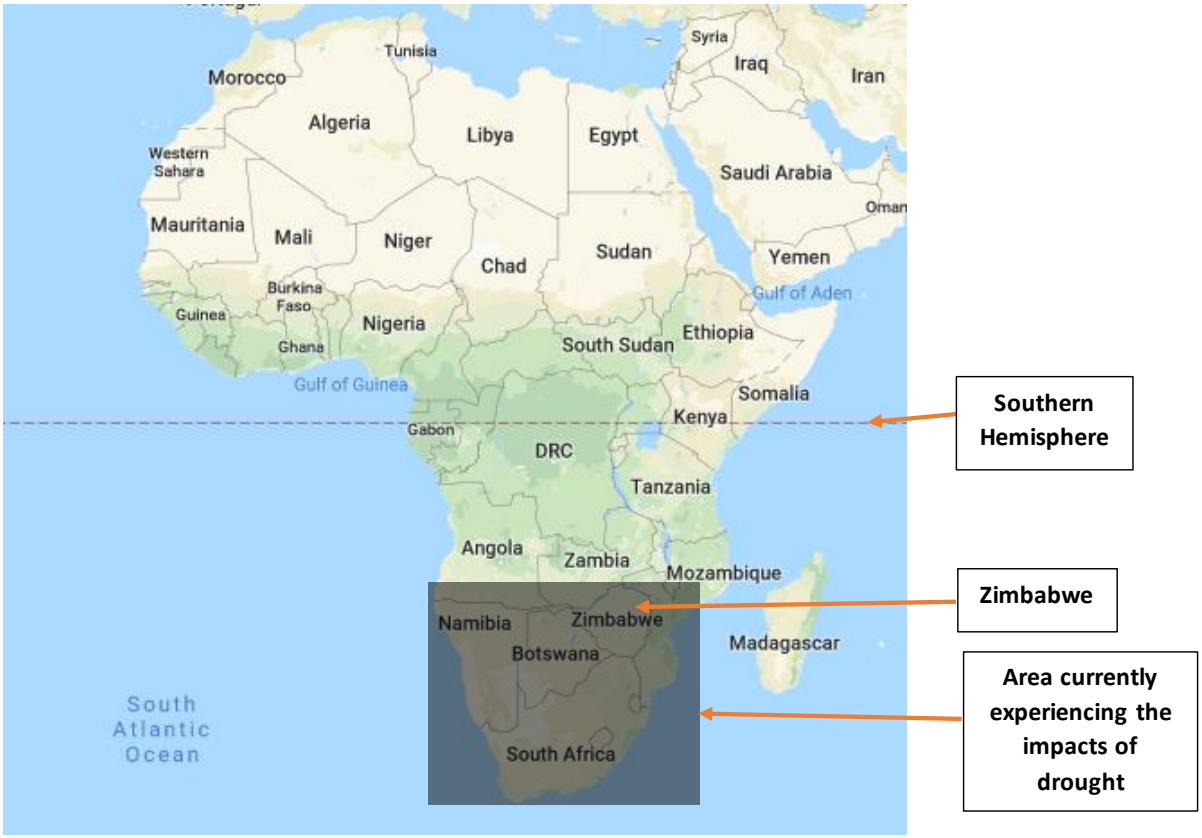


Figure 1.0 A map showing the location of Zimbabwe within Southern Africa (Google Maps, 2019)

Introduction

A natural hazard is an extreme event that occurs naturally which can cause harm to humans. This harm can be directly through loss of life or in other ways such as economic damage, mental wellbeing and loss of infrastructure. This article will discuss the devastation caused by the drought that has ravaged the country of Zimbabwe over the past year and explain the impacts to the environment, economy and people. A drought is a natural hazard that lasts over a significant period in which rainfall is far less than expected. Droughts are not uncommon for the country of Zimbabwe; however, its longevity was far greater than previously experienced within the region. The Zimbabwe drought took place over the October 2018 to May 2019 cropping season and has been considered a national disaster by the Zimbabwean Government (ACT, 2019). The drought was unexpected and as a result had major impacts on those effected. The droughts timeframe was so long and intense that it destroyed vast amounts of crops being grown, dried up rivers leaving only small amounts of moisture in soil beds and left animals parched and desperately wandering closer to settlements endangering those living there. As a result of the drought many living there have experienced food shortages and a lack of water availability, as well as income loss from poor crop yield and increased disease form using silt filled water extracted from riverbeds.

Authoritative Account

Zimbabwe is a landlocked country within South- East Africa and is resident to over 14.7 million people (World Population Review, 2019). Zimbabwe although an LEDC country is not new to the experience of a drought and has experienced many within the past.

However, overtime the number of droughts and the intensity of the droughts have continued to rise. In the 1800’s Zimbabwe experienced the impacts of 5 droughts, this number rose to 11 over the 1900’s and is again expected to rise. This year’s drought has been classified as a level 2 Red-Class event by the GDACS (Global Disaster Alert and Coordination System). The system looks at the expected and current damage

alongside that of socio-economic data to determine the magnitude of the event (GDACS, 2019).

Droughts within Southern Africa have often been linked to a weather event called El Niño. El Niño is said to occur over a 4-year period however it has been known to last beyond this. Typically, the South Pacific Ocean experiences trade winds which blow from east to west, causing warm air to be pushed west resulting in warmer waters near Australasia and colder waters near the western coast of Africa. However, El Niño changes this effect as winds die down reducing the distance the warm air is carried and isolating warmer sea air within the centre of the Pacific. This changes rainfall patterns within Southern Africa with most of the rainfall being seen between September and November during “Rainy season” and then a severe lack of rainfall throughout the rest of the year (National Oceanic and Atmospheric Administration, 2019). This lack of rainfall left crops to wither leaving many desperate for food, water and necessities to survive.

The 2019 drought has greatly impacted both humans, the environment and wildlife within the region as Zimbabwe is an area of poor economic stability. The 2016 El Niño event prior to this one already had large impacts on these factors and hasn’t allowed the country time for recovery. The country has lacked the wealth to support water treatment plants such as Morton Jaffray in chemical purchases which has resulted in production being stopped and one million people within the capital city of Harare being left without running water. Families within the region have had to limit themselves to the extremity of only allowing one toilet use per day, no showers and no clothes washing.

The United nations suggest 50 to 100l of water a day is a necessity for people however, Zimbabweans are currently way below this standard. Children are being sent to queue at water bores from as early as 3am and often don’t receive any water until late afternoon (Kingsley, Moyo, 2019). This has only worsened problems for the Zimbabwe government. Rivers have played a crucial role in providing drinking water and assisting in agricultural uses. However, rivers such as the Zambezi have dried up. This has taken away vital hydro-electric power production alongside a huge loss in foreign tourism with the Victoria Falls evaporation and the money brought in, only worsening economic issues.

This lack of natural water supply has resulted in people trying to extract water from riverbeds, this is often unclean and unsafe with waterborne diseases such as Cholera. This solution is also becoming less viable as the electricity needed to power the borehole machinery has been cut off and resulted in areas having power cuts for over 18 hours of the day. Also, with no water availability and an extremely poor crop yield levels of hunger are rising and are expected to continue to rise with many sufferings from malnutrition. This has left the people of Southern Africa in a state of famine as told by the (EABW, 2019) and in desperate need for help. The intense heat is not only impacting humans but also wild animals with water drying up, so animals are venturing closer to human settlements and putting people at risk. Hundreds of protected animals in Zimbabwe’s national parks are said to be dead particularly those considered as prey due to a lack of energy to escape (Mutasa, 2019). Action is being taken place to protect animals by moving them to the countries wildlife agency however with little resources available to the Zimbabwe government they will have to be focused on protecting people (Guardian, 2019).

The impacts of this drought have been so severe due to the short time period given to recover from the last event which occurred during the late 2015 to early 2016 period. This previous drought already disrupted a large portion of agricultural success. This left many struggling to afford to live and depleted large amounts of food supplies (UNOCHA, 2018). With a shortened time scale between droughts the Zimbabwe population has not had enough time to recover. The 2019 El Niño event has left 9.6 million people within Southern Africa food-insecure, five million of which are Zimbabweans (The Guardian, 2019). Alongside a lack of agricultural growth to provide for its own nation comes a desperately poor economy which relies heavily on farming. The government is losing money at a substantial rate as more is called upon them to support farmers, water treatment plants and electricity provision. The increase in length and severity of droughts also comes as a result of rising global temperatures, caused by an increase of greenhouse emissions. Periods of heavy rain are becoming fewer with a reduced amount of rainfall. Alongside this, warm periods are prolonged and as a result water sources area consistently reducing overtime.

Technical Interpretation

Droughts are not an uncommon natural hazard to Southern Africa. This is due to the warm air that passes across the southern hemisphere called trade winds. These droughts come in periods as a result of an irregularity within the areas climate. This is called the El Niño Southern Oscillation (ENSO) (NIWA, 2016), where wind patterns, sea surface temperatures and climate all become inconsistent of what is expected. Zimbabwe is known to feel the global impacts of the ENSO due to its situation along the Southern Hemisphere. The ENSO process takes place in 3 stages, predominantly within the Pacific Ocean due to it being situated along the equator which receives the greatest amount of sun rays which are absorbed by the ocean (Kauffman, 2018).

The first phase is called “The Neutral Phase”. This neutral phase is the expected normal environmental

conditions for the region based on consistency overtime. As the Pacific Ocean becomes warmed trade winds push the warm water west towards Australasia. This warm water provides a warmer environment and as warm water evaporates it rises through convection (NOAA 2019). This warm air then cools as it rises into the troposphere and then condenses over the western pacific. This cool dry air then travels east and begins to fall from the troposphere making eastern regions cooler. This cycle then repeats itself as trade winds push the air again in what is called the Walker Circulation. The second stage of ENSO is the El Niño effect. During this the stage the Pacific Ocean is heated as it normally would however the trade winds are much weaker than normal. This results in the warm ocean current not being pushed towards that of the Western Pacific but rather remains stagnant within the centre of the Pacific Ocean.

This demonstrates the oscillation process of the ENSO effect. The warm ocean current then reduces and displaces the cooler ocean current previously found at the eastern pacific moving it deeper below the ocean. This then breaks up the Walker Circulation (NOAA, 2019) and as a result large amounts of rainfall are experienced near south American countries but regions such as Australasia and Southern Africa received little to no rainfall often resulting in periods of drought. The third and final stage is called La Niña. During this stage the trade winds are stronger than that of the neutral phase and pushes the warm ocean water found near the eastern pacific all the way to the western pacific. This immediately causes deep cold water to rise at the eastern pacific through the process of thermocline. This then allows for the Neutral phase to take place again and restart the ENSO cycle.

The food shortages are being felt severely with over 5 million Zimbabweans, one third of the population being at risk, as stated by (BBC, 2019), (Marawanyika, 2019) and (Mutasa, 2019). The current bore hole solution to acquiring water is creating a sanitation issue with water being infected with cholera as the number of those diagnosed within Southern Africa are increasing (Nevett, 2018), (UNOCHA, 2018). Finally, there is little hope for any relief from the droughts as it is predicted that there is an 80% chance of another El Niño event taking place over the 2019 – 2020 period (Rowling, 2019), (NOAA, 2019).

Conclusion

In conclusion, this article has established the impact of droughts as a natural hazard and why it is so damaging to countries such as Zimbabwe who lack the economic strength to be able to continually fight it. We have identified the repercussions it places on Zimbabwe’s food supply and its capability to feed its starving population who are fighting famine, whilst also drying up natural water sources which is relied upon so heavily for its hydro-electric power and tourist industry, two key components in the fight to save them. Zimbabwe’s government is trying its best to provide for its people by ensuring money is given to water treatment companies to provide clean water for its people as well as obtain food aid in order to feed everyone. Animals although not the primary focus are still being considered and as much resources able to be spared its being used to ensure their longevity.

However, with the impacts of ENSO events becoming more frequent and more volatile with changing global temperatures it seems like an endless economic downfall which will need a huge investment in order to protect the livelihoods of those who live within Zimbabwe. To ensure the survival of Zimbabwe and other Southern African countries more is needed to be done to reduce global warming and carbon footprints around the globe as these factors have contributed to exacerbating the El Niño effect affect. With the problem becoming more common more international action will be taken towards addressing the issue. This combined global effort may be the solution that Zimbabwe so desperately needs.

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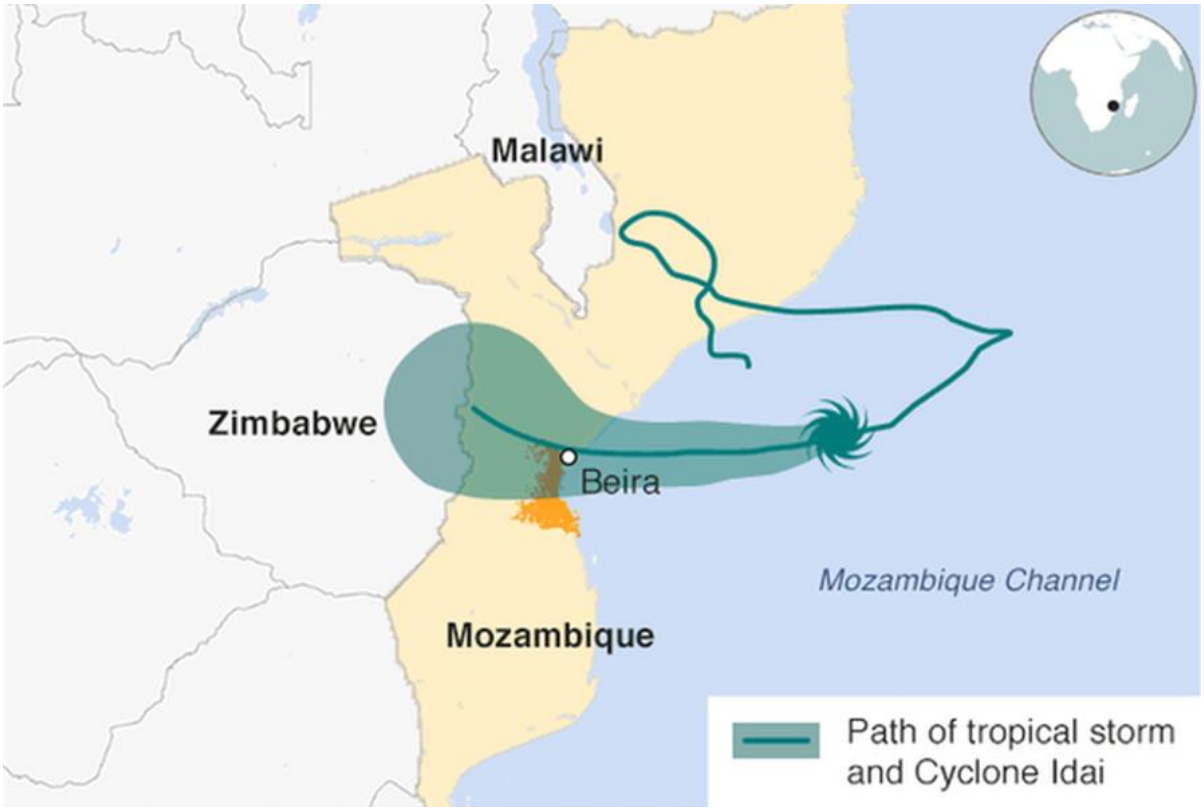
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2019 Cyclone Idai – Mozambique

Christopher Karanec



Introduction

Cyclone Idai was a tropical cyclone which occurred during March 2019, and affected a number of countries on the east coast of Africa, with Mozambique experiencing the most severe impacts, with over 1.85 million people affected (International Organization for Migration, 2019a; Rumney & Eisenhammer, 2019; Business Insider, 2019). The storm is the second deadliest ever recorded in the southern hemisphere (Warren, 2019), with 602 people confirmed to have died from the cyclone (International Organization for Migration, 2019a; Al Jazeera, 2019). The storm caused a range of social, economic and environmental impacts which proved to be devastating for Mozambique, which is shown on a map in Figure 1

Formation of the storm

Prior to the formation of Cyclone Idai, a tropical depression formed within the Mozambique Channel. Météo-France, a meteorological service based in Réunion, issued a warning on the 4th March 2019 that this depression would make landfall within the coming hours, bringing wind speeds of up to 35 mph and heavy precipitation (Météo-France, 2019a). Following this, the depression moved eastwards towards the Mozambique Channel, and Météo-France issued another warning, stating that as a result of this, the depression was likely mature and a weather system with high intensity was highly likely to land over Mozambique (Météo-France, 2019a). Figure 2 shows the combined path of both the tropical depression and Cyclone Idai.

Immediate Impacts

Cyclone Idai arrived onshore near Beira City, Mozambique, during the evening of 14 March with a coastal storm surge of 2.5m (World Meteorological Organization, 2019), however other reports suggest a storm surge of up to 4.4m (European Commission, 2019). Satellite imagery of the cyclone making landfall can be seen in Figure 3. Heavy rain led to widespread flooding, and strong winds were reported up to 170km/h (Weather News, 2019), with a number of reports suggesting wind speeds reached 205km/h (Regional Maritime Information Fusion Centre, 2019; Africa Insiders, 2019).

Damage to buildings and infrastructure was severe, as a result of strong winds and flooding, and aid workers reported that every building in Beira, a city of half a million people, had been damaged. The city was left with no power or telecommunications, and buildings had entirely collapsed (Kirkaldy, 2019). It was estimated that ninety percent of the city of Beira had

been damaged or destroyed (Onishi & Moyo, 2019; Owoseje, 2019), with severe damage to infrastructure, which is illustrated in Figure 4. The social effects of Cyclone Idai were widespread, with 602 deaths (International Organization for Migration, 2019a; Al Jazeera, 2019), and over 1,600 were reported to have been injured in the aftermath of the storm (UNOCHA, 2019a; Bandsom, 2019). 400,000 people were reported to have been displaced (IFRC, 2019; Chitagu, Schemm & O'Grady, 2019), and nearly 150,000 houses had been recorded as destroyed or damaged within the Sofala province alone (UNOCHA, 2019b). Cyclone Idai destroyed over 715,000 acres of crops within Mozambique (Gulland, 2019), including corn, beans, rice and groundnuts such as peanuts as a result of the floods and high winds (Care, 2019a). This had a huge impact on food security within Mozambique, as many people within Mozambique rely largely on subsistence farming for food security. As the cyclone occurred at the end of harvest season, any food that had been cultivated was lost (Gulland, 2019). This affected Mozambique socially, environmentally and economically, and affected food security significantly.

Secondary Impacts

After the landfall of Cyclone Idai, a number of impacts followed for months after the storm had dissipated. A significant social impact which followed the cyclone was the increased risk of malaria and waterborne diseases such as cholera. This is due to receding flood waters providing more breeding space for mosquitoes. Other health conditions such as skin infections, measles, respiratory infections and mental health disorders were likely to affect the worst-hit areas (Devi, 2019). As a result of this, health services were severely disrupted, affecting treatment for tuberculosis, diabetes, and hypertension. Within two weeks of the dissipation of Cyclone Idai, cholera had claimed two lives and over 1,000 cases of infection had been reported within a space of four days (AfricaNews, 2019), with some sources reporting up to 3,100 cases (Stubley, 2019) . This number increased to 3,577 cases by the 8th of April (WHO, 2019).

As a result of the loss of agricultural land, malnutrition became a problem within Mozambique. 2,420 children were reported to suffer from severe malnutrition by July (UNICEF, 2019) and by September, 1,000,000 people, including more than 150,000 children under the age of five, were facing food shortages, with the number of children affected expected to rise by 50,000 in the following months (Jordaan, 2019).

Immediate Response

The response after the cyclone had made landfall largely focussed on providing aid and supplies to those who were in the worst affected areas. In response to Cyclone Idai, The International Organisation for Migration distributed shelter kits to 4,104 families living in the affected Sofala province. In addition, non-food items were provided to 62,381 households in need in Sofala and Manica provinces, including toolkits, tents, blankets, kitchen sets and solar lanterns. (International Organization for Migration, 2019b). In order to deal with the 400,000 displaced people, temporary shelter was provided by a number of aid organisations, such as Care International, who provided sheltered camps, food, water and sanitation facilities (Care, 2019b). By the 20th of March, 128,941 individuals and 26,425 total families were being accommodated in 143 evacuation centres throughout Mozambique (International Organization for Migration, 2019c). At the same time, 15,000 people within Mozambique were still waiting to be rescued from flooded areas (BBC News, 2019).

After the Ministry of Health in Mozambique declared a cholera outbreak on the 27th of March, the Mozambique Government rolled out an emergency cholera vaccination campaign that reached over 800,000 people in four districts, in order to control the spread of the disease (Fusco, 2019; WHO, 2019). Around 900,000 vaccine doses were later distributed throughout Mozambique as part of the wider vaccination programme (WHO, 2019).

Technical Interpretation

Formation of tropical cyclones

The formation of tropical cyclones, knows as tropical cyclogenesis, is a complex process which requires a number of factors in order for a cyclone to form. Briegel and Frank (1997) identified four factors which are crucial in the formation of cyclones. These are: 1) sea surface temperatures above 26.5°–27.0°C, alongside a relatively deep oceanic mixed layer; 2) cyclonic low-level vorticity; 3) weak vertical wind shear; and 4) deep convection in an area with large-scale ascending motion. The location and time during which Cyclone Idai formed provided the ideal conditions, as identified, for an intense cyclone to form, largely due to the location of the storm and season during which it formed.

Seasonality and Wind

Seasonality played a key role in the formation of Cyclone Idai. 85% of cyclones in the South-West Indian Ocean form with the summer months of November to April, during the cyclone season when ocean temperatures are high. (Mavume, Rydberg, Rouault & Lutjeharms, 2010). However, the potential intensity of a tropical cyclone depends not only on sea surface temperatures, but also on the difference between the sea surface temperatures and the cyclone outflow temperatures (Gilford, Solomon & Emanuel, 2017). Sea temperatures must be high enough to power the storm, however outflow temperatures must

be low enough to ensure efficiency of the cyclone (Emanuel, 1986). The period in which Cyclone Idai formed was towards the end of summer, at a time where surface ocean temperatures had heated over the previous summer months, and air temperatures were sufficient enough for the cyclone to be efficient.

Vertical wind shear also plays a significant role in the formation of tropical cyclones. Generally, vertical wind shear speeds below 10m/s are required for a cyclone to intensify and develop, with wind speeds between 2 and 4m/s favouring rapid intensification. Shear values higher than 10m/s are associated with cyclone weakening, with values greater than 12m/s favouring rapid dissipation (Paterson, Hanstrum, Davidson & Weber, 2005). Cyclone Idai's vertical wind shear was estimated to be between 2.5 and 5m/s (PDC Global, 2019), explaining the rapid intensification of the storm. The way in which vertical wind shear affects the formation and intensity of cyclones involves the 'tilting' or 'tearing' of the storm (Zhang & Tao, 2013). When the storm becomes tilted, it covers a larger surface area, and so the cyclone can begin to dissipate as dry air is drawn in and the flow of moist air into the cyclone diminishes (Chen, Knaff & Marks, 2006). The 'tearing' of a storm involves the storm being entirely separated due to the high wind speeds. As cyclone Idai had low vertical wind shear speeds, the storm had time to draw in the warm ocean air. The effect of vertical wind shear on the formation of tropical cyclones is shown in Figure 5.

In addition to this, tropical waves have been found to have an impact of the formation of cyclones. Tropical waves can enhance cyclone circulations by increasing the forced upward vertical motion, thus creating a more powerful storm. Around 80%–90% of all tropical cyclones form within 20° of the equator. This suggests that cyclone formation may be influenced by equatorial waves. Tropical waves cause cyclones to form when low level winds pass through the wave, and cause convection, therefore starting the process of tropical cyclogenesis (Frank & Roundy, 2006). The location of Mozambique is within 20° of the equator, indicating tropical waves may have played a key part in the formation of Cyclone Idai.

Climate Change and Tropical Cyclones

The intensity of tropical cyclones has risen significantly over the past three decades. The number of intense tropical cyclones increased from 36 during 1980-1993 to 56 during 1994-2007, despite an overall decrease in the total number of cyclones. During this period, the mean sea surface temperature increased by 0.12˚C (Mavume, Rydberg, Rouault & Lutjeharms, 2010). As a result of this, six of the ten deadliest cyclones to hit the Southern Hemisphere since 1900 have happened since 1994, with Cyclone Idai being one of them, and this is likely due to warmer oceans leading to rapid intensification of tropical cyclones (Warren, 2019).

With regards to the future of tropical cyclones, a 2°C rise in global climate is projected to impact tropical cyclones significantly, by increasing flooding as a result of rising sea levels, and a projected 14% increase in precipitation from storms. Additionally, the frequency of category 4 and 5 storms is expected to rise by 13% (Knutson et al, 2019).

Conclusions

To conclude, Mozambique was severely affected by Cyclone Idai, with a range of social, economic and environmental effects. A crucial factor in the severity of the impacts of Cyclone Idai was the preparation of Mozambique for the storm. The government of Mozambique raised the cyclone alert to the highest possible level following weather alerts, and advised people to evacuate threatened coastal areas three days before the cyclone made landfall. Although some people evacuated by boat, many people did not respond to warnings or were unaware of them (Goodman and Giles, 2019), making a large proportion of the population vulnerable. This was largely due to poor communication and the fact that Mozambique had no official evacuation plan.

Additionally, in 2012, Beira built a new drainage system and wave barriers with $120 million from the World Bank Cities and Climate Change Project (The World Bank, 2019; Anna, 2019). This was intended to help Beira withstand the increased frequency and intensity of storms (Shapiro & Lambert, 2019). These defences were unable to withstand the strong winds brought by Cyclone Idai (Click Orlando, 2019), highlighting the unpreparedness of Mozambique. The Red Cross also provided around $340,000 to 7,500 people in vulnerable areas within Mozambique (Wilkinson & Barr, 2019), and support was provided to strengthen houses (German Red Cross, 2019). The project was unsuccessful, as the intensity of the storm was too great (Wilkinson & Barr, 2019).

The lack of sufficient defences and preparation for Cyclone Idai made Mozambique particularly vulnerable to the storms impacts. In its current state, Mozambique is not prepared for any future extreme weather events. As tropical storms are predicted to become more intense in the future, Mozambique must prepare for any future events in order to avoid a repeat of Cyclone Idai. The focus must be on implementing a disaster plan, such as that in Australia (ABC, 2019), that the population are aware of, and improvements in building quality are also an important factor in reducing economic and social impacts. Until Mozambique has a suitable emergency plan, its population will remain vulnerable to tropical storms.

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2018 Chipinge, Zimbabwe Earthquake

Georgia Fells

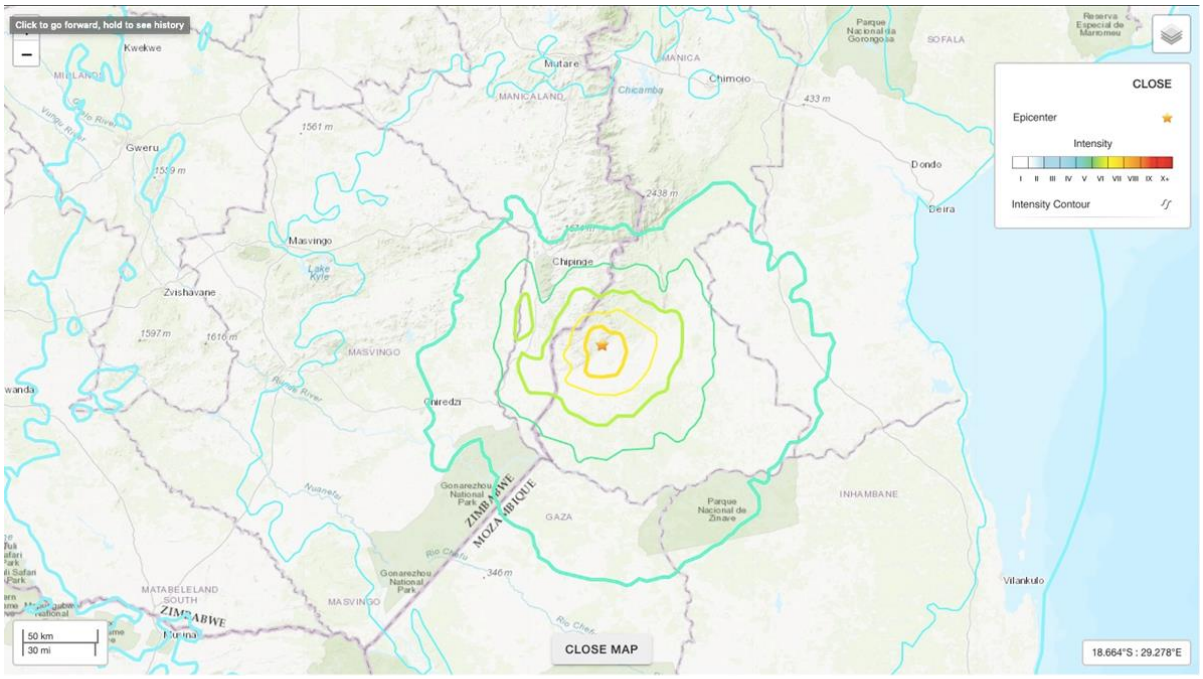


Figure3: An interactive map (contributed by US) representing the intensity of the tremors felt in relation to the proximity to the epicentre. (Source: USGS, 2018, December 22) Retrieved from: https://earthquake.usgs.gov/earthquakes/eventpage/us2000iw7g/executive

The Chipinge Earthquake was a natural disaster which occurred during late 2018. Situated 53 kilometres from Zimbabwe's south-eastern town of Chipinge; affecting some neighbouring parts of Mozambique (Eye Witness. 2018, December 22). The relatively shallow earthquake with a magnitude of 5.5 and a depth of 7.62km; was registered by the USGS as M5.5 which hit Zimbabwe; Mozambique border region at 05:37 UTC (07:37 Local) on the 22nd December 2018 (Volcano Discovery. 2018, December 22) (Times Live. 2018, December 22). The earthquake that hit the local town; Chipinge, left 10 people suffering tremor-related injuries and 40 houses damaged; 108 houses destroyed from the impact and severity of the shaking and 319 damaged in Mossurize (Eye Witness. 2018, December 22).

Contextual Information.

Chipinge is a district which lies in Zimbabwe in Manicaland Province distributed in south-eastern Zimbabwe; neighbouring the border with Mozambique. The Manicaland Province covers eastern Zimbabwe and its proximity to the border of the African plate means it lies at a destructive plate-margin basin along the East African Rift System (EARS), see figure 1. EARS is currently seismically active causing multiple earthquakes to hit this region on an annual occurrence (Eye Witness, 2018, December 2018). Approximately 50 earthquakes have impacted Zimbabwe; just in the year 2016 (The Sunday Mail., 2018, December 23). Much the same as the Chipinge earthquake, many recall the 7-magnitude earthquake that occurred during 2006, again near Chipinge (Eye Witness. 2018, December 22). This displacement between the plates; posing a threat of creating a new continent, suggests that while the convection currents continue to rise, Zimbabwe including the Chipinge district, will be affected by numerous earthquakes in the future.

Natural Disaster: Dimensions.

Much of the Manicaland Province is seismically active, the magnitude of the earthquakes in this region range between moderate and high; occurring annually (Xinhua. 2018, December 23) (Blašković, T. 2018, December 22). Although, as a Southern African land locked country; Zimbabwe has experienced numerous earthquakes due to tectonic plate movements extending to Mozambique and Manicaland. This caused mild tremors to be reported in areas, namely; Chiredzi, Chimanimani, Dorowa, Chimoio, Beira, Gweru, Harare and Polokwane; while similarly moderate tremors central to Chipinge; expected when considering the regions proximity to Mozambique (The Sunday Mail., 2018, December 23).

During the early hours, a 5.5-magnitude earthquake hit eastern Zimbabwe and adjacent parts of Mozambique leaving villagers in a panic; affected by the impact. According to Blašković, T. 2018, tremors affected most villagers across the Eastern regions of the country in which buildings and rooftops began to rattle lasting 3 minutes. It was then later confirmed by the US Geological Survey the vibrations were caused

by seismic activity of an M5.5 earthquake affected by 'tectonic plate movements in the East African Rift System' (The Sunday Mail., 2018, December 23). These vibrations occurred during early hours of a Saturday morning; reducing the vulnerability of Chipinge's average population of 18,860 by reducing the risk of exposure to collapsing buildings.

Result.

The severity of the aftermath from the disaster is compromised and had the potential of a medium humanitarian impact due to its magnitude of a moderate 5.5 on the Richter scale, exposed population and their vulnerability. Approximately 56,000 residents living within areas where the disaster struck, were directly affected by very strong shaking, refer to figure 2. An additional 218,000 are estimated to have felt strong shaking, some of 656,000 felt a moderate level and 9,194,000 witnessed a weak level of shaking (Blašković, T. 2018, December 22). Many of the people affected took to social media to express their alarm, via Twitter. In Harare the approach to social media was with the aim to express the distress it had caused though no severe damage has been reported.

Economic Impact.

The Zimbabwe Broadcasting Corporation (ZBC) released an early statement discussing that it was discovered during the aftermath of this event that at least 40 homesteads in the town of Chipinge had been affected by the shock (Chirisa, S., 2018, December 22) (Xinhua, 2018, December 23). A report later confirmed that 108 homes had been completely destroyed and 319 damaged in Mossurize. This caused immediate displacement of population; 1% of the households in the district of Mossurize have access to electricity, increasing their vulnerability. In response to the Chipinge Earthquake; the USGS issued a yellow alert for shaking-related fatalities and economic losses, some of which accounted for 1% of GDP of Mozambique's economy.

The Global Disaster Alert and Coordination System activated an account; monitoring the hazard in response to the disaster. Much of the population within the affected region resides in structures that are significantly vulnerable in cases of shaking (Times Live. 2018, December 22): (Blašković, T. 2018, December 22). The predominant building types vulnerable to shaking are: mud wall with wood and informal construction; compact timber, GI and metal. Rural buildings composed of this less-resistant foundations have suffered significant damage; focusing in the Beacon area. As a result of the impact against weak structured buildings and granaries many homes 2km from the border with Mozambique have been left with cracks posing threats of collapse and further destruction.

Aftermath.

Reports varied with some residents of Zimbabwe's Eastern city of Mutare claiming to feel tremors even 180 kilometres away while in fuel queues (Eye Witness, 2018, December 22). It became of a great concern that villagers within the affect region, approximately 26 kilometres radius, has reported that they have experienced aftershocks resulting in some having to take camp outside their homes. According to a news report published by Tapiwa., K. 2019, one villager expressed their concern by urging authorities to evaluate the degree of risk of the homes affected by the tremor of the earthquake as cracks are appearing while aftershocks are constantly being felt (Tapiwa., K., 2019, January 11) (Xinhua. 2018, December 23).

Technical Analysis.

Rationale.

Previous census data has revealed that the earthquakes experienced in Zimbabwe are linked to those occurring in regions such as; Mozambique, Malawi, South Africa, Tanzania and Kenya; countries considered as part of the African Rift Valley. The country, Zimbabwe, can be divided into three main seismic zones, specifically; the Zambezi region, Central Area and the Eastern border area (Masukwedza, I., 2016). The East African Rift System is the key example of present-day rifting encouraging continental breakup (Yirgu et al., 2006). Central-Africa is notoriously known for its continuous seismic occurrences as a cause of its positioning on the African Plate influencing earth surface movement during an earthquake.

Tectonic Summary.

Studies confirm that the East African Rift System is a Cenozoic age continental rift and diffuse zone measuring 3000km long of crustal extension while extending from the Afar Triple Junction; lying between the horn of Africa and the Middle East, over to Western Mozambique, joining the three plates (Nubian, Somali and Arabian) involved in the rift system (Wood, J & Guth., A. 2019) (US Geological Survey, 2006). EARS is considered as an intracontinental ridge system comprised of long aligned successions of neighbouring individual tectonic basins, commonly referred to as rift valleys (Chorowicz, 2005). EARS is formed above a significantly low-velocity zone, referred to as the African Superplume; rising from the core-mantle boundary into the mantle transition zone. It is reported the only rift system currently active over a continent-wide scale and is composed of numerous dynamic rift zones that originated during different periods of the Cenozoic (previous from 45 Ma to 10 Ma) (Yang, Z & Chen, W-P. 2010). Zimbabwe's seismicity is closely related to the East African Rift System as it spans most of the African continent (Tepp, G. et, al. 2018). Earthquakes, especially within the Chipinge Manicaland Province district, along the border of Mozambique, are prominent here due to the EARS developing seafloor spreading within the Afar Triple

Junction zone while continental rifting occurs in the Southern Western Rift and southernmost eastern Rift (Ebinger, C., & Scholz, C. A. 2012). Tectonic features in central-southern Africa distributed over the southern tip of the East Africa Rift System is closely interrelated to the rift system.

Situated within Africa, Eastern Zimbabwe lies at the southern tip of the East African Rift System (EARS); notorious for moderately significant earthquakes influenced by regular seismic activity and natural plate tectonics (Times Live., 2018, December 22). Zimbabwe lies on the African plate; where the earthquake in 2018 occurred is along the bottom of the East Africa Rift System in Chipinge, see figure 2. The region in which the earthquake hit lies on a divergent tectonic plate-margin basin boundary which extends from the Altar Triple Junction southward across Eastern Africa. This African Plate boundary is in the process of splitting into two new plates at a rate of 6-7 millimetres annually, as a result of rising convection currents causing ruptures in the crust and vibrations felt across Chipinge (US Geological Survey, 2006). These incipient plates have been referred to by geologists as the Nubian Plate; covering most of the African region and the Somali Plate; a fracture in the earth's surface widening overtime away from the Arabian plate to the north thus creating the rift system in which Zimbabwe lies. While being found in the Manicaland Province, a region depicted by its continuous seismic activity, the epicentre of the earthquake was located across the border of Mozambique, shown in figure 3; just 54km (35 miles) SSE of Chipinge, 126km (78 miles) ENE of Chiredzi, Zimbabwe (Blašković, T. 2018, December 22) (Dzingire, S., 2018, December 23). Close proximity to the epicentre, Chipinge felt tremors of a higher severity in contrast to other neighbouring districts because of its close proximity to the epicentre; point in the crust where a seismic rift develops.

Conclusion.

Earthquakes within the Zimbabwe region can have a moderate humanitarian effect dependent upon the monitored magnitude, the population and their level of vulnerability to this type of natural hazard. The Manicaland Province districts are vulnerable to earthquakes of a moderate to large nature on an annual reoccurrence (Xinhua. 2018, December 23). According to a news report "Earthquake hits Zimbabwe" published by Dzingire, S. (2018), 2016 witnessed 50 earthquakes ranging from magnitudes on the Ritcher Scale of 1.5 to 4.6. As a result of this, the Met Department released a statement warning that districts within Zimbabwe, especially Chipinge along the border of Mozambique.

Although Zimbabwe's vulnerability against natural disasters such as this one is significantly high when considering Lake Kariba; where both natural and reservoir influenced earthquakes occur and damaging rock bursts in the Zambezi Valley and Eastern Border, much of the vulnerability equates to its economy. After critically evaluating this natural hazard during 2018, the greatest concern in terms of vulnerability, in not only the Chipinge district, but within the whole of Zimbabwe is the impact of shaking on the poorly structured buildings. Much of the infrastructure within Chipinge, the Beacon region; less than 2km away from the Border of Mozambique along the East African Rift System, is composed of weaker buildings and granaries. This was a major issue during February 2007 within Save Valley, Mozambique where the biggest Southern African earthquake struck measuring 7.5 on the Richter scale. As an immediate impact to the tremor, 9 people were left injured and property loss in the Chipinge district and other neighbouring eastern parts of the country (Betera, L. 2011). As a result of this, the Department of Civil Protection have published a document discussing institutional arrangements and plans to help many of the districts within the Manicaland Province protect against natural disasters which they are most vulnerable against.

Technology is advancing and as a result the opportunity for monitoring of seismic activities, mitigation, infrastructure development, CPO and regional collaboration schemes are now put in place to help reduce the impact of natural disasters such as this in less developed areas like Chipinge where infrastructure is still developing at the same level as its economy. This prevents the impacts and extremity of future events benefitting its population and providing a safer and securer community.

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Namibia Droughts

Tom Lett



Figure 1 -Dead Livestock highlighting the drought in namibia (BBC 2019)

Account

The planet is experiencing dramatic shifts in climate change and an area that is no exception to this is Namibia. Namibia is a region in southwest Africa that has consistently suffered from droughts in the recent past. The country is known for its semi-arid and desert landscapes, and in recent years has succumb to increasingly erratic weather patterns, hampering the country's cultivation over the last decade. Droughts are a regular occurrence in the Namibian environment, especially on a local scale. Local areas within Namibia can receive localised weather patterns, leading to droughts on a small scale. However, larger droughts can affect the whole country, due to a shift in global weather changes (Rothauge, A 2019).

In 2019 these problems have mounted due to the amount of rainfall dropping to its lowest levels in over 90 years (New Era 2019). The president of Namibia has declared the droughts as a "natural disaster" and a state of emergency has been announced; the second in three years. It is estimated that 500,000 citizens have already been affected with 1 in 5 Namibians without access to enough food resources (BBC 2019). A drought on the scale as the one seen recently in the past year should not be occurring regularly, however recently the amount of drought across the country has increase. Not only can this severely hamper the country's economy but can also become a huge humanitarian crisis for the people living there (Rothauge, A 2019).

Namibian Climate

Namibia lies within the range of the sub-Tropical High-Pressure Belt and is largely a dry and arid area in Southern Africa. Throughout the year Namibia's climate largely stays the same with high temperatures and clear skies common all year round. Moreover, Namibia receives short rainy periods often lasting only 3-4 weeks between September and November, and February to April (Real Namibia 2010). Namibia is home to a wide range of diverse species due to its erratic weather. Rainfall is often low and erratic leading to Namibia becoming scarce of water sources and stores, leading to less than 5% of the country said to be fit for agricultural purposes (World Bank 2009). The lack of land for agriculture combined with the heavy droughts has led to the supplies of the country severely diminishing over the past year.

Figure 1 clearly shows the diminishing levels of rainfall over the past year, specifically in 2019. The red arrows indicate a decrease in rainfall when compared to the average. Between June and October in 2019 the area received no rainfall. This has special significance as rainfall is supposed to be heaviest between September and October, maximising the effects of the low rainfall earlier on in the year, creating a heavier drought.

Water supply and Infrastructure:

Namibia is and extremely arid landscape and is said to be the driest country in sub-Saharan Africa. Moreover, it is an area that relies extensively on groundwater supplies and additional help from surrounding country's due to Namibia's inability to store water affectively (iwrm-namibia 2019). Namibia's groundwater supplies are distributed unevenly across the country, leading to certain areas becoming more hospitable for crop production and livestock farming. This had led to the creation of an extensive network of pipelines throughout Namibian territory. Without the implementation of these pipelines Namibia would struggle to cultivate all the country (iwrm-namibia 2019).

Another form of water supply in Namibia is surface water storage. This form of water supply is extremely limited due to surface water from rainfall only being available in the rainy months. Often Namibia relies on extreme periods of rainfall allowing for the rivers within the country to flood (iwrm-namibia (2) 2016). In order to store this rainwater Namibia uses large storage dams to make the most of extreme rainfall. However, these dams are only affective in period of extreme rain leading to areas near the dam suffering due to the recent lack of rainfall.

A final method used to maximise water supply and storage is the use of boreholes. Over 100,000 boreholes have been drilled over the past 100 years (Christelis G & Struckmeier, W (2001). Whilst this has helped many Namibian communities on a local scale, the boreholes again rely on rainfall to stay fresh and full, meaning, many communities have suffered from a lack of fresh water over the past year. The diminishing supply of water in Namibia has led to problems associated with livestock and crop production on national scale.

Potential Hazards and their impacts on Namibia

The erratic weather patterns and inconsistent rainfall has created a large threat of drought in Namibia. This lack of rainfall in recent years has led to one of the largest recorded droughts in Namibian history in 2019. From October 2018 to May 2019 Namibia received its driest period in 38 years. As a result of this poor rainfall season many Namibian people have been severely affected resulting in crop production diminishing by 42% below the average production levels thus leaving up to 260,000 Namibians without adequate food supplies (ADBG 2019). The large drought combined with Namibia already suffering from poor water supply and agricultural facilities had exuberated the effects of the ongoing drought.

Figure 2 shows the affect of the drought on forms of life. A major negative effect of the drought is the number of livestock killed. Livestock has been the worst area affected with around 60,000 domestic animals dying as a direct result of the conditions created by the lack of rainfall (BBC 2019). Consequently, this has created a shortage of livestock across the nation, drastically affecting food supplies, directly effecting the people of Namibia. The country has also been involved with animal conservation efforts in recent years. Therefore, the Namibian government has also authorised the sale of around 1,000 wild animals, such as giraffes and elephants to limit the loss of life and to generate funding for the ongoing problems related to the drought (Guardian 2019). As around half of the population of Namibia relies on agriculture, with the majority living rurally, a drought as serve as this can create large scale malnutrition and suffering. Moreover, due to many Namibians living rurally, getting aid and support to them because a massive challenge.

Response and Reaction

The drought in Namibia has led to the rivers in the north of the country drying up. Consequently, people are relying on water and food relief from the government (BBC 2019). In response to the crisis the President of Namibia, Dr. Hage Geingob declared a state of national emergency in May 2019 (UNICEF 2019). Additionally, the cabinet of Namibia has approved drought intervention funding worth $30.8 million until March 2020 or until the budget runs out (UNICEF 2019). This relief will be managed by the National Emergency Disaster Fund. Moreover, Namibia has had a natural disaster plan in place since 1998, which includes preparation measures 'disaster droughts. The plan highlights possible cause of the drought such as the 'el nino' affect, which is the incursion of warm surface waters into colder waters, combined with human induced changes. Additionally, an early warning system had been established to monitor rainfall levels and groundwater levels, in order to evaluate risk to livestock and life (ISE 1998).

UNICEF has also put a humanitarian strategy in place aiming to deliver aid to the most vulnerable parts of the population in line with UNICEF's Core Commitment for Children in Humanitarian Action (CCCs) (UNICEF 2019). This strategy mainly targets vulnerable children and their families in order to maintain a good level of sanitation and health around the affected areas. UNICEF will also be working with the UN in order to offer any support necessary.

Despite the reaction from the government and Charitable organisations such as UNICEF, drought can be a tough natural hazard to prepare and react to. Firstly, in an area that already receives little rainfall, creating water stores for moments of emergency in Namibia is hard due to the lack of volume of water falling and the rapid rate of evaporation of water stores. Whilst Namibia has built dams to supply additional water in times of drought, the shear scale of the country and arid landscapes puts great strain on the stores (Weiser M; White J 2015) Secondly, the effects of drought are not instant and initially dramatic

like other natural hazards can be. In turn, this can lead to an area being neglected on a global scale by more economically developed countries and humanitarian aid organisations. Droughts often choke a countries water and food supply over a longer period leading to prolonged suffering and thus little aid when compared with other natural disasters.

Interpretation of Hazard and Future Management

The drought that has affected Namibia over the past year have posed large risks to agriculture and livestock and thus severely affected the state of the country and the well being of its people. Climate change and increasing extreme weather events is likely to increase the chances and risk of a drought, especially in Sub-Saharan Africa (ISOE 2019). Therefore, it is important to create future strategies for coping with such an event. Using scientific methods have become increasingly more valuable when assessing droughts in order to make countermeasures. As a result of the Namibian drought, researchers at the Institute for social-ecological Research have developed an instrument that covers all environmental and social characteristics of a drought (ISOE 2019).

Furthermore, providing relief quickly and efficiently is key when managing a drought. In Namibia, the use of NGOs when responding to a drought was an obstacle to the effective integration of long-term emergency management and thus a National Drought Task Force was created to try and deal with future droughts (Wilsner, B 2012). The question is therefore placed on whether this form of support is adequate. Namibia is an area that is drought stricken so in theory should have a clear and efficient protocol in place to deal with such an event. Whilst some support has been given from the Namibian government, working with NGOs and other surrounding countries to try and stop the drought at its beginning would prove a more useful way of trying to lessen the hazards of drought.

Climate change also has a major role, regarding the management of future droughts. Rainfall in Namibia is already very unpredictable, so climate change is only going to make event like the on seen over the past year more likely. It is likely that climate change will lead to increasing temperatures, and limit precipitation in Namibia, exacerbating food insecurity in areas of poverty and hunger (Ndeyapo M. 2015). Malnutrition is a large problem in times of drought and can be sensitive to rapid levels of change from lack of rainfall and an increasing temperature.

Conclusion:

To conclude, the drought that has affected Namibia has had a major effect of the agriculture and people of Namibia. Up to 500,000 people are said to have been affected making the scale of the drought unprecedented. The drought has led to crop production and livestock rapidly decreasing, an integral part of the countries ability to function. This puts large economic strain on Namibia. Conclusively, droughts are a common occurrence in Namibia due to its very arid landscape and range of deserts. Therefore, more preparation clearly needs to be made in the future to try and mitigate the risks associated with the droughts as climate change is only going to make weather patterns more unpredictable.

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October 2018 Bududa Landslide in Eastern Uganda

Eoin Kiddle



Figure 3: This photograph shows a comparison between the indigenous vegetation on the mountain (Right), and the land that has been cleared for homes and farming (Left). There is significantly less vegetation left behind, specifically trees and lower lying shrubs.

Background

The Budada region in Eastern Uganda, and more specifically Mount Elgon, has a recent history of deadly landslides over the course of the last decade, well documented by both global and regional news sources such as the BBC, CNN or Al Jazeera. In 2010, 300 people were killed and thousands displaced after major landslides destroyed much of the infrastructure in 6 villages on the mountain slopes (Okiror, 2018, France-Presse, 2018). Despite this event, and the frequent reoccurrence of landslides over the following ten years of varying magnitude and impact (Broeckx, et al. 2018), there remained a large, predominantly subsistent-agricultural population who inhabit villages in the same at-risk areas. This is an important factor in understanding both the causes and effects of the deadly 2018 landslide, and the subsequent policy responses from regional and local government.

The Event

The second annual wet season through September and October, saw an average amount of rainfall for the region of between 150 - 200mm (IGAD, 2018). Although eye-witness accounts recorded by S. Okiror (2018, 2019) in multiple publications, claim a persistent body of rain fell throughout the 2 days prior to the disaster. This heavy rainfall led to a rapid rise in the level of the nearby Tsume River, which supports many villages and much of the cropland in the immediate area on the slopes of the mountain, while acting as a tributary for the larger river Manafwa, as seen in figure 2 (France-Presse, 2018). After heavy rainfall throughout the morning of the 12th of October, around 1pm the Tsume river burst its banks, and made its way down the slopes of Mount Elgon toward the village of Bakalasi (Al Jazeera Sources, 2018).

As the water flowed downhill, it destabilised the heavy volcanic-soil slopes (Mugagga, 2012. Broeckx, 2018) and triggered a landslide, which swept with it objects such as boulders and trees as it moved downhill. This process of uprooting and carrying debris was the determining factor in the severity of the event according to Broeckx et, al. (2018) who modelled landslide severity and frequency for the Mount Elgon region specifically. Though another key factor was the high saturation rate of the already thick soil after 2 days of consistent rain, causing the landslide to be triggered by the flash flooding of the Tsume river (Broeckx et, al. 2018). The debris-laden mudslide then gained momentum down the sheer slopes, and into Bakalasi Village (Okiror, 2018. France-Presse, 2018).

The village itself consisted of mostly smaller and non-substantial dwellings - like the ones seen in Figure 4 - featuring a school, and a small number of businesses such as bars or stores. The force of the mudslide, coupled with the falling boulders and debris killed a total of 46 people, collapsing buildings, sweeping away crops and livestock, and destroying infrastructure such as the bridge connecting Bakalasi to neighbouring villages. The local school, which was inhabited at the time, was engulfed by the mudslide, trapping over 30 children and staff inside (Okiror, 2018. Act Alliance, 2018, France-Presse, 2018).

Contributing Factors to the Landslides' Severity

Uganda, like many less developed nations, has a high fertility rate (5.1) coupled with a recently declining infant mortality rate (33.8) (The World Bank, 2017), culminating in a rapidly expanding population. This is especially relevant in regions like Budada where contraception is yet to be widely available and effective. Healthcare though, is seeing rapid improvement from sources such as the Ugandan Red Cross, and the Department for Health who have a growing staff of 272 (Bududa Health Department, 2018), resulting in a declining death rate as the availability of treatment and the spread of information accelerates. This means a rapidly expanding population in the region, with a demographic of mainly subsistence farmers.

This way of living requires more space for housing and cropland, so trees and other indigenous vegetation are felled in order to create room for crops, homes, businesses and roads, the effects on the landscape are evident in Figure 3. The removal of local vegetation results in the weakening of topography/soils, and therefore the slopes of the mountain. The slopes become more loose with the removal of vegetation, as the roots act like a binding agent for the heavy nutrient-rich topsoil (Broeckx et, al. 2018). This looser soil is therefore at risk of contributing to landslides on the slope, especially when water comes into contact with it and reduces its stability as the soil saturates, where it begins to move down the slope rather than sticking, gathering momentum over time and destabilising more of the slope below (Broeckx et, al. 2018).

This clearing of vegetation also affects the runoff time of rainfall, which is a key factor when examining the causes of the landslide itself, as explored by Zimmerman et, al (2006). The clearing of land reduces the volume of vegetation in the area dramatically, the extent of which can be seen in Figure 3. With less vegetation to intercept, absorb or store rainwater, a greater volume enters the local water table or is stored at a surface level. This water is then able to more rapidly enter local water systems quicker than it otherwise would be, as it has far fewer obstacles to overcome in order to get into the nearest river. This was a large contributing factor to the event, as the flash flood from the Tsume river was the trigger for the landslide, (Okiror, 2018. France-Presse, 2018) saturating large volumes of soil which destabilised the slopes (Broeckx, et, al. 2018). Clearing the land around the river is therefore very likely to have contributed heavily to the flash flood, whereas if the land had not been cleared it is unlikely the same volume of water would be present in the water system, especially considering most of the rainfall occurred over a 2 day period (Okiror, 2018).

In order to cater for the expanding population homes are built in the district, most of which are not typically strong enough to stand up to the impacts of a landslide. They mostly consist of Brick and corrugated metal, as well as weaker wooden sections as seen in Figure 4. These building standards mean the population of Budada and more specifically Bakalasi, are constantly at high risk from landslides even in their own homes, as was proven in 2018.

To make matters worse, there are also cultural influences on typical living arrangements in the area (Namono et, al. 2019. Maes, et, al. 2018. Okiror, 2019). Due to the inability of certain sections of society to earn (children / the elderly for example), multiple generations tend to cohabit in one dwelling. The high concentration of individuals in a relatively small amount of dwellings therefore further increases the risk of fatalities, as a higher number of people are susceptible to landslides at any given time. Okiror (2019), specifically cites a case in The New Humanitarian where 3 generations were in the same house at the time of the landslide, the grandchildren and mother were able to flee the house, however the grandmother could not, and remained trapped in the house, though she survived by pure chance.

Relief Efforts

Relief efforts were hampered primarily by the thickness of the mud, and the direct effects of the landslide itself. The destruction of what little infrastructure there was (a bridge for light vehicles as well as minor dirt roads) meant that access by most means of transport was impossible (Namono et, al. 2019). Although, given the regions' economic power and lack of heavy machines or specialist equipment, much of the relief was limited to the survivors of the disaster itself and those from neighbouring villages, utilising whatever tools were available; hands, rudimentary tools, and a small number of construction machines such as diggers which became available after a few hours. Though by this time the damage had largely been done, and there was little relief to be provided save for the recovery of bodies and whatever infrastructure could be salvaged; clearing roads, moving boulders and clearing the riverbed which was now choked with debris. The thickness of the mud meant that pulling survivors and bodies from beneath the landslide was difficult without the proper equipment (Okiror, 2018), and those trapped under

buildings and debris, for example in the school, could not be helped for a few hours. This likely contributed to the death toll, as those trapped by the mud faced dire chances of survival over this time frame.

Specialised equipment and short term supplies were provided later that day by the Ugandan Red Cross and Regional Government (Okiror, 2018). Jerry Cans, tents, blankets and food were amongst the supplies distributed to those affected. This short term relief was coupled with a long term plan; to move affected people and those at further risk to neighbouring districts. This same strategy however faced opposition 8 years prior when 300 people were killed in a more severe landslide; local politicians cited cultural roots to the Budada region, as well as the fertile soil on the slopes of Mt. Elgon needed for the subsistence farmers who dominate the social demographic of Eastern Uganda (Maes et, al. 2018. Okiror, 2019). Coupled with the high flood risk in the regions below Mt. Elgon, this strategy will likely face further resistance from politicians and locals alike.

Possibilities for the Future

Plans for the future of the area hinge on a few key points, which local and regional government are attempting to reconcile: For most people in the region, homes or small businesses like bars represent the vast majority of their capital (Okiror, 2018), leaving those directly affected with few options but starting from scratch, and threatening those who remain on the slopes with the same. Those affected must therefore rely mostly on what government help is available, as given the average income of residents within the district (Maes et, al. 2018) it is unlikely they will be able to help themselves. Furthermore, the slopes are still unstable as shown by the frequency of landslides in recent history, and it is likely this will continue due to factors such as soil composition, farming activity and forest clearing (Broeckx et, al. 2018. Muggaga, et, al. 2011). Despite the high likelihood of this there remains a cultural draw to the area for locals, given the historical roots for people in the area who have lived off the land for generations. People are therefore loathe to abandon their heritage in most cases, despite the clear danger putting them at further risk (Okiror, 2019). Given these issues, there are some plans which the Government is examining and some which may be effective in this scenario.

Relocation to neighbouring districts is the most widely proposed and obvious solution, though this comes with its own set of issues; Politicians in Buguda and the neighbouring district of Bulambuli both have their own grievances with the proposed migration of those affected or in high risk areas (Okiror, 2019. Okiror, 2018), citing a lack of willingness among the population to sanction such a move:

As discussed; cultural heritage, fertile soils and existing homes are some of the reasons why the majority of the affected populace wish to stay in Bukalasi Village, rather than migrating to the potentially safer Bulambuli district (Okiror 2018, 2019. France-Presse, 2018). Although, the proposed move location is not necessarily much safer, suffering cattle ranchers, disease outbreaks and flooding (Okello et, al 2016). This is also evidenced in the fact that many of those who were already moved by the government, migrated back to Bukalasi and Bududa within one month of being moved (Okiror, 2019).

A more suitable and long term solution is therefore being examined by Namono et, al. (2019), who observed that early warning systems for those in affected villages did not work nearly as well as was necessary, which may have affected the final death toll. Instead of moving from the area, they propose a more effective early warning system, based on already present radio networks; enhancing its usage, as well as people's reaction (Namono et, al. 2019).

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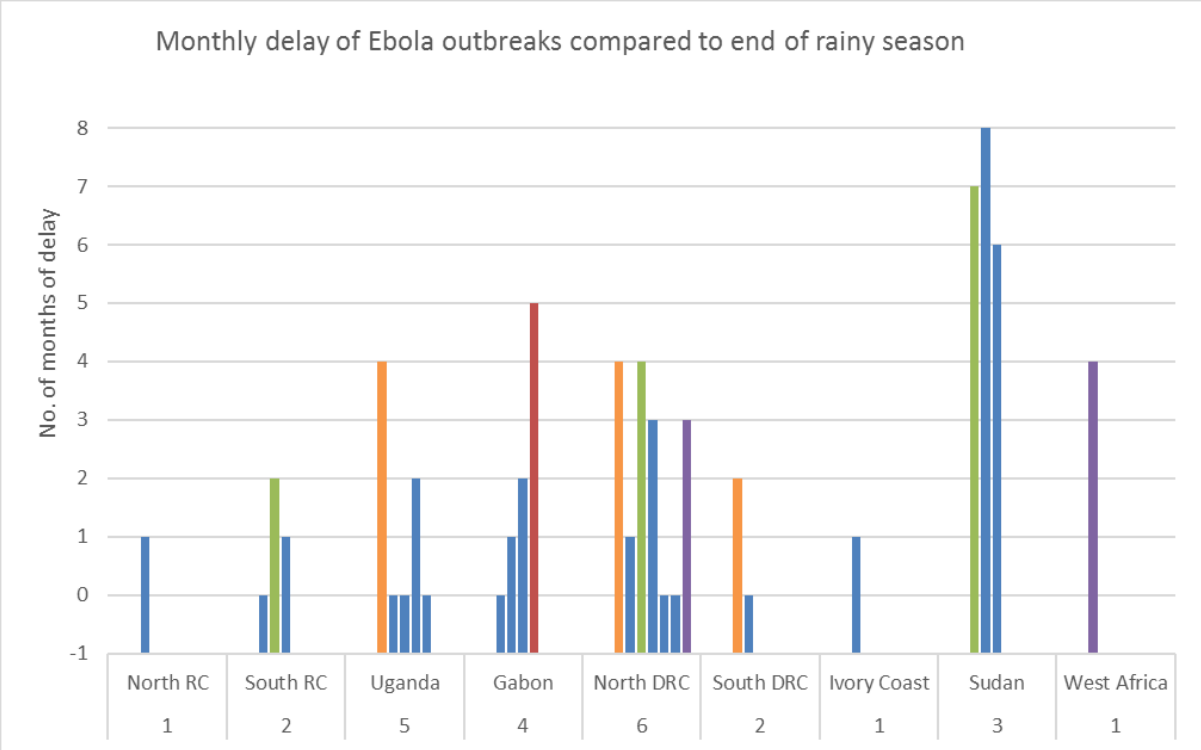
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The Ebola Outbreak in the Democratic Republic of the Congo, 2018-2019: The effect of conflict and climate in its spread

Juliet Hayes



Authoritative account of the event:

Initial outbreak

The declaration of an Ebola Virus Disease (EVD) outbreak in the Democratic Republic of the Congo (DRC) occurred on August 1st 2018 (World Health Organization, 2018a). North Kivu, to where the initial outbreak was attributed, is situated in the east of the country and has been in conflict since 2002, after an agreed national peace treaty failed to curb violence in the area (Stearns, 2012). This particular outbreak coincided with the end of a similar outbreak in the north western Équateur Province, the 9th in the country to date (WHO, 2018b).

Further spread

There has been relatively little spread of the disease outside of Kivu, with most cases concentrated in North Kivu, South Kivu and Ituri Provinces (WHO, 2019a; Figure 1). Ebola was first detected in South Kivu in August 2019 (Beaumont, 2019; CBS, 2019). Transmission outside of these three provinces has occurred. As of the 30th of September 2019, there has only been one reported death in Uganda (Hunt, 2019; Winsor, 2019).

Attempts to prevent spread

There is potential for the number of EVD cases and fatalities to rise in neighbouring countries considering cross border movement restrictions are not yet in place (Xinhua, 2019). The border between the DRC and neighbouring Rwanda was closed on August 1st 2016 due to fear of disease spread as Goma, a city in close proximity to the Rwandan border, had confirmed cases of EVD (Doshi, 2019). Despite this seemingly preventative measure, intended to prevent movement of EVD between the two countries, there are concerns regarding the effect of long-term border closure and its potential to increase Ebola spread, and access to provisions such as food (Turse, 2019; Social Science in Action, 2019).

Death toll

The death toll as of September 29th 2019 is 2,134 (including 1 in Uganda) (WHO 2018c; WHO 2019b), and as of October 1st 2019 is 2,137 (CMRE, 2019). Figure 2 and 3 show the increase in incidence and fatality rates due to EVD over the period of August 1st 2018, when the outbreak officially began, to September 29th 2019. It has been officially designated the second largest outbreak of Ebola in the world, behind that of the West African outbreak of 2013-16 (Wannier, et al., 2019).

The number of cases of Ebola spiked in early May 2019, with up to 133 new cases of EVD occurring at the disease's current peak infection rate. A similar pattern to that of the number of EVD cases has

emerged with the number of recorded deaths. Between August and September there was a marked decline in both EVD cases and deaths.

Barriers to spread management

Early efforts in September to trace the spread of the disease were hindered as a result of a rebel attack in Beni, one of the cities with confirmed EVD deaths (BBC, 2018), with widespread attacks on WHO workers continuing into late 2018 (Wazwaz, 2018) and throughout 2019 (Aizenman, 2019). Widespread beliefs amongst residents of North Kivu that the Ebola outbreak was a hoax (Vinck, Pham, Bindu, Bedford and Nilles, 2019) have impacted control efforts, as resistance to vaccination efforts and decreased likelihood of visiting hospital in the event that EVD symptoms are experienced may lead to further deaths and spread of the virus (Legrand, Grais, Boelle, Valleron and Flahault, 2007).Medecins Sans Frontieres (MSF) put its medical activities on stand-by in February 2019 following an attack on an Ebola treatment centre in Butembo, where assailants set some of the compound alight – this happened a week after a similar attack on another Ebola treatment facility in a nearby district (MSF, 2019).

Similarly, during the week beginning 14th September 2019 there were several localised attacks in Lwemba, preventing sanitary burial and vaccination efforts, along with a more serious incident in response to the death of a local health worker from Ebola (Grady, 2019). The resulting vandalism and violence caused the mandatory suspension of all activities (WHO, 2019b). The prospect of further suspensions being put in place due to violent attacks has the potential to increase case rates as it enables the movement of people without any checks.

Technical interpretation:

Method of spread

The Ebola Virus Disease is transmissible via contact with bodily fluids, such as blood, mucus and semen (Groseth, Feldmann and Strong, 2007) of those infected with the virus, and causes death in 25-90% of all cases (Formenty, 2014; Falasca, et al., 2015). It is thought that the Ebola virus in humans originated from a natural reservoir of the disease in bats, with their consumption as bushmeat presumed a likely method by which the disease was transmitted from animals to humans (Malvy, McElroy, de Clerck, Günther and van Griensven, 2019). The most virulent strain is the Zaire Virus (Sullivan, Yang and Nabel, 2003), which is also the strain associated with the Kivu outbreak (Cohen, 2018).

The influence of climate

It has been suggested that climate may directly influence the timing of Ebola outbreaks, as a number of EVD outbreaks have coincided with the end of the African rainy season (Rewar and Mirdha, 2014; Figure 4). The rainy season in the Democratic Republic of the Congo's capital city, Kinshasa (4° 19' 20.8092" S, 15° 18' 5.3620" E) begins in October and continues to the end of May, with a short break in February (Mbanzulu, et al., 2017). The outbreak in question began in August, though there had previously been an outbreak in the northeast of the country from May to June 2018 (WHO, 2019c), thus these particular outbreaks correspond with the conclusion of the rainy season.

Central African culture may have an influence on why there appears to be a link between Ebola outbreaks and the end of African rainy seasons. Many African nations have historically partaken in 'rainmaking' activities, with the onset of rain being a celebration within communities (Gumo, 2017).The end of the rainy season coincides with the harvest season in many African countries (Müller, Sanfo and Laube, 2013), and therefore the number of people in proximity to one another picking crops could have some weighting on disease transmission, particularly if bushmeat is eaten as part of these meals (Nsio, et al., 2019).

The influence of migration

Considering the conflict occurring in the DRC currently, the movement of people is likely to have had an impact on the speed and locations of the disease's spread. The porous nature of the country's border with Uganda has allowed for transport of the virus into neighbouring provinces – trade and fleeing violence have contributed to the proliferation of the border by virus-carrying members of the public (IOM, 2019). Uganda's biggest imports from the DRC are scrap iron, coffee and sawn wood, all of which are manually tracked across the border (FRAYM, 2019; OEC, 2017). This movement of goods and labour can provide the means by which the virus can be transported across international boundaries (FRAYM, 2019).

Violence in the eastern provinces provides one of "the most formidable challenges to stability" in the DRC today (Stearns, 2012:7). The conflict is continuing, with rebels and foreign forces contributing to this (Gakwerere, 2019), consequently affecting efforts to contain and treat EVD cases (Wannier, et al., 2019). The main reason for cross-border migration originating from Bunia, Ituri Province, was "forced movement due to conflict" (IOM, 2019:3).

Despite the influence of conflict, in May 2019 the majority of people crossing the border of the DRC into Uganda did so for economic reasons (IOM, 2019). This movement has the capacity to spread the disease to younger, healthier populations who tend to migrate for these economic reasons; 70% of those migrating into Uganda in May 2019 were between the ages of 18 and 59, which is likely to be indicative of the average age of all crossing the DRC-Ugandan border (IOM, 2019).

The influence of culture

Those who die in Africa are traditionally buried in public ceremonies (Van der Geest, 2002; Manguvo and Mufvadze, 2015; VOA News, 2019), considered vital for the restoration of social order (Gysels, Pell, Straus and Pool, 2011), with people refusing to forgo many traditional burial rites involving physical contact with the body (Deutsche Welle, 2019). This can enable the virus to spread quickly between attendees, and thus funerals have been dubbed "super spreader events" (IFRC, 2015). The rapidly spreading nature of the 2013 West African outbreak has been attributed to close contact at culturally significant funerals, with unsafe burials contributing an estimated 3 additional secondary deaths per funeral (Tiffany, et al., 2017).

Critical comment on impact, vulnerability, preparedness and future risk profile

Impact of Ebola on society

The impact of Ebola on local society has been profound, in that this outbreak is currently the second largest ever experienced. It has resulted in just over 2,000 deaths in the 12 month period October 2018 to October 2019, with over 2,100 deaths recorded in the entire 13 months the outbreak has been active to date (WHO, 2019b).

Community response to outbreak

The response to this outbreak has been relatively quick compared to that of the 2013-16 West African EVD outbreak, as there are already vaccines licensed for treating and inoculating against Ebola which were created in the wake of the West African outbreak. These have been distributed to affected areas, with ring vaccination, the methodical vaccination of people who are most likely to become infected, reportedly proving to be 97.5% effective in this case (Mole, 2019). Despite this, many are still reluctant to believe in the science behind the outbreak and are unwilling to alter their behaviour, providing the potential for further spread (Vinck, et al., 2019).

Future outbreak preparedness and risk profile

The Democratic Republic of the Congo is ill-equipped to deal with another Ebola outbreak despite the occurrence of 9 previous outbreaks of the disease, although the World Health Organisation now has access to more than one Ebola vaccine as of November 2019 (BBC, 2019). The two licensed vaccines are currently being distributed for use throughout the regions where both active outbreaks and potential outbreak zones are located (Mazumdar, 2019). There are intentions to stockpile these in case of any further outbreaks.

The vulnerability of the Democratic Republic of the Congo to future outbreaks is fairly high. The country has very limited resources for containing contamination and potential EVD cases, and its own healthcare services are severely underprepared and are reliant on MSF and WHO assistance (Kelly, Mukadi and Dhillon, 2018). It has been demonstrated that the country is not prepared to deal with Ebola outbreaks, as although there was a previous Ebola outbreak in the western DRC province of Équateur only weeks before this outbreak began, there have still been over 2,000 deaths to date.

There is relatively very little spending on health by the government, with only 4.3% of GDP spent per year, equating to $32 USD per capita (WHO, 2014). This is compared to the UK which spends approximately 9.7% of GDP on health, or £2,989 ($3,858 USD) (Office for National Statistics, 2017).

The likelihood of reoccurrence of the disease is in the DRC is high. As a relatively underdeveloped country with poor economic stability and a culture which encourages physical contact with deceased family members, the probability of further outbreaks to occur is great.

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Tanzania's flooding during May 2019

Fraser Macdonald



Figure 3, a picture taken during the flooding showing the action being taken to tackle the flooding, also showing the result of damage, (World Bank, 2019)

Introduction to Tanzania and previous floods with responses:

The United republic of Tanzania is a country located along the east coast of Africa, within this section of the continent lies the African great lakes region, bordering Uganda to the north, Kenya to the Northeast and Mozambique to the south. Tanzania also has a coastline of approximately 1424kilometers in length, this coastline consists of the Indian ocean. This means that the country is located along the Inter-Tropical Convergence Belt. This belt causes a low-pressure zone to develop, leading to often rapid rainfalls historically happening during the months of March to May and later in the year around September (National Bureau of Statistics & United Nations, 2012). These rainfalls have consistently caused problems for the populations along the east coast as this is the most densely populated area in Tanzania with the biggest city, Dar-es-Salaam being located along the east coast. These flash floods often occur as a result of sudden changes in weather, soil characteristics, land use and vegetation cover (Kimambo, Chikoore, & Gumbo, 2019). Often flash floods are attributed to changes in climate leading to greater rainfall which puts cities and towns in more risk of flood (Kvocka, Ahmadian, & Falconer, 2018).

During early May 2019, the areas Tanga, Morogoro and Dar-es-Salaam all experienced flooding as a result of heavy showers and thunderstorms. During the two days leading up to the flood that happened on the 9th, Dar-es-Salaam saw 144mm of rainfall (AL JAZEERA, 2019). The amount of rainfall that was expected during May was 198mm (Met Office, 2019), this led to nearly a whole months expected rainfall occurring over two days which caused many problems within the city and surrounding areas of the east coast (International Federation of Red Cross And Red Crescent Societies, 2019).

Post flood results:

This rapid rainfall had not been a surprise for this area of Tanzania due to the wet months often resulting in flooding and local rivers surrounding the urban areas overflowing. As frequency of floods has become regular around the wet seasons from March to April, the outcome of the flash floods can be seen as increasingly less disastrous for the civilians living around the flooded areas and the infrastructure affected (Kijazi & Reason, 2009). The flooding caused significant impact to people through the damage to properties and livelihoods, shown in the number of people that became displaced which ranged from 1212 – 2570 as reported from different sources (Floodlist news, 2019). The numbers where used from local media in Tanzania that have reported that over 400 homes were also destroyed mostly in the areas shown in red in Figure 2 above. Destruction of homes

has led to many citizens finding temporary accommodation within friends and neighbours' homes. Many of the destroyed homes are built with less than ideal materials to withstand storm level weather and the power of flash flooding such as corrugated iron and scrap materials.

Materials used for housing often varied due to the lack of building controls and regulations which has meant thousands of people have lost their homes through the flash flood causing unrepairable damage. With the loss of homes also comes the loss of possessions and objects of value to the person which can lead to further trauma for the former house owner as possible former family possession and meaningful objects were lost.

In addition, overcrowding in the homes that were not built to hold as many people that got displaced caused others to turn to taking refuge in public service spaces such as schools and religious buildings like churches and mosques (International Federation of Red Cross and Red Crescent Societies, 2019). This sudden surge of displaced people also meant that the overcrowding in the buildings had caused disease to spread more easily due to the close proximity of people and lack of sanitation due to the wreckage of the sewage works and water pipes that run through the city (Anande & Luhunga, 2019).

Technical interpretation of the Tanzanian flash floods:

Creation of the storm:

Rainfall within the months of February to May are attributed to the Inter-Tropical Convergence Belt, this is an area of low pressure that is located along and near the equator that stretches across the entire earth. This is the area where trade winds converge together, the north and south winds joining is the main feature of what makes this such a hazardous zone across the earth due to the low pressure zone being created leading to vigorous storms over areas such as the east coast of India, Central Africa and the north of South America (McClanahan, 1988). The Inter-Tropical Convergence Belt is found to be more active above landmasses and less active above the oceans (Hills, 1979).

The seasonality of storms within Tanzania can be attributed to the position of the belt following the movement of the sun to a slightly delayed speed, often thought to be around 1-2 months. This movement of the belt generally correlates to the thermal equator. Changes in the latitude of the belt happen all year round as the belt is found 5 to 15 degrees north of the equator (Nabil, El Hussainy, Eid, & Mahmoud, 2019). However long-term changes in the movement of the belt can lead to server floods or droughts, this can be seen throughout different regions of central Africa along the equator as disasters are becoming more common and flooding is getting more regular with larger consequences (Skybrary, 2018).

The intense sunlight and warm weather attributes to the heating of air around the around the equator area within the Inter-Tropical Convergence Belt leading to the creation of low-pressure zones. These low-pressure zones are the periods when flooding is enabled due to the rapid flash rain bought as a product of this.

The geology of the Dar-es-Salaam also played a role in the flooding due to the surrounding areas affected consisting of raised reef limestone along the coast close to the sea, then more inland within the densely populated area consists of clay bound sands and gravels as shown in Figure 3. Both materials that makeup the land below Dar-es-Salaam are relatively weak and are easily moveable with fast infiltration for water to travel through. Without a strong flood drainage system, it creates a vulnerable area to flooding which is what Dar-es-Salaam experienced (Sawio, 1998).

The combination of all of these factors in addition with the lack of co-ordination of storm drainage management and consistent dumping of building materials in the rivers outside of the city have led to the water within the rivers to build up over a very short period of time, leading to the flash flooding.

Previous storms and what was done to overcome flooding:

When looking at previous floods and flash floods that have happened in this area of Tanzania, it is clear to see that the amount of rainfall that took place in this disaster was nothing out of the ordinary when looking at past comparisons of flash floods. The average rainfall from March to May often consists of high amounts, averaging out at 200mm (millimetres) of rainfall per month during the months of March to May (Climatestotravel.com., 2015). However, 144mm of rain occurred over the course of two days, which created a massive problem for the inner city of Dar-es-Salaam and the drainage systems surrounding.

The annual flood events often leave a lasting impact on the economy, it is estimated that Tanzania loses $100million a year to flooding (Dodman, Kibona, & Kiluma, 2011). Therefore the annual cost of flooding can be looked at when thinking about the mitigation and preparation Tanzania take when approaching the flooding seasons, Tanzania can be seen as a country that is not effectively dealing with the flooding problem they are experiencing as the damage numbers are not showing any signs of dramatically decreasing.

Technology is often looked at when combating flooding in areas such as this due to the ability of being able to predict floods based of previous flood data from past years being a reliable indicator in other locations. This could be an opportunity for the government to use an example such as a One model that has been created for the Tanzanian goverment.

This predicts that 8% of the population live within a zone vulnerable to a 1 in 100-year flood event by 2070, the event is predicted to cost $35million to $5billion when it happens (Kebede & Nicholls, 2012). The assessment was based on GIS information around the potential impacts of climate changes and sea-level rise, two problems which are very real possibilities around Tanzania and should aim to be addressed as soon as possible.

However, in order to put the technology to effective use, the funds must be there to support the research being done and actions being carried out to counter the flooding. The economy can be seen as not strong enough to protect the most vulnerable areas. An estimate of 2% of the annual GDP (Gross domestic product) is lost each year due to flooding (Mlozi, 1996). A statistic which is looking to increase with the slow increase in heavier storms as climate change occurs.

An example of combating the flooding can be seen in Japan which frequently faces flood threats along the eastern coast due to earthquakes in the local areas. Japan has bought in strict building regulations to combat infrastructure damage and loss of housing throughout the cities (Yamada, Kakimoto, Yamamoto, Fujimi, & Tanaka, 2011). However, this method of strategy may not be viable due to the lack of funding to afford strong building materials and lack of availability of strong materials with people to carry out the building efficiently. This problem can be seen in many developing countries such as Bangladesh which also experiences similar annual flooding but on a larger scale.

Conclusions around future responses and lessons learned from the flooding:

Dar-es-Salaam is an area prone to flooding annually, an occurrence which is yet to be overcome due to the lack of funds and education on all levels from government officials to residents. However efforts are being made and progress is being seen, the use of sandbags to reduce the coverage of water in homes, in addition to raised doorsteps, are the local methods of dealing with floodwater reaching into homes across the whole city (Sakijege, Lupala, & Sheuya, 2012).

On a government level, education of officials is taking place in order to allow them to understand the causes of the flooding and actions possible to combat this annual occurrence. Education is also being funded by The World Bank to challenge developing countries and allow them to improve the development of urban and land use planning in addition to infrastructure. This is achieved by presenting a 3-step plan to identifying the risk, reducing it and preparing for the next one. Education is currently being carried out with the view that any reduction in damage is movement in the correct direction to move in as each flood is a setback for development.

However, Tanzania is not the only country experiencing a lack of funding as many developing countries such as Bangladesh and The Democratic Republic of Congo also experience the same lack of economy to fix the flooding risk completely. This is the staple problem which will continually hold them back from eliminating the risk of disaster until the necessary steps have been put in place to counteract the flooding.

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Severe Drought Situation in Somalia, 2018-2019

Beth Healey

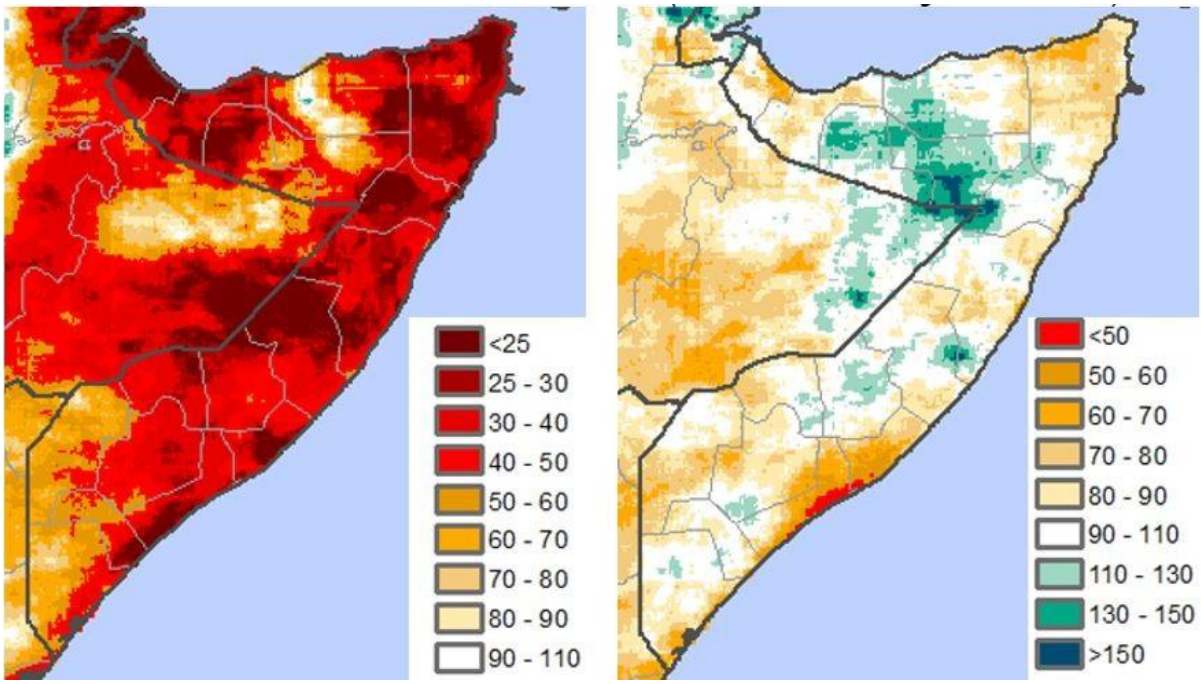


Figure 1, CHIRPS rainfall as percent of the 1981-2010 average, April 1-30, 2019 (left) and April 1-June 20 actual + June 21-30 forecast (right), FEWS 2019a).

Authoritative account of the event:

Overview of 2019 drought

Drought in Somalia is becoming a seemingly more apparent hazard to the country. Located on the East coast of Africa, in a region known as the Horn of Africa, Somalia is susceptible to extremely dry weather conditions (REF). This was no different in 2019 as the country faced a severe dry period due to the poor rainy seasons and unusually hot, dry weather (FEWS. This led most areas of the country into drought conditions like previous years, however this season is among top two of the driest ever recorded for Northern Somalia (REF). The delay of the Gu rains led an estimated, 2.2 million people into crisis levels of food insecurities (Norwegian refugee council 2019, FEWS 2019a, OCHA 2019a), leading around 2.6 million people being internally displaced (FEWS 2019a, OCHA 2019a).

Rainfall

Combining the poor Deyr rains (October-December 2018), with the unusually hot and dry Jilaal season (January- March 2019) and then the recent failed Gu rains (April- June 2019), the country faced another prolonged drought period in 2019 (OCHA 2019a). The Gu rains, which usually peak in mid-April, were suppressed by around three weeks, only starting in early May.

Figure 1 indicates that around only 50% of the average rainfall was received in Somalia and areas such as Bari, Galgaduud, and Nugaal received less than 25% of the normal rainfall in April. This resulted in severe drought conditions across Somalia. The late Gu rains in May did restore some of the drought conditions across the country, however in the South, the Lower and Middle Shabelle regions were still suffering significantly due to the erratic rainfall distribution.

The failure of the rainy season caused upper river catchments in the Ethiopian Highlands, which drain through the Shabelle river in Southern Somalia, to nearly dry up (FEWS 2019b).

Figure 2 shows the Shabelle river level in 2019 compared to the long-term average. It is clear to see the river level before the Gu rains in late April is significantly lower than the average. Where it would typically be at an average of 4m, it is only approximately 1m. Therefore, due to the low river levels and lack of water during the drought, main irrigation sources for many people were suspended. This had a large impact on the crop production in many regions who rely heavily on farming as a main income.

Food insecurities

Agriculture is second most common occupation in Somalia (Aquastat, 2005), therefore the prolonged

drought had a severe impact on the population, as planting was delayed around two-three weeks. The delay in rainfall meant the effects of the previous year's drought were intensified, leading the damage from the current drought, such as water scarcity and food insecurity to be exacerbated (FAO 2019b). Southern agropastoral and riverine areas faced crop failure as the seasonal Gu rains which usually begin in March, did not start till mid-May. This meant a large crucial time frame for agricultural farmers to plant their crops was missed, combined with the already fragile water scarcity situation due to previous intensely dry and hot seasons, crop failure across most agropastoral areas was irreversible. The Gu cereal harvest was recorded as the lowest since 1995, being 70% below the average in 2019 (FEWS, 2019b), this pushed approximately 6.3 million people in crisis levels (IPC phase 3) of food insecurity (FAO 2019b), with some Northern and central pastoral areas being pushed into Emergency (IPC phase 4).

Those who rely on agriculture as a means for income, are severely affected by crop failure, as they are unable to meet minimum food needs due to the lack of income from the significantly lower crop deficits. The rate of malnutrition is still very high as households do not have the means to access sufficient amounts of food, with approximately 1 million children facing acute malnourishment (UNICEF, 2019). The lack of job prospects and food insecurity displaced people out of the rural areas (FAO 2019a).

Displacement and Conflict

The already existing conflict in Somalia is aggravated by the effects of the drought. Food insecurity, water scarcity and decline in livestock cause the levels of displacement to increase.

2.6 million people are internally displaced within Somalia, with 100,000 being down to drought in 2019 (Norwegian refugee council 2019). Conflict remains to be a large reason for displacement in Somalia. However, a large portion of this could be linked to the drought. With depleting levels of food, water and resources, conflict can arise as tension become high and people may become desperate to provide for their families. Consequently, the higher levels of conflict accelerated the number of people displaced, thus creating a chain of events.

As people become displaced, they are then more exposed due to the inadequate access to safe drinking water and sanitation, meaning already vulnerable people are more susceptible to diseases (OCHA 2019a).

Relief efforts

A large portion of the population rely on international or humanitarian aid after suffering the effects of the drought. The fragilities were already there, past droughts and conflict now coupled with the current drought caused the problems to be exacerbated. Consequently, with food insecurity is reaching emergency levels in central and Northern Inland Pastoral zones in Somalia, funding for aid is essential to limit the damage caused to the Somalia population.

OCHA (2019b) state that the 2019 Humanitarian Response Plan sought after $686 million dollars for relief efforts. By May 2019 funding for aid only reached 20% of the goal, which was a significant decrease compared with the response to previous years efforts as shown in figure 3, leaving major funding gaps during the most crucial time (OCHA 2019b). Towards the end of 2018 however, funding had reached up to 80% of the response plan (Financial tracking service 2019). From the funding, $350 million of the funding is allocated to relieving food insecurity, with immediate live saving relief, emergency livestock asset production and emergency support to agricultural farmers through replenishing seed stocks (UN Office for the Coordination of Humanitarian Affairs 2019,.

Temporary and long-term water systems to meet the needs of at least one million people vulnerable to water scarcity, will be implemented to for sustainable results (UN Office for the Coordination of Humanitarian Affairs 2019,. This includes 300 strategic boreholes, on top of 80 existing water systems. Emergency kits are provided for those internally displaced people, where a majority are living in densely populated shelters in search of food and water (UN Office for the Coordination of Humanitarian Affairs 2019). Marginalized communities will bare the brunt as aid will be harder to reach them due to vast rural areas. In addition, increasing armed conflict and the presence of al-Shabaab in some regions mean aid is disproportionally distributed.

The UN World Food Programme's country director for Somalia has said they are focusing on improving food supply chain, supporting producers and the market, using cash or food vouchers. By working with the World Food Programme, a Strategy for Somalia (2019-2021) has been implemented, in order to achieve food security with more resilient, nutritious and inclusive food systems by 2021 (OCHA, 2019a).

Technical Interpretation

With Somalia being located on the East coast of Africa, 5o degrees north of the equator, the countries climate is hot all year round with outbursts of precipitation, mainly determined by the movement of the inter-Tropical Convergence Zone (ITCZ).

However, the seasonal rains could potentially be indirectly affected by weather systems over the Indian ocean REF. Proximity to the equator means the mean temperature is higher, however the likely hood for cyclonic activity is very low. Whereas further south of the equator, in the Indian ocean, near Mozambique, conditions for cyclones are more than ideal as shown in Figure 4. The map shows where the main localised

areas for cyclonic activity, with a large cluster forming in the Indian ocean (insert square) as shown on the map. It is known that warm waters and intense winds are the basis for any tropical storm.

An indirect connection between tropical storms over the Southwest Indian Ocean (SWIO) and drought in East Africa was (Shanko and Camberlin, 1998). A study showcased that there was a negative correlation in terms of rainfall in east Africa and frequency of tropical depressions over SWIO (Shanko and Camberlin, 1998). This meant that as the number of tropical depressions increased, the level of rain decreased, however, there were only a few were recorded to be at a 95% significance (Shanko and Camberlin, 1998). Therefore, the tropical storms are likely to only indirectly influence rainfall. These systems are thought to reduce the moisture influx to East African countries (FAO 2019b)

When applied to the 2019 drought in Somalia, it could be suggested than tropical cyclone Idai, which hit Mozambique in March could be responsible for the delay in Gu rains, consequently causing widespread drought through April and May (FAO 2019b).

With knowledge of the current global increases in temperature, hotter weather means sea surface temperatures will rise. Meaning more unstable air, and higher chances of the formations of tropical storms. Therefore, if the frequency of tropical storms increases with the current climate problem, Somalia's rainfall may be indirectly affected, leaving the country more susceptible to drought conditions in the future.

Conclusion

Vulnerability

Even with aid, Somalia is still a very vulnerable country, where socio-economic problems are exacerbated by current climatic situations. Due to the informal nature of the economy (Mubarak. J, 1997), the country is very sensitive to the changes in seasonal precipitation as much of the population rely on agriculture and livestock as a mean of living. Long term solutions are essential for Somalia to recover and withstand future climate shocks. More secure ways of farming need to be implemented so people aren't relying on the unpredictable weather conditions. Modern techniques, such as hydroponics could be introduced to the country, according to Laurent Bukera, a UN WFP Country director for Somalia. He explains how modern techniques could cut out 90% of the need for water (OCHA 2019a). However, will such modern techniques be able to be implemented into Somalian lifestyle?

Future Risk Profile

It can be hard to distinguish between drought related problems and pre-existing needs however. To help mitigate future drought related problems, concern could be focused on preventing the current conflict fragilities in the country from worsening. Conflict and insecurity are very prevalent across Somalia, therefore when a drought occurs, it just intensifies these problems. There is a vicious cycle of events happening, so, aiming tackling the original causes of conflict and fragilities could alleviate some of the problem associated with drought. Leaving better access to aid and funding.

However, softening socio-economic problems in Somalia is not going to prevent the country from future severe droughts. The rate of natural hazards is increasing globally as we continue to pollute the planet, driving the temperature up globally. This knock-on effect is of rising temperatures could be responsible for the higher magnitude of tropical storms due to changing weather patterns. These extreme events then come back around, almost plunging countries such as Somalia, into a humanitarian crisis.

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Flooding in Southern Mauritania, 26th August 2019

Emily Farrell



Figure 1- A map of the Senegal river basin, along the border of Senegal and Mauritania. (Kmusser, 2019)

Account of the event

The hazard and its impacts

On August the 25th, southern parts of Mauritania started to experience heavy rainfall patterns, this rainfall lasted for a prolonged period of time where on the 26th of August disaster hit and effected the southern region of Guidimaka Wilaya (Celestial, 2019). These patterns were very unusual due to 200mm - 300mm of rainfall falling in a short period of time throughout the region (Floodlist, 2019; IFRD & RCS, 2019), compared to the 160mm average August rainfall. (Climates to travel, 2019). This extreme rainfall pattern led to the national office of Meteorology giving people in southern and western Mauritania flood warnings prior to the event. However, the region still suffered from a vast number of social, economic and environmental impacts (IFRD & RCS, 2019).

The most effected place throughout the Guidimaka region was the regional capital of Selibaby, in which heavy rainfall caused severe flash flooding when 200mm of rainfall fell in 24 hours between the 26th and 27th of August (IFRD & RCS, 2019). This then caused various issues such as the damaging of road networks, infrastructure and even costing the lives of 3-5 people in Selibaby due to building failure and drowning. (IFRD & RCS, 2019; Global NGO Impact news, 2019). One in which was an infant.

Further impacts in Selibaby included the flooding of 3 schools and the destruction of around 4,200 households (33,600 people). Out of them 850 were shelters for the homeless, increasing the vulnerability of people in Mauritania and increasing the impacts the hazard brought (IFRD & RCS, 2019). As well as this, the high waters seriously damaged Selibaby bridge and this is an important infrastructure as it connects Selibaby to the western parts of Guidimaka, meaning communication and a place of safety was cut off during and after the hazard (Gardaworld, 2019).

Not only did the flood cause direct impacts, the Guidimaka region was still experiencing indirect impacts after the initial flash flood on the 26th of

August. These impacts included the loss of drinking water, health care and electricity in which these all come under the basic living requirements and make the recovery process a lot harder for the residents (Gardaworld, 2019). This is further exacerbated by the fact that stagnant water still surrounded the land 15 days after the initial flood, leading to an increased risk of waterborne diseases (Celestial, 2019), during which this water infiltrated buildings and led to more infrastructure failure (IFRD & RCS, 2019).

The impact the hazard had on the Guidimaka region can be seen through eyewitness accounts by the growing influence of social media. Although the exact location of this image is unknown, figure one shows a photograph of Selibaby taken on the 26th of August, showing just how high the water level was and how unsanitary flood waters can be.

Eventhough Selibaby was seriously affected, there were many other areas in and around the Guidimaka region that was also affected. Including the districts of Ould Yenja and Ghabou. In Samba Kandji, houses were completely destroyed and just 25km north of Selibaby is an area called Hassi Chaggar, here around 70 houses had been damaged, and their cattle had been drifted away (IFRD & RCS, 2019), ruining their livelihood and any chance of a quick recovery.

Also, the living structure in the Mauritania region is made up of many communes, in which most of these were affected by the floods, one being the Khachbaye commune. Here the consequence of 76 households being damaged was that residents had to resort to staying in schools/mosques (IFRD & RCS, 2019). This leaves the residents very vulnerable as a commune is a small community, self-sufficient and to survive they rely heavily on hard labour (Sosis & Bressler, 2003). Due to this the impacts from the hazard in communes such as Khachbaye is heightened due to them not having any alternative incomes.

Immediate response after the hazard

The Guidimaka region is highly vulnerable in situations like this, due to the poor infrastructure and the high-density population. A 2013 censor stated that the Guidimaka region held a population of around 177,707 (Turner, 2013) in which the current day population would have grown exponentially due to population growth. Increasing the vulnerability of people Mauritania and the magnitude of the event.

This high vulnerability of the region meant that urgent assistance was needed immediately after the hazard had occurred. In Mauritania, the people request the assistance of the government and national/international civil society organizations due to them not being able to recover easily. This help was shown on the 27th of August in which a crisis committee was held in Nouakchott, and two teams of 6 got put to the task of visiting households and caring for the essential needs of the people (IFRD & RCS, 2019). This immediate response was even more important as the region received more heavy rainfall just 3 days after the initial flash flood on the 26th August, increasing the magnitude of the next flood event due to the already saturated ground (Celestial, 2019).

Technical interpretation

Factors affecting flooding

There are many types of flooding such as costal, flash and river flooding, in which physical and human characteristics impact on the type. On the 26th of August Mauritania experienced flash flooding, in which this can be defined as a sudden high impact flood event where the prolonged and heavy rainfall falls onto the saturated ground and floods. (Schroeder, 2016)

The frequency and magnitude of a flash flood event all depends on a variety of physical and human factors within the area. Such as the physical factors of topography, land use/type and catchment size, and human factors such as population density, deforestation and management strategies (Bitesize, 2019). Most of these factors contributed to why the Guidimaka region experienced a severe flash flood event.

Physical characteristics contributing to the flash flood in Mauritania

The Guidimaka Wilaya region is in Mauritania and is located in the valley of the Senegal river, shown by the red dot in figure 2. This region is in the middle of the Senegal 375,000km2 drainage basin where it can receive up to 2000m of rainfall a year (Anderson, Refsgaard & Jensen, 2001). Making southern Mauritania already vulnerable to river flooding when the volume of water exceeds its capacity.

On a closer scale figure 3 shows an elevation model on the worse affected place of Selibaby. This shows the change in topography between the Southern parts of Selibaby and Central Selibaby. In which Southern Selibaby itself has a high topography between 71m to 114m whereas in Central Selibaby elevation levels drop down to between 61-64m (Google earth, 2019).

The difference in elevation levels only means that overland flow will travel down the steep slopes into the regional capital at a greater speed, meaning the lag time of rainwater getting into the nearby stream is dramatically shortened and increases the flood risk in Selibaby.

Furthermore, climate records are a big indicator to why an area has flooded, in which records show that on a yearly basis the region receives around 475mm of rainfall with August averaging at 160mm (Climates to travel, 2019). For this particular time period of August 2019, 200mm fell in 24 hours in Selibaby, which is over the monthly average and nearly half of the yearly rainfall, meaning again the region wasn’t

used to or able to cope with the mass amount of rainfall leading to a flash flood.

So, taking into consideration the vast amount of rainfall, the location being along the Senegal river and the steep topography of places such as Selibaby, it was no wonder that a flood event occurred on August 2019.

Human characteristic contributing to the flash flood in Mauritania

One factor affecting the magnitude of a flood event is population. The higher the population the more demand there is for infrastructure, leading to increased economic loses in an area. The Guidimaka region holds just over 10% of the country's population, meaning the region was heavily impacted and lots of infrastructure was lost (4,200 households), increasing the impacts of the hazard (Scheffran, Marmer & Sow, 2012).

Also, factors within the living structure can increase the magnitude of an event. In the region, the demographic consists mainly of elderly, women and children. The reason being is because of the harsh working environments that comes with living in a poor place. The young fit men choose to leave home to find sustainable work, leaving less capable people behind and increasing their vulnerability (Scheffran et al, 2012). Stating the reasoning behind why one of the deaths was an infant. (IFRD & RCS, 2019).

Lastly, the poor communities and high intensity farming practises in Mauritania leads to deforestation, as most communities fell trees for fuelwood and building materials while also creating open space for their farming activities (Thiam, 2002). Eventhough this boosts there economic and livelihood it makes them more vulnerable to flooding as there are no roots to infiltrate the water, leading to increased runoff.

Previous flood events in Mauritania

Through research, many previous flood events in Mauritania have emerged. Such as the 2013 flood where southern parts of Mauritania received around 15cm of rainfall in 24 hours on October the 1st, killing 8 people and affecting 5,600 people (Davis, 2013). Also, another being on September the 4th 2019 where heavy rainfall fell for 4 days killing 18 people throughout the southern regions of Assaba and Brakna (Floodlistnews, 2019).

From this, the patterns of flooding events in Mauritania tend to happen in the south when heavy rainfall occur and with the threat of climate change being so relevant the frequency and magnitude of these events will increase, making Mauritania more vulnerable.

Conclusion

The vulnerability in Mauritania is already high without any hazards due to the fact that they are in national poverty, as 26% of the population is affected by food insecurity (International Monetary fund, 2013). This poor economy only heightens their risk as a study on previous flooding in Africa have stated poor people are the most vulnerable from flooding as their circumstances make them prone to the effects (Khandlhela & May, 2006). Meaning when a hazard hits Mauritania the impacts are greater and have longer lasting effects.

Through looking at past events, intense prolonged rainfall patterns seem to be the cause of flooding in southern Mauritania, in which knowing the effects of climate change, it will only increase the future risk and most likely be a higher magnitude. This together with population growth contribute to the high vulnerability in Mauritania and encourage the need for better management strategies for the future. By learning from there past events, official have set up a good analysis, target and scenario plan. Their main management strategies are to focus on the initial needs of the people such as emergency shelter, WASH activities and food, with guaranteed supplies for 1,500 households, around 12,000 people (IFRD & RCS, 2019).

Mauritania have lots of support from their emergency plan of action scheme, with a diverse network of 6,000 volunteers, including UNICEF and the French red cross. In which they both contributed to the initial help after the August flash flood (IFRD & RCS, 2019). However, due to the high vulnerability of the region, Mauritania should be advised to focus more on reaching the Sendai framework goals, such as reducing direct economic losses by 2030 and reducing global disaster mortality by 100,000 throughout the decade 2020- 2030 (UNDRR, 2019).

Overall, better management and preparation for the future will mean that next time a hazard hits southern Mauritania, the impacts will be managed better, and aid will be capable of helping more than just the current 12,000 threshold out (IFRD & RCS, 2019).

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North Sudan: The Nile Flooding

George Lindsay

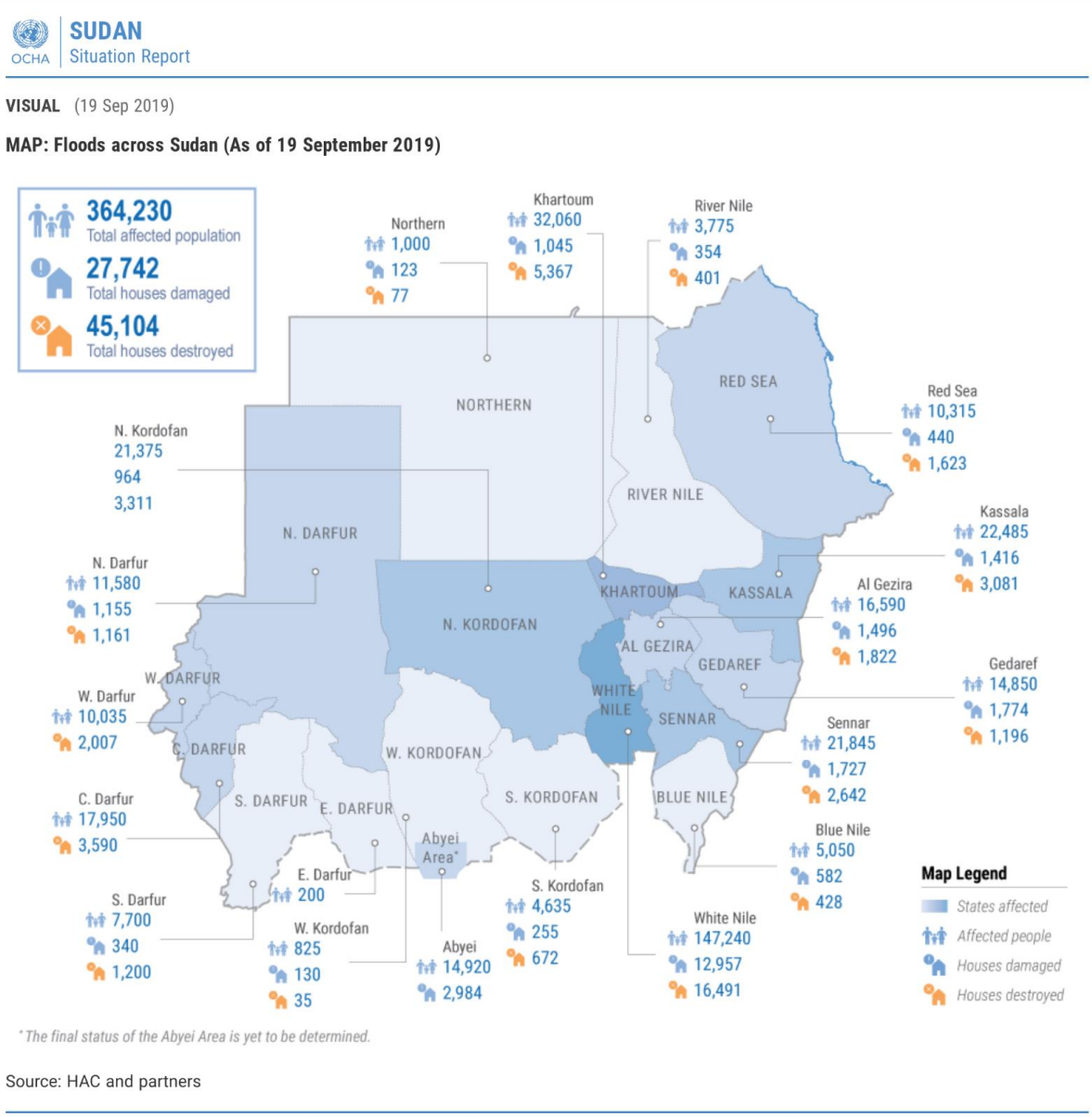


Figure 1 - Map of the affected states in Sudan due to the flood (OCHA, 2019).

Authoritative Account

Introduction

Natural disasters, specifically flooding and desertification, have historically occurred throughout Sudan and contributed to the underdevelopment of the country (UNEP, 2007). Despite the serious water scarcity, Sudan is prone to variabilities in rainfall. This rainfall, on which most of the country is reliant on for agricultural activity, is erratic and unpredictable. This unpredictability, as well as its concentrations into short growing seasons, highlights the vulnerability of Sudan's agricultural systems (Zakieldeen, 2009). The infamous rainfall poses an immense flooding threat to Sudan, due to flash flooding or the overflow of the major Nile River and its tributaries. This risk proved ever present this year when flash floods occurred after constant heavy rainfall which affected 364,000 people across Sudan. In total, 78 people lost their lives (Radio Dabanga, September 1, 2019). The majority of damage was reported in White Nile, Kassala, El Gedaref, Khartoum, El Gezira, Sennar, and Red Sea. An additional 8 deaths were reported weeks later due to the disease cholera. This outbreak is highly likely because of the floods due to an increased exposure to vibrio cholera bacteria which survives better in wet environments (Lipp et al, 2010).

Sudanese Climate

Even though Sudan lies within the tropics, the climate ranges from an arid north to a tropical wet-dry south west. They have a significant climate variable across the country with rainfall and the length of the dry season. Variations in the length of the dry season depend on which of two air flows predominates; dry north-easterly winds from the Arabian Peninsula or moist south-westerly winds from the Congo River basin (Berry et al, 2015). Between the months December and March, Sudan is under the influence of the dry north-easterly winds, leaving Sudan with very little water. By the end of April, the south-westerly winds begin to encompass Sudan and become the predominant air flow. This enables the monsoon wet season which occurs between June and October (Zhang et al, 2012). Figure 1 highlights the extreme variability in rainfall during this season in comparison to the rest of the year across Sudan for 2015.

The Hazard and its Impacts

This unpredictability and variation of the rainfall poses a great threat to flooding within Sudan. Consequently, this extreme weather resulted in the flooding of Sudan in 2019. Radio Dabanga (August 11, 2019) reported that torrential rain and flash floods had caused the death of six people, two from Central Darfur, and the others from North Darfur. The Undersecretary of Sudan's Federal Ministry of Health reported on August 5th that 12 states in the country were affected by heavy rains. Floods had affected most of the country, including the capital city Khartoum, which is situated in the centre of Sudan. Figure 2 highlights the extent of the flooding.

The flooding caused partial or total damage to over 45,000 houses which left people displaced and in need of shelter, sanitation, hygiene services, and health and food supplies. In some areas, families had to find schools for shelter to protect themselves and their children from further flash floods. The governments Humanitarian Aid Commission (HAC), as reported in Figure 3, illustrates the impact across the whole of Sudan highlighting that 364,230 people were affected during this flood (OCHA, Oct 17, 2019). Overall, 78 people lost their lives as a direct impact of the flood mostly due to electrocution as well as collapsed houses (Vall, September 3, 2019).

In developing countries like Sudan, the frequency of contagious and non-contagious diseases spreading through floods is extremely high. These diseases are generally reported during the first few weeks following the floods (Olga, 2012). This trend continued with the Sudan floods as cholera was reported within the Blue Nile and Senner state to the South East of Sudan following the recent floods. According to OCHA (October 17, 2019), 288 cases with 8 deaths were reported as of the 15th October 2019. Fortunately, the oral cholera vaccination has been launched within these states providing aid for the 1.6 million people at risk. Humanitarian partners have developed a cholera readiness and response plan and are seeking US$ 20.3 million for the next three months (OCHA, October 17, 2019). Due to their underdevelopment, management and prevention is hard to achieve as the country is uneducated about the impacts and economically dependent. Further management and education needs to be introduced in Sudan for the impacts to be reduced.

Emergency Response and Reaction

Sudanese authorities at a national and state level were held responsible for the overall organisation of the response effort. The Humanitarian Aid Commission (HAC) activated the Flood Steering Committee as well as the Flood Task Force (FTF) to meet up and discuss a credible response planning for the flood effected areas. Both these organisations remained active in helping the Sudanese people up until the end of the rainy season which comes at the end of October 2019 (Acaps, August 22, 2019). Furthermore, on a national and state level, the Sudanese Armed Forces also joined in on the clean-up as they helped by opening drains (OCHA, October 17, 2019). Subsequently, this hazard inevitably led to a massive clean-up at state level and internationally.

A huge international response capacity came about from the floods especially with UN agencies like WHO, UNICEF, UNHCR and IOM, and several INGO helping the affected areas with critical aid including tents, water, shelter, food and nutrition supplies (OCHA, August 20, 2019). For example, UNICEF had a rapid response to the floods in helping people in the affected areas which included providing water tanks to secure water, thermal blankets, tents and hygiene kits. UNICEF also provided medicines and health supplies to nearly 40,000 people and bed nets to nearly 12,000 people (UNICEF, August 23, 2019).

Flooding spreads the risk of vector-borne diseases because standing waters, that are caused by heavy rainfall, are perfect breeding grounds for mosquitos and in turn emphasise the risk of diseases like malaria and dengue (OCHA, August 20, 2019). Furthermore, due to this risk, the need for mosquito nets and further shelter was necessary. As already expressed, water-borne diseases such as cholera proved a vital risk and management area for emergency response to be conducted. The State Ministry of Health (SMoH) as well as many other disaster management agencies distributed long-lasting insecticide nets (LLIN), insecticides and spray pumps to prevent the spread of water-borne diseases due to the stagnant water (OCHA, October 17, 2019). On the 6th October, humanitarian partners in Sudan launched the Cholera readiness and response plan seeking $20.8 million to address the current outbreak. The response plan targets an estimated 2.5 million people who are at risk

across Sudan in 8 'high risk' states (OCHA, October 17, 2019). Unfortunately, as of 17th October, the death toll of Cholera had risen to 8 people. Even though a response plan was in place, people were still affected and that crisis still is occurring today.

Interpretation of the Hazard/ Future Management

The UN Office for the Coordination of Humanitarian Affairs' (OCHA) report on the Sudan flooding listed many outstanding gaps to the emergency response of the floods. They state that despite all the response efforts by the different authorities, not everyone received the assistance that they needed. As of the 17th October (OCHA, October 17, 2019), in the White Nile, Sennar, Khartoum, and Gedaref states, an estimated 36,000 people still needed water, sanitation and hygiene assistance. Furthermore, they state that there has been a limited educational assistance provided. Consequently, emergency aid on this natural hazard has been rapid but with few exceptions on the quantity of assistance. Moreover, little has been done educationally to prevent the same impacts upon Sudan from occurring in the future. This is also highly likely due to the annual rainy season that occurs between June and October.

In addition to this, the findings of Abbas and Routray (2014) show that around 30 percent of households in Sudan are highly vulnerable to flood risk. They also found that the rural houses are more vulnerable to health risk whereas the semi-urban areas are more at risk of flooding. Subsequently, from researching this hazard, it indicates little is being done to reduce these numbers and the efforts are instead to reduce the immediate impacts of the hazard. However, this could also be the case because of geopolitics and the underdevelopment of Sudan. Sudan itself is a poverty-stricken country faced with multiple hazards as discussed. Therefore, they rely on other countries to assist their development. More needs to be done by the UN and international agencies to assist Sudan in doing this. Possible interventions across Sudan could be the intervention of flood defences surrounding the major Nile as well as its tributaries. In reference to the National Audit Office (2007), there are variations of hard and soft engineering that could be possible to reduce the impacts caused by flooding. However, in relation to Sudan, these adaptations would be expensive. Therefore, a cheap engineering solution like embankments that raise the rivers banks so it can hold more water could be the most appropriate adaptation. Consequently, this could be a possible job for the more advanced countries to assist Sudan in making this occur or, like suggested, improve the educational services to the country so intervention could be possible.

Climate change also has a huge role in the future of flooding hazards in Sudan as well as the management and interpretation of it. Rainfall in Sudan is already unpredictable, but sources suggest it is becoming even more of a variable to dry seasons as well as both areas becoming more intense. The coefficient of rainfall variability (CV) measures the percentage deviation from the mean (Zakieldeen, 2009). Therefore, in this case, it is the uncertainty of rainfall with the higher the CV percentage meaning the more uncertain the rainfall. In Sudan, the CV decreases in the North to South from 190% to less than 15% respectively (Zakieldeen, 2009). This exemplifies the variability across Sudan even more. However, the CV seemed to increase between 1941 and 2000 according to data from some weather stations. Average rainfall also seemed to fall during this period (Fadel-El Moula, 2005). Evidently, climate change has impacted on Sudan making the temperatures increase even more with less rainfall but also increase the unpredictability of the rainfall events. The increased variability as well as the prolonged extreme heat conditions has contributed to drought conditions across Sudan, which in turn, adds to a greater need for water and food. Sudan uses the rainfall as a necessity for its agricultural production, however, if that is affected their vulnerability can be further increased (Nimir & Elgizouli, 2019).

Conclusion

The floods that affected Sudan in 2019 had a devastating outcome on the nation causing the loss of thousands of homes as well as 78 people losing their lives with a horrific knock on effect of Cholera. Furthermore, the floods affected the agricultural production of Sudan which is vital for the economic growth of the country. However, this hazard was preventable or as such its impacts reducible. Ultimately, these variations in rainfall are a common annual phenomenon in Sudan with expectancies across the monsoon months. Therefore, more preparation needs to be interpreted by advanced countries as well as organisations that already help the country. There needs to be more educational services for the people of Sudan as well as an increase in financial services in aid of Sudan so flood prevention can be applied.

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August 2019 Wildfires in the Democratic Republic of the Congo

Jacob Hobson

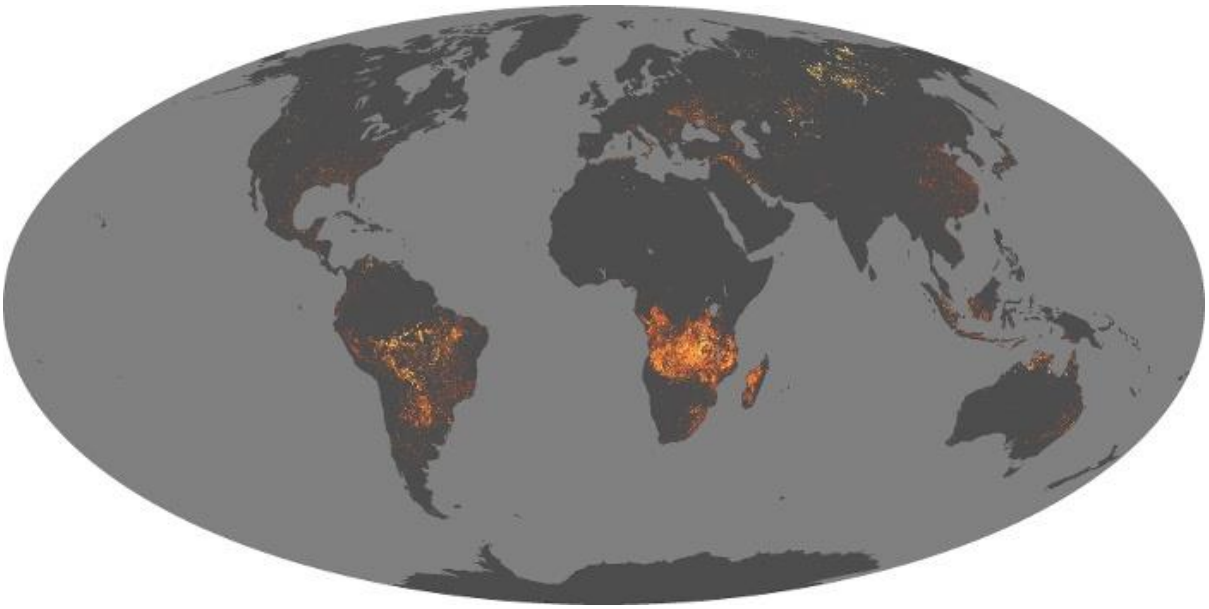


Figure 1: Satellite image of global forest fires during August 2019 (Nasa Earth Observation. 2019)

Introduction.

Wildfires are becoming more and more frequent in the world today with their intensity increasing and the duration of wildfire season doing so as well, in certain areas of the world droughts and wildfires are common.

The Congo Basin is over 500 million acres (3.3 million km2) of land stretching from the Atlantic Ocean in Angola and Cameroon to the far East side of The Democratic Republic of the Congo (DRC) where one third of the rainforest is located, (Cascais, A. 2019) making it the second largest rainforest in the world after the Amazon making it larger than the state of Alaska, home to 10,000 tropical plant species where 30% of these species can only be found here. (Cesareo, K. Newman, K. Huijbregts, B. 2019), the Congo basin also lies on the equator where it has the highest level of sun exposure. (Hartmann, D, L. 2016)

This chapter will focus on the fires that spread through this large rainforest within the Democratic Republic of the Congo on the 22nd to the 23rd August 2019 and the problems it faced in the media.

Background and media reported accounts of the Wildfires.

On August 22nd 2019 fires broke out across the world where the eyes of the world were on the 2000 fires occurring in the Amazon, across the Atlantic ocean in the Democratic Republic of the Congo over 3000 fires could be seen from satellites. These Fires across Africa in the Congo Basin burned for over 48 hours and where 3 times more intense than those seen in the Amazon. (Varley, K. 2019.) (Martinez, M, R. Fleischmann, A. 2019) (BBC. 2019).

Many of the 67,000 fires that were reported in June 2018 were due to a farming technique called slash and burn (Varley, K. 2019), this is a traditional farming method used at the end of dry seasons to burn dry bushes and trees to use the ashes as fertilizer for farming, the President of the Democratic Republic of the Congo (DRC) fears that if the nation does not move away from using wood fires as a source of energy and agriculture the Congo basin rainforest maybe threated by more extreme wildfires due to the deforestation. (RFI. Hird, A. 2019) (BBC. 2019).

Although the number of fires in the DRC are greater than those in the Amazon, the agricultural practices and conflicts that occur have lead to the increase in fires over the last few years and in some areas they believe it is possible to control these fires despite the size and frequency of their occurrences across Africa and in the DRC. According to the Global forest watch fires since the 1st of July there have been over one million sources of fires with in the Democratic Republic of the Congo in around the Congo Basin but have not occurred with the Rainforests sensitive areas according to Greenpeace. (Martinez, M, R. Fleischmann, A. 2019). (Cascais, A. 2019) Nasa released satellite images of the fires showing a red band across Central Africa and show the frequency of the fires that occur within these areas (Figure 1). (Cascais, A. 2019) (RFI. Hird, A. 2019) (BBC. 2019) (Nasa Earth Observation. 2019) (Varley, K. 2019).

Despite most major fires occurring between the 22nd and 23rd of August Nasa satellites still captured around 3395 fires occurring on the 24th of August within the Democratic Republic of Congo, where their frequency was still higher than the recorded for the Amazon at that time. According to some international press reports the fires that was still happening within the Democratic Republic of the Congo still ranked first in the extent of the recent wildfire outbreaks, despite this it was not considered a major concern. (Cascais, A. 2019). Some world leaders such as the French President Emmanuel Macron tried to address these issues within the Congo basin while also addressing the crisis in the Amazon at the G7 summit in Canada with other world leaders after people tried to bring about attention to the issues in Africa over social media, however some people disagreed with his decision to help the Congo basin as the Amazon was a more pressing concern. (BBC. 2019)

The local African media have ignored what is occurring in the Democratic Republic of the Congo and not reported on the blazes but have been focused on the fires that have occurred in the Amazon over their own rainforest (Martinez, M, R. Fleischmann, A. 2019). As these events happen annually, they are ignored due to how common the agricultural practice of slash and burn is within the country, it is a cheap alternative to clear land, kill diseases and also provides a fertilizer for the upcoming rainy season to help crop growth. As this is a common practice and occurs annually it is been said not be a great concern despite the Congo basin, that is primarily located within the Democratic Republic of the Congo, been named the worlds 'second green lung' and the lasting environmental damage these practices could cause to the world aswell as the Congo basin rainforest. (BBC. 2019). (Turkewitz, J. 2019) (Cascais, A. 2019)

Technical analysis of Congo Basin Wildfires.

Wildfires are becoming more frequent due to anthropological interference from pollutants and the effects of climate change causing a steep rise in factors linked to natural causes of wildfires such as the increase in temperature during dryer months. (Pechony, O. Shindell, D, T. 2010).

Democratic Republic of the Congo is around the equatorial line where these is the most solar insolation incident on the surface as the average annual insolation at the equatorial line is approximately 400 Wm-2 which is the most on Earth. (Hartmann, D, L. 2016). The large amount of insolation results in the hot, arid environments found here, and climate change is resulting in larger amounts of solar insolation been present (Pechony, O. Shindell, D, T. 2010) and reflecting off of the clouds due to their albedo (Hartmann, D, L. 2016.) been trapped at the surface prolonging the dry periods leading to more kindling for a fire to ignite and the dense forests can result in dependant fires . (Pechony, O. Shindell, D, T. 2010)

Deforestation is an occurring problem across the Congo Basin and especially in the DRC where the local communities relay the wood provided by the Forest for charcoal in places such as Virunga National Park (which is the oldest National park within Africa) where locals and refugees of surrounding conflicts have been left to survive off of the land. There has also been an increase in the palm oil trade as this puts stress on the forest and surrounding rivers. (Cesareo, K. Newman, K. Huijbregts, B. 2019)

Nasa were the first to detect Figure 1 shows the number of fires occurring during the month of August 2019 from the Nasa satellite where 1 pixel is equivalent to 1000 km2 where an dark red / orange colour represents up to 10 fires per day and the white pixels show up to 30 fires within the area. The satellite image shows large clusters surrounding Congo and central Africa where there are thousands of pixels ranging from light orange (10 fires per day) to white pixels (30 fires per day) show the true scale of wildfires occurring during warm, dry summer periods where large spreads of agricultural burning occurs each year . (Nasa Earth Observation. 2019).

Within and around the surrounding countries of Democratic Republic of the Congo wildfires occur throughout the year annual spiking around the dry periods during summer however during the fires of August 2019 there was an unusual increase in the scale and frequency of the fires engulfing the countries and the Congo Basin. (Nasa Earth Observation. 2019). In Democratic Republic of the Congo a farming method called slash and burn is commonly used (by 20 million farmers in 1999) within the Congo basin and is a form of deforestation (Wilkie, D. Morelli, G. Rotberg, F. Shaw, E. 1999) and is a likely cause of the wildfires that occur within the Democratic Republic of the Congo annually however these methods when unmanaged could have led to the extreme fires that have occurred in the Congo basin on August 22nd 2019.

Another problem that is occurring and increasing the risk of wildfires (reference) is climate change, this is resulting in the average temperature of the area to increase leading to dryer areas which provide kindling and can be used as ladder fuels to escalate the fires, slash and burning can be a cause effect of climate change from deforestation as it is removing trees from the rainforests and later abandoning the area (Wilkie, D. Morelli, G. Rotberg, F. Shaw, E. 1999) reducing the carbon stores available to help fight climate change. (Leahy, S. 2019)

Conclusion: vulnerability and likelihood of occurring again and responses.

Global responses to the fire were minimal due to the active fires that were happening in the amazon

rainforest at the same time. In some areas of Africa, it is hard to reach and record data due to local problems which and lead to areas not been reported as often as other areas that are more accessible and therefore have a lack of understanding the possible risks and hazards present in these areas such as the Congo Basin, therefore better management and monitoring need to be present within the Congo Basin to fight against deforestation and reduce the risk of future wildfires so the correct actions can be taken to ensure such large scale fires are minimized and can be better contained and slash and burning techniques are replaced by more sustainable and more environmentally friendly alterative methods such as the use of fertilizers to help reduce the amount of deforestation occurring in the Congo basin.

As both this fire in the Congo basin and the Amazon rainforest occurred at the same time the likelihood of a large scale wildfire breaking out again within the Congo basin of Democratic Republic of the Congo is highly likely due to its location at the Equator and the rising threat of climate change Leading to more frequent and intense fires in areas at risk.

The major problem faced with this hazard was the lack of recognition it received as it was largely overshadowed by the Amazon wildfires that broke out at a similar time, both of these large rainforests are key to helping tackle climate change to reduce such scale and frequency of these hazards occurring again. The media has been warned not the be concerned with the problematic agricultural practices found within the Democratic Republic of the Congo as they are occurred annually despite their growing size and number of fires started across the rainforests.

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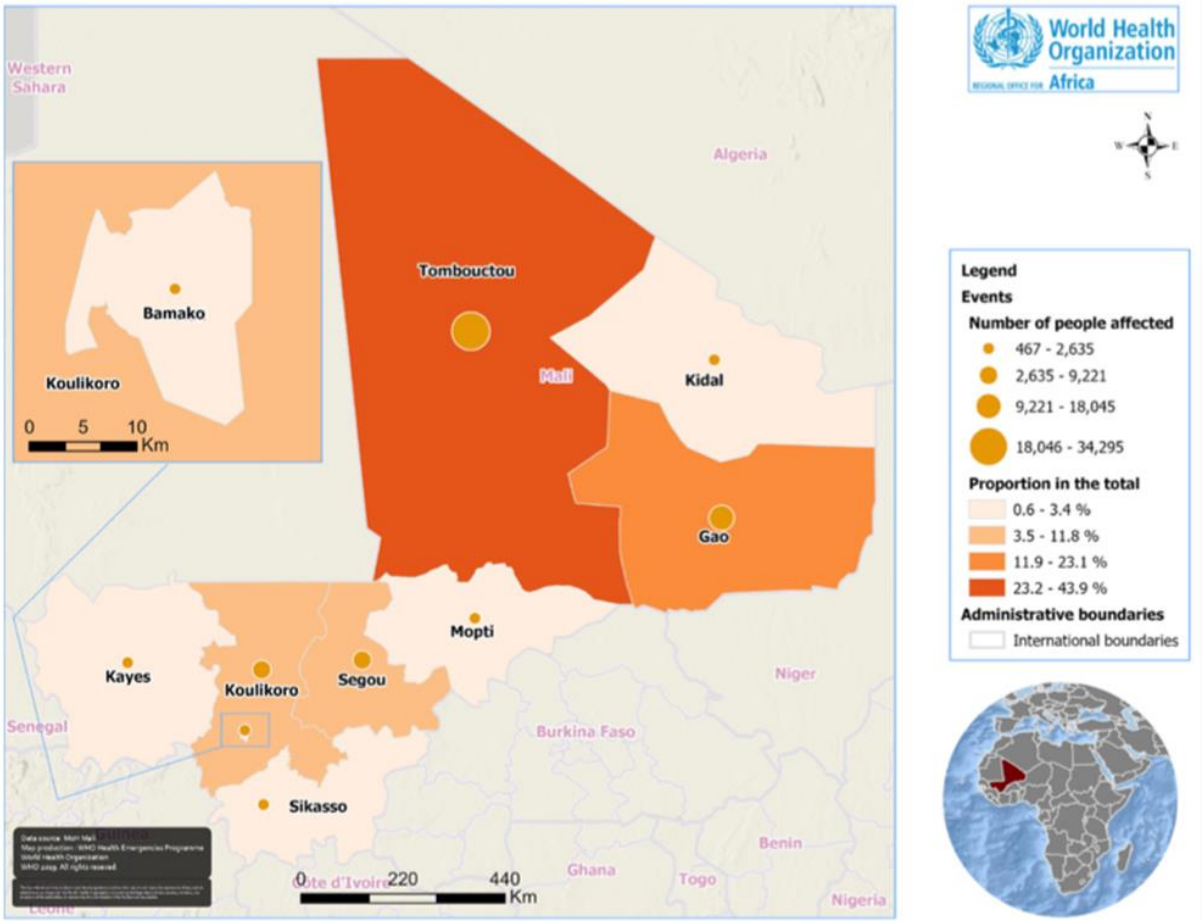
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Flooding in Mali

Michael Ireland



Authoritative Account

Background

Mali is a nation located within West Africa (Southwest of Algeria), Mali covers 1,240,192km2 and is severely affected by floods during the rainy months (typically August – November), especially in areas that are local to the inner delta of the Niger river. The Inner Delta in Mali is the largest flood plain of West Africa and is the most frequently flooded area in West Africa with an estimated land cover of 50,000km2 (Mahé, G., Orange, D., Mariko, A., & Bricquet, J. P, 2011). Mali's capital Bakamo is one of the many regions prone to flooding, one example of flooding here occurred on 16 August 2013 saw the death of at least 24 people and the destruction of many homes and vehicles (BBC NEWS, 2013).

Event Description / Detailed Account of Events

Islamic Relief Canada (IRC) reported 3 September 2019 that heavy rainfall and flash floods had caused significant damage and loss of life throughout Mali, with their emergency responses providing food and shelter to those impacted by the flooding (IRC, 2019).

An Emergency Plan of Action (EPoA) was later published 9 September 2019 by the International Federation of Red Cross and Red Crescent Societies (IFRC) stated that heavy rainfall began 24 August 2019 and lasted for three days until 27 August 2019, these three consecutive days of rainfall releasing approximately 290mm rainfall combined with already high levels of groundwater throughout Mali resulted in extensive damage being inflicted on many regions of Mali (IFRC, 2019), with Timbuktu, Gao, Segou, Koulikoro, Mopti and Bamako being amongst the most affected regions (WHO, 2019). Figure 1.1 illustrates the number of people impacted by the flooding throughout various regions within Mali. The initial assessment revealed that the prolonged rainfall and flooding of Mali and surrounding regions had already affected 6,474 people / 1,729 households, resulting in 845 houses being destroyed. Other news reports referenced IFRC's initial assessment, stating that food stocks had been washed away by the flood water and hundreds of people were left homeless as a result of the flooding (Floodlist, 2019, Reliefweb, 2019). Other impacts experienced as a result of the flooding included loss of livestock, destruction of agricultural land, habitat destruction and massive soil

erosion, which collectively impacted the rural economic sector significantly (WHO, 2019).

Initial Response(s)

Following the initial response from IRW 3 September 2019, further responses were outlined in IFRC's EPoA which began operating 6 September 2019 and was published 9 September 2019. This plan outlined the current situation and responses, including responses from the Host National Society (NS) (Mali Red Cross (MRC)) who had the capacity to support communities and managed to distribute essential supplies throughout the affected areas by having branches in all regions (IFRC, 2019, MRC, 2019). An overall budget of $245,890 was established within the EPoA, this budget successfully provided resources including food, water, clothing, shelter and household kits to an estimated 4,000 people and 800 households (MRC, 2019), despite difficulty reaching severely flooded areas. Local volunteers and MRC staff however provided further support and resources to the population after assessing the damage caused by the flooding, figure 1.2 depicts this situation and highlights the conditions that response teams had to work with.

Interpretation

Climatic Influence

Mali's total area is covered by approximately 65 percent of desert or semi-desert landscapes as illustrated in figure 2.0 with the country lying in the torrid zone, making it amongst the hottest countries in the world. The thermal equator crosses through the country, causing Mali to receive negligible rainfall and frequent droughts, with the rainy season taking place between late April to early October especially in the southmost areas (Library of Congress Federal Research Division, 2005). Flash floods may occur frequently during this period and pose a significant threat to human life and infrastructure, however there is often a lack of data on key hydrological processes in arid areas (Gheith. H., Sultan, M. 2002), limiting the ability to minimize the associated impacts of flash-flooding. Improvements in key hydrological data within Mali would make drainage and construction planning more effective, helping to reduce the associated impacts of flash-flooding in areas that experience flooding annually (Foody, G. M., Ghoneim, E. M., & Arnell, N. W. 2004).

Average temperature throughout August was 36.6□C up until 24th August when the heavy rain started (Accuweather, 2019). High temperatures can cause permeable channels in sedimentary rock such as shale to become smaller due to the combined effect of both thermal and volume stress, causing the permeability of the rock to decrease (Shao et al, 2016). Mali consists of vast flatlands of shale and granite covered by sandstone and alluvial quartz (Middleton, J., & Ajayi, J. A. 1997), the high temperatures experienced throughout August may have reduced the permeability of the sandstone and shale as described by Shao et al, reducing the absorption rate of water into the ground below and therefore resulting in flash-flooding to occur on the surface. The excessive rainfall that occurred between 24 – 27 August was likely to cause any permeable ground to quickly become saturated as groundwater levels were already high (IFRC, 2019), increasing the speed of flooding which likely caused impacts to manifest quickly, leaving minimal time for the population to prepare for the event. This lack of preparation resulted in larger portions of the population experiencing the severe impacts of the flooding.

The River Niger's Inner Delta

Two of West Africa's great rivers (River Niger and River Benue) meet in central Nigeria and flow into the Atlantic Ocean as a single river, the banks of these rivers often overflow during the rainy season and cause flooding in several areas along the course of the river(s) (BBC NEWS, 2018). The Inner Delta illustrated in figure 2.1 located in Mali is a floodplain of the River Niger and experiences frequent flooding during the rainy season due to its proximity to the river and the frequent rainfall during this period such as flooding that occurred during 2004. The River Niger experienced a substantial rise in discharge due to the increase in rainfall between 24th-27th August, this caused the riverbanks to overflow, causing further flooding in areas such as Mopti that were already experiencing flooding due excessive precipitation (IFRC, 2019). The Inner Delta is home to one tenth of Mali's population over an area of 50,000km2 (Mahé, G., Orange, D., Mariko, A., & Bricquet, J. P, 2011), infrastructure and the people of Mali are therefore abundant throughout The Inner Delta, this increased the amount of damage inflicted on both the infrastructure and the population of Mali.

Least Developed Countries

The Least Developed Countries (LDC's) consist of the world's 49 poorest countries which have a per capita GDP of under $900 as well as having low levels of social, capital and technological development (Huq et al., 2004). Mali is included in the list of LDC's which makes Mali very vulnerable to external shocks and disasters such as the flooding experienced during late August (United Nations Conference on Trade and Development, 2001), this increased vulnerability is due to the lack of essential institutional, economic and financial capacity to cope with impacts of disasters such as those caused by climate change (e.g. flooding), the low GDP of the LDC's such as Mali hinders the rebuild of infrastructure that was damaged as a result of the disaster (Sokona, Y., Denton, F., 2001). The lack of money available in LDC's such as Mali has many impacts on the population when a disaster occurs, for example poor quality housing like those built throughout Mali often aren't able to survive the force

of the flooding, also the lack of sanitation an clean water supplies available within LDC's such as Mali contributes towards the loss of lives during a flooding event (MarkedByTeachers, 2019). A severe lack of money within Mali and other LDC's resulted in the populations settling compactly such as the thousands of individuals that are located on The Inner Delta of The Niger River, this often increases the damage and loss of life experienced during a major flooding event (MarkedByTeachers, 2019).

EPOA

IFRC published their EPOA 9 September, this involved multiple partner organisations and branches of the Host National Society assessing the current situation of the flooding event and planning how to effectively provide support and resources to communities and families that were in need of assistance. Despite the overall destruction caused by the flooding, the EPOA was crucial in communicating the relevant information to partnering organisations such as The United Nations Children's Fund (UNICEF) and The United Nations Office for the Coordination of Humanitarian Affairs (OCHA) and in providing the distribution of essential resources to the affected areas. The organised collaboration of multiple organisations throughout the EPOA provided the crucial support needed to aid the vulnerable population, a lack of planning can lead to areas being further exposed to the risks of flooding, especially in areas that are relatively underdeveloped such as those found throughout LDC's (Adelekan, I., O., 2010). Despite the EPOA positively contributing to the support of the affected communities, the operation began almost two weeks after the initial downpour therefore significant damage had already been inflicted throughout Mali. Having a plan established before the event occurred would have significantly reduced the impacts of the flooding and would have allowed both communities and local organisations to be better prepared and equipped for the flooding event.

Conclusion

Many regions of Mali such as Mopti experienced significant impacts of the flooding due to various factors that increased the vulnerability of Mali to disasters such as low GDP as discussed by UNCTD. Mali's status as an LDC arising from low GDP resulted in poor infrastructure that is commonly found throughout less developed countries being destroyed easily and a lack of resources available to cope with the many impacts of the flooding (Sokona, Y., Denton, F., 2001). The contribution towards the loss of life caused by the lack of clean water and sanitation available in Mali further highlights how countries with a lower GDP are often more vulnerable to disasters such as floods then more developed countries.

Mali's location on The Inner Delta of The Niger River is another major factor contributing to the vulnerability of this country to flooding, one tenth of Mali's population residing on this floodplain are therefore at risk every year to flooding during the rainy period that is commonly experienced between April and October (Mahé, G., Orange, D., Mariko, A., & Bricquet, J. P, 2011). Mali's flooding during 2013 killing 24 people supports the suggestion that Mali will continue to be vulnerable to every year. Mali's low GDP prevents sufficient amounts of money from being being invested into flood defences and improved drainage which would significantly reduce the vulnerability of Mali to flooding and therefore reduce the impacts associated with flooding that were experienced in August.

Hotter regions commonly found in the Northern regions of Mali such as Tombouctou were made more vulnerable to the occurrence of flooding as a result of the hot desert climate experienced within Mali reducing the permeability and porosity the bedrock materials such as sandstone which was explained by Shao et al, this allowed flash-flooding to occur on the surface which impacted areas of Mali significantly. High temperatures caused by Mali's proximity to the torrid zone will continue to make the ground less permeable and will therefore leave the country vulnerable to flash-flooding during the rainy season when precipitation increases. Investing in improved drainage and flood defences would combat flash-flooding within Mali despite the lack of money available to invest.

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Cyclone Kenneth, Mozambique April 2019

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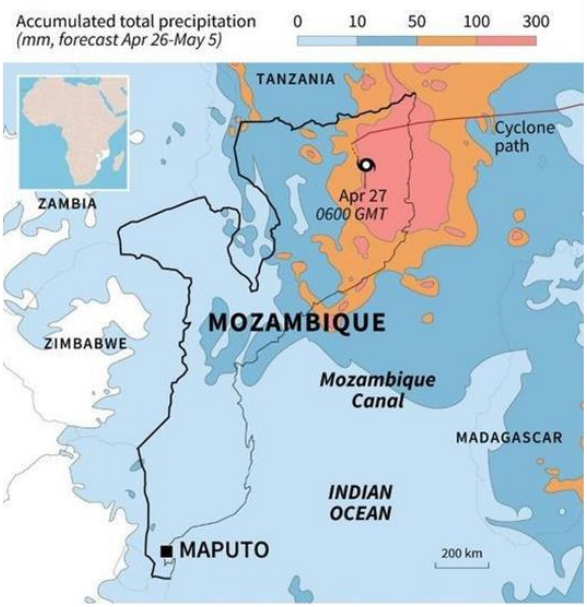


Figure 1: Map of Mozambique and surrounding territories displaying the intensity of cyclone Kenneth (ECMWF/meteologix.com, 2019)

Measuring as a category 4 intense tropical cyclone on the Saffir-Simpson classification scale, cyclone Kenneth was recorded as the strongest weather system to make landfall in Mozambique since modern documentation began. Whilst the damage was mainly centred around northern Mozambique, significant extents of the Comoro Islands and Tanzania also felt the impacts (see figure 1, below). The damage done in Mozambique by Kenneth was further exacerbated by the recent high frequency of tropical storms during 2018–19 South-West Indian Ocean cyclone season (see figure 2, below). The 2018-2019 cyclone season was particularly active; Kenneth was the fourteenth tropical storm and the record breaking tenth tropical cyclone of the period. The arrival of cyclone Kenneth in Mozambique was also preceded in March by cyclone Idai; a vortex that UNICEF would later define as the worst natural disaster to hit Southern Africa in the last two decades.

Timeline

The metrological timeline of cyclone Kenneth began on the 17th of April, 2019, when the Météo-France office in La Réunion (MFR) first identified a vortex north of Madagascar that would later become cyclone Kenneth. Within their initial April 17th report, MFR stated that whilst connective activity in the region was increasing, there was no risk of development of a tropical storm within the next five days (MFR, 2019A). This assessment of the situation would not hold true. MFR would later note an increase in deep convective activity and falling environmental pressure during the 24 hours leading up to April 21st. Extrapolation of the April 21st data showed favourable atmospheric conditions for the development of "defined surface circulation" at the time. The risk of tropical storm formation over the next five days was subsequently raised to moderate and local inhabitants were advised to monitor the progress of the system over the following week (MFR, 2019B). on April 22nd, the Joint Typhoon Warning Centre (JTWC) issued a tropical cyclone formation alert whilst MFR re-designated the vortex as tropical disturbance 14 and began issuing advisories (JTWC, 2019A, MFR, 2019C). JTWC would later classify this system as tropical cyclone 24S on the 23rd and began issuing their own advisories as a consequence (JTWC, 2019B). Shortly thereafter, MFR upgraded the now westerly moving tropical disturbance 14 to a tropical depression and then to a moderate tropical storm within a series of hours on the 23rd. Cloud top temperatures decreased to −90 °C and storm was assigned the name Kenneth at 12:00 UTC the same day (MFR 2019D, 2019E).

Abruptly after its naming, Kenneth began a process of rapid intensification, leading to the development of a formative eye feature (JTWC, 2019C). By the 24th, MFR had upgraded the system to a severe tropical storm with JTWC following suit briefly after by classifying Kenneth on the Saffir-Simpson hurricane scale as an equivalent category 1 hurricane (MFR, 2019F, JTWC, 2019D). At 18:00 UTC, cyclone Kenneth further consolidated into a category 3 hurricane. Wind speeds of 36 knots (67 km/h) were recorded 55 km to the North of the weather system by the Hahaya International Airport on Grand Comore, in the Comoros Islands (JTWC, 2019E). at 0:00 UTC on the 25th of April, Kenneth was upgraded intense tropical cyclone status by the MFR, who pointed out the steadily cooling convective ring and increasingly compact core of the system.

Kenneth was still at this point maintaining its Westward vector towards the coast of Mozambique, with landfall expected before evening between 100 and 150km North of Pemba. MFR correctly predicted and warned that this landfall would be accompanied by heavy rain and storm surges up to 4 meters in height (MFR, 2019G). Cyclone Kenneth reached its peak intensity at 6:00 UTC; a minimum central pressure of 934 hectopascals and a peak ten-minute sustained wind speed of 115 knots (213 km/h) was recorded (MFR, 2019H). At this time, JTWC was concurrently estimating cyclone Kenneth to be peaking with a one-minute sustained wind speed of 124 knots (230 km/h) as a category 4 equivalent intense tropical cyclone (JTWC, 2019F). From this

point forward the weather system began to gradually deteriorate due to the frictional forces exerted on in by its interactions with land as it approached the Mozambique coastline. Kenneth made landfall north of Pemba as an intense tropical cyclone at 13:15 UTC, with one-minute sustained windspeeds of 118 knots (220 km/h) (Masters, 2019). These windspeeds made Kenneth the record-breaking most intense tropical cyclone to make landfall on Mozambique in recorded history (Miller, 2019). Kenneth also marked the second time two intense tropical cyclones made landfall in Mozambique during the same cyclone season since records began (Al-Jazeera News, 2019).

Due to its waning strength as an overland tropical cyclone, Kenneth was promptly re-classified as an overland depression after making landfall. As the weather system moved west and further inland, its degeneration became more rapid (MFR, 2019I). by the end of the April 25th, JTWC assessed the central convection of overland depression Kenneth have both warmed and shrunk drastically, with only a very small portion of it still remaining overland. This marked the last warning issued on Kenneth by the JTWC (JTWC, 2019G). MFR issued its final warnings on Kenneth shortly thereafter on the 26th at 0:00 UTC. They reported centre of "Ex-Kenneth" to be approximately 110 km inland with recorded ten-minute sustained wind speeds of 35 knots (65 km/h) (MFR, 2019J). Kenneth began to stray southwards as its wind speeds continually weakened, eventually falling below the gale force surface windspeed threshold. Whilst Kenneth's central mass remained overland, soon drifting back northwards, subsequent thunderstorms developed off of Mozambique's coastline on the 27th (MFR, 2019K). Kenneth later re-emerged off of Northern Mozambique's coastline on the 28th before completed its dissipation on the 29th of April, 2019, at around 12:00 UTC due to enduring unfavourable weather conditions (MFR, 2019L).

Impacts and Responses

Thanks to early warnings issued by monitoring centres such as JTWC and MFR, over 30,000 people were evacuated from Kenneth's predicted path in Northern Mozambique by local authorities prior to the storm's landfall on the 25th (Al-Jazeera News, 2019). Overall, conservative estimates by UNICEF place cyclone Kenneth's total death toll in Mozambique at 45 whilst other sources such as AON suggest it could be greater than 48 people, coupled with financial damages in excess of US$100 million (UNICEF, 2019, AON, 2019). The rain and wind across the Comoros Islands generated by cyclone Kenneth killed a further 7 people and injured as many as 200 others. An estimated 60-80% of all staple crops on the islands were also destroyed (UN Children's Fund, 2019).

Widespread damage was reported throughout the city of Pemba by the IFRC after Kenneth made landfall to the north. The city received massive damage to its's infrastructure; power outages were frequent and many of the city's poorly constructed houses were destroyed (IFRC, 2019). It was reported by Fox News that as many as 90% of homes on Ibo Island were destroyed, whilst provinces such as Cabo Delgado saw the loss of a further 2,500 homes along with damage to numerous schools and hospitals, making further loss of life less preventable (Aaro, 2019). These figures were also corroborated by the Associated Press, who also reported on 4 ships being sunk near Palma town by storm surges predicted by MFR, along with the death of a woman in Pemba who was hit by a falling coconut tree (NBC, 2019).

With the low gross domestic product per capita of US$593.20 per year, Mozambique represents a much more at-risk demographic during times of crisis than other countries (Trading Economics, 2019). Whilst wealthier communities typically deal with the aftermath of a natural disaster such as cyclone Kenneth independently for the most part, Mozambique was left relying on international aid. The United Nations released a $13 million emergency aid package to Mozambique and Comoros to help repair damaged infrastructure, as well as provide water and food to the displaced (Reuters, 2019). The European Union also donated a further US$1.7 million to provide immediate assistance to those affected (European Commission, 2019). An unexpected development during the aftermath of cyclone Kenneth; violent Islamist insurgency in Mozambique saw a drastic reduction throughout the rest of the month of April before conflict started up again midway through May (Nhamirre, 2019).

Contextual Interpretations and conclusions

The most unique aspect of cyclone Kenneth was its fast arrival after cyclone Idai. Six weeks prior to cyclone Kenneth's formation, Idai swept across the south of Mozambique, killing 603 people. The confluence of these two massive disasters raised fears that Mozambique's humanitarian crises could be exponentially worsened by the combined devastation (Belles, 2019). UNICEF reports that Kenneth and Idai have left almost 1.4 million children at risk across Mozambique, Zimbabwe and Malawi. UNICEF launched an appeal for US$122 million to aid with their humanitarian responses throughout these regions (UNICEF, 2019).

Overall, it can be seen that poorer countries such as Mozambique are particularly at risk to natural disasters, especially larger ones such as cyclone Kenneth. Whilst international aid is important to developing country in a time of crisis, it could be argued that preventative measures taken before the disaster are more helpful. Early warning systems such as those at the Météo-France office and the Joint Typhoon Warning Centre helped prepare

Mozambique for the damage. 30,000 people were evacuated from the major impact zones based on the warnings provided. Whilst these warning systems functioned efficiently, they could still be improved. MFR's initial assessment of the pre-Kenneth vortex on the 17th of April stated there was no chance of development into a tropical storm – an incorrect assessment that could clearly use improvement. Improvements such as these may be difficult due to the mostly unpredictable nature of these atmospheric weather systems. Developments like these may not be possible without large global investment into the creation of more sophisticated monitoring technologies.

Future risks to developing nations during times of natural disaster may also stem from the poorer infrastructures that define these areas. Disjointed road networks separate communities whilst the lack of personal communication devices across the impoverished population reduces their ability to receive updates on these situations. Developed countries such as Japan have seen great success through an early-warning text message system that is both tested regularly via drills and used as soon as a potential danger is detected. Systems like this would likely be ineffectual in Mozambique. For now, though, greatly impacted areas like Pemba and the Comoro Islands will continue to rebuild through the aftermath of tropical cyclone Kenneth by utilising the international aid sent to them, and will rely on the instructions of early warning systems filtered down through local officials to avoid as many casualties as possible the next time this happens.

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Cyclone Idai, Malawi, March 2019

Sean Coleman

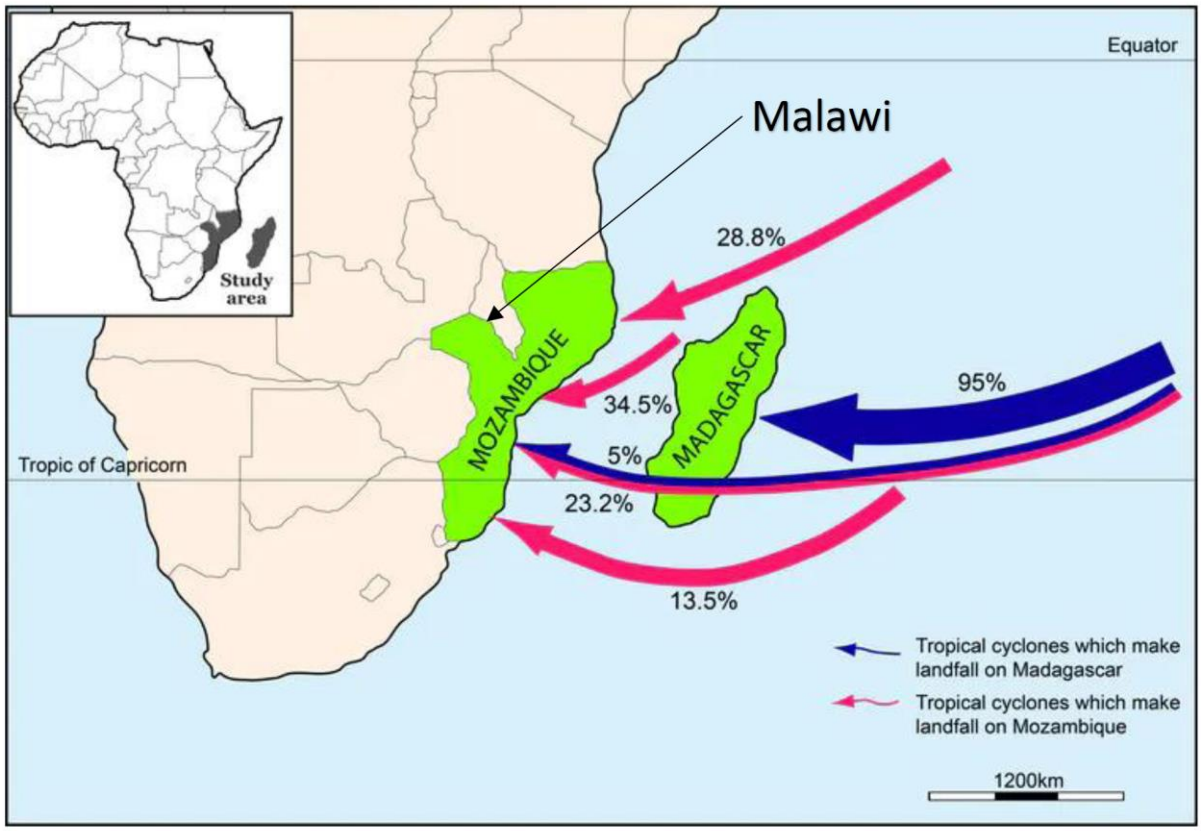


Figure 3 Cyclone paths in the Malawi/ Mozambique area (The conversation 2017).

Tropical storms

Tropical storms are intense low-pressure weather systems that produce extreme winds and torrential rain. The weather events these systems produce are extremely hazardous to human life and cause catastrophic damage to infrastructure, crops, and ecosystems (Chand 2018). Tropical storms vary in destructive power, this destructive power is measured using the Saffir–Simpson Hurricane Scale which categories tropical storms based upon wind speeds and storm surge heights (Garrick 2008).

Cyclone Idai was a natural disaster that took place in March of 2019. When Cyclone Idai made landfall, it was a category four tropical storm (Conversation 2019, Relief web 2019) meaning it had wind speeds between 131–155 mph and torrential rains (Garrick 2008).

Background Situated in the great African Rift Valley, Malawi is highly vulnerable to extreme weather events such as tropical storms. Other common hazards that affect Malawi are floods, there have been nineteen major floods in the last 50 years (Reliefweb 2019). A natural hazard is the probability of a natural event causing harm to humans. The probability of harm is increased when an area is less prepared to deal with the characteristics of a natural hazard, for example poorly built infrastructure in high winds (Sarafoglou, Kafatos 2013). Malawi has experienced rapid population growth with unsustainable urbanisation, this has led to high population density. Environmental degradation has also taken place with agricultural land deteriorating. This is a key issue as degraded soils cause a reduction in quantity and quality of crops (Tun et al 2015). This means a reduction in the amount of food available for livestock and the public which results in adverse social factors. These factors make Malawi more vulnerable as it is harder for them to deal with the hazard both during the event and after as there is less means of recovery (relief web 2019). This is because there is less food available which increases the amount of people that are vulnerable to malnutrition. In 2015 Malawi experienced a severe flood causing damage to crops and infrastructure, leaving the country in a weak state. This was followed by a long period of drought in 2016. The combined negative effects of these two events caused food shortages which affected 3.3 million people and put more pressure on the already degraded agricultural soils. As a result, the national poverty percentage was 51.5% putting the citizens of Malawi in a less than favourable position to deal with the natural disaster that would occur in March of 2019 (Government of Malawi 2019).

Disaster

On March the 3rd 2019 a tropical disturbance began to develop off the coast of sub Saharan Africa. Heavy rains occurring on the 5th of march caused severe flooding across Malawi and kept soil conditions saturated. This flooding caused major damage prior to the arrival of Cyclone Idai. The damage led to food and water being limited, this meant the effects of the tropical storm would be felt even more as the people of Malawi were already suffering and less able to deal with the effects (World vision 2019, Solomon's porch 2019).

The tropical disturbance developed from March 3rd until it became a tropical depression on the 11th of March. The Cyclone carried on growing and built in intensity in the Mozambique channel (World vision 2019, Solomon's porch 2019). In consideration of the impacts of a tropical storm the Government of Malawi declared a national state of disaster in 13 districts and 2 cities prior to the landfall of Cyclone Idai on the 8th of march.

The Cyclone would make Landfall on the 14th -15th of March with wind speeds reaching between 131–155 mph with torrential rains (Garrick 2008). Following Cyclone Idai on the 20th of March heavy rains continued whilst search and rescue operations and damage assessments were still ongoing which

hindered the efforts. International aid arrived on March 21st with governments and humanitarian agencies providing medical and relief supplies (World vision 2019, Solomon's porch 2019).

Aftermath and response

The effects of Cyclone Idai were devastating to the people of Malawi with 60 deaths caused by the floods and high winds. 672 people were injured and required medical assistance, for those surviving the event, the ordeal was not over as 99,728 became homeless after the event with the severe floods destroying many homes (Government of Malawi 2019). In the months following Cyclone Idai 60,880 of the people made homeless remained in displacements camps. The condition in the displacement camps was terrible with often no food and little water. This led to some people leaving and seeking refuge elsewhere. These camps also experience corruption with men in a position of authority at the camp coaxing girls to exchange sex for food (IPPF 2019).

Food became a stark problem to the people of Malawi with over 731,879 in need of immediate food assistance (Unicef 2019). This was because over 91,000 hectares of agricultural land was destroyed during the event reducing the supply of food significantly. In addition to the damage of agricultural crops, there was significant damage to livestock with 47,504 deaths further reducing food supply. This caused over 500,000 farmers to lose a large proportion of their yearly income (Government of Malawi 2019). To aid the resurgence of these farmers Irish Aid distributed tools and seeds to enable them to plant crops giving them a source of food or capital (Concern worldwide 2019).

Assessments show that the damage caused by Cyclone Idai amount to US$220.2 million. Of this US$220.2 million US$106.6 million was lost in the housing sector. The complete recovery and reconstruction from this event has been valued at US$370.5 million. For this recovery to be sustainable and resilient Malawi must improve its disaster risk management and the structural construction of buildings, so it incorporates appropriate hazard resistance (Government of Malawi 2019).

Technical interpretation

Prior to the landfall of Cyclone Idai heavy rains meant that the soils of Malawi were already pre saturated with water. This meant that only small amounts of precipitation were required for the soils field capacity to be full (Horne, Scotter 2016). Once soils reach their field capacity, they are unable to hold any more water therefore anymore precipitation is not absorbed by the soil and is simply just flood water (Lopez, Barclay 2017). As there had been floods only days before the arrival of Cyclone Idai soils in Malawi were close to their field capacity. Figure 1 shows Cyclone Idai then produced an additional 100-200mm of water in rainfall in a matter of hours (Probst, Annunziato 2019). The average annual rainfall for Malawi is 1,056 mm, this means Malawi received between 10 and 20 % of its annual average rain fall in a matter of days (Trading economics 2019). The combination of these factors produced the severe flooding that cause catastrophic damage to Malawi.

The 131–155 mph winds caused the great damage across Malawi (Garrick 2008). The National hurricane centre of America (NHC n.d.) state that housing that experiences wind speeds of this magnitude will sustain severe damage to the buildings structure and roof. Furthermore, it is also likely that areas receiving this level of wind will require substantial reconstruction and will be un-habitable for many weeks following the event. The characteristics above are relative to the housing quality in America. It is important to note that the housing quality in Malawi is significantly worse with 65% of the population living in traditional housing built with mud walls and a thatched roof (Nations Encyclopaedia n.d.). Figure 2 shows what a traditional house looks like in Malawi. As the structural integrity of the houses is not as good as in America; the winds caused considerably more damage than it would have caused in America. This explains why just under 100,000 people became homeless after this natural hazard has occurred.

Malawi is a land locked nation, but it is still in close proximity to the ocean with Mozambique separating it from the coast. 500 km off the coast of Mozambique is the land mass of Madagascar (Davie 2014), Figure

3 shows that the land mass of Madagascar acts as a shield with 95% of tropical storms coming from the east making landfall at Madagascar rather than the continent of Africa. Figure 3 also shows where Malawi is situated within Africa

When a tropical Cyclone makes Landfall it begins to dissipate, this is because the Cyclone can no longer extract sufficient energy from the warm ocean. This causes the intensity of the tropical storm to subside. Therefore, the presence of the Madagascar dramatically reduces the amount of tropical storms that hit Malawi as its presence eradicates the storms source of fuel (Zehnder 2019). This is good as the social, economic, and environmental effects produced by tropical storms hinder the development of Malawi and reduce the quality of life for its residents. However, the reduction of tropical storms that hit Malawi may also be seen as an issue as there is less investment into the mitigation of tropical storms. This means that when a tropical storm actually hits Malawi the probability of harm is increased as the nation is less adapted to manage the effects of a cyclone.

Madagascar not only reduces the number of Cyclones that hit Malawi but also reduces the intensity of the ones that do. Figure 3 shows only 5% of Cyclones that hit Madagascar hit Africa as well. The 5% that hit Africa will often be weaker as the presence at Madagascar causes significant dissipation of the Cyclone itself.

During Cyclone Idai Malawi was not shielded by Madagascar as the Cyclone formed in the northern most part of the Mozambique channel which can be seen in figure 4. The Cyclone then headed west toward Madagascar before spiralling 180 degrees. This spiralling gave the Cyclone an extended time period to grow which explains why the Cyclone was able to grow so large and may explain why Cyclone Idai had a significantly greater catastrophic impact than other Cyclones that have hit Malawi (Zehnder 2019).

Conclusion

The response to cyclone Idai was very poor, this was because months after the cyclone had occurred 60,880 of the people who became homeless remained in these displacement camps. These displacement camps were centres of corruption with little food and water available to the public. This further reduced the quality of life for Malawi's residents and increased the level of people with mental health problems. The displacement camps offered no help for people to rebuild their homes and lives only a place to stay temporally. This is a poor response as it reduces the likelihood of people getting their lives back on track as people have no resources to reconstruct homes. Everything they owned has been destroyed by Cyclone Idai. This causes negative social and economic factors for Malawi which hinders the development of Malawi.

The future poses high amounts or risk for Malawi; this is because the country has invested little into cyclone mitigation such as emergency provisions and evacuation routes. This means during future cyclone events the people of Malawi will still face the dangers a cyclone presents with limited mitigation strategies in place both during the cyclone and after. This means the probability of the hazard causing harm to humans remains high.

Climate change means the risk that cyclones pose to Malawi are going to increase. This is because the quantity of cyclones occurring annually are said to increase, this makes it is more likely that Malawi will be exposed to more cyclones. In addition, the warmer ocean temperatures mean these cyclones will increase in intensity and therefore destructive power. Therefore, future potential risk is likely to increase (GFDL 2019).

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Republic of Namibia Drought 2018/2019

Owain Kril

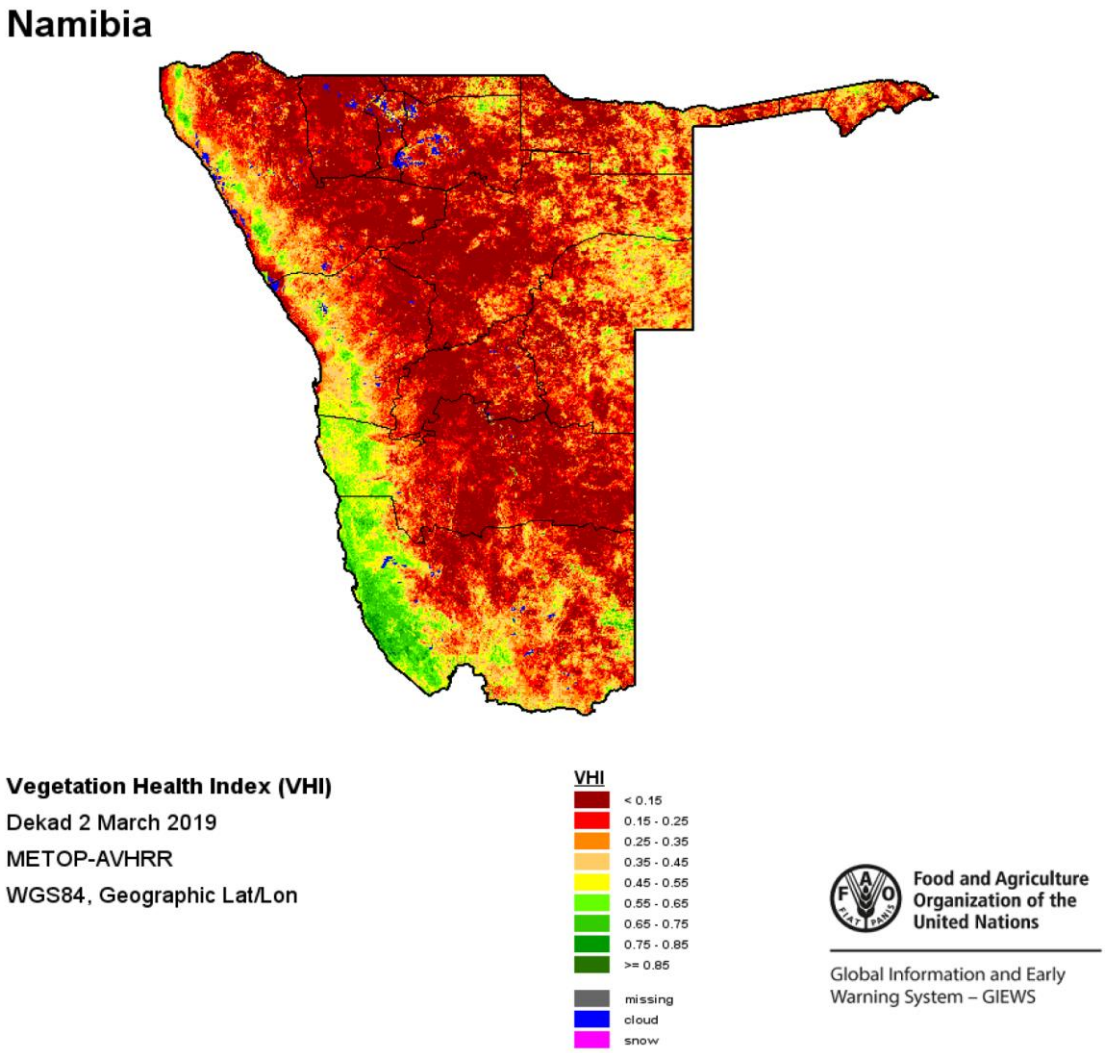


Figure 2 – Vegetation Health Index for Namibia, 2nd March 2019
Source – Food and Agriculture Organisation of the United Nations
http://www.fao.org/giews/earthobservation/country/index.jsp?lang=en&type=21&code=NAM

Introduction

The Republic of Namibia on the western coast of Southern Africa sharing its borders as shown in figure 1. Namibia is the driest Sub-Saharan Country with an arid, desert like climate (IWRM, 2016), boasting an average of 300 days of sunshine per year (info Namibia, 2019; World Travel Guide, 2019). Namibia's rainfall varies from 600mm per year in the Caprivi strip in the North East, to as low as 50mm in the coastal deserts, and an average rainfall of 350mm per year (IWRM, 2016; Encyclopaedia Britannica, 2019).

Namibia is heavily reliant on its rainy season for agriculture, power generation and economic stability. The season begins around October, through their summer in December and January, with crucially increased rainfall usually experienced between February and April (Namibia Weather, 2019; UNICEF, 2019; EC, 2019). Namibia and most of Southern Africa is prone to drought conditions. From October 2018 to May 2019, Namibia has experienced its driest rainfall season in the past 38 years. This has been heavily influenced by the 'El Nino' climate phenomenon during the Autumn of 2018 (BBC, 2019).

The resulting drought with existing water scarcity issues due to meteorological and sociological factors, has greatly affected surface and ground water supplies. Water for domestic, agricultural and industrial purposes was at a critically low level. On the 6th May 2019, the Namibian Government declared a national emergency in an attempt mitigate

the impacts of the drought (ADB,2019; UNICEF, 2019). The American Embassy also declared an emergency on the matter on 22nd May 2019 (ADB, 2019) and the Global Disaster Alert and Coordination System classified the drought as a Level 2 Red-class Event as of mid-August 2019 (GDACS, 2019). Described as "life threatening impacts: migrations and internal displacements, famine or starvation, violence explicitly related to water resources conflicts. International humanitarian aid is needed or has been requested/dispatched" (GDACS, 2019).

Agricultural Impacts

Crops

70% of the Namibian population relies on agriculture either directly through subsistence farming, or indirectly through the commercial sector (FAO, 2019). The drought is responsible for a decline of 53% from last year's harvest and a drop-in crop production estimated to be 42% below Namibia's 20-year average (ADB, 2019), and leaving some 257,383 without adequate food (ADB, 2019; UNICEF, 2019; The Guardian, 2019). The Ministry of Agriculture, Water and Forestry (MAWF) estimated in December 2018 that cereal production in communal areas could drop as much as 80% and fall 15% in commercial areas heavily affecting food security.

In the north of the country ephemeral rivers have dried up making Government aid essential (Haidula, T. 2019). MAWF stated food supplies for 42,899 households will be needed to save lives from starvation and malnutrition between June 2019-March 2020. Provision of agricultural inputs to drought affected farmers is also critical as well as health and nutritional support to vulnerable groups (ADB, 2019). In 2018 about 64% of consumed garden produce was imported into the country (Amukeshe, L. 2019) and 96% of all fruits (Tjitemisa, K. 2018).

Livestock

Below normal rainfall levels since 2013 has not allowed for recovery of exhausted grazing lands, culminating in further deterioration with land quality ranging from fair to poor (ADB,2019). Figure 2 shows the Vegetation Health Index for Namibia, used to identify drought-related agricultural impacts from remote sensing data (IDMP, 2018). Red colours show areas of severe and extreme drought conditions as of March 2019. Drought has resulted in animal death, crop failures, soil erosion and land degradation (FAO, 2019). Due to poor grazing conditions in Namibia's parks the Government attempted to sell 1000 wild animals to avoid starvation and to raise funds towards wildlife conservation and park management (The Guardian, 2019). Approximately 60,000 domestic animals died in the 6 months leading up to May 2019 as a direct link to drought (The Guardian, 2019; BBC, 2019) with the worst affected region, Kunene North, losing 12,200 cattle, goats and sheep (UNICEF, 2019).

Response

After the 6th May 2019, the Government of Namibia approved a package of interventions, including food assistance, livelihood support, increased access to safe drinking water, borehole rehabilitation and seed distribution (ADB, 2019). The Directorate of Disaster Risk Management (DDRM) estimated the cost of providing food to the recognised 42,899 affected households of around US$14.2 million and US$2.9 million to cover logistics of the operation. Namibia could only fund $9 million, forcing reliance on financial aid from The United States ($100,000), the United Nations ($1 million) and support from organisations such as The World Food Programme, World Health Organisation, and national companies within Namibia to bolster relief efforts (ADB, 2019).

Technical Interpretation

Drought origin

The Southern African climate is affected by the El Nino Southern Oscillation (ENSO). The 2018/2019 ENSO contributed to the drought conditions in Namibia. ENSO is a naturally occurring phenomenon caused by fluctuating ocean temperatures in the Pacific. When accompanied by large scale fluctuations in air pressures in the same region, warm waters from Indo-Australian Oceans flow towards the East Pacific (WMO, 2014). This renders some areas cooler and wetter and others such as Southern Africa warmer and drier (NOAA, 2016).

Water scarcity Surface water is only available to the central regions during summer months when rivers flow after heavy rainfall, which can divert into large dams designed to store the seasonal rains. Figures 3/4 show the tendency of evapotranspiration compared to the amount of rainfall if not effectively stored artificially or in naturally occurring aquifers. The only perennial rivers in Namibia are found along its national borders and crossing the Caprivi and a number of ephemeral rivers flow during rains (figure 5), but the majority of the population don't have access to river water. Therefore, 80% of the population rely on groundwater for their livelihoods sourced from depleted boreholes (IWRM, 2016).

Namibia relies on water for electricity generation at Ruacana Power Station in the North West along the Kunene River, producing 330MW of power, accounting for up to 90% of all power in Namibia (Grantham Institute, 2018; Conway, D. 2017). The majority of water originates from Angola which is prone to similar climate conditions as Namibia (Nakayama, M. 2003). Any drought induced decreased water discharge can lead to power outages, resulting in economic destabilisation.

Past drought events

El Nino events occur irregularly every 2-7 years lasting between 9 Months and 2 Years. In 2013 a drought emergency, killed around 4,000 animals and affected about 300,000 people (UNICEF, 2019). The 2014-2016 ENSO was one of the strongest since 1950, resulting in devastating consequences (Sithole, V, B. 2016): -

- Over 500,000 children suffering from malnutrition
- 3.2 million children with reduced access to safe drinking water
- Income sources diminished due to loss of income from crops and livestock
- 643,000 livestock deaths throughout 5 countries
- 28.5 million people affected as of June 2016

The vulnerable in Namibia were still tackling the impacts of the last drought as the 2018/2019 drought started (FAO, 2019). In response to the 2014-16 drought most Southern African countries declared a state of emergency and appealed for international assistance (Sithole, V, B. 2019). However, emergency responses are costly and as drought frequency may increase, it will put a serious strain upon the Namibian economy. Heeding Early warnings about ENSO events and contingency planning is vital to the future of the country.

Climate Change

Global warming may exacerbate the dry conditions experienced in Namibia in the future, with effects already being felt today. Average temperatures will increase every year by 0.2 degrees which is roughly three times the global mean (Midgley, G et al. 2005). Namibia is already suffering below average rainfall since 2012/2013 with weather becoming more unpredictable. Rains can cause intense flooding, soil erosion and other related hazards (Reid, H. Sahlen, L. Stage, J. Macgregor, J. 2008). The occurrence of disasters such as droughts and floods have already increased across Namibia (Dilley, 2003). The Government of Namibia (2002) predicted reduced precipitation in the future, however, this has had little influence on Namibian policies thus far.

Reid et al (2008) and Wilhelm (2012) stated that during the previous 20 years there has been an annual decrease in Namibia's economy of up to 5% of GDP as a direct result of climate change impacting on the countries natural resources alone. Namibia is highly dependent on natural resources with over half the population involved in agriculture and 78% of land being used for farming (Mendelsohn, 2012).

Cost of doing nothing

In a report by IFRC (2019) "The Cost of Doing Nothing", providing basic support to everyone needing assistance from climate related disasters globally is around $12 Billion and is expected to reach $20 Billion by 2030. The report also states that if sufficient action is taken to mitigate the effects of natural disasters, there could be 90% less people affected by 2050. Relevant Government intervention could save lives and reduce Government expenditure

Investment

Water management projects

Water management projects and programmes are in effect such as The Namibia Water Resources Management Project (NWRM-project) and the 'Groundwater for the North of Namibia' project. Both are joint ventures between Namibian organisations and the German Government looking at improving sustainable basin management, access to safe drinking water and information concerning groundwater resources.

Desalination

Desalination, the removal of salts and minerals from water, has increased in popularity over the last decade (Jones, E. et al, 2019). China, India, South Africa and California have all resorted to building desalination plants to provide fresh water for their population (Robbins, J. 2019). Namibia already has a few small plants, but these only support a university campus and uranium mine (Hartman, A, 2009, 2019). Using solar energy to power new desalination plants is ideal for Namibia and should see future investment.

Hydroponics

Hydroponics has begun to gain traction in Namibia due to the poor soil quality and lack of irrigation water. Hydroponic growth doesn't require soil and uses 90% less water compared to typical farming methods (Al-Ghafri, A. 2018). The Namibian Government has approved a subsidy scheme to support small scale farmers venture into this production method. The Prime Minister Saara Kuugongelwa-Amadhila said these systems could produce fodder in seven days and feed many cattle and that training farmers on the use of hydroponics is planned for the future (Nakale, A. 2019).

Conclusion

Recent meteorological events are suggestive of a worsening pattern of flooding and drought conditions, affecting food, power production, and economic growth. Namibia needs to increase its capacity to absorb the negative environmental effects and enhance the positives in a sustainable approach. Timely responses to predicted El Nino events will hopefully lead to effective mitigation of possible disasters.

Urgent investment in methods of harvesting/storing water, both for use in its lucrative mining and diamond industry, the largest contributor to GDP (Namibia High Commission London, 2019), and to create agricultural independence are needed to future

proof the Namibian economy. Expansion of desalination plants and storage reservoirs are vital. Ample solar energy allows the powering of desalination plants to create fresh water. This could then be pumped inland to storage facilities to protect the most water isolated residents.

Promotion of hydroponics should be hastened as it will increase food security, decrease water usage and decreased reliance on subsistence farming. Decreasing the reliance on food imports and international aid, increasing job security thereby stabilising the economy.

Namibia needs to take initiatives to ensure that future policies and activities are environmentally proofed and increase the resilience of their economy. Namibia will inevitably need to manage general policies to manage droughts and economic threats in the future.

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Continental Asia and the Indian Subcontinent

Earthquake in Zhoujia, China

Beth Robins

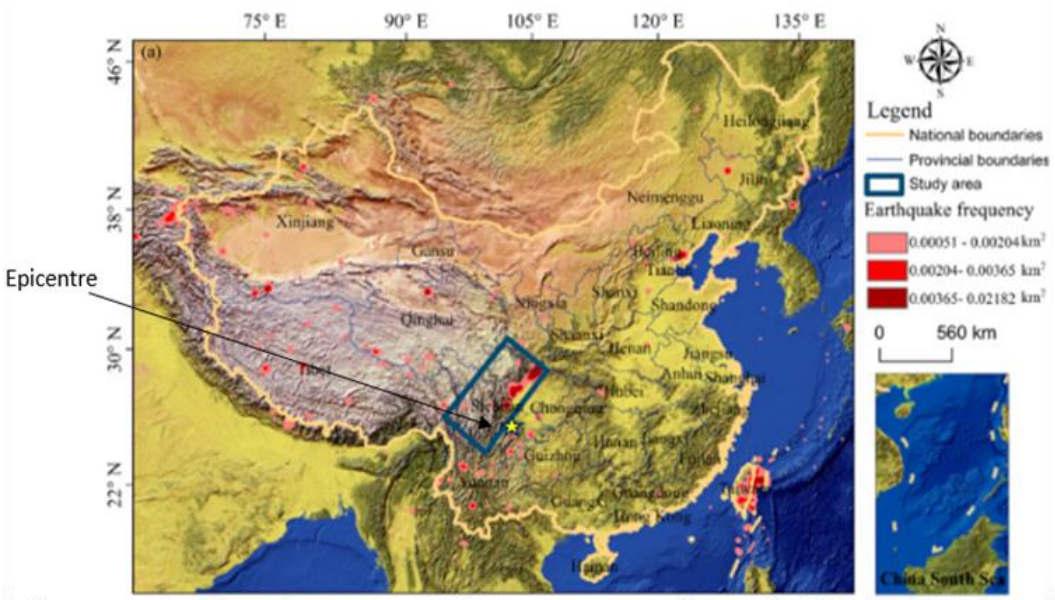


Figure 3: *The area within China where earthquake frequency is greatest (Cao et al., 2019). The box is located in Sichuan and the location of the epicentre of the 2018 Zhoujia earthquake is indicated by a yellow star.*

At 12:46pm on Sunday 16th December 2018 an earthquake hit Zhoujia, Xingwen County in southwest China's Sichuan Province (GDACS, 2018; Liangyu, 2018). The earthquake's epicentre was 70km away from the densely populated city Yibin and 270km from the province's large capital Chengdu (CENC, 2018) (Figure 1).

According to news reports from Mackie (2018) and Liangyu (2018), the earthquake was of moderate magnitude 5.7 but struck at a shallow focal depth of 12km. No fatalities were reported, but 16 people suffered injuries (Li, 2018; Petley, 2018). Had it not been for the effective preparation and quick-thinking emergency response teams on-site, the number of casualties would have most likely been greater. This is an authoritative account based on limited sources as, due to the small-scale of the earthquake, there is a lack of information about the event. Upon researching the earthquake, I found that most sources were Chinese newspaper articles or websites; it did not receive much global attention. Therefore, I looked out for as many Chinese newspaper articles and websites at the time of the earthquake as possible.

Background of the earthquake

Sichuan is a land-locked province in Southwest China (Figure-2). It is located on the east-side of the Qinghai-Tibetan Plateau, a vast elevated area referred to as the 'roof of the world' as it stands at an average of 4.5km above sea-level (Gramling, 2019). Sichuan is the 2nd largest province in China; it has a population of 80 million people and is densely populated in many areas such as Chengdu, with 8,867 residents per km2, (Pan et al., 2015). However, it also has remote areas, such as Daocheng County, with 4.58 residents per km2. Additionally, Sichuan is an area of significant industrial importance as well as having a developed tourism industry and abundant energy resources (Shi & Seeland, 2019). Therefore, earthquakes are detrimental to not only a large vulnerable population but well-established industries.

This earthquake was just one of many earthquakes to hit China. As Wu et al. (2018) stated, although China represents just 7% of the Earth's landmass, it accounts for over 35% of global earthquakes of magnitude 7 or above. Hartmann et al., (2014) agreed with the figures, but expands by mentioning that, of 1,200,000 fatalities caused by worldwide earthquakes during the 20th century, China accounted for 590,000 (49%) of these. A high proportion of these earthquakes and their associated fatalities occurred in Sichuan, one of China's 5 major earthquake zones, characterized by high seismicity (Shi & Seeland, 2019) (Figure-3).

As Figure-3 shows, the epicentre of the Zhoujia earthquake was close to the high-frequency earthquake zone in Sichuan. Just this year Sichuan has suffered from 37 earthquakes of magnitude 5 or above, as of 10th December 2019 (earthquaketrack, 2019). This earthquake came 10 years after the Sichuan earthquake on 12th May 2008, one of the most significant earthquakes in Chinese history (Johnson, 2018). The quake was of magnitude 7.9 and occurred 19km below the earth's surface (Daniell,

2013). Although the earthquake was not a record-breaker in terms of energy released, it was a stand-out event in terms of the number of people affected; there were over 87,000 fatalities and over 370,000 injuries. Most deaths and illnesses were due to buildings collapsing and falling debris as 80% of the structures in the area collapsed, including schools (Pletcher & Rafferty, 2009). The remoteness of the area made it difficult for soldiers and relief workers to reach, and lack of modern rescue equipment also contributed to the high death toll.

Fortunately, there were no fatalities during the 2018 Zhoujia earthquake, however a total of 16 people were injured (Li, 2018; Petley, 2018). Additionally, 629 people were evacuated, and 6,145 villagers suffered damage to their properties. According to Xinhau (2018), 15 homes collapsed, and 231 homes were severely damaged (Figure-4). The severe damage included several large cracks appearing across walls of buildings (Liangu, 2018). There were reports of up to 23 aftershocks and the quake was also felt in nearby cities including Yibin, Chengdu and Chongqing (CGTN; 2018, Xinhau, 2018). One resident in Chengdu reported feeling the floor shaking for 5-10 seconds, causing the office chair to move 10cm back and forth several times (Taihe, 2018). The disruptions caused an economic loss of around 50 million Chinese Yuan Renminbi, equivalent to approximately $US 7.5 million (Seismological Society of America, 2019). As Sichuan is prone to earthquakes, they are generally well prepared for them in terms of building design and equipment (Figure-5a) as well as education and warning systems (Figure-5b). Especially after the 2008 earthquake, China has invested heavily in preparation and response techniques to minimise loss of life and money (Taylor, 2018). Preparedness techniques involved the retrofitting and rebuilding of buildings, educating children about hazards and risks of earthquakes, doing regular drills, installation of satellites to track and monitor hazards and online warning systems. Hours before the 2018 earthquake occurred, Global-Disaster-Alert-and-Coordination-System (GDACS) (2018) issued an overall green earthquake alert, with a low GDACS alert score 0.8.

The GDACS alert score assesses the overall impact an earthquake has had/will have on the affected countries on a scale of 0-3, with 3 being the worst impact (GDACS, 2018). To calculate the score, it uses an integrated system considering factors such as magnitude, depth, distribution of population within 100km from the epicentre, vulnerability and coping capacity of the affected countries. In this case, GDACS (2018) identified there was an exposed population of 10,190,000 people living within 100km of the epicentre, but the earthquake was expected to have a low humanitarian impact due to the low magnitude and vulnerability of the affected population. Automatic alerts of predicted impacts of the quake were sent out via e-mail, fax or SMS. This was an effective method for warning the locals with what to expect and what to do next.

Response techniques involved having trained rescue teams. In 2008, China had just 27 earthquake rescue teams (Xinhau, 2018). Ten years later, they have 3,000 rescue teams in addition to 700,000 trained rescue volunteers. As China Daily (2018) mentioned, during the 2018 Zhoujia earthquake a level-IV emergency response was activated by the 'Ministry of Emergency Management' and work-teams were dispatched to guide and assist with emergency rescue work; over 300 rescuers were sent to the quake site. The rescuers set up makeshift tents to aid affected people, especially as the region had experienced snow and rain (Liangyu, 2018; Zhiling, 2018) (Figure 7a and 7b). The injured were admitted to a local hospital. The victims were also provided with medical services as well as electricity, food, quilts and bedsheets at the temporary relocation site (Xinhau, 2018). As many as 2,000 tents, 600 quilts and 400 coats were provided to 1,229 affected people. As Beautiful China (@lijiafei01) (2018) mentioned on twitter, although the earthquake happened early morning, that did not stop volunteers from arranging for relief materials, e.g. super noodles and mineral water to be delivered to the resettlement sites. Police and militia helped the villagers build tents. Had it not been for the prior-warning and response from the emergency teams and volunteers, there would have been more casualties.

Moving on from this, as a result of the Zhoujia earthquake, landslides occurred in the region, cutting off many roads, making them inaccessible (Liangyu, 2018; Petley, 2018) (Figure-8). Landslides refer to a mass-movement process in which a large coherent mass of material moves downslope, under the influence of gravity, but remains undeformed. (Holden, 2012). They are triggered by different factors, including earthquakes. As Gabler et al. (2014) mentioned, many mountainous regions have enormous slabs of rock supported by weak materials, poised on the brink of detachment. They are waiting only for an earthquake to occur and set them all in motion. Earthquakes greatly reduce the friction and strength of the material, therefore reducing the power of the 'glue' cementing the rock and soil grains together (BGS, 2019). Located on a slope, the rock is no longer strong enough to resist the forces of gravity acting upon it, hence increasing the slope's susceptibility to landslides. To prevent damage, building near sleep slopes must be avoided, particularly in earth-quake prone areas like Sichuan (USGS, 2019).

Causes of the earthquake

One of the main reasons for the occurrence of earthquakes in Sichuan is its proximity to plate boundaries (Figure 9).

As Figure-9 shows, Zhoujia, is located close to the boundary between two tectonic plates: the Indo-Australian plate (combining the smaller Indian and Australian plates) and the Eurasian plate. It is the collision between these two continental plates that causes frequent earthquakes (Gao, Ma & Li, 2011). The Indian plate is continually converging northward towards the Eurasian plate at the convergent boundary (Figure 10).

According to Marutirao (2016), it is estimated the Indian Plate convergences northwards against the Eurasian plate at a rate of around 50mm/year. The Qinghai-Tibetan, Sichuan is formed by the continental-collision of these plates at the convergent boundary (Deng et al., 2014). Earthquakes occur at convergent boundaries as a result of the gradual build-up of stresses and strains on the rocks as they collide (DeVecchio & Keller, 2014). As the 2 tectonic plates move past each other, friction is caused along the fault line separating the plates, causing the movement to slow down. This puts stress on the rocks resulting in the rocks undergoing stress and deformation (De Blij & Mason, 2016). Once the stresses on the rocks exceed the strength of the rocks, the rocks break suddenly, forming a fault with one side slipping past the other. It is this sudden slip that causes earthquakes. As rocks slip suddenly the stored elastic strain energy that accumulated as a result of the stress and deformation of the rocks is released (Sulphey, 2016). The energy is released as seismic waves which cause the intense shaking of the earth's surface during earthquakes. This process is what caused the 2008 Sichuan earthquake; Pletcher and Rafferty (2009) explain it was caused by the collision of the Indo-Australian and Eurasian plates along the Longmenshan thrust fault. The stresses produced by the northward convergence of the Indian plate against the Eurasian plate shifted a section of the Tibetan plateau eastward. The compressional forces associated with this shift sheared the ground and caused the ground to thrust upwards by 9 metres (Fang & Westcott, 2018).

On the other hand, there are sources claiming the earthquake may have been induced by hydraulic fracturing (fracking), rather than its tectonic setting. Earthquake-prone Sichuan is a site of extensive fracking operations (Stanway, 2019). It accounts for around 1/3 of China's total shale-gas production. Changning anticline, located at the southern margin of the Sichuan Basin near where the earthquake occurred, is a key area for shale gas exploitation (He et al., 2019). Lei, Wang & Su, (2019) states the tremor occurred suspiciously close to hydraulic fracturing zones of horizontal wells where fracking was ongoing. Since the systematic hydraulic fraction operation began there in 2014, there have been 11 earthquakes of magnitude 4 or above in the region near fracking wells (as of April 2019). This is a dramatic rise in the region's earthquake rate, according to (Seismological Society of America, 2019). The primary cause of fracking-induced earthquakes is believed to be the hydrocarbon extraction process when liquid is injected into rock layers at such high pressure the rock fractures (Golden & Wiseman, 2015). Furthermore, another cause of fracking-induced earthquakes is believed to be due to disposal of the liquid wastes from drilling and fracturing via underground injection into disposal wells. According to Seismological Society of America (2019), the earthquake coincided in time and space with an injection at a nearby fracking well pad. This adds to evidence the earthquake was potentially fracking-induced.

Conclusion

Sichuan is one of the most seismically active regions in the world and will continue to be seismically active since the earth's tectonic plates are constantly in motion. For as long as the Indian plate is converging towards the Eurasian plate there will continue to be stresses built-up, eventually to be released as energy, causing earthquakes. Therefore, the population of Sichuan will continue to be vulnerable to earthquakes, particularly as Sichuan is densely populated in many earthquake-prone areas. Although the province has relatively good preparedness and response teams, as demonstrated during the 2018 earthquake, it will only need to be improved as population and earthquake frequency are increasing. Since fracking was introduced in the area, earthquake frequency has increased significantly. In future, it is essential that research is done to determine whether the occurrence of earthquakes is linked to human-induced fracking. If so, immediate action is required to ensure the activity is halted or closely monitored to prevent further damage. Accessibility needs improving so rescue workers can reach remote areas of Sichuan. Warning systems will also be improved. In May 2019, it was announced that Sichuan would provide advanced early warning systems by the end of 2019 (Sichuan Earthquake Administration, 2019). This includes multiple broadcasting systems to alert residents seconds before seismic waves, complying with research stating that 63% of causalities could be saved by being warned up to 20 seconds beforehand (Yan, 2019). Additionally, the warning system will offer basic information 1-2 minutes after the quake strikes, its magnitude 2-5 minutes after and an assessment of the disaster within 2 hours. Hopefully these warning systems will reduce casualties and losses.

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2019 Kerala Floods

Tom Smyth

Figure 2

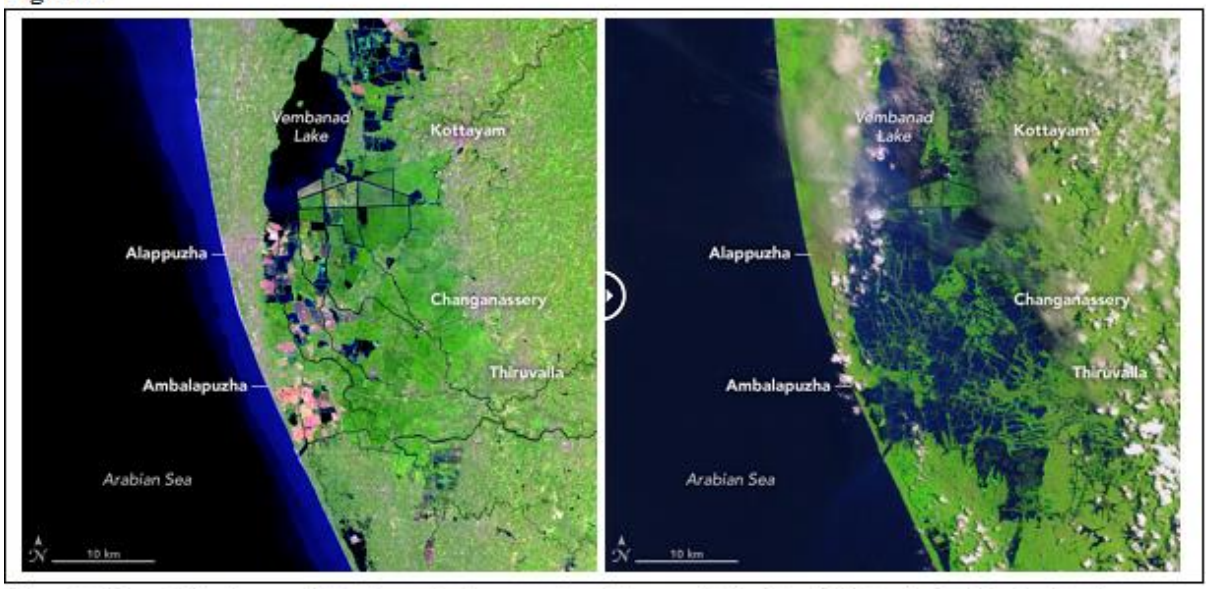


Figure 1: Two satellite images which give a visual perspective of the magnitude of the 2018 flooding in Kerala. The image on the left shows Kerala on 6th February 2018; the image on the right shows Kerala on 22nd August 2018, after the flooding had taken place. As seen, the floodwaters covered the majority of land in the region. Images taken from: NASA Earth Observatory (2018).

In August 2019 severe floods hit the state of Kerala, India. The floods were caused by periods of heavy rainfall during the monsoon season (Business Today, 2019). 40 people were seriously injured as a result of the flooding (India Today, 2019), whilst the number of deaths is disputed – some sources report deaths of 121 people (India Today, 2019), whereas others claim the figure is over 180 (International Federation of Red Cross and Red Crescent Societies (IFRC), 2019). There was widespread damage to property and infrastructure, the full extent of which is still yet to be confirmed (Wikipedia, 2019).

This report will identify available literature to create a comprehensive account of the event and provide brief technical analysis. It is worth noting, however, that because of the recent nature of event, there is a limited number of sources from which information can be obtained.

Account of the Event

Background and Geography

Kerala is an Indian state, located on the Malabar coast in the southwest, shown on the maps in Figure 1. It is the 23rd largest Indian state by area and the 13th largest in terms of population, with over 33.3 million inhabitants according to the 2011 Indian Census (Census 2011, 2011). Kerala is characterised by flat coastal plains to the west, the Western Ghats mountain range to the east, and hills and valleys in the centre, where most of the rivers which flow through the state originate from (Sadasivan, 2010; MapsOfIndia.com, 2013).

Much like its geography, the climate of Kerala is also diverse – it experiences three distinct seasons throughout the year: summer, winter, and Monsoon season – which begins in June and ends in November, barring a small interval in September (Kerala Tourism, 2019).

The Monsoon season has always been welcomed in Kerala, as these rains provide a vital water source for farm output, replenishment of water supply, and economic growth – more than 70% of India's annual rainfall comes in these months (Reuters, 2019) – but in the process they cause widespread death and destruction each year (Al Jazeera, 2019; Reuters, 2019). Since the 2018 floods, monsoon rains have become more synonymous with fear and loss (Jacob, 2019).

Kerala faces several natural hazards such as drought, landslides, and flooding (Kerala State Government, 2018), the latter of which has been a periodic threat across the state throughout its history. Severe

flooding in 1341 CE led to drastic modification of the terrain and shaped the way the region was to be developed (Krishnachandran, 2018). It is estimated by the Keralan government that more than 26% of the total geographical area of Kerala is prone to severe flooding, and over 18% of the state's population lives in this vulnerable area (Yesodharan et al, 2007).

Flooding in Kerala is becoming more frequent and increasingly severe (Kerala State Government, 2018) – epitomised in August 2018 when it was affected by catastrophic floods, the result of unusually high levels of rainfall during the monsoon season. The magnitude of the flooding is shown in Figure 2, which compares two satellite images of Kerala – one before and one after the 2018 flooding. It was the worst flood to hit the region in almost 100 years (Baynes, 2018; Kerala State Government, 2018), and affected over 5.4 million people. 483 people lost their lives, whilst over 140 others were reported missing (The Indian Express, 2018).

August 2019 Floods

On 8th August 2019, monsoon hit Kerala, resulting in widespread torrential rainfall (Business Today, 2019). The week 7th – 14th August 2019 saw 45% more rainfall than the average for that week (NASA Earth Observatory, 2019). The flooding that followed triggered dozens of landslides, which destroyed thousands of properties, killed masses of people, and left hundreds more trapped beneath debris (Al Jazeera, 2019). In the first two days of flooding, over 2500 homes in Kerala were damaged, and 57 people were reported dead (The New Indian Express, 2019), with that figure rising to 95 by the fifth day (The Guardian, 2019). Table 1 shows a breakdown of the first two days' destruction caused by the flooding.

As is indicated in Table 1, some districts were much worse affected than others, with Malappuram and Ernakulam the worst hit in terms of people displaced. Malappuram and Kozhikode were the states which suffered the highest number of deaths. As seen in Figure 1, these three districts are all on the west coast and in northern Kerala. They were among the those which suffered the highest damage to agriculture, with the flood washing away thousands of hectares of summer-sown crops several areas (Al Jazeera, 2019; NASA Earth Observatory, 2019). In total, over 13 hectares of crop area in Kerala were destroyed by the flooding (IFRC, 2019).

There was also widespread damage to infrastructure, with roads and railway lines destroyed in numerous areas (Al Jazeera, 2019; NASA Earth Observatory, 2019), whilst Cochin Airport in Ernakulam was forced to close for three days after the runways became waterlogged (Onmanorama, 2019).As well as the direct damage and destruction which the flooding caused, it also triggered over 80 landslides (IFRC, 2019), and on 10th August over 40 people became trapped under debris following a large landslide in Malappuram district (European Commission, 2019a).

Response and Aid

Reaction to the flooding was relatively quick, and red alerts were rapidly declared in Idukki, Malappuram, Kozhikode and Wayanad, where it was predicted that more than 200mm of rain would fall in just one day (Floodlist, 2019; Reuters, 2019).

A largescale rescue, relief, and evacuation operation was initiated, involving 83 teams from the National Disaster Relief Force (NDRF) and 173 teams from the Army, Navy, Air Force, and Coastguard (IFRC, 2019). Widespread evacuation took place across several districts, with over 265,000 people ordered to leave their homes in the first few days (Relief Web, 2019). However, inclement weather conditions and repeated landslides meant that rescue efforts were impeded in some districts, particularly in Wayanad, Malappuram, and Kozhikode (The Hindu, 2019a).

River levels quickly rose to dangerously full levels, whilst dams in the region rapidly reached full capacity, prompting state authorities to order the precautionary release of excess flow (European Commission, 2019b). However, this would prove to exacerbate the effect of the floods elsewhere.

The Red Cross enlisted over one million volunteers to provide relief and first aid to affected people, as well as to assist in the clean-up operation of villages in northern Kerala (IFRC, 2019). More than 15,000 areas in the Wayanad district were identified as requiring urgent clean-up of mud and slush in houses and wells (IFRC, 2019). The Red Cross also distributed tarpaulins, mosquito nets, kitchen sets, and emergency clothing to over 500 households (IFRC, 2019). On 14th August, the Kerala State Government announced provision of an emergency flood relief package, which would make available financial aid of up to 10,000 Rupees (equivalent to £108) to every affected family (News 18, 2019). Further aid packages of 400,000 Rupees (£4330) would be awarded to those whose houses were left uninhabitable or completely destroyed, whilst an additional 100,000 Rupees (£1083) would be awarded to those who had lost land as well as homes (News 18, 2019). Transnational charities and non-governmental organisations (NGOs), such as the Humane Society International (HSI), provided further aid, particularly relating to animal rescue operations. The Catholic Agency For Overseas Development (CAFOD) provided rapid response to the flooding by providing hygiene kits for women and teenage girls; emergency packs including water, food, clothing and bedding; as well as providing hygiene and sanitation training to over 10,000 people to prevent the spread of disease (CAFOD, 2019). The HSI distributed over 8000 kg of animal feed to starving cattle, goats, and dogs throughout Kerala, particularly in Wayanad (The Hindu, 2019b), whilst many other local NGOs and

activists rescued stranded animals from rising floodwaters.

Technical Analysis

Climate Change and Other Factors

International disaster statistics consistently document that floods are the most frequently occurring natural disaster, and that they affect more people than any other single disaster type (Lamond et al, 2011). Each year they result in the deaths of thousands of people, and have indirectly contributed to millions of illness-related deaths (Lamond et al, 2011). Flooding manifestly poses a significant threat to Kerala, but why is it that such a frequent event consistently causes such widespread destruction?

Climate change is widely accepted as the reason for the worsening flooding that hits Kerala each year (CAFOD, 2019; Mishra and Shah, 2018; Shaji, 2019). However, the Kerala Forest Research Institute (KFRI) says that flooding in Kerala is becoming increasingly severe not solely due to the effects of climate change, but because of both triggering factors and co-operating factors (Abraham and Balan, 2019). The triggering factors being the increasing rainfalls, and the co-operating factors being poor land use practises (Abraham and Balan, 2019; Nidheesh, 2019). Each year, flooding in Kerala results in dangerous landslides, which are the cause of the majority of deaths (Nidheesh, 2019). In 2019 the flooding led to landslides in 31 locations across the districts of Wayanad, Kozhikode, Malappuram, Palakkad and Idukki (Abraham and Balan, 2019) – locations which, as shown in Table 1, suffered some of the highest numbers of flood-related deaths in 2019.

Natural Consequences of Human Negligence?

Research by the KFRI found that 25 of those 31 locations are located within Ecologically Sensitive Zones (ESZs) – areas which were identified by the Western Ghats Ecology Expert Panel (WGEEP) in 2011 (Abraham and Balan, 2019). The WGEEP, led by ecologist Maghav Gagdil, recommended the designation of such areas and suggested strict regulation within these areas to limit development activities such as mining, quarrying, and large infrastructure projects (Gagdil et al, 2011).

However, after the WGEEP report was submitted in 2011, its advice was not implemented. This was partly due to the unwillingness of the state to accept ambitious environmental management plans, and partly due to shortcomings in the report – it was ill-defined and failed to provide critical review of previous, failed environmental management plans (Puyravaud and Davidar, 2014).

It has been alleged that the state receives monetary benefits from quarrying companies in return for allowing the development of larger areas than is necessary, resulting in geological instability (Abraham and Balan, 2019). The lack of regulation has led to extensive unrestricted quarrying and mining operations, contributing to extreme and accelerated environmental degradation (Jacob, 2019). Deforestation in the Western Ghats has led to higher surface run off, which affects flood peaks (Mishra and Shah, 2018), whilst further research has shown that these intensive operations have led to soil piping (Jacob, 2019). This alone can contribute up to almost 50% of stormwater discharge (Jones and Beven, 2010). Soil piping refers to the subsurface erosion of soil caused by percolating waters, which produces pipe-like conduits below the ground (Jacob, 2019). It has wide environmental implications but, more significantly for Kerala, soil piping in the Western Ghats effects hillslope drainage patterns and run-off systems (Jones and Beven, 2010; Bhagyalekshmi et al, 2015), which subsequently has a great effect on the risks brought about by flooding. The underground conduits produced by soil piping increases the porewater pressure (Arjnoi et al, 2009), which when under conditions of extreme rainfall increases stress and driving force until the point that landslides occur.

Conclusions

The 2019 flooding was a "disaster waiting to happen" (Nidheesh, 2019) according to experts, who found links between the flooding and destruction of the Western Ghats. Whilst climate change is the cause of increased rainfall, poor management systems mean destruction in the Western Ghats enhances the risk and danger of flooding. State authorities appear to not learn from previous disasters and a lack of adequate planning for floods means that the government spends more on compensation that it does on flood prevention (Times of India, 2019). State agencies are failing to adapt forecasting techniques to factor in changing weather patterns as a result of climate change, whilst the lack of regulation on developments in the Western Ghats exacerbates destruction and extends the area of risk (Times of India, 2019). Computer modelling systems to predict water flow are used in Europe and the USA, however Indian authorities seem reluctant to implement such methods (Padma, 2018). Furthermore, the management of dams and reservoirs is "unscientific" (Padma, 2018), and the decision to release water from dams ultimately resulted in more damage.

Whilst the 2011 WGEEP report had its limitations, it is widely accepted that the primary reason it was ignored was the state's unwillingness to implement its recommendations, as it has gone on to approve infrastructure projects across the Western Ghats, many without environmental impact assessment reports (Padma, 2018). A plan to implement construction restrictions following the 2018 floods

was scrapped due to fears it would adversely affect infrastructure developments (Jacob, 2019). "Our government is not bothered about the scientific of the [WGEEP] report," said an official from the Geological Survey of India (Abraham and Balan, 2019).

Although the Indian and Keralan governments cannot alone prevent the effects of climate change, they can certainly work to try and mitigate these effects. There are many lessons which authorities must take away from the flooding of 2019, not least the need to take note of scientists and change land use policies. Kerala's poor planning and lack of geological protection in the form of ESZs will exacerbate its vulnerability to future flood events, which will happen more frequently and more severely in coming years (Padma, 2018). It is a matter of when, not if, the next flood event occurs in Kerala. Flooding is not preventable, but its effects and can managed and mitigated, if the state plans effectively. "The next time such a disaster occurs, there is no excuse for not being better prepared" (Narayanan, 2018).

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Disaster Details, by district (08/08/2019 to 10/08/2019)						
District	No. of Emergency Camps	No. of Families in Camps	No. of People in Camps	House Damage		Deaths
				Partially Damaged	Fully Damaged	
Thiruvananthapuram	7	157	656	50	4	0
Kollam	0	0	0	193	4	0
Pathanamthitta	39	474	1877	64	2	0
Alappuzha	17	363	1519	382	27	2
Kottayam	94	1607	5078	104	9	0
Idukki	19	393	1158	46	6	4
Ernakulam	133	6584	23,158	54	2	0
Thrissur	149	5291	18,684	1	1	3
Palakkad	81	2335	8269	316	53	0
Malappuram	185	6834	24,151	453	65	19
Kozhikode	287	11,055	37,409	154	3	14
Wayanad	197	8628	32,276	12	0	10
Kannur	91	1946	8708	223	3	5
Kasaragod	19	733	2577	251	19	0
TOTAL NUMBER	**1318**	**46,400**	**165,519**	**2303**	**198**	**57**

Table 1: Breakdown of the death and destruction caused in the first two days of flooding in Kerala, arranged by district.

Adapted from a table published by The New Indian Express (2019).

December 2018 Nikol'skoye Earthquake and Tsunami Warning

Emma Thornber

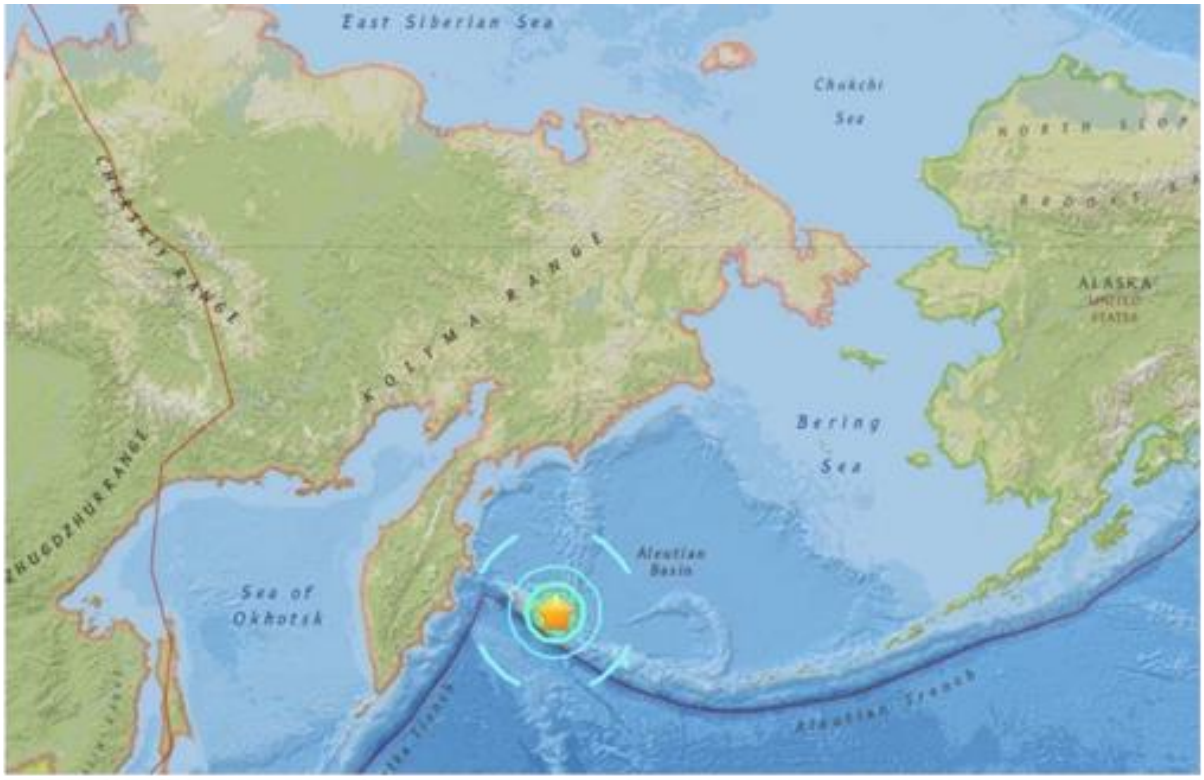


Figure 1: Location of Epicentre courtesy of CNBC Coverage of the initial 7.3 magnitude Earthquake (CNBC, 2018)

On Friday the 20th of December 2018, a magnitude 7.3 earthquake occurred in the northern Pacific Ocean, near the connection of the Kuril-Kamchatka oceanic trench and the Alaska-Aleutian oceanic trench. The Alaska-Aleutian trench is a subduction zone, with the Pacific Plate subducting under the North American plate and creating the Aleutian volcanic islands. Also, this area is filled with volcanoes and other geothermal activity (United States Geological Survey, 2019).

The initial quake on the 20th of December struck just 51.6 miles west of sparsely populated Nikol'skoye, Bering Island, Russia (Allon, 2018). The earthquake had a depth of about 9.6km or just under 6 miles and struck before 5am on Friday 20th December. At least 12 aftershocks have been reported ranging from 4.3 to 6.5 on the Richter scale since the earthquake, and have been throughout the preceding 12 hours after the 5am quake (Allon, 2018).

The Earthquake in Nikol'skoye could produce Tsunamis of roughly 1.1m tall (Allon, 2018) and these waves were at risk of hitting the Eastern Coast of Russia. However, they could hit within the 300km surrounding the earthquake epicentre, possibly hitting the Kamchatka Peninsula. (Schmidt, 2018). Looking at the regional data for the Alaska-Aleutian oceanic trench, the arc of the trench extends roughly 3000km from the Gulf of Alaska in the east, to the Kamchatka peninsula in the west. This arc and its subduction zone have been responsible for the formation of generations of the volcanic Aleutian Islands within the region. However, no tsunamis occurred within the initial 48 hours of the quake (CNBC, 2018). This area of the globe generates tsunamis regularly, with Alaska receiving the most serious Tsunami risk within the United States (Fairbanks, 2019), and other countries within the Alaska-Aleutian plate boundary region.

Nikol'skoye 2018, was the result of Oblique Faulting, and a steep strike slip fault towards the southwest, or a moderate strike slip fault towards the north west of Nikol'skoye. Strike slip faults are often the largest faults along continental landmasses – they typically have conspicuous geomorphic expression. Similar strike-slip fault events include earthquakes reported along the San Andreas Fault and the Queen Charlotte-Fairweather Faults (James P. Calpin, 2009). Strike-slip faults have long histories of seismic activity because they often pass through populated areas and therefore the earthquakes experienced there have affected a substantial proportion of people.

Looking at the historical data for earthquakes at the Alaska-Aleutian oceanic trench, the history of events has a variety of location and extremity. With

earthquakes ranging from magnitude 5, to some reaching Magnitude 8.7 (United States Geological Survey, 2019).

With reference to the Alaska-Aleutian Arc characteristics and points made previously, the arc also displays volcanic hazards and megathrust earthquakes in the west, particularly at the Wadati-Benioff zone. Moreover, the Western Aleutians, stretching from the western end of the Rat Islands in the east, to the Komandorskiye Ostrova in the west (Commander Islands, Russia – where Nikol'skoye is Located) is tectonically different to the central and eastern portions of the Aleutian Arc – which is evidenced by diminishing volcanism in the area. This means that although the Alaska-Aleutian arc is notoriously riddled with active volcanic events, parts of the arc are quieter than others. With the Western-Aleutians being less active than other parts of the Arc. (United States Geological Survey, 2019)

Moreover, this is also apparent due to the last active volcano being located on Buldir Island, in the far western portion of the Rat Island chain, and the fact this portion of the subduction zone has not hosted intense, or large megathrust earthquakes in recorded history. With most earthquakes in this area being small, shallow strike-slip events with magnitudes between 5-6, and deeper earthquakes occurring at 50km deep at M<4. (United States Geological Survey, 2019) However, greater, and more devastating earthquakes occur along the base of the trench, at the interface where the Pacific plates and North America plates meet - thrust faulting occurs. Deformation also transpires, with the pacific plate subducting under the thick continental crust of the North America plate, earthquakes forming at intermediate depths of 250km occur. The seismicity along this interface means deep earthquakes, at around 40-60km and are much stronger and higher magnitudes than around the Rat Island region, and far more devastating if affecting populated islands. Since 1990, the Alaska-Aleutian Arc has hosted twelve large earthquakes, which are categorised by earthquakes larger than Magnitude 7.5 (United States Geological Survey, 2019).

The Alaska-Aleutian Arc, the plate margin which caused the event on the 20th December in Nikol'skoye, is notoriously a seismically active region and often causes tremendous tectonic events and volcanic hazards. The population who live along this plate margin will have been affected by events like this in the past. Some of these events include a magnitude 6 earthquake at the Andreanof Islands in May and the April 2nd M6.4 earthquake in the Rat Islands. However, these are sparsely populated areas of the Aleutians, and not many people were affected, just like in Nikol'skoye 2018. (Dengler, 2019)

Technical Interpretation of Nikol'skoye 2018

To examine, and therefore understand, the 20th December earthquake that shook Nikol'skoye, and the events that transpired over the following 24 hours, it is important to draw several factors and viewpoints. This includes understanding the seismology of the Alaska-Aleutian arc/trench, the people affected who live in the small fishing town Nikol'skoye, the media and scientists monitoring the event, and ultimately the response to the event by the relevant authorities.

Looking at Dengler: 2019 Earthquakes at the Halfway Point: It's not the magnitude of an earthquake that is the primary factor in impacts, but the exposed population and how well built the structures are. The seven earthquakes of M7 or larger this year only caused 4 deaths. (Dengler, 2019) This is a critical point, as many earthquakes happen globally that are considered "extreme" and are usually Magnitude 6 and higher. However, it is not the earthquake's extremity that will cause the most damage to infrastructure and loss of life – it is the infrastructure and its quality that will cause a chain reaction of destruction that could take life or injure people. This is important to remember as the Nikol'skoye 2018 earthquake affected a low populated island with simple infrastructure (the island is mostly small buildings like houses and small cafes), with some distance from the populated area itself. The earthquake was high magnitude, and struck some 51.6 miles from the fishing town, allowing the quake to dissipate and strike with less intensity. Also, with this distance and with the style of faulting (Oblique Faulting, and a steep strike slip fault towards the southwest, or a moderate strike slip fault towards the north west) means the waves predicted from the quakes epicentre (1.1m tall) never struck the shore of Nikol'skoye, possibly because the intensity of the waves reduced with distance and caused no problems for the people there. (James P. Calpin, 2009)

Looking at the seismology of the Alaska-Aleutian arc will explain the behaviour of the 2018 quake and will also link to understanding the reaction to this event, as this is a seismically active region of the world which often experiences high magnitude earthquakes. Looking at the USGS website subsection of the Alaska-Aleutian arc, the source states that the area experiences many moderate to large earthquakes each year.

On Tuesday 18 July 2017 at 08:02 a news article was posted by the independent detailing a similar earthquake reaching 7.8 magnitude that stuck 125 miles from the city of Nikol'skoye, Bering Island. The epicentre for this quake was west of Attu, the westernmost island in the Aleutian Islands and the event prompted tsunami warnings for waves 50cm tall within 300km of the epicentre. Similar to Nikol'skoye 2018, the tsunami warnings were dropped. The earthquake was shallow, roughly 6 miles below the seabed, which is what initially prompted the tsunami warning, but as the epicentre was far from mainland the intensity of this event was reduced and there were

no reports of any casualties or damage. (Osborne, 2017)

Looking at the reactions of the Nikol'skoye 2018 quake from the media, which are usually aided by the reactions of scientists monitoring the Earthquakes that strike, we see a pattern of high alert which then dissipates into a low-threat and little-coverage event. The initial coverage of the 7.3 magnitude earthquake that hit Nikol'skoye reported the location of the epicentre and intensity within the initial 24 hours of the event, and reported a chance of 1.1m high tsunami waves – a hazard that on low lying land can cause infrastructure damage and potential injury to people, and maybe deaths.

However, the coverage of the event dropped down to a low-threat event after the initial 24-hour coverage. This could be due to the simple fact that Nikol'skoye is a remote island, off the coast of the eastern coast of Russia which is also sparsely populated and therefore a smaller population of people could potentially be affected. This could have also been dropped from the media radar as the tsunami waves dissipated before they hit Nikol'skoye, and even though the magnitude of this earthquake event was 7.3, there was a very small chance this earthquake could cause any more problems for Nikol'skoye after USGS reports stopped.

Referring to my previous statement on the little coverage that this event got, researching this event was challenging, as the little coverage available for the event was sparse and straight to the point on how this event did not cause damages. To finialise on this point, the media attention was dropped as the event did not cause loss of life, or damage to any residential, industrial or commercial buildings.

Conclusion

Reflecting on the events of the 7.3 magnitude earthquake that struck Nikol'skoye on December 21st, 2018, it is important to remember that this was a high magnitude event. Tsunami warnings were issued for this quake, and waves of 1.1m were predicted to hit the coast of Nikol'skoye. 1.1m does not sound high, but on low-lying islands without tsunami defences this kind of event could be devastating. Nikol'skoye is a small fishing town, and the infrastructure there could not be suitable for large tsunami waves. If this event had faced tsunami waves of 1.1m, vulnerable communities of people would have been impacted. Nikol'skoye is a remote town and aid would take time to arrive, houses there would have been lost, and people could have been injured.

Although it struck 51.6 miles away, this quake could have caused much more structural damage and loss to life had it been closer to populated areas. The distance from Bering Island meant the events intensity had time to reduce and dissipate without causing damage or loss to life. An earthquake similar to this striking loser, and more intensely, could be a future risk to infrastructure and peoples lives on Bering Island.

The area affected in this case study was a sparsely populated island, located in an incredibly seismically active region as Bering Island resides along the Alaska-Aleutian trench, a powerful subduction zone known for high intensity earthquakes, volcanoes, and tsunamis. When looking at the reactions from the media and local people, it is apparent that even though this was a high magnitude earthquake, this event was not treated as seriously as it would, had it hit Nikol'skoye harder and with more people impacted. The media attention dissipated after 48 hours of reporting, and each news article covering the event kept the description of the situation brief, but direct and straight to the point – possibly to avoid confusion and/or panic as a tsunami warning was issued.

To conclude, this event was at first treated like a high-intensity, dangerous situation, but after some time, the event managed to reduce in intensity, meaning Bering Island did not have to face a disaster situation on December 21st, 2018.

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2019 Monsoon Flooding Kathmandu, Nepal

Tilly Lewis



Figure 1 – A map of Nepal with Kathmandu outlined (Google Maps, 2019)

Summary

In July 2019 Nepal suffered a series of flash floods. In the space of a week it was recorded that 83 floods and 92 landslides affected Nepal as a whole.(Relief Web, 2019) The hazards particularly hit two areas; Kathmandu, the capital shown in Figure 1, and Terai. (Wikipedia, 2019) As a result of this, many people suffered the effects of the floods from loss of lives to tens of thousands being displaced, (CNN, 2019) as well as the loss of their livelihoods floating away. The people living within this region are the highest affected by natural hazards at 62%. (United Nations Human Settlements Programme, 2015)

Cause of the Floods

Being the 11th most vulnerable country to hazards in the world, floods are prevalent in Nepal due to the disaster prone conditions the country possesses. The country is positioned on rugged topography which results in the trigger of many landslides after extreme rainfall. The extreme rainfall is caused by a Monsoon. A monsoon is a seasonal change which is associated with heavy rainfall, especially during the summer months between April and September. (National Geographic, 2019) The Monsoon that hit Nepal brought mass levels of rain, seeing their monthly rainfall in three days. With Kathmandu in particular receiving 150mm in 12 hours. (Nepali Times, 2019) Due to the influx of rain over short periods of time floods and landslides became unavoidable. Floods and Landslides are prevalent in Nepal due to the disaster prone conditions the country possesses. However, it is not only physical factors that are held responsible for the natural hazards that occur. Human activities such as infrastructure positioned in the hilly regions add to prompting the disaster to happen. Furthermore, deforestation has further caused increasing of floods. (The Kathmandu Post, 2019)

Floods and Landslides Impacts

There are many impacts associated with the flooding caused by this monsoon within Kathmandu. One of the largest was the mass numbers of death. As the rain continued to fall, the number of deaths only increased. As of July 13th, Aljazeera reported 27 people had been killed due to the landslides, primarily caused by the incessant rainfall. The weather department issued a warning that more heavy rain was to be expected, causing more distress as shown in Figure 2. (Aljazeera, 2019) A day later on the 14th July it was stated that ‘in the past three days (death) rose to 55’ with dozens missing. The home ministry had confirmed these deaths and the number of those injured, as well as noting the economic loss, leading to an assessment being made and potential aid starting to make its way to the people.Sharma (2019) By 25th July the number had risen to 111 lives and 41 others said to be missing. Adhikari. (2019) Meaning that in the short amount of time increasing numbers showed

the extent the floods effect those living in Kathmandu. The worse the rainfall became, the more died as a result of the hazard.

Loss of infrastructure

Not only did the flooding within Kathmandu cause destruction to lives, but also to infrastructure. The Kathmandu Post (2019) released an article about the delay in construction of the road that connects Kathmandu and Hetauda. The deadline had been moved back due to the fact the road had been 'heavily damaged by floods and landslides'. Not only had the extension meant the highway would not be operational, but also had destroyed infrastructures worth Rs (Nepealese Rupee) 320 million. Putting money that should have been spent elsewhere on the long over-due road. Further infrastructures that are affected by the landslides and floods which occupy Nepal are the losses to property that are both public and private. These examples include: houses, schools and telecom towers. All are of great importance to the locals whose areas are destroyed by the extreme flooding, worsened by climate change. With the schools having been destroyed it meant that education will be further held back and could have potentially been the reason that the people of Nepal have little understanding of how to protect themselves if future hazards caused delays in the re building of schools.

Food insecurity

Not only are the lives of those who inhabit Kathmandu a complication of the monsoon but food insecurity quickly becomes very problematic. At the beginning of the floods, reports highlight the damages to food stock, crops and livestock that impact the region, increasing the vulnerability of those affected to death and malnourishment. It is estimated that, as of the July 11th the floods had caused 212,000 people's food insecurity. Later, on July 30th there are still 176,00 people who are deemed are significantly affected, highlighting the ongoing impacts of the floods on the crops and livestock replied upon. (Reliefweb, 2019) The World Food Programme were quick to act on presenting aid for those in need. Due to the fact that the two main affected areas are already poor it is noted that 'families that have lost food stocks have nothing to fall back on' (World Food Programme, 2019) An assessment was issued 48 hours after the first flood on July 11th determining the extent of the affected districts. Aid was then offered in correlation to the most impacted areas. Furthermore, with the lack of unsafe water it means that the people of Kathmandu are susceptible to disease outbreak, making aid imperative, which is discussed further on. (The Kathmandu Post, 2019)

Technical Interpretation

The 2019 floods of Kathmandu are the most recent disaster that the city has faced, however they are regular occurrences that cause destruction each year. The last recorded flood due to the heavy monsoon season was in 2017. Due to the fact that Nepal lies in an area of the world which is prone to flash floods and landslides because of the geology and torrential precipitation it is likely that future events will cause more damage. Past events have shown that hazards such as earthquakes have caused other events such as flash floods, for example the Gorkha earthquake. Climate Change has led to worsened impacts when the torrential rain comes when combined with the already unstable slopes of the Earthquake. It has made flash floods more common and brings horrendous damage such as increasing numbers of fatalities and loss of habitat. In July 2017, the district Chahqtine Khola experienced rainfall that lasted 4 hours long and affected the structures impacted by the Gorkha earthquake of 2015.

The floods brought along many problems such as the displacement of people for shelter in nearby villages due to many homes being completely ruined. The water supply had also been destroyed leaving many families without water for many days. The pipes had been displaced and many were destroyed by debris carried in the floods. Furthermore, electricity was completely cut off due to the electrical poles being destroyed and washed away meaning the supply wasn't fully resumed until the first week of August, nearly a whole month later. (Journal of Building Engineering, 2018) The impacts of this flood were similar to those in 2019 such as the displacement of people as their homes were lost and the amount of lives lost due to the landslides caused by the flooding.

Both the 2019 and 2017 floods have highlighted the influence of torrential rain on Nepal and how this has become a mechanism for disastrous impacts on its country. The rainfall is caused by an annual monsoon which brings mass amounts of precipitation, combined with being one of the most disaster-prone countries, meaning that there is a greater loss of property and structure. The losses have become larger is more recent years due to climate change bringing worsened impacts such as landslides resulting from the rain. (Glaire, S. Castro Delgado.R, Arcos Gonzalez, P. 2015)

The monsoon season lasts between June and September meaning that two thirds of rainfall is received in the space of 4 months, causing overflowing river banks that burst. (Dewan.T. 2015) It is a seasonal change in sea breeze circulations and is caused by the heating of the surface of the Tibetan Plateau and has strong variations between active rainfall and break (no rainfall) periods. (Pokharel, A. Hallett, J, 2015)

Combining the monsoon features and the fact that Nepal has more than 6000 rivers which mostly originate from the Himalayas, of which many areas are sitting on floodplains that are damaged when the

rivers swell in the wet monsoons, means the floods have become more frequent and therefore are more impactful on the people, with more and more loss of lives each time a monsoon arrives. (Dewan, T.2015)

Conclusion

When concluding the floods of Kathmandu 2019 it is clear to see the hundreds of thousands who become vulnerable. Individuals who are most are risk but least considered are women. Women have not achieved the same status as men in Nepal and therefore suffer a lack of respect, meaning they may be in more danger during a disaster. (Everest Uncensored, 2019)

Due to the lack of support for women, kits called 'Dignity Kits' were offered in order to protect them. Supported by the United Nations Population Funds, the kits were offered to more than 1,7092 women. These kits included basics such as shampoo, torches and toothbrushes, as well as protection and hygiene tailored to women's needs. After being assessed by the government it was found that sanitation and hygiene were given high priority for issues the flood victims faced. These kits were vital to women's safety as they meant that girls were at less of a risk to sexual violence during a time where they most vulnerable. As women are not always concerned as high priority during hazards during the gender bias, it was essential that mothers and young girls were considered as being affected too. (The Himalayan Times, 2019)

Not only did the United Nations Population Funds offer aid during the catastrophic events, but Direct Relief also. Direct Relief is a 'humanitarian aid organization' who are aiming to improve the lives and health of people affected by poverty or aid. The aid that they offered during the monsoon supported Mountain Health Nepal who conducted mobile camps made up of volunteer medical teams. In order for Mountain Health Nepal to be equipped, Direct Relief dispatched Emergency Health Kits, made up of '200 essential medicines and medical supplies.', presented in Figure 3. These were stocked at the organisation's warehouses so that they could be handed out rapidly during the disaster in order to prevent any spreading of disease or worsening of ones caught already. (DirectRelief, 2019) They are similar to those offered to women but are less specific to women needs.

When reviewing the economic losses, it is almost impossible to find a total of economic aid offered. This may be due to the fact it is a recent event and is perhaps still receiving aid at this current time. However, during the flooding food security was heavily impacted. It is suggested that food harvests for winter had been affected, with 75% of households having lost their food stocks and therefore depending on government distributions such as the one previously mentioned. (Relief web, 2019) Therefore, more and more money will be given overtime in order to attempt to give back to those who lost their livelihoods.

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Cyclone Fani

Rachael Kofoed

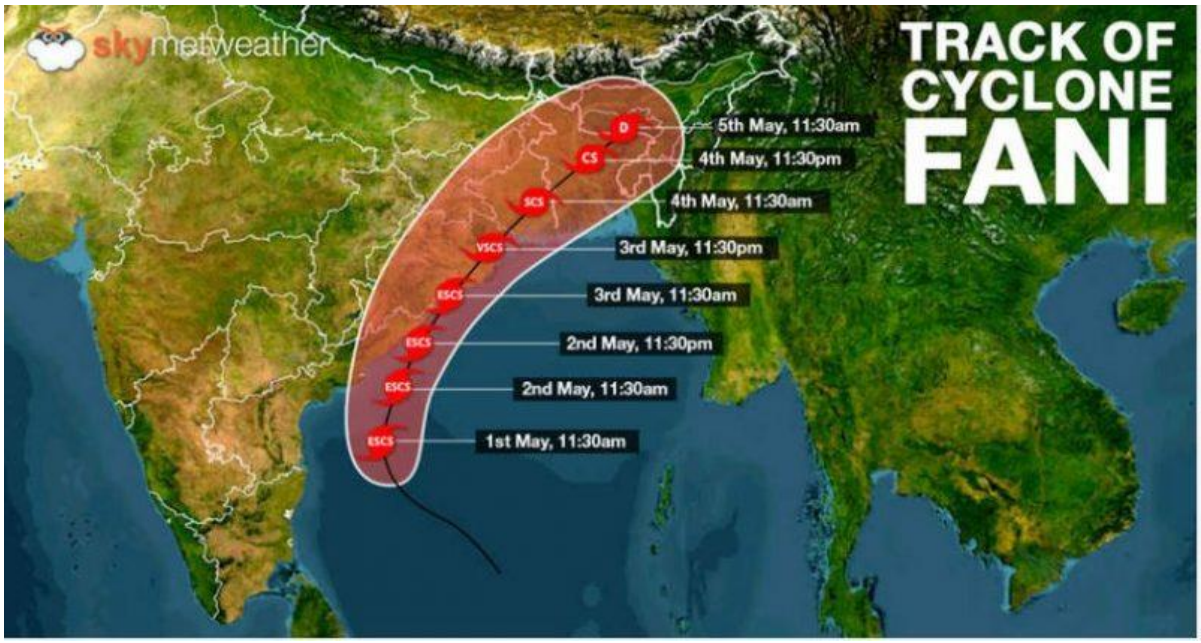


Figure 1.0 – Track of cyclone Fani – (Photo: Skymetweather.com, 2019)

Account of the event

Prior to the event

On the 26th of April 2019 the Joint Typhoon Warning Centre that is located in Hawaii was the first to tract the development of a tropical depression in the Indian Ocean near Sumatra which later developed into Cyclone Fani. The depression strengthened as it drifted westward towards the coast, developing into an extremely severe cyclone storm. These types of storm as very common during this time of year as cyclones develop outside the monsoon months between April- June and September to November. In the Bay of Bengal this occurs due to monsoon winds being in heavy rainfall that have been generated from the ocean's temperatures being higher (Reid, 2019).

Action by authorities prior to event.

With the knowledge of the storm's path and estimated regions of where the storm will be the most intense the local authorities and disaster management personnel were able to evacuate 800,000 people before the storm hit (Guardian, 2019).

As it was estimated that the storm would make landfall in the state of Odisha, the government conducted one of the largest emergency exercises in preparation for the storm with 45,000 volunteers and organises working with emergency services to ensure the lowest amount of people were affected (Unicef,2019). Information via social media was send out to try to inform people about what to expect when it hits and "do's and don'ts" when ensuring safely during the cyclone. Vulnerable people were targeted before the event, moving them to multipurpose flood and cyclone shelters and an estimated 850 shelters were available which would be able to accommodate 1 million people if needed. Emergency action was hoped to have everyone displace by Thursday the 2nd of May before it made landfall (Guardian, 2019).

Event.

As Fani travelled towards the coast on May 2nd at 7.50am local time it was classified as a severe cyclonic storm with estimated wind speeds of 201kmph (125 miles per hour) before and during making land fall (Jenner, 2019).

Early hours (around 8 am) on May 3rd, 2019, Cyclone Fani made landfall in the Indian state of Odisha near Puri (Safi, 2019). Puri a costal district that is home to Shree Jagannath which is one of the holiest temples that received over a million pilgrims each year was advised by the government that all non-essential travel in this region to be rescheduled and all pilgrims to leave the holy town to ensure safety (Guardian, 2019). After making landfall, Fani's intensity increased after the eye of the storm passed over the land. Bhubaneswar – the direction the cyclone was heading in – was experiencing thunderstorms prior to event causing downdrafts and increase in wind velocity

adding to the wind speed of the cyclone Fani as it travelled over the state (Economic Times, 2019).

The cyclone travelled northwest over the state towards the city of Kolkata passing over low-lying communities along the Bay of Bengal and through some very highly populated areas – One of the worlds most vulnerable regions to flooding. Many districts in the state were put on high alert before the storm hit to ensure safely of the residents living there (Safi, 2019). As Cyclone Fani passed over the state many areas were destroyed by the high intensity rainfall and wind speed. It was estimated that combined storm serge and overall rainfall for the coastal areas were around 3 metres (10 feet) (Economic Times, 2019). Bhubanewar, capital of the state experienced major damage to the main roads leading in and out of the city along with damage to powerlines and the city's main railway station. Along with the major infrastructure in the most highly populated areas caused severe damage mud huts and thatched roof houses across the four main affected districts (Safi, 2019).

It was estimated that the state of Odisha experienced 64 deaths from the intensity of cyclone Fani. In the Puri district alone there was reports of damages to move than 189,000 homes (Adil, 2019). On May 4th the storm moved across Bangladesh, towards Bhutan dropping around 8 inches of rain meaning closer to schools and fisherman requested to return to shore (Kumar and Ramzy, 2019). By the 5th of May the cyclone had reduced into a tropical depression. Figure 1.0 shows the journey of cyclone Fani.

Action during and after the event.

Although the cyclone weakened as it travelled over the districts, destruction still occurred which ultimately let to the death of around 89 people in total from all the areas the cyclone hit. Casualties during the event were mainly caused by falling trees and walls due to heavy rainfall and high intensity winds. However, if the authorities of the different areas did not have the correct implemented precautions the death toll could have been considerably higher (IFRC, 2019).

Action after the event was done by many charitable organisation and government funding that help to get families back on their feet. 5000 thousand families where given household supplies such as bed sheet and kitchen sets that would have been destroyed in the storm and thousands of people were given water purification units. The government in different regions had schemes developed before the event took place to ensure everyone would be able to recover. In Khurdha district, families that were affected by the event and who was covered by the food security scheme received 50kgs of rice to last one month along with housing schemes in all areas that stated they would help to rebuild houses that were completely damaged during the event (IFRC, 2019).

Technical interpretation

Tropical cyclones often occur in the northern hemisphere rather than the southern hemisphere and are low pressure systems. These intense tropical cyclones have a typical structure when developed consisting of the eye which is known to have the lowest atmospheric pressure on the surface along with eye wall, home to a region of cumulonimbus clouds and the outside rain bands that are spiralling anticlockwise. (Varotos et al, 2019).

Preparation and forecasting

Cyclone Fani was a very rare to hit the Bay of Bengal in the summer months. Although Fani was one of the worse cyclones to hit India since the 1999 Odisha cyclone, the preparation that was done prior to the event ensured the safety of the people by keeping numbers of affected people to a minimum. The accuracy of the early warning systems and the governments natural disaster schemes including a clear communication plan and volunteers meant people could be evacuated away from the areas of intensity. This disaster management plan was put in place two months after the 1999 cyclone as 9,658 people died. This management plan has considerably changed people's safety in this area as death toll has dropped 99% in the past 20 years (Dora and Padhee, 2019).

20 years on from the super cyclone hitting India, early warning systems and investment into forecasting has significantly reduced the death toll. Following the cyclone that hit in 1999, 0SDMA was formed - Odisha State Disaster Management Authority. This program developed awareness campaigns, improved early warning systems and built 800 flood and cyclone shelters. Cyclone Fani did leave a lot of destruction to infrastructure however with these precaution in place there was a low loss of life (Amach, 2019).

These storms threaten over 50 countries with the risk to the economy and people's livelihoods from damages caused by floods, intense rainfall and very strong winds. As this weather event can cause destruction, forecasting and monitoring is very important and is under continuous investigation for the best possible method to detect when an event could happen. This attention can look directly at the relationship between atmosphere and the ocean. Meteorological research and satellite data can be collected to detect the conditions that would be necessary for tropical cyclone formation. There is lots of evident to suggest that momentum exchange, moisture and heat are the primary factors in the maintenance and intensity of a tropical cyclone (Varotos et al, 2019).

It is not possible that only one forecasting technique will detect all cyclones as they are individual with different climatological and geographical characteristics of cyclone basin formation. Therefore,

to increase forecasting accuracy, multiple forecasting methods need to be combined with basin specific technology to predict when and where it will occur. Forecasting techniques that have been developed in the past have been modified and used in conjunction with new technology. New techniques such as the neutral network-based technique can be used alongside meteorological data

using satellite imagery to try and identify some of the parameters that are most common with tropical cyclones. This will be used in India to predict formation and is used vastly in less economic developed countries as this software is available on standard PC s meaning it can produce accurate data and is easily accessible (Roy & Kovordányi, 2012). With these advances in forecasting, on May 3, NASA infrared satellite imagery measured the temperatures of the cloud tops of the thunderstorms that made up Fani. The imagery showed warming cloud tops and significantly reduced deep convection (rising air that forms the thunderstorms that make up a tropical cyclone). This allowed for an evacuation to take place (Jenner,2019).

Characteristics of a cyclone.

It was stated by Gray, 1979 that there are different factors that contribute to the frequency of tropical storms, these are listed below.

- Average vorticity needs to occur in the low-level atmosphere. This builds friction and creates convergent winds towards the storms centre which feeds moisture, heat and momentum to generate the storm.
- Tropical storms will not form within a 4o – 5o latitude band around the equator as rotation from the Coriolis effects is needed for them to generate.
- Weak vertical shear of horizontal winds to allow the storm to intensify. The intensification of the cyclone forms from a warm core that is accumulated from moisture and heat being transported to the upper part of the troposphere.
- For evaporation to occur sea surface temperature needs to be exceeding 26 degrees C as the top layer provides moisture and heat required for tropical storms.
- Conditions need to be coherent through the upper and lower troposphere and this will happen if there is a strong vertical motion causing vertical coupling through the whole of the troposphere (Vitard, 2004).

Conclusion

The tropical cyclone, Fani that developed in the Bay of Bengal caused enormously damage to the infrastructure in the district of Odisha and many other regions including Bangladesh and Bhutan. As this was one of the most powerful cyclones to hit the east coast of India in two decades the death toll could have been considerably worse. The forecasting of this cyclone was very accurate due to the use of specified satellite imagery and meteorological forecasting that allowed for a predicted path to be drawn out. This allowed the districts to evacuate over 1 million people and help to save people's lives. From the damage that was done if theses civilians where not evacuated into cyclone shelter more people would have been killed from falling infrastructure. The most vulnerable people were targeted prior to the event and emergency action was implemented by the 2nd of May to ensure people were safe before the cyclone made landfall. Although 89 people died, the action that was done made sure that the destruction that occurred from the 1999 Odisha cyclone would never happen again. Governmental and charitable organisations came together after the event to assure that people would be safe providing them with water and shelter until homes where rebuilt or the location was safe enough to return to. The action from the government to remove people from their home and place them in a safe environment was very successful relating to the 1999 cyclone. I believe that if an event was to happen again like this one that they would be prepared as they have enough recourses to home 1 million people in this specific area. An investigation should be done into the deaths that occurred to see if there are any of variables that should be looked at and to ensure everyone has the best chance of surviving.

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Myanmar Landslide 22nd April 2019

Sam Sheron



Figure 1: Image showing the rotational failures of the landslide (STRINGER/AFP/Getty Images via Pressfrom.info, 2019)

In Myanmar (Burma) on the 22nd of April 2019, a landslide triggered the collapse of a jade mine in northern Myanmar's Kachin State in Hpakant, with the location shown in figure 1. At 11:30pm, a mud-filled pond above the mine collapsed, engulfing the mine's sleeping quarters along with 54 sleeping jade miners along with 40 pieces of heavy machinery 30 metres deep BBC News, 2019). During the attempt to rescue the miners 2 rescue workers were also killed and so further rescue attempts were cancelled (Lynn, 2019). Landslides represent a serious danger across the world, especially in areas that are subject to tropical storms, which trigger thousands of them (Alvioli et al, 2018).

Background

Located near Hpakant, a small mining town in northern Myanmar's Kachin State as seen in figure 2, a region best known for its jade mining industry, as it produces the highest quality jade found in the world. Myanmar's jade industry has been notoriously treacherous (Ellis-Petersen, 2019) with the minimal regulations resulting in dozens of deaths, with most of those being migrant workers, every year (BBC News, 2019). This jade industry has long been criticised for seemingly prioritising the profits of the owners of the mining companies rather than adequately addressing the safety issues of its largely migrant workers, resulting in many deaths annually, especially during the monsoon season (Ellis-Petersen, 2019). The Hpakant region in northern Myanmar has become a hotspot for mass movement activities, such as rockfalls and mudslides, that result in fatalities. Between the start of 2015 and September 2018, there were 33 recorded fatal landslides with 807 recorded fatalities, although the true figure is likely to be even greater with many going unreported (Petley, 2018) It is reported that the value of Myanmar's jade industry is approximately $31 billion in 2014, nearly half of the countries entire GDP, potentially explaining why they are so unwilling to increase the regulations, despite repeated assurances to the international community from the Myanmar government that they would do exactly that.

Disaster

At approximately 11:30pm on the 22nd of April 2019, a series of rotational failures (Petley, 2019) as a result of human activity in the form of mining weakening the stress points of the slope (Keim, 2015), resulted in a landslide after the mud filter pond collapsed, engulfing 54 miners under a 'mud lake' in their sleeping quarters (BBC News, 2019, Al Jazeera, 2019). 4 bodies were recovered with the remaining miners assumed dead.

Response

After the landslide, a rescue operation was initiated on the 23rd of April. The miners were buried 30m deep (Ellis-Petersen, 2019) and so the prospects of their rescue were extremely slim, with local official Tin Soe stating "They won't survive. It's not possible because they are buried under mud". By the 24th of April, only 3 bodies had been recovered from the landslide, with 4 bodies recovered in total. Unfortunately, the rescue attempts had to be called off after a second mudslide struck, killing two volunteer rescue workers that same day (Lynn, 2019). Kyaw Swa Aung, Hpakant's township director was quoted as saying "As there were possible landslides and mudslides, search for the bodies became risky." Following the landslide, acting UN Resident and Humanitarian Coordinator to Myanmar Knut Ostby called for urgent action in order to better protect the health and safety of miners in northern Myanmar (RTL today, 2019). Subsequently, the Myanmar central government then suspended mining operations in 17 mining blocks in Hpakant (Myanmar Times, 2019).

Technical Analysis

The term landslide encompasses a wide range of ground mass movement, from rock falls and avalanches to slumps and mud flows (Keim, 2015). These types of mass movement can be either wet or dry, each type with different rates of movement, with gravity playing a key role in all of them. According to McColl (2014), the stability of the slopes vulnerable to landsliding is dependent on a variety of time-dependent and time-independent factors which, when unfavourably aligned, results in the failure of the slope and subsequently, a landslide. Destabilising pressures are present in all slopes, but whether or not these pressures will result in slope failure is dependent on the pressures present in the slope that are resisting failure. (Davies, 2015, & McColl, 2014). Some of the factors are inherent to the slope and will therefore never change, such as lithology, the mineral composition of the rock or sediment in the slope (Park & Allaby, 2013), whereas other factors will be variable, such as precipitation fall on the slope (Davies, 2015), with intense rainfall being the primary meteorological factor directly associated with causing landslides (Osanai et al, 2010).

Landslides in South Asia

South Asia is an area that is very susceptible to landslide activity. This is due to a variety of factors, such as the mountainous terrain like the Himalayas, as well as the tropical storms and monsoons that increase the likelihood of slope failure and are an annual issue for the region. According to Petley (2012), the majority of fatalities across the globe occur in Asia. The monsoon season in particular is a vital factor on the amount and severity of landslides in Southern Asia, with the Asian Summer Monsoon (ASM) the strongest monsoon system in the world (Liu et al, 2019). Monsoons bring a large amount of rainfall with it, therefore increasing the destabilising stresses present on the slopes in South Asia, with intense rainfall seen as the primary factor directly associated with triggering landslides (Osanai et al, 2010). Every year this monsoon system causes landslides resulting in loss of life, property damage, and economic losses (Ahmed, 2015) from places such as Myanmar to Bangladesh and India.

Probable Mechanism of the Landslide

The stresses which prevent slope failure can be referred to as 'resisting stresses', whereas those leading to slope failure are given the term 'driving stresses' (McColl, 2014). Both the driving and resisting stresses have the potential to change over time, therefore the slope stability is referring to a particular point in time, with the vast majority of slopes stable in this moment, but all with the potential to fail in the future depending on the changes in these stresses (McColl, 2014, & Davies, 2015). Once shear stresses, a stress tending to cause deformation of material by slipping & being intimately linked to the downslope movement of material (Shear Stress, 2019), have been developed in a slope, there is a greatly increased tendency for failure in a slope (McColl, 2014). Rotational failure is the most adverse known failure mechanism in slopes of both homogenous and non-homogenous soils (Chen et al, 2017). The likely cause of the landslide is a rotational slide, which as stated previously, is the most adverse failure mechanism, following the collapse of the mud-filled pond at the top of the slope. Rotational slides are very common in homogenous material and is relatively slower than transitional slides, however with the collapse of the mud-filled lake the speed of the slide was likely increased. Petley (2019), states that there may be some confusion between the collapse of the mud lake and the liquefaction process. Liquefaction is the changing of the behaviour of a soil from that of a solid to a liquid (Ishikara, 1993). However, it isn't possible to know whether this is true or false. Figure 3, an image of the landslide source area, shows a series of rotational failures experienced on the slope which resulted in the collapse of the slope onto the miners. This is clear because of the platforms seen as the slope moves down in the centre of figure 3 as well as in the top right of the image.

Conclusions

Assessment of Impact and Preparedness

The landslide in Myanmar had devastating impacts with the 54 deaths from the initial failure of the slope with the burying of the miners as well as the subsequent 2 rescue workers who were killed afterwards by a secondary failure resulting in the rescue attempts being called off (Lynn, 2019). The

landslide also had substantial economic impacts on the Hpakant region with an entire building and 40 pieces of heavy machinery being buried by the failed slope. There were also secondary economic impacts of the landslide when, following the 2 volunteer rescue workers being killed and rescue attempts being called off, the Myanmar central government suspended mining operations in 17 mining blocks in the Hpakant region (Myanmar Times, 2019), resulting in people being unable to work to earn as well as the jade mining companies unable to produce jade in order to sell it, usually to China, with the Jade industry being worth nearly half of Myanmar's total gross domestic product and so will likely have had a impact on the national economy, rather than just the regional economy.

The Hpakant region is notorious for consistent landslides induced by mining activity, with Petley (2018), recording 33 fatal landslides between the start of 2015 and 28th September 2018, resulting in 807 fatalities, with the true figure likely to be even higher with many landslides likely going unreported. Figure 4, created by Petley (2018), shows the cumulative number of fatalities since the start of 2015, with rapid rises in fatalities in 2016, with a significant slowing in 2017-2018. However, this graph doesn't consider those who have been seriously injured in this time. This ongoing trend of high numbers of fatal landslides with incredibly high fatalities recorded shows the repeated failures of the Myanmar central government in their preparedness for landslides in the region, likely due to the minimal regulations on the mining industry (BBC News, 2019) as a result of high levels of corruption in the industry. This comes even after repeated promises from the Myanmar central government to increase the regulations on the industry and work towards guaranteeing the safety of their miners, promises which seem to have not been kept. For example, in Japan, as a measurement against the risk of landsliding, they have installed structural measures such as catch dams and retaining walls in valleys where homes are at a high risk (Osanai et al, 2010). This is a step that could be taken by the Myanmar central government in order to protect their miners and decrease the dangers involved with jade mining.

Impact Relative to other Landslides Internationally

The vast majority of landslides all across the world do not result in any fatalities and even often go unreported, with the most common impacts being economic impact. Although, every year, particularly in Asia where the majority of fatal landslides occur (Petley, 2018), significant death tolls can occur from individual landslides. This is the case with this landslide, where 54 were killed from the initial landslide. However, this landslide was not even the highest death toll reported in Myanmar in this year, with a landlside on August 9th reportedly killing upwards of 59 people (The Thaiger, 2019, NASA Earth Observatory, 2019) as a result of heavy rains from monsoons, although it is possible that some of the deaths could be attributed to flooding, rather than a landslide. Other landslides internationally with high death tolls include a landslide in the Guizhou region of China in which 34 were killed (BBC News, 2019), as well as a mudslide burying 20 properties with 36 killed and 15 missing. The 22nd April landslide will likely have had higher economic impacts than many others around the world, due to the shutdown of 17 jade mining blocks, disrupting the exportation of jade from Myanmar, therefore impacting on the national economy with the jade industry a massive part of Myanmar's national GDP.

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2019 Siberian Wildfires

Sam Paisley

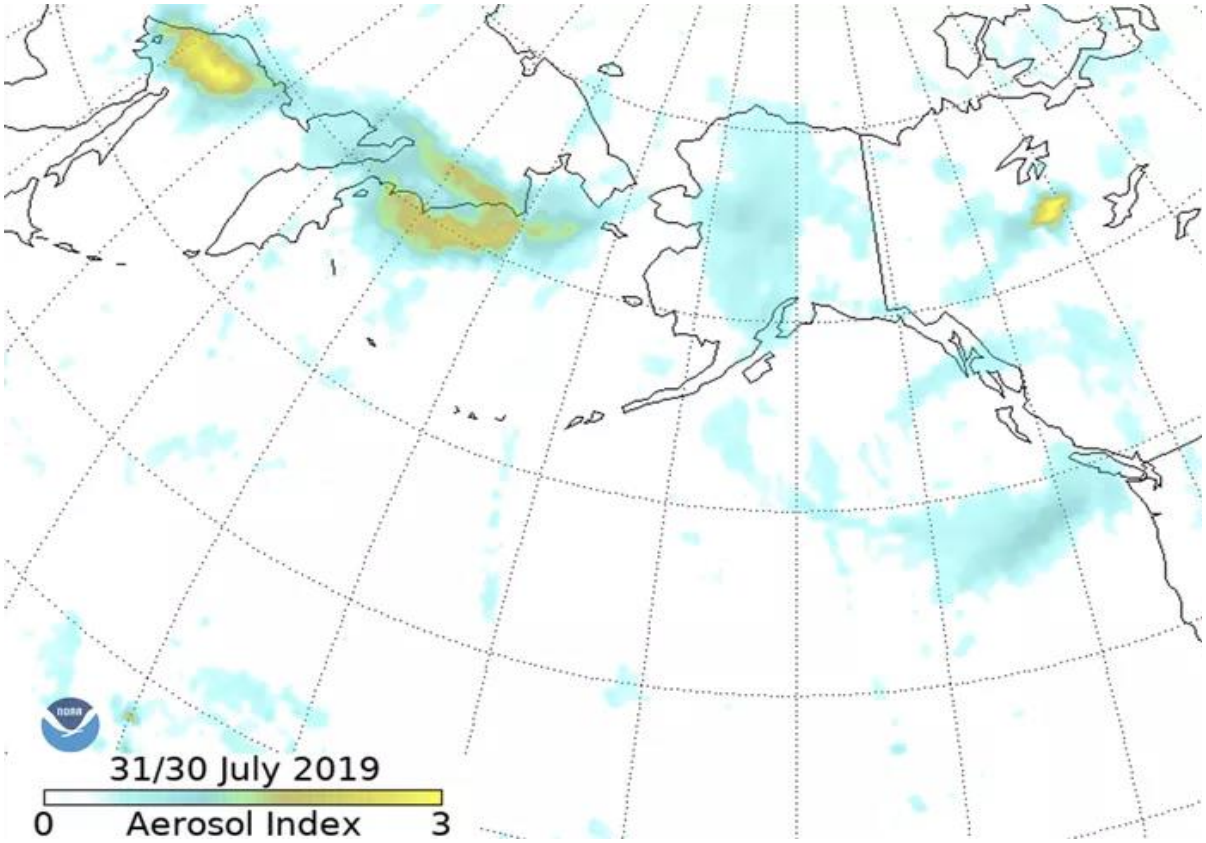


Figure 1: Map showing the intensity of smoke plumes caused by Siberian wildfires across the United States (Vox, 2019)

Background

Siberia is a vast region of Russia which spans an area of 13,500,000 km2 (1,350,000,000 hectares) (Morris, 2016). It is home to a population of roughly 37,600,000 people, which makes up only around 27% of the total Russian population despite the area of Siberia being accountable for 77% of the countries land area. Due to its large land area but relatively small population, the region has a population density of only around 3 people per sq. km, this means that the region of Siberia as a whole is one of the most sparsely populated areas in the world.

Within the Siberia region it is not uncommon for there to be the presence of wildfires as they usually face them on an immense scale (Vox, 2019) (DW, 2019). However, the blazes that have occurred over the summer of this year reached an unprecedented size and strength, boosted by atypical climatic conditions (Greenpeace, 2019).

***Conditions Prior to the Even*t**

Before the great number of blazing fires began to burn in the region, there had been an uncharacteristically hot and dry summer, with record breaking temperatures reaching a consistent 30oC heat, that left the forests of Siberia primed to burn (NASA, 2019) (ESA, 2019). Alongside this there were also strong winds in the area which aided in the spread of the fires, allowing them to move quickly across large areas. It is also clear to be seen that the conditions in this particular year have produced favourable conditions for wildfires as an unprecedented number of wildfires have been raging in the Arctic, including Greenland and Alaska, as well as in the US (ESA, 2019).

Timeline of Events

The spate of wildfires that have raged across the Siberian landscape for the past few months began in early July, covering an area of 2.6 million hectares by the end of this month alone (NASA, 2019). It is believed that the fires started due to a number of causes. The Krasnoyarsk Forest Fire Centre say that the fires were started by natural causes, due to the 30+oC heat, strong winds and dry thunderstorms (NASA, 2019). In addition to this, it is thought that a number of the fires were started by human activities. Russian prosecutors believe that some of the fires in the Irkutsk region were started by arsonists in an attempt to conceal illegal logging activities which were occurring in the area (Moscow Times, 2019). Following this initial ignition of the fires, the areas that fell under the mercy of the flames grew exponentially with substantial areas of forest being

devastated by the torching fires as they passed through from one area to the next. By the end of the month of July, Russia had declared an emergency over the huge fires in the region (DW, 2019). At this stage, there were hundreds of fires as can be seen in figure 1.

During the following few weeks another area of around 1 million hectares of forest has succumbed to the infernos taking the total area burnt for this series of blazes to 4.3 million hectares, and the total for the region for the year up to 13.1 million hectares (Greenpeace, 2019). According to NASA (2019), at this point in time there were 437 fires burning in the Siberian region, 289 of which had simply been left to burn naturally. This was because it was believed that they do not pose any threat to settlements and objects of the economy and the projected costs that would come with trying to extinguish them would exceed the projected damage that they may cause (NASA, 2019). The other 148 fires that were being actively fought covered a much smaller area of 0.25 million hectares, but posed a threat to nearby towns and cities, hence why the authorities decided to step in and combat the flames.

Finally, after hundreds of blazes torched huge swaths of Siberia for the third month in a row (Vox, 2019), at the end of September the authorities stated that all of the fires affecting people living in the region had been extinguished (Moscow Times, 2019). Having covered an area larger than the size of Belgium, the fires had not only devastated areas of the Siberian forests, but the smoke that has been produced by the fires has contributed air pollution to areas far greater. The smoke extended well beyond just Russia, covering an area larger than the European Union by mid-august (Euronews, 2019). Even by the end of July, smoke from the fires was already being tracked across as far as North America and more specifically the north coast of, as can be seen in figures 2 and 3 respectively.

Impacts

Smog engulfed the many major cities, carrying air pollution into specific regions such as Kemerovo, Tomsk and Altai (Moscow Times, 2019) (ESA, 2019), leading to authorities declaring the levels of smoke in these regions as emergencies which needed to be addressed. Russia's third largest city (Novosibirsk) which is located in the South of Siberia suffered from very poor air quality. This led to hacking coughs, stinging eyes and many hospital visits, all of which made the authorities more aware of the large impacts the fires could have when left to burn (Vox, 2019).The economic impact that the fires had on the area of Siberia, despite many of the fires being left to burn naturally, were massive. The total damages of the fires and expenses from the fires that were being fought totalled in excess of $100 million in damages (Moscow Times, 2019).

Many fires in these zones could have been extinguished at an early stage, which would have significantly reduced the area covered by fire, the smoke of settlements and CO2 emissions into the atmosphere (Greenpeace, 2019). During the burning of forests from wildfires, many toxic gases and harmful pollutants are released into the atmosphere (ESA, 2019). It was estimated that during the burning of the Siberian wildfires over the summer period of 2019, more than 166Mt CO2 was emitted, which is around the same as roughly 36 million cars emit in a year-long period (Greenpeace, 2019).

Responses

Due to lack of money in areas of Siberia, many of the fires in the rural areas were left to burn, just as they usually are in the region (DW, 2019). It was only the fires that posed a threat to the cities and any economic product of the state that were aimed to be stopped. Large areas were being left to burn despite the thick smoke which began to dominate the landscape, with it being said that "most likely the fires not being fought will only be put out with the rains that come in October or with the first snow" (NASA, 2019).

Looking at the wildfires from an outside perspective, there were many major social media campaigns which criticised the Russian authorities' slow responses to the fires. Across the world scientists and environmentalists "rang the alarm" over the levels of carbon emissions caused by the fires, saying that the problem with wildfires should be addressed on an international level in the global climate agreements if we want to keep global warming levels below 1.5oC.

Technical Interpretation

Across the world, there are no continents other than Antarctica which are free from the various combination of ignition source, fuel and weather conditions necessary for a wildfire hazard to occur (Smith, 2013). Currently, the majority cause for the start of a wildfire is due to anthropogenic activity, where in the past they had been mostly started naturally by lightning strikes and dry thunderstorms in unpopulated areas (Smith, 2013). Within Europe, the wildfires which occur in the Mediterranean basin are other Mediterranean-type areas of the world, area most commonly human-caused fires (Keeley, 1982), contrary to other regions of the regions of Europe such as the Boreal forests where lightning is classified as the most common cause of ignitions. (Johnson, 1992).

In Russia, the environmental conditions often create the perfect conditions for wildfires to start and spread; during the summer months, Siberia can experience extreme droughts of up to 100-120 days in the large uninhabited areas, which are often supplemented by abnormally high temperatures (Shvidenko and

Schepaschenko, 2013). At this time, ground fires are a common occurrence in the unmanaged high latitude forests, located in the perennial permafrost area.

Wildfires are an essential part of the evolution of forest ecosystems and the present state of forest cover in Russia (Shvidenko and Schepaschenko, 2013). They are part of the natural mechanism which prevent there being a decrease in the productivity of the forest, its green desertification and water logging (Ostroshenko, 2006) (Sedykh, 1990). However, fires cause the most harmful natural disturbances that determine the successional dynamics of forest, mosaicity and the structure of forest fund, also leading to considerable ecological, economic and social losses (Shvidenko and Schepaschenko, 2013).

The forests in the Boreal region, located in the North of Siberia, are of a significant ecological importance due to the crucial role which they have regarding the global carbon budget (Sukhinin et al., 2003) (Neigh et al., 2013). Within this region, the wildfires represent the major factor which determines the dynamics of carbon pools in the ecosystems located here. When the fires burn in this region, they can have be specifically dangerous to the environment, and furthermore climate change, as they are a major source of black carbon; this settles on the Arctic ice and accelerates the melting rates as it causes the ice to absorb more light and heat energy in comparison to normal levels (Greenpeace, 2019).

The Intergovernmental Panel on Climate Change (IPCC) have used models in order to predict what is going to occur in the future. These models have forecast a consistent and significant acceleration in the current trends surrounding climate change for the Siberian region of the country (Shidvenko, 2013).

Conclusion

When it comes to managing the risks associated with the wildfires in Siberia, it is extremely complicated as there is such a low population density, and there can be extreme difficulties with accessing many areas of the forests where the fires burn through (Paton et al., 2014). Consequently, it is impossible for the Russian authorities to entirely control the fires that will inevitably occur in the region. However, it is not the fires themselves that cause the problems to human populations, it is the smoke and deteriorating air quality which follows. This leaves the people living in the country, close to the forests, very vulnerable to the effects as they don't have a way to combat the decreasing air quality and are just subject to its affects within their own homes.

The wildfires that have occurred in over the summer months of 2019, were not dissimilar to those which occurred in the summer of 2010. Several major European Russian cities and highly populated regions were subject to continuous episodes of extreme air pollution in this year, due to thousands of large wildfires, provoked by an unprecedented intensive heatwave (Konovalov et al., 2011). Due to the 2010 fires having such a large impact on the Russian population, leading to the authorities declaring a national emergency, it was expected that there would be more investment into the fighting of wildfires in the Siberian region, however due to the low economic strength of many of the towns and cities this was not the case. Hence, the population have been left vulnerable and the environmental impact of the fires is still extremely high.

Looking to the future, in order to reduce the impacts felt by the Russian population both socially and economically, as well as reducing the contributions to climate change that the wildfires have, the Russian authorities need to rethink the way that they go about tackling the fires. Currently many fires are left alone due to access and money issues, but these fires in the "control zones" need to be monitored more closely so that it can be sure they are not going to escalate and cause major problems to cities and towns within the potential vicinity.

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New Mirpur Earthquake (Pakistan)

Leon Marsh

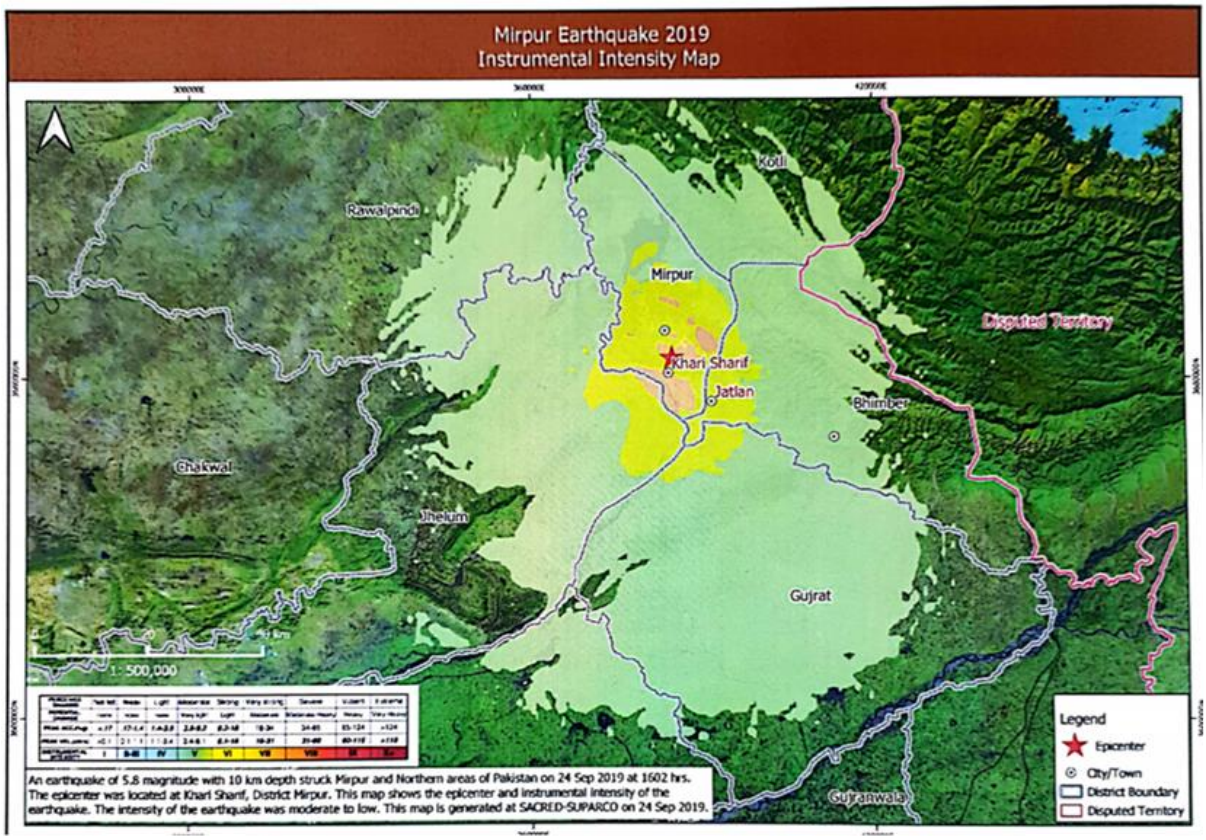


Figure 1: Diagram of earthquake epicentre and energy output (NDMA, 2019)

The New Mirpur Earthquake (also known as the Pakistani Earthquake) was a "5.4 magnitude earthquake" (United States Geological Society, 2019) that struck the Mirpur District in Pakistan (Azad Kashmir region) on Tuesday the 24th of September 2019. Striking the area at 16:02 local time, the quake had a relatively shallow depth of around "10km" (USGS, 2019), however tremors were not just felt in New Mirpur, instead they travelled throughout the "Kashmir" region affecting neighbouring areas such as the "Punjab" area of Eastern Pakistan and "Northern India" (Bhatt, 2019). Despite the magnitude not being significantly high on the Richter scale, the earthquake had a maximum felt intensity of "VII" on the "Modified Mercalli Scale" resulting in considerable damage, most prominent in New Mirpur. The energy radiated outwards from the epicentre just south of Mirpur as seen below in figure 1.

History of the Kashmir Region

The larger 'Kashmir' region in which the earthquake took place is a "disputed and troubled territory" according to 'The Guardian' (2019). With separate "Indian and Pakistani regions" the epicentre of the quake occurred near Mirpur City in the "Pakistani-administered region, which is nominally self-governing" 'The Guardian' (2019) continued. This is evident below in figure 2, with both the Pakistan and Indian administered parts of Kashmir identifiable. Mirpur City (indicated in the red font and dot) is located in the southern area of the Pakistani region as seen below, close to the border of Indian controlled Kashmir.

Tectonic Setting

The Kashmir region of which New Mirpur and the subsequent 2019 earthquake was located is mostly positioned "in the Himalaya mountains", inhabiting a "crossroads between the Middle East and Asia" (Naranjo, 2008). As a result of this, "it lies atop a web of active geological faults" (Naranjo, 2008) as seismicity "dominantly results from the continental collision of the India and Eurasia plates, which are converging at a relative rate of 40-50 mm/year" (Koshy, 2019). "The Main Central Thrust" is one of the "Himalayas three master thrusts" (Upreti, 1999) and is responsible for accompanying the movement of these plates which has resulted in many damaging earthquakes within this region throughout history.

Impacts

The damage from the 5.4-5.8 magnitude earthquake resulted in the deaths of "38 people and injured roughly 723 more". "33 out of the total deaths" were located in the "Mirpur District" with the rest occurring in the neighbouring "Bhimber" (4 deaths) and "Jhelum (1 death) districts" (NDMA, 2019) evident below in figure 3. There are some disagreements regarding these figures however, with news website 'Purdu Point' placing the death toll at "40" and the number of injuries at "850" (Irfan, 2019) whilst the USGS placed the magnitude at "5.4" instead of the "5.8" magnitude provided by NDMA in figure 3 below. According to Reuters a large number of casualties were due to "shoddy homes" with "numerous "old village houses collapsing" worsening the total "damage" (Greenfield, 2019), by turning the buildings into death traps for the people located inside of them. The damage to infrastructure overall was severe with "135 houses" in the Mirpur district being significantly damaged and a further "319" receiving "partial" damage of some sort (NDMA, 2019).

Aside from housing, there was also damage to "2 bridges" within the region as well as several roads (most noticeable through "14km" worth of damage to the "Main Jaltan Road" (NDMA, 2019)). "Mobile phone towers and electricity poles" were also "badly damaged" in the area according to "Naeem Chughtai, a Mirpur resident living near the city's main hospital" speaking to "AFP" (The Guardian, 2019). According to the 'National Disaster Management Authority Chairman' Lieutenant General Mohammad Azfal in a press conference held several hours after the earthquake (Tuesday evening), besides the city of Mirpur damage was worse felt in the small town of "Jatla" and 2 small villages of "Manda and Afzalpur" (DAWN, 2019). General Azfal also placed great emphasis on the fact that most damage was to infrastructure within these areas and not on the people living there. Another noteworthy impact, was that of the "Mangla dam". The dam which is Pakistan's major water reservoir was not damaged in any way however "power generation" had to be "suspended" for a "couple of hours" (safety precaution) which resulted in a loss of power to Pakistan's National Grid, however "power restoration at Mangla resumed at 7.20pm restoring 700MW to the national grid" (Hasnain, 2019).

Aftershocks

On Thursday the 26th of September (2 days after the initial earthquake) another smaller quake shook the Kashmir region. According to Muhammad Riaz, a man described as "Pakistan's top meteorologist" and additionally "the National Seismic Monitoring Centre in Islamabad" the earthquake was "a magnitude 4.4 tremor" and the epicentre was "12 kilometres deep" (Naqash, 2019). However, the United States Geological Society placed the magnitude at a higher "4.7 magnitude" on the Richter scale with a depth of "10km" (USGS, 2019). Regardless of this dispute, the aftershock resulted in the "minor injuries of 67 individuals in Azad Jammu and Kashmir's Mirpur city" (Naqash, 2019) further damaging the area following on from the more severe damage 2 days earlier.

Response

The response to the earthquake was relatively swift. National Disaster Management authority vehicles immediately travelled to the affected areas to provide relief. On these vehicles were "200 tents, 800 blankets, 200 kitchen sets and 100 medical sets" according to Lieutenant General Mohammed Azfal (DAWN, 2019). This provided much needed aid to residents of Kashmir, especially those whose homes had been destroyed, and also reinforced hospital supplies as the amount of injured people began to take a strain on the resources available to medical staff. On top of this relief effort, "the prime minister of Pakistan controlled Kashmir 'Raja Farooq Haider Khan'" also became involved in the crisis. By cutting "short a visit to Lahore" Khan "headed back to his native region soon after the news of the damage surfaced" (Masood, 2019) in order to provide his assistance and help authorities in dealing with the situation.

Technical Interpretation

With Kashmir being positioned within the Himalayas, it is undoubtedly a certainty that the area will experience frequent tectonic activity. Because of this you would expect the area to be well prepared for the possibility of earthquakes and would have measures in place to mitigate any damage that could potentially arise from the Indian and Eurasian tectonic plates colliding into each other. This is partly evident within this region through the National Disaster Management Authority, which has been set up to deal with and combat the impacts of disasters. With Kashmir covering both India and Pakistan, the headquarters of the NDMA are located within India, however the agency has jurisdiction in Pakistan, emphasised through the aid provided to the affected areas in and around New Mirpur in Pakistan. This therefore provides evidence to support the theory that this part of Asia has practises in place to alleviate the impacts of earthquakes and other natural disasters.

However, Pakistan along with its neighbouring countries is not in an economically advantageous position – its annual defence budget is "$9.6 billion" (Gurung, 2018) which is nearly 10 ten times less than Japan's at "$930 billion" Obe (2018) for example. Because of this, Pakistan delegates significantly less amounts of finance towards natural disaster defence in comparison to countries whose economic finances are stronger. To make matters worse, due to ongoing hostilities between India and Pakistan along the border of the Kashmir region, finance from Pakistan's

defence budget is being sent to the Kashmir location, but unsurprisingly it is not being used on earthquake defence specifically, instead it is being invested in Pakistan's border control and defence. This has been emphasised recently, during the "2018-19" period which has seen a "20% increase in Pakistan's defence budget" to the "$9.6 billion" mark, however according to the 'Economic Times' in India, there is a strong indication that this increased investment is being utilised by the "Pakistan armed forces" in an attempt to increase their "basic operational capability" along the border (Gurung, 2018). As a result of this many areas throughout Pakistan aren't well prepared in terms of earthquake defence, with buildings not reinforced properly (as building companies can't always afford to follow building regulations) and other forms of infrastructure lacking the basic needs to withstand the shaking an earthquake produces. This was evident in the village of "Sahankikri, on the outskirts of Mirpur" where "residents said almost all the 400 houses were damaged" according to The Guardian (2019) (however this number appears unrealistic when compared with the NDMA's figures).

This is of stark contrast to other areas of the world, such as 'Japan' for example where in 2015 "87% of buildings" in Tokyo were "built to withstand earthquakes" (Lufkin, 2015) and recently in 2018 the "infrastructure and transport ministry" requested a "19% increase" in its finances "to fund infrastructure improvements to cope with natural disasters such as earthquakes" (Obe, 2018). This means that despite the knowledge within Asian countries that their areas are susceptible to earthquake damage, it is not financially possible to make these areas earthquake proof and subsequently as highlighted already in this case study, when natural disasters finally arrive damage is unfortunately inevitable (as the National Disaster Management Authority lacks the funds it needs to operate adequately and mitigate the impacts of earthquakes).

Although the earthquake that struck Kashmir on the 24th of September caused damage and deaths to the region, the devastation experienced was minimal in comparison to what preceded this earthquake 14 years earlier. In October 2005, a significantly larger earthquake measuring "7.6" on the Richter Scale struck the same region, killing more than "75,000 people" and leaving "hundreds of thousands homeless" (Masood, 2019). It is unsurprising that the impacts were so much more severe in 2005 when the magnitude of the earthquake is compared to that of its counterpart in 2019. However, if lessons were learnt from the devastation of 2005, and new methods and improved practises were put into place to mitigate the impacts of future earthquakes in Northern Pakistan, this could potentially have played a role in minimising and making the damage less severe in September 2019. But, as already discussed due to Pakistan's limited defence budget it would have been increasingly hard for government officials to put practises into place that would have been adequate enough to significantly mitigate the future impacts thus minimal practises were put into place resulting in the damage experienced in September of 2019.

Concluding Section

In conclusion, with New Mirpur and the Kashmir region being located along the tectonic fault of the Himalayas, this region is without doubt going to experience more tectonic activity via earthquakes in the future. It is unlikely that significant changes will be made following the New Mirpur earthquake as the impacts were not severe in comparison to other quakes that have struck this region in the past as well as the numerous quakes that strike other areas along the Himalayan fault line annually. Although it is obvious what caused most of the deaths (poorly built buildings/houses), Pakistan doesn't have the financial resources to regulate and reinforce all buildings throughout their land and therefore because of this, regions within this part of Pakistan will always be vulnerable to potential damage arising from future earthquakes unless the country's economy begins to miraculously prosper at some point in the future or if tensions between Pakistan and India decrease.

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A Case Study of the Siberian Wildfires of 2019

Cameron Marshall

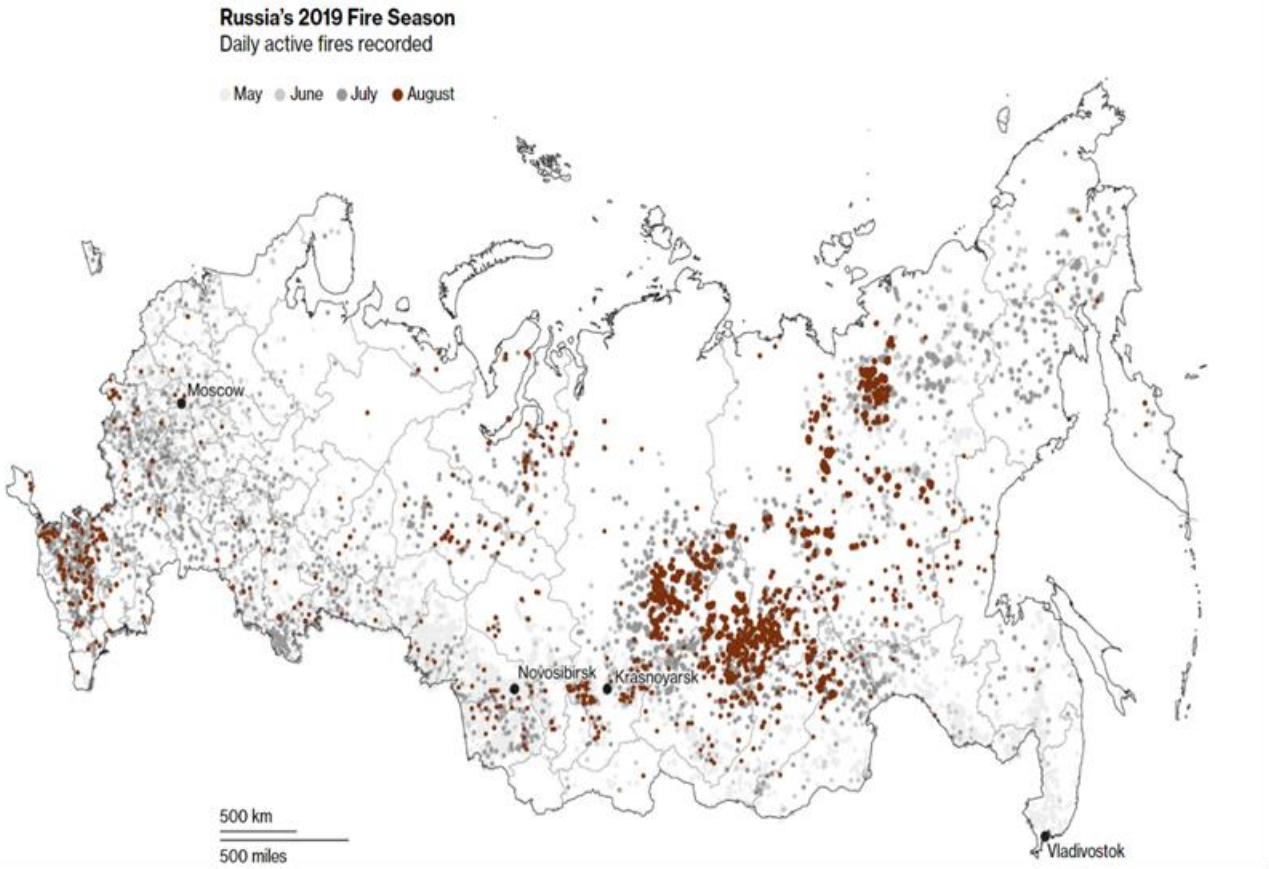


Figure 1: A map of Russia showing daily active fires during Russia's 2019 Wildfire season (NASA Earth Data Fire Information for Resource Management System, 2019).

A timeline of the events

To begin, it is difficult to determine the precise moment the Siberian wildfires began due to their extremely rural nature. Based on images taken by NASA's Moderate Resolution Imaging Spectroradiometer (Modis) Aqua Satellite we know there were multiple active fires occurring within Siberia and the Krasnoyarsk region specifically by June 28th, 2019 (NASA Earth Observatory, 2019). Now, based on the timeline of contemporary News Reports released during the event we know the wildfires continued to burn through until the end of July. This is when Russian President Vladimir Putin initiated mitigation tactics in response to the wildfires by declaring a state of emergency in five regions and instructing Army personnel join the local regional efforts in extinguishing the wildfires (France- Presse, 2019). Continuing on, based on Figure 1, seen below, we know the wildfires carried on throughout August, however although the fires continued, response work by the Russian Government and Local Communities along with support from international Non-Government Organisations (N.G.O's), such as Greenpeace Russia, caused the fires to reduce to a manageable level by the end of August (Rosenberg, 2019).

Causes of the Wildfires

We must first outline the conditions in the region before the Wildfires developed. Knowledge of the region's prior conditions allows us a greater understanding of why the event unfolded over time as it did. Firstly, June of 2019 had a higher European average temperature than any other June on record (The Copernicus Climate Change Service, 2019). So, during the month before the wildfires developed the region was experiencing record breaking 30 degrees Celsius temperatures combined with dry thunderstorms throughout the month (Jenner, 2019). Now we understand the previous conditions we can discuss why the wildfires occurred with more clarity.

So, to begin, the cause(s) of the wildfires can predominantly be attributed to several factors

coinciding at the same time leading to an environment within Siberia in which large-scale wildfires were more probable. Siberia suffered from the hottest June on record, meaning the area suffered from an extremely dry summer, combined with continuous strong summer winds and seasonal dry thunderstorms the conditions were perfect for the development of wildfires (Jenner, 2019). It was during these dry thunderstorms that multiple lightning strikes striking the dry ground vegetation and plant-life across different Siberian regions originally ignited the fires (Bailey, Blunt & Rodgers, 2019). Most of the wildfires began as lightning strikes during dry thunderstorms within the Krasnoyarsk Krai, Sakha Republic and Zabaykalsky Krai regions of Russia's Siberian Provinces (Jenner, 2019). Nasa's Earth Observatory (2019) and The Alaskan Interagency Coordination Centre (Bailey, Blunt & Rodgers) both separately confirmed through satellite imagery that dry thunderstorms were the predominant causes for the wildfires.

Scale of the Natural Disaster and it's Impacts

The physical blazes themselves have been seen to consume an area the size of Belgium (Rosenberg, 2019). Meanwhile, the smoke clouds created by the blaze were greater in size than the entire European Union and the Finnish Meteorological Institute estimated an area of 5 million Kilometres squared was affected by the fires (Kravchenko, Pogkas, Rudnitsky & Warren, 2019). At least 11 of Siberia's 49 regions have experienced wildfires (Helmore, 2019) and 4 were forced to declare a state of emergency (Watts, 2019). Moreover, not only has the smoke cloud covered a large area of Russia it has travelled a great distance too. Data retrieved from NASA's Suomi NPP Satellite shows us that smoke from these Siberian fires has spread as far as Western Canada and Alaska (Jenner, 2019). This information clearly portrays the vast size and scale of the wildfires. They physically covered an extremely large area and the smoke clouds travelled far meaning they had an effect on a greater region. Not only were the wildfires uniquely large, but they lasted for an unexpectedly long duration. The wildfires spanning over three full months is a longer duration for wildfires in the region than any other period in European Satellite's Monitoring System 17-year dataset (Watts, 2019). So not only did the fires span a far larger than average area for wildfires in the region, but they also occurred for a greater duration than any fires in the region's recorded history.

Now, we have a clear view of the massive scale and size of the wildfires we can discuss the varying impacts of the disaster. Firstly, we can discuss the short-term impacts. It is estimated that every year approximately two million hectares of Taiga forest are lost to wildfires in Russia (Greenpeace, 2019). Within the three-month span from mid-June to mid-August alone in 2019, Russia's Federal Forestry Agency estimates three million hectares have been destroyed by these wildfires (Frances- Presse).This is a massive increase over the yearly average and will have significant impacts on the ecology of the region, and although all the impacts cannot be quantified and understood yet since the disaster happened so recently we know that wildfires can negatively affect the soils, water levels and biota of a region (Deveechio & Keller, 2014). Furthermore, there were massive impacts on the human communities all across Siberia. As we can see in Figure 2 below Cities, towns and small rural communities across the entire length of Russia were impacted by the fires and in particular the massive smoke clouds.

The smoke clouds created by the fires spread over multiple large Siberian cities within multiple regions as well as towns and smaller settlements including the ones highlighted inside red boxes within figure 2 (BBC, 2019). The acrid smoke covered areas in Western Siberia, the Urals and Atals regions (Frances-Presse, 2019). As expected, the overall air quality in the locations massively declined leading to health concerns for the residents (Helmore, 2019). As can be seen in Figure 3 below, within the town of Nizhnevartovsk the visitation had been reduced dramatically. This level of smoke is extremely bad for human health and is clear evidence of how daily life was massively disrupted by the wildfires affecting economic production also as people are unable to leave their homes or work (Helmore, 2019).

Moving on to the secondary effects, the heat and smoke released from the fires could have a global impact as the carbon emissions, which equates to 150 plus mega tonnes in total, will exacerbate climate warming for years (Ayres, 2019).

In summation, the hottest June on record combined with dry thunderstorms and lighting strikes were the catalyst for the worst Russian wildfire season on record engulfing a region the size of Belgium in flames, destroying over 5 million square kilometres of land and engulfing a region the size of the European Union in a blanket of smoke affecting the health and livelihood of people in 11 regions of Russia's Siberian province.

A technical interpretation of the event

The Processes of a Wildfire

Within an ecosystem, bacteria do not decompose vegetation matter fast enough to keep the equilibrium between productivity and decomposition, therefore wildfires are naturally part of the process of decomposing vegetation and other biomass. This occurs as the biomass is rapidly oxidized and breaks apart through combustion and then burning (Deveechio & Keller, 2019). This is the basic process by which all wildfires occur. Once this process happens through the decomposition of vegetation all the pollutants absorbed via photosynthesis including

carbon dioxide and carbon monoxide are released back into the atmosphere impacting air quality on a hemispheric scale (Arishnov et al, 2009). Lastly, the frequency of fires is strongly linked to incoming solar radiation as Kharuk, Ponomarev and Ranson (2016) note. Meaning the greater amount of solar radiation incoming the higher the frequency of fires, and this can be seen within Siberia specifically also (Kharuk, Ponomarev, Ranson, 2016).

Moving forward we can discuss, at greater length, the mechanisms at play which caused these particular wildfires and how the environment preceding them further increased the likelihood and intensity of the fires. Firstly, the blazes were ignited by lightning from dry thunderstorms, these are particularly likely to cause wildfires due to their nature. As their name would imply during a dry thunderstorm the precipitation evaporates before contacting the ground (Dolce, 2017). This is particularly dangerous as there is even less moisture in the soil and atmosphere leading to more arid conditions which highly increases the potential for wildfires (Deveechio & Keller). Moreover, these particular wildfires burnt in such a large scale and for so long due to the Peat underlying the vegetation in the region. The underlying peat also caught ablaze and this material has the capability of burning continuously for months (Rosenberg, 2019). Also, Siberian Larch Forests release large quantities of black carbon and carbon monoxide in particular (Arishnov et al, 2009). These forms of pollutant are extremely bad for the environment and can increase the speed of global warming in large enough quantities as were seen during these wildfires (Kravchenko et al, 2019). Furthermore, the wildfires are cyclical and sue to soil melioration caused by the fires will lead to Larch forest regrowth at a greater rate in the permafrost zone (Dvinskava, Im, Kharuk, Ranson, 2011).

In summary, a combination of past and present factors were all involved in creating conditions in the region which made the likelihood of wildfires higher, and also caused the intensity of any possible wildfires to be greater than usual or expected. The previous conditions of the region: the hottest June on record, created a dryer environment meaning there was a greater chance of the ignition of a blaze. Furthermore, the dry thunderstorms and high winds in the area meant ignition and spread of fire and smoke clouds was greater. So, we can state past conditions combined with weather conditions led to the hazard itself and were pivotal in creating a disaster by increasing the probability of the events intensity.

Critical evaluation of the event

Responses to the Natural Disaster

Finally, we can discuss the response to the event by Government agencies, And the civilians in affected regions, as well as potential future risks and how they can be mitigated or prepared for. First of all, there has been some criticism of the Russian government's response, and the speed with which they responded. Greenpeace criticised the Russian governments speed responding to the event stating they waited far too long to send aid and response teams to the areas affected (Greenpeace, 2019). This notion was reciprocated by local residents of Podymakhino village who believed the help they received was too little too late (Rosenberg, 2019). However, there was an eventual response from the Russian government, 5 of the 11 regions affected declared a state of emergency and the Russian army was sent to fight the blazes (Watts, 2019). Moreover, a fleet of 10 helicopters and 10 planes were mobilised and distributed to the Krasnoyarsk region as well as 2500 plus firefighters (France- Presse, 2010). On the other hand, the residents of local villages and towns also made their own efforts to respond to the blazes. For example, residents of Podymakhino village implemented bulldozers to remove vegetation and pest from areas surrounding the blazes to detach the fire from any new burnable material (Rosenberg, 2019). Furthermore, after implementing policy in 2015 which stated unless the damgae caused is more expensive than the response to the fire no response will be instituted (Ayres, 2019) many have been critical of the slow response times and immoral policy.

Future Vulnerability to Wildfires

Now, Siberia will always be vulnerable to wildfires due ti their seasonal nature within the region, however if the response times from the Russian government are so regularly lackadaisical in future years then the health, economic and environmental effects of the disaster will continue to increase.

In conclusion, both local people and the Russian government mobilised in response to the event, there was much criticism of the government's response from local people and outside organisations however once they responded they mobilised a large force in response to fight the blazes.

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Sichuan Province, China Earthquake (17/06/19)

Daniel Morris



Figure 1 - Image showing the destruction of a house and search teams attempting to rescue survivors (Lang, 2019).

Account of Hazard

Introduction

On 17th June 2019 at 22:55 local time, an earthquake rating 6.0 on the Richter scale, struck the Sichuan Province in southwestern China, near the city of Yibin with the Changning and Gong counties particularly affected. The focus was at a depth of 16km and was recorded at 28.34 degrees north, 104.90 degrees east according to the China Earthquake Networks Centre (ChinaDaily, 2019). There were reports of the ground shaking as far as a few hundred kilometres from the origin of the earthquake.

The event

Multiple reports from early morning on the 18th, the day after the earthquake struck, state the number of deaths as 12 with more than 100 being inured (BBC, 2019; Zuo, 2019; ChinaDaily, 2019). Rescuers say that most of the deaths were caused by the collapsing of houses and buildings with nine deaths occurring in Changning and the remaining 3 in the nearby Gongxian county (ChinaDaily, 2019). However, this number rose to give a total death toll of 13 people and a further 220 people who were injured (Xinhua, 2019c). There was extensive damage to the region with over 10,000 buildings destroyed and more than 100,000 people affected according to a statement by the local government. Damage to houses is shown in Figure 1. Most of these damages were in the epicentre at Changning county in Yibin. Land subsidence also occurred along with landslides which blocked off major highways and roads with workers being sent out to clear the way for response teams (Zuo, 2019). 80,000 people have been evacuated to safety (Xinhua, 2019c) with more than 4,000 people having to be relocated due to their homes being destroyed by the quake (BBC, 2019; ChinaDaily, 2019). The direct economic loss that was totalled was estimated to be around 10.82 million yuan ($1.59 million) (ChinaDaily, 2019).

The response

The response from the Chinese authorities was rapid with more than 500 firefighters having been deployed to the area along with 800 police forces and 1,000 armed police forces who were deployed for reinforcement. They brought with them specialist equipment such as life detectors and forcible entry tools to help with the search and rescue efforts. The Ministry along with the National Food and Strategic Reserves Administration and the Red Cross Society of China has supplied further rescue teams with 5,000 tents and 10,000 folding beds with 20,000 quilts among other supplies including many search and rescue teams (BBC, 2019; ChinaDaily, 2019). A team

of nine medical experts in their different fields of critical care, epidemic control and prevention and psychology, were sent off to the area from leading hospitals in Beijing by the National Health Commission with further teams ready to be deployed at a later date if they were required.

Warning Systems

China has early warning systems in place for detecting when earthquakes have happened and are about to strike the surface. They cover an area of 2.2 million km2 which provides a service for around 90% of China's population who live in earthquake-prone regions. In recent years the system has successfully provided warnings for 52 destructive earthquakes. On the evening of this earthquake, residents in the provincial capital Chengdu, which is located more than 200km away from the epicentre heard a countdown from an automated public broadcasting system. Following this, a siren sounded at the time when the seismic waves hit the city. The early warning system also alerts the public through radio and television stations along with mobile apps and the internet. In Yibin, alarms were sounded 10 seconds before the earthquake hit. The system was jointly built by the organisation Care-Life which studies earthquakes and local emergency management. Wang Tun, the director of Care-Life said "The system was not designed to predict earthquakes. It uses the theory that radio waves travel faster than seismic waves and provides warning seconds before the earthquake waves arrive". Earthquake research has shown that just being aware of an earthquake three seconds beforehand can save 14% of casualties, 10 seconds can save up to 39% and 20 seconds as many as 63% of the casualties (Xinhua, 2019b).

The Province

The Sichuan province is often hit by earthquakes with two major quakes occurring within the last decade. In 2008, more than 87,000 people were killed in a 7.9 magnitude tremor 80km north-west of Chengdu and in 2017 a 7.0 magnitude quake saw the death of more than 20 people (BBC, 2019). There is the question that the earthquake may have possibly been caused by recent fracking activities which have taken place in the region. Hydraulic fraction has been increasing dramatically all over the world as countries aim to increase the production of oil and gas (Shengji, 2019) and China has been no exception.

Technical Interpretation

Why do earthquakes occur?

The outer layer of the Earth is called the lithosphere which is divided into many different continent-size sections of rock which are called tectonic plates. These plates sit on top of another layer of the Earth, a flowing layer of hotter mantle known as the asthenosphere. The plates move due to a large-scale circulation system of heat (convection currents) from the mantle which transports the plates horizontally (Tilling et al., 1994). The movement of the plates results in a local strain within the crust due to the compression and friction developed between two different plates. Over time, stress builds up until the plates next move causing this to be released which results in a shock radiating through the Earth's crust in all directions (Scholz, 2019). This is known as an earthquake.

China's tectonic setting

China is located near the boundary of 2 different tectonic plates; the Indian and the Eurasian which meet at a convergent plate boundary where the plates are moving towards each other due to convection currents. However, the tectonic setting of China is much more complicated than this as there are a number of cratonic blocks that are present. A cratonic block is a stable portion of continental crust which is part of the crust, the lithosphere and the uppermost mantle, found in the interior of tectonic plates (Petit, 2010). Western China is composed of the Tibetan Plateau, numerous mountain ranges as well as important oil-and-gas-bearing basins (Zheng, Xiao, & Zhao, 2013). Sichuan can be divided into 2 separate tectonic areas; the eastern area of the province consists of the Sichuan basin and the western area consists of numerous mountain ranges which lie at the eastern part of the Tibetan Plateau. There are many fault lines along here, such as the Longmenshan Fault which ruptured during the earthquake in 2008 (Burchfiel et al., 2008). The Longmenshan fault runs along the base of the Longmen mountains in western Sichuan on the boundary of the eastern edge of the Tibetan Plateau where uplift has caused the mountains to rise above the lowlands of the Sichuan basin (Jia, et al., 2006). Fault lines are small fractures in a tectonic plate that occur where larger plates come into contact with one another (Carlson, Langer, & Shaw, 1994). The stress caused by this contact result in the formation of faults and the collision between the Indian and Eurasian plate was the reason for this fault being present (de Michele et al., 2010).

Causes of the earthquake

The causes for this earthquake are currently not known due to the event being recent, but it is likely to have been caused by another slip of a fault line which happens quite often in this region due to the historical seismicity of the area. This is due to the Sichuan basin being constantly in collision with the Tibetan Plateau which causes the entire region to be prone to earthquakes. A similar earthquake to this most recent one occurred in 2008 along a nearby fault line and so there may be a resemblance between the two quakes. In 2008, there was a 7.9 magnitude earthquake in Sichuan that occurred over a fault parallel to the Longmenshan thrust belt with a slip estimated to 10m with the rupture occurring at 10-20km depth (Burchfiel et al., 2008). There are a lot of faults in this

region due to the Tibetan Plateau being uplifted above the Sichaun basin and any of these faults can cause earthquakes to occur.

Was fracking potentially the cause?

However, there is a possibility that fracking was the cause of the quake due to the Sichuan Basin being the site of fracking since 2010 with fracking injection wells becoming more common since 2014. Both wastewater disposal and fracking have caused earthquakes in the Sichuan basin and according to the Geological survey of Japan there is evidence that suggests that earthquakes in December 2018 and January 2019 were caused as a result of fracking (Lei, Wang, & Su, 2019). They pinpointed the location of the earthquake and found that the depth was quite shallow which you would expect if they were triggered by the fracking.

Conclusion

Vulnerability

The Sichuan region in China is vulnerable for earthquakes and is often prone to having them as the Sichuan basin is surrounded by tectonic plates that are historically seismically active. The basin is in continual collision with the Tibetan Plateau which causes the region to be frequently struck by earthquakes. These strains between the blocks can cause devastating earthquakes such as the one that was experienced in 2008 and so the region will be vulnerable to more in the future.

Response

The response for the quake by the Chinese authorities was quite rapid as rescue teams made up of firefighters and police arrived at the epicentre of the quake. At 8am the following morning after the earthquake struck, eight people had already been rescued from the debris of buildings and over 600 people had been relocated. Supplies had been brought in and tents had been set up for residents. For all of this to be done only 9 hours after the earthquake and for it to have happened over night as well really highlights how quick the response really was especially due to the earthquake casing damage to a major highway connecting Yibin and Xuyong county to be closed and other smaller roads that were blocked off due to landslides. Perhaps the response was so quick because of the vulnerability of the region to receiving earthquakes and so the authorities were prepared for the next earthquake to happen allowing the correct procedures to take place in order to carry out rescue attempts efficiently and quickly to ensure that as many lives as possible were saved.

Education also played a vital role in the response to the earthquake as the early warning systems would have ensured that people were able to get to a safer place to ensure that they survived. This would surely have had a difference to the death toll as due to the time of the earthquake many people would have been in bed or asleep and therefore more vulnerable if not for the warming they received.

Potential future risk

There is a high potential for future risk of earthquakes in the Sichuan region as the region is prone to receiving earthquakes and there have been some since this event, including the many aftershocks witnessed following. If fracking was a potential cause and this continues, then there is a chance that the earthquakes could become more regular if this practice continues.

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Monsoon India 2019

Sarah McAdoo



Figure 1 People in Mumbai affected by flooding Sourced from https://www.news18.com/photogallery/india/relentless-rain-savages-maharashtra-6-killed-400-stranded-2207705-1.html



Figure 2 Train services affected at a station in Mumbai https://www.news18.com/photogallery/india/relentless-rain-savages-maharashtra-6-killed-400-stranded-2207705-4.html

Monsoon Event 2019

The monsoon season in India is an annual occurrence and runs from June to September. The monsoon rain is caused by differing temperature trends over the land and ocean (www.tripsavvy.com). During this monsoon season a record amount of rainfall had fallen, with over 3,475 mm of rainfall falling in total over the year. This has beaten the previous record of 3,452 mm in the year 1954, over 6 decades ago (www.indiatoday.in). Rain has only recently begun to cease as of the 15th of October whereas the normal date of withdrawal stated in many articles is October the 10th over the country (https://timesofindia.indiatimes.com). This extra 5-day rainfall period added to an already waterlogged country causing additional destruction. Rains in India this monsoon season were also delayed until the 25th of July, with rain normally arriving on July the 10th. This is one of the most delayed start dates in 45 years (The Times of India, R. Pinto, 2019). Due to this late start date, farmers in the region began to brace themselves for a possible drought risk, and water shortages were observed all over the country.

Due to this monsoon season having the heaviest recorded rainfall for nearly a decade, impacts on population and infrastructure such as road, rail and air traffic were significant. 55 planes were diverted and a further 52 cancelled at Mumbai's Chhatrapati Shivaji Maharaj International Airport following a potentially serious incident where a plane skidded on the mud on a runway in Jaipur due to the wet weather (The Hindu, 2019).

Wall collapses were the main causes of death in this event. Prolonged rain causes walls to become unsteady and collapse unexpectedly causing injuries and fatalities. Slum areas are predominately at risk due to the low quality and unstable infrastructure. One of the main incidents occurred on the 2nd of July when a wall collapsed in the Western suburb of Malad. Various figures have been reported, however the death toll of this event reached 31 as of the 20th of July according NDTV, 2019. An additional 90 were injured in this event (NDTV, 2019). In Pune, located East of Mumbai in the Maharashtra state, an additional 9 labourers were killed, and 3 others injured after a wall collapsed (The Hindu Business Line, 2019). In total over Southern and Western India, 95 people have been killed in rain-related incidents, 40 of these being from the South Western state of Kerala and predominately still from wall collapses (BBC News, 2019). Two people died after their car was flooded at a subway in suburban Malad (Times of India, 2019), where previous wall collapses had taken place.

Effects of the monsoons in Mumbai have been worsened over the years due to a construction boom which has involved the destruction of many of the mangrove forests along the rivers. Mangrove forests are instrumental in absorbing the flood water thereby enabling the city to more effectively deal with the impacts. Another factor which increases devastation caused by flooding is the global rise in sea level. Mumbai is particularly susceptible in this respect as it is situated on the West coast of India as seen in Figure 1 below (New York Times, H. Kumar, 2019). Due to the prolonged rains, agriculture in India has also begun to be affected with farmers noting that their vegetables are beginning to rot, sky rocketing the prices of onions from 20 rupees (23p) to 80 rupees (around £1), onions being a stable ingredient in Indian cuisine (The Guardian, A.Dhillion, 2019).

Technical Analysis of Monsoons in Mumbai

Construction

With monsoon flooding being an annual hazard in Mumbai, the city should be adapted to these rainfall events, but the ever-sprawling cities of India have

been built onto wetlands and floodplains due to a lack of regulations and policies. Thousands of people travelling each day to Mumbai (India's financial capital) in search of jobs causing a hurried need for construction with no thought into how flooding will be managed during the inevitable monsoon seasons (BBC News, 2019). Mumbai is home to 4 rivers: Mithi, Poisar, Dahisar and Oshiwara, all of which flow from the hilly regions in the North-East to the West to join the Arabian sea. Previously, mangrove forests had lined the 4 rivers, absorbing a significant amount of the monsoon water. Due to the construction boom in Mumbai, these mangrove forests have now been replaced by properties and developments, causing a change in LULC (Land use and land cover) from permeable to impermeable terrain, causing an increase in surface run-off and therefore more intense flooding. According to a study by the Indian Institute of Technology Bombay, urban heat islands and therefore urbanisation could also be a significant factor in the intensification of thunderstorms over Mumbai (Chandrashekhar, 2019). Meanwhile, poor urban planning has resulted in a lack of ecosystem-based flood management approaches which are promoted by a number of international agencies. These approaches include: the planning of cities with ponds and permeable surfaces; restoration of wetland and forests; the regulation of development on floodplains and hills. These strategies have been said to yet have caught on in India. Flood-zone mapping and regulations along the Ulhas River had also been suggested several decades ago however they have yet to be implemented.

Previous Monsoon Events

The monsoon season of 2005 saw an unprecedented 994mm of rain fall in the first 24 hours, starting from 8:30 on the 26th of July. This flooding event killed near to 1,000 people and caused serious delays to train services and traffic networks, with traffic coming to a halt and railways becoming impassable. 3.8 million people are daily commuters and so a significant number of these people were affected by the closure of railway stations (Dow Jones Institutional News, 2011). A total of 40,000 commercial businesses and a total of 30,000 vehicles were damaged having a significant financial impact. In 2011 Mumbai was hit again with 178.6 mm of rain falling within the first 24 hours of the monsoon season. In August 2017, 5 people were killed when 939mm of water fell in one day (New York Times, H. Kumar, 2019).

Poor drainage

Poor drainage, alongside urbanisation has increased Mumbai's vulnerability to flooding. The city has been criticised by a number of sources for having an ageing drainage system which has contributed to the floods in Mumbai and left them unable to deal with the levels of rainfall. The capacity of storm drains continues to be an issue and waterways are inundated with plastic, general rubbish and debris from construction (The Guardian, 2019). This means that the waterways are not available to occupy the added rainfall and therefore fill up faster. The inadequacy of the drainage systems this year was represented by a neighbouring district of Mumbai, Thane, which experienced flooding despite a 27% rainfall deficit. This highlights the inadequacy of the current drainage systems in that they are unable to deal with this intensity of rainfall. After the flooding event of 2005, drainage systems had been modified from designs equipped to deal with a rainfall intensity of 25mm/h to a rainfall intensity of 50mm/h (P.E Zope et al., 2015). Due to the flooding in 2019, it has become apparent that the drainage systems are still inadequate to deal with these increasing rainfall levels.

Climate Change

A significant factor in Mumbai's vulnerability to annual monsoon flooding is Climate Change. The area of Greater Mumbai is surrounded on three sides by sea: the Arabian Sea to the West and the South, the Harbour Bay and the Thane Creek in the East as seen in figure 4 above (Hallegatte et al., 2010). This means that Mumbai is vulnerable to sea-level rise on a number of its coasts, home to a large majority of Mumbai's vulnerable population (Low-income earners accounting for about 50% of India's population) (Kumar, Jawale & Tandon, 2008). The addition of the 4 rivers running through Mumbai means that flooding also effects many of the settlements located along the rivers including damage to surrounding catchment areas. Rising land and sea temperatures due to climate change have been suggested to exacerbate thunderstorms over Mumbai causing this increase in rainfall and intensity of the rainfall (Yale E360, 2019). Sea level is expected to rise at the rate of 2.4 millimetres (mm) per year in India (IPCC, 2019) resulting in low-lying areas such as Mumbai being increasingly inundated with flood water during monsoon seasons.

Summary

Flooding events caused by monsoons will continue to destroy livelihoods and infrastructure of Mumbai years into the future as they are an annual hazard. Unfortunately, impacts are likely to worsen as rainfall increases due to Climate Change and impacts worsened by global rising sea levels. Wall collapses will continue to occur particularly in poorly built areas, and more water pumps will be needed in the future to deal with the increased flood waters. Ageing drainage systems have been an important element in the vulnerability of India in monsoon floods, as well as the increase in urbanisation and change in LULC which has involved the removal of a lot of mangrove forests which previously absorbed a significant amount of the flood water. The Mumbai district needs to think about how systems can be improved in order to deal with the effects of these annual monsoons.

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Urban flooding in Karachi and the larger Sindh province, Pakistan

Alexander Rigby

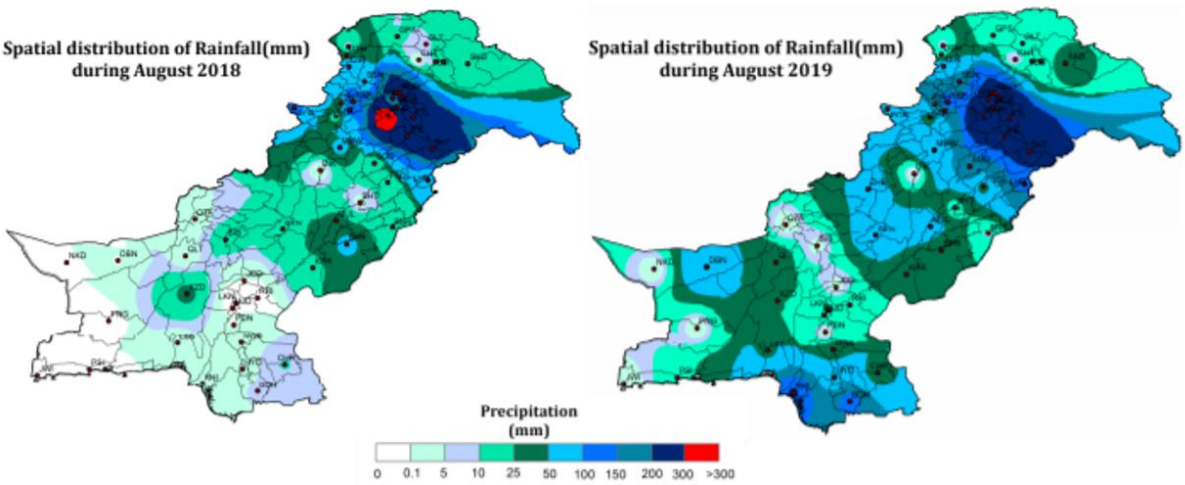


Figure 1: Comparison of spatial distribution of rainfall in Pakistan for August 2018 and 2019. Sourced from: (Pakistan Meteorological Department, 2018; Pakistan Meteorological Department, 2019).

The province of Sindh

This report focuses on the floods that occurred in the south-eastern province of Sindh, Pakistan (Figure 1) between late July and early August. This case study has a focus on the coastal capital city of Karachi, as this has been identified as the worst affected area. This is a result of its location, adjacent to the Indus river and at a significantly lower altitude than the northern part of the country, as well as its high population of almost 16 million people (Macrotrends LLC, 2019).

Main causes of the urban flood

In late July, monsoon rainfall reached northern Pakistan. This rainfall proceeded to migrate southwards and entered the Sindh province from the bordering state of Rajasthan, India (Arab news, 2019). The rainfall lasted from July 29th to July 31st and resulted in mass flooding across the province.

The impacts of this monsoon rainfall were exacerbated due to the antecedent conditions of the area, primarily drought. In the leadup to the heavy rainfall, Sindh had been undergoing the worst drought since 2000, with around 11 million people in southern Pakistan affected (ECHO, 2019a). The Pakistan Meteorological Department (2018) documented record low precipitation levels with July rainfall at less than 5mm for Karachi (Figure 2).

This figure highlights the clear contrast in precipitation levels for 2018, which was a significant factor in the urban flood of 2019. This is a result of the soil saturation levels being considerably lower than usual, which causes increased flooding as less water can be absorbed into the dry ground.

Impacts of the flood

On July 29th the first of the monsoon rain hit the Sindh province. This resulted in extensive flooding throughout the districts, with the worst affected area being the provinces' capital city of Karachi. Early reports stated that up to 6 people were killed in the initial rainfall (Yagoda, 2019; Khaleej Times, 2019), due to electrocution as cables became submerged by the rising waters (Arab news, 2019; Tribune, 2019). By the start of the next month the rainfall had stopped, however the urban floodwater persisted. The total number of deaths for Karachi had reached 26 by this stage, with 19 being a direct result of electrocution and the rest due to drowning in the inundated rivers that pass through the city (Tribune, 2019; Dawn, 2019). In addition to the impacts within Karachi, the wider Sindh province was also affected, with numerous reports of casualties in neighbouring towns and cities. This includes four people that were killed as a result of lightning strikes in the Badin and Hyderabad districts and one villager of the Umerkot district that was killed when the heavy rainwater caused the roof of his room to collapse (Ayub, 2019).

The flood also had several secondary effects on the population of Sindh; this was primarily through the disruption of services. The high number of deaths associated with electrocution forced the utility company K-Electric (K-E) to cut power to Karachi to limit the loss of life. This left many people without any form of electricity for well over the predicted period of 24 hours (Dawn, 2019). In addition to this, the sewage systems in Karachi were quickly

overloaded by the flood waters, resulting in sewage inundating the streets as a result of the poorly maintained systems (Ali, 2019). This also impacted the transport networks of the city, as the impermeable road and walkway surfaces resulted in significantly higher surface runoff in Karachi, resulting in flooding as the water could not drain away from the city. The main roads affected were the Korangi Causeway, which was closed for three days to allow the rainwater to drain, and the Karachi-Hyderabad Motorway (Figure 3) as a result of the Thaddo Dam breach (Dawn, 2019). These factors culminated in basic commodities, such as clean water and electricity, being unavailable to the locals for up to three days in parts of Karachi (Tribune, 2019).

Responses to this event

Due to the severity of the incident, the Pakistan Army were deployed on July 30th and focused on five main locations to control the situation (Dawn, 2019). This included blocking the flood water from entering an electrical grid owned by K-E after the Lath Dam overflowed (Tribune, 2019) and preventing Saadi Town from being flooded by constructing temporary dams (Ali, 2019; Dawn, 2019). This effort helped mitigate the impacts of the flood, preventing additional damage to property and loss of life due to their quick response. The army was involved in multiple search and rescue operations within the Sindh province, including the salvage of people trapped in the Lyari river (Ali, 2019). To prevent the number of people in need of rescue, many residents were forced to leave the worst affected areas in Karachi, such as the low-lying region of Scheme 33. ECHO (2019b) state that around 128 people were evacuated to a relief camp in Matiari, located north of Hyderabad (Figure 1).

Electricity was suspended to all areas inundated with floodwater, however many unaffected areas were also cut off from the power grid as a precautionary measure (Ali & Khan, 2019), resulting in around 50% of the city without power for up to three days in some towns, such as Scheme 33 (Ali, 2019). This resulted in anger towards the utility company as the local population found this an unacceptable amount of time. Furthermore, the company was accused of being liable for the 26 electrocutions, with the MQM-P and PSP political parties demanding compensation for the families (Dawn, 2019). These claims followed the recent accusations of negligence by K-E which resulted in a decay of infrastructure and was a key component in many of the deaths from this flood.

Technical interpretation

Mechanisms for flooding in Sindh, Pakistan

The Sindh province of Pakistan suffers flooding events as a response to a variety of different causes. These include monsoon rainfall, cyclones, high Mediterranean waves and Himalayan snowmelt. The main trigger for flooding in the Indus Basin is monsoon rainfall between July and September (Tariq & Giesen, 2012; Kazi, 2014); this is aided by preliminary snowmelt which increases the river discharge to above average levels. These factors can eventually result in the Indus bursting its banks and flowing out into the floodplain. The Sindh province is composed of mainly flat terrain (Figure 1), with the river flowing at a higher elevation than the surrounding areas due to previously deposited alluvium (Hasmi, Siddiqui, Ghumman, Kamal & Mughal, 2012). This means that the water cannot rejoin the river and will instead flow a considerable distance over the province. Furthermore, the antecedent conditions will impact whether a flood event can occur. Prior to the 2019 flood Sindh was undergoing a severe drought. This meant that when the intense monsoon rainfall arrived, the soil could not absorb the large quantity of floodwater from the Indus which consequently flowed over the surface across the province. However, although the mechanics for the flooding events are known, there is no fixed cycle for the timing of these heavy monsoon rainfalls (Bakhsh, Rehman, Shakir & Khan, 2011). This makes predicting the occurrence of the next major flood in Sindh considerably harder.

Comparison to previous flooding events

Extreme weather events have considerable negative impacts on Pakistan. The country ranked 8th in the long-term Climate Risk Index (CRI) according to data collected from 1998 to 2017 (Eckestein, Hutfils & Winges, 2018). This highlights the adverse effects flooding events have had on the Sindh province; however the scale of these events differs significantly. These vary from the disastrous tropical cyclone flood of 1965 which resulted in over 10,000 deaths in Karachi (Paulikas & Rahman, 2015) to the case study flood in 2019 which resulted in 26 deaths. This severe contrast highlights the devastating impact that a different source of flooding can have on the coastal city. In addition, it shows that there is no standard scale for floods in Sindh as this can vary significantly.

Similarly, flooding in Sindh as a result of monsoon rainfall can also have significantly different impacts on the population. The flood events of 2010 and 2011 in the Sindh province caused significantly more damage than the recent flood of 2019. This was a result of the substantially higher rainfall intensity for these years, with around 450mm of rain for August 2011 (Cheema, Zaman & Rasul, 2012) compared to below 300mm in 2019 (Figure 2). This is reflected in the number of casualties for Sindh with 441 deaths and 269 deaths for 2010 and 2011 respectively (Hashmi et al., 2012; Cheema et al., 2012). These values are significantly higher than the chosen flood in 2019 due to the larger impact they had on the rural communities. Due to limited available space and the cost of living in urban locations, an increasing proportion of the population migrated to rural areas in

the Sindh province (Table 1). As these rural areas are located in the large flat floodplains of the Sindh's river systems, the residents here have limited protection from the floodwaters once the Indus exceeds capacity (Hashmi et al., 2012).

A critical exceptional feature for the 2019 flood is the proportion of people that were killed by electrocution. This highlights a vital problem with the country's governance. Karachi is the economic centre and capital of Sindh (Bakhsh et al., 2011), yet its infrastructure is poorly maintained and unable to cope with even comparatively small volumes of water. This resulted in the roofs of buildings collapsing, sewage systems overflowing onto the streets, and most significantly, electricity lines being submerged by water. This shows the negligence by the Government of Pakistan, as well as the utility companies such as K-Electric, which resulted in deaths that could be avoided.

Critical review of vulnerability

Future flooding in the Sindh province is inevitable, with the occurrence and scale of these events likely to increase as a result of climate change. This is due to the increasing precipitation levels throughout most of the country, with 41 out of 54 meteorological stations in Pakistan recording increasing rainfall trends between 1901 and 2000 for the summer months (Khan, Khan, Ali, Ahmad & Ahmad, 2016). As well as this, the average temperature across the country has risen, which will result in an increase in the quantity and duration of droughts in the province. As stated above, intense rainfall onto an area affected by a drought will result in flooding as the water cannot infiltrate into the soil quick enough (USGS, 2019). Therefore, the impact of these future flood events will likely be more severe.

In addition to the increased risk as a result of natural causes, human factors will also influence the impacts of future flood events. Karachi is economic hub for Pakistan, and therefore large proportions of the population migrate to the outskirts of the city looking for work. However, this urban sprawl is resulting in the construction of buildings on areas of river floodplains (Akhtar & Dhanani, 2013), which are in critical danger of flooding. Similarly, the addition of more impermeable surfaces reduces the waters capacity to infiltrate into the soil and therefore surface runoff is considerably higher.

Finally, improvements to the infrastructure of the Sindh province is essential, especially in the capital city. The negligence by the local authorities and the companies resulted in a minimum of 19 deaths during the Sindh floods of 2019. Rana and Routray (2018) outline a vulnerability model that assess the risk of urban flooding for areas of Pakistan. The application of this model onto the city of Karachi would be vital in discovering the main areas of vulnerability and implementing strategies to minimise them.

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Cyclone Gaja

Tara O'Reilly



Figure 1: Visible image of the formative eye of cyclone Gaja heading towards the south eastern coast of India on November 15th, 2018. (Nasa Worldview, Earth Observing System Data and Information System (EOSDIS), 2018).

Introduction

The cyclone Gaja was a tropical storm which occurred in south eastern India, over a period of time in the November of 2018. The severe cyclonic storm first originated as a low pressure system over the Gulf of Thailand. This then intensified into a depression over the Bay of Bengal on November 10th until eventually becoming a cyclonic storm on November 11th (NDMA, 2019). The cyclone Gaja has left a trail of destruction in numerous states of India some including Tamil Nadu, Kerala and Puducherry, claiming at least 45 lives and evacuating around 250,000 people in Tamil Nadu and Puducherry alone (Thomas, 2018) (Act Alliance, 2018).

Event

The development

Cyclone Gaja was first classified as a cyclonic storm on the 11th November 2018 in the Bay of Bengal. Over the next few days it travelled towards southern India until it finally made landfall over Tamil Nadu on 16th November at 1:45am (Act alliance, 2018). During this five day period NASA's Suomi NPP and Aqua satellites passed over the Bay of Bengal. These satellites analysed the storm in infrared light thus allowing NASA to gather accurate temperatures of the cyclone, which then provided an indication of how strong cyclone Gaja would be (Gutro, 2018). On the 15th November (the day before the cyclone hit landfall), NASA confirmed that the cyclone had sustained a maximum wind speed of 55 knots (102kph) however, it was expected for these speeds to weaken as it neared closer to the south-eastern coast of India. Later that day it was reported that, with the use of infrared imaging, a visible light image of cyclone Gaja was obtained revealing what appeared to be a cloud filled eye in the centre of the cyclone (figure 1). The joint typhoon warning centre confirmed this and stated that the system of cyclone Gaja was much more compact than what they first thought, and the formative eye seen in figure 1 was

showing no signs of weakening or dissipating. The Atmospheric Infrared Sounder (AIRS) instrument aboard the Aqua satellite also found cloud top temperatures, in thunderstorms within the centre of the cyclone, to be as cold as -63°F (-53°C), indicating that the storms were capable of producing high winds and heavy rainfall (Gutro, 2018).

The disaster

When the cyclone eventually made landfall in Tamil Nadu, heavy winds of around 120kmph and over were experienced (Economic Times, 2018) (India Today, 2018). As a result of these high winds, the Tamil Nadu state Disaster Management authority evacuated around 80,000 people from the low lying area and provided about 470 relief camps for those displaced (Economic Times, 2018). The highest wind speeds sustained by the cyclone was recorded in the town Adhirampattinam at 165kmph and 160kmph at Muthupet (NDMA, 2019). Along with the high wind speeds Tamil Nadu as well as other coastal towns such as Nagapattinam, Pamban and Cuddalore, received heavy rainfall ranging between 3cm to 8cm deep (Economic Times, 2018). According to the state government, multiple government officials and teams from the National Disaster Response Force were appointed to various districts across southern India (Act Alliance, 2018) (Economic Times, 2018). These were deployed prior to the event occurring in order to evacuate and aid those who were in imminent danger. Overall cyclone Gaja affected 8 districts, Nagapattinam, Thanjavur, Thiruvarur, Pudukottai, Karaikal, Cuddalore, Trichy and Ramanathapuram (NDMA, 2019).

The aftermath

Approximately, 300,000 people across southern India were affected by the brutal force of cyclone Gaja (Thomas, 2018). Those who died in the disaster (45 people) were most likely killed by trees uprooted by the strong winds or collapsing roofs and buildings. The youngest person known to have died was a 3 year old boy in the town of Adhirampattinam (town of highest wind speed recorded), whilst the eldest is a retired 67 year old who was killed due to a falling tree in Pulangudi (Withnall, 2018).

The infrastructure and environment of various districts were also severely damaged. There was a major loss of flora and fauna along the coastal cities, in Tamil Nadu alone 17,000 trees were uprooted as well as another 5000 in Puducherry (Thomas, 2018). According to India's government sources, over 170,000 coconut and banana trees were uprooted and thousands of cattle, birds and goats died due to the cyclone (Act alliance, 2018) (Thomas, 2018), leaving many farmers without a home or means of support. Numerous carcasses of deer, horse, cattle etc. have also been washed ashore on the Karaikal coast as a result of Gaja hitting a wildlife sanctuary (Times of India, 2018). Traffic was also disrupted in the Nagapattinam state as a result of uprooted trees laying across the road (Arockiaraj, Karthik & Sivaakumar, 2018)

Many districts also had their power supply cut off as the force of the strong winds had caused electricity poles to be destroyed and electricity transformers to be damaged (Thomas, 2018) (Arockiaraj, Karthik & Sivaakumar, 2018). In the states of Nagapattinam, Pudukottai, Thiruvarur, Thanjavur and Puducherry a total of 102 substation power generators were damaged (Arockiaraj, Karthik & Sivaakumar, 2018). Although most states power lines were shut down, the government did also issue various helpline numbers for different services and departments that may have been needed during the wake of the cyclone (India Today,2018) (Arockiaraj, Karthik & Sivaakumar, 2018).

Across many of the state's, schools have been shut down and university exams postponed until further notice as it is unknown when the schools will be up and running again. A holiday has been officially issued in the Nagapattinam state for all educational institutions (Economic Times, 2018) (Arockiaraj, Karthik & Sivaakumar, 2018). Weather warnings in all areas in southern India are on high alert and as a result of rough sea's fishermen have been asked and advised not to enter the Bay of Bengal, as a precaution (Withnall, 2018). Two Indian naval warships have also been diverted to the Karaikal coast in order to provide humanitarian aid and distress relief to the most affected regions (Times of India, 2018).

Technical Analysis

Tropical cyclones are intense atmospheric vortexes of low pressure composed of huge masses of revolving moist air (Niyas, Srivastava and Hatwar, 2009), which form over warm ocean waters in tropical regions (Montgomery and Farrell, 1993). The Indian subcontinent is the most affected region of the world and is exposed to almost 10% of the world's tropical cyclones (NCRMP, 2019) due to its climate and large coastline. India's 7516km2 of coastline subjects 13 different states to tropical cyclones every year (Figure 2). Although tropical cyclones affect the entirety of the Indian coastline, the eastern coast is much more prone compared to the western coast (NCRMP, 1019), this is due to the higher sea water temperatures in the Bay of Bengal. Cyclones in this area develop in the months May-June and October-November, with November being the peak period.

Tropical cyclone formations

Tropical cyclones are large scale rotary systems (Montgomery and Farrell, 1993), which occur due to the combination of shallow coastal plains and favourable thermodynamic environments allowing for high surface winds, torrential rain and significant wave height patterns to be created (Belanger et al. 2012). Cyclones are influenced mainly by the

underlying ocean surface which they are formed and travel over (Niyas, Srivastava and Hatwar, 2009). Tropical cyclones gain their energy primarily from evaporation from the ocean and the associated condensation in their convective clouds, which are concentrated within the centre of the storm (Holland 1993), as long as they remain over warm water, they will have an unlimited amount of energy. Tropical cyclones are referred to differently in various parts of the world e.g. they are known as hurricanes over the Atlantic Ocean and typhoons over the Pacific Ocean, however, they are all first referred to as low pressure systems. As these low pressure systems develop into a much larger scale storm their status is classified according to their wind speed over their oceanic areas (Niyas, Srivastava and Hatwar, 2009). The classifications for those over the Indian Ocean can be seen in figure 3 below.

Tropical cyclone occurrence in the Indian subcontinent

Tropical cyclones are the most frequent natural disaster in India (NDMA, 2019). As shown in figure 2, cyclones are mainly formed over the Arabian Sea and the Bay of Bengal and then travel inland towards the Indian coastline. Most cyclone events are more likely to occur in the Bay of Bengal than the Arabian Sea, as the Bay's water maintains the critical temperature needed for cyclogenesis to take place (Niyas, Srivastava and Hatwar, 2009). Westward moving remnants of tropical cyclones formed in the West Pacific Ocean will also increase the cyclogenesis within the Bay of Bengal. Due to being one of the highest population density areas in the world, along with the low socioeconomic conditions, the landfalling of several tropical cyclones have been devastating, in fact 8 out of 10 of the deadliest cyclones have occurred within this region (Belanger et al, 2012). Although cyclones are considered to be much weaker in intensity and smaller in size compared to other areas around the world, it has the highest number of death tolls than any other region making it the worst affected part of the world, in terms of damage and destruction (Singh, Kishtawal & Pal, 2012). Much of this devastation is due to a number of reasons such as the shallow bottom topography of the land, the coastal configuration and that some people are reluctant to leave their homes even when under threat by a cyclone. As a result of tropical cyclones being the deadliest and costliest natural hazard (Pielke et al. 2008), there has been a significant increase in developing models to be able to track these events thus allowing more time for communities to evacuate areas of danger.

Vulnerability and Response

Most of the districts along India's coastline are highly vulnerable to tropical cyclones due to its tropical climate (NRCMP, 2019). Data previously analysed by the NDMA showed that on average, annually 370 million people are exposed to cyclones in India. In late 2017, the towns of Tamil Nuda and Kerala were hit by a tropical cyclone which caused an estimated £2.3 billion damage and killed around 250 people (Withnall, 2018). Due to cyclones being so prevalent in this region some towns were prepared for when cyclone Gaja made landfall for example, Tamil Nadu's chief minister had stated that relief work had already began and the state had thousands of workers on standby on the 16th November, the day the cyclone hit (Withnall, 2018). Aside from this it has also been stated by government officials that the families of the deceased will be provided with £1085 from a public relief fund (Withnall, 2018), farmers will also receive a beneficiary of around £500 for those who lost their land and cattle during the cyclone. As a result of previous cyclonic storms which have occurred within this region, coastal districts in India have now put in a place a pre-preparedness disaster plan for when future cyclone events, like cyclone Gaja, occur (NDMA, 2019). The Indian subcontinent is susceptible to tropical cyclones, therefore over the past few decades scientists have also looked into improving the forecasting and tracking of these weather systems (Rakesh & Goswami, 2011) in order to prewarn communities allowing them to evacuate the area before the storm hits. There are high hopes that through continuous studies and by educating communities on tropical cyclones, people will be made more aware of what to do in this type of situation and overall will potentially reduce the amount of devastation to this region during future cyclonic events.

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Typhoon Jebi

Owen Glenn

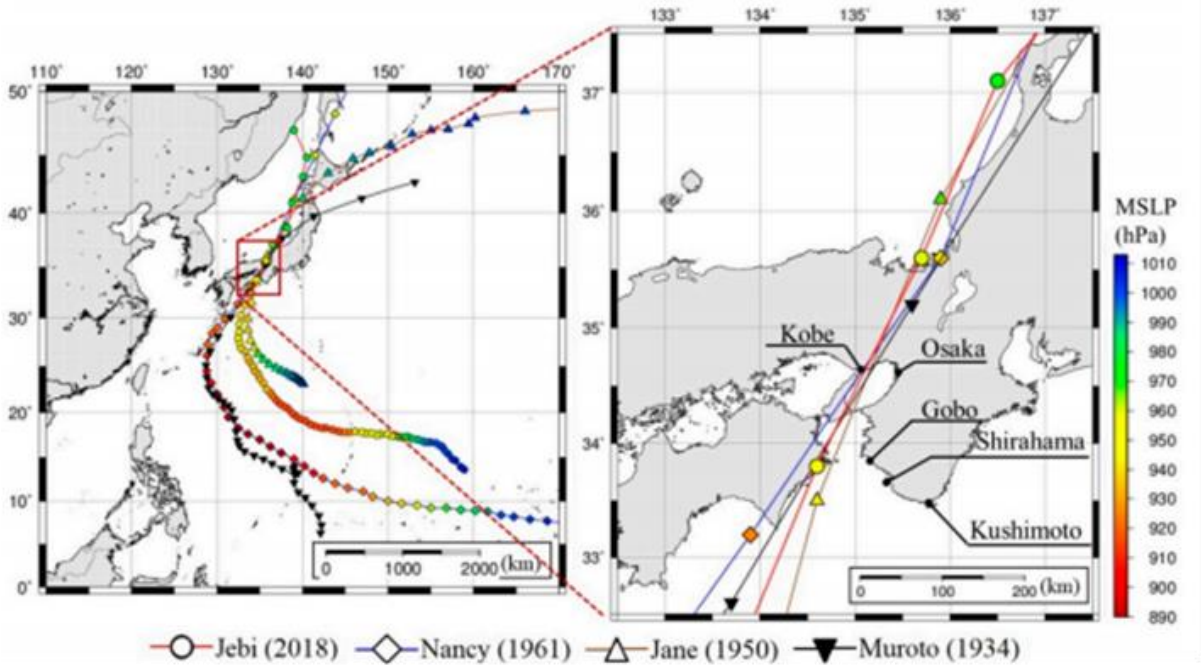


Figure 1: Map of the predicted route of Typhoon Jebi highlighting Osaka and other high-risk areas (Geoscience, 2018)

Introduction

A Typhoon is a tropical storm and meteorological that only hits in the Indian or West Pacific oceans. This is because these tropical storms happen all over the world therefore, they get given a certain name in order to identify where about in the world this tropical storm takes place; For example, a Hurricane occurs in the central or north eastern part of the Pacific or Caribbean Sea and Cyclones occur in North Atlantic Ocean.

Typhoons are a tropical storm that start to form when strong winds pull moisture from the oceans in the form of evaporation. The moisture heat and wind all combine together moving in an anti-clockwise direction, thus creating the 'eye' of the tropical storm in this case a typhoon. And with all of this heat and moisture in the air it causes mass rainfall and really strong winds causing detrimental impacts to landscape and the lives of people that live in these areas. (C. Cockburn, 2013)

Typhoon Jebi

Typhoon Jebi occurred on the 4th September 2018, and impacted on the coastal area of Osaka Bay due to really strong winds and the storm surge that came along with the Typhoon. However, the storm actually began to form on the 28th August 2018 suggesting that there was more than plenty of time to issue out potential storm alerts to the public in order for them to leave the coastal areas and migrate more inland or to higher areas so the flooding aspect of the Typhoon. This could have made the Typhoon less detrimental and not take any lives which could have kept this weather event a hazard and not allow it to further become a disaster which forms from the aspects of the loss of lives and the amount of damage caused in monetary value. With this being said a storm alert was sent out just six hours before the Typhoon hit on the 4th which gave people and communities very little time to evacuate their homes and places of work. When the storm began to form it had a potential to bring winds of 198 kilometres per hour on the 28th yet when the Typhoon hit land it had a decrease of 40 kilometres per hour, which could have had the potential to cause even more damage than it already had.

The Japanese already had defences put in place on the coast of Osaka with a 3.9m defence of water rise in the form of dikes which are naturally formed ridges that are formed in order to stop water from being able to get over them. In this case the dikes were very weak and were breached instantly from the pressure of the wind and storm surge these winds brought with it. (Pure and Applied Geophysics, 2019)

Typhoon Jebi also contributed to the destruction of over 22,000 homes and other poorly built aspects of infrastructure that were made out of materials such as wood and other materials that aren't very durable

meaning they didn't have the strength to withhold something as strong as a Typhoon with wind strengths of 158 kilometres per hour and rainfall which created floods as deep as 3.5m. Also many industrial features were impacted due to this horrific storm, such as the international container port which was built on reclaimed land which experienced a flooding the depth of 2 metres which would have cause a lot of monetary deprivation as the trade sector had now been put to a minimal as lots of goods were damaged as a result of the Typhoon.

Also with the long lasting impacts of a flood meant that nothing more could have come in to these ports and nothing else could have gone out of them with severe water damage; potentially meaning that Japan were very limited when it comes to the restoration costs of the redevelopment of the places and communities which were affected, which could imply that the Japanese government heavily relied of tax money for this redevelopment structure that had been put in place. (M. Nobuhito., et al, 2019)

It is said that insurance costs alone are still on the rise until this day. This is because with the rebuilding and regeneration of cities are still underway or not long finished, people are moving back to see where their homes are or were and are making claim backs from home insurance companies and other forms of insurance providers which the communities have adhered to. In a result of this it has been stated that "Utility poles litter a road in Sennan, Osaka prefecture in Japan after Typhoon Jebi hit in September 2018. Insured losses could rise to $16 billion," This suggests that Typhoon Jebi could be considered as a natural disaster as the cost deprivation linked with Typhoon Jebi is astronomical yet this isn't even including the rebuilding and regeneration costs of the buildings, homes and buildings that were destroyed that the government are going to have to fork out the money for. However, the claims are to the people that have lost their jobs, their houses and potentially their livelihoods because of this natural hazard event. (L. Chordas, 2019)

Devastatingly this Typhoon had taken 13 lives along with it and had injured very close to 800 people. With the loss of lives and a very high amount in damage costs the Typhoon that occurred in this case Typhoon Jebi is more commonly known as a natural disaster and not a natural hazard to this day as it happened in the year of 2018. With the loss of life being introduced to the Typhoon there is more than just damage to record it about getting people the help that have lost their loved ones which also costs a lot of money, it getting the right infrastructure built for if a weather event like this was to occur in the future, the country of Japan will be more prepared and secure to limit the potential devastating impacts onto the country and it's communities that surrounded the area of which the Typhoon had or will take place. (Pure and Applied Geophysics, 2019)

Interpretations

Typhoon Jeb really could have relied on the alert system that was put in place for the communities that surrounded the coast of Japan. This is because it would have let the population evacuate this area sooner as it had already been stated that the Typhoon originally formed on the 28th of August 2018 which would have given the communities a whole week for people to gather their belongings and loved ones making them able to move more inland. Yet, for some reason the Japanese government only sent out warnings six hours before the storm actually took tole on the mainland of the coastline stretching defences and destroying homes and businesses, also taking lives. The alert system and the amount of time the government had gave the potential to completely minimise any risks to human lives which was sacrificed for some unknown reason as they had graphs and charts which correctly pointed to the Typhoon affecting these specific populated areas.

Another factor in which was poorly managed was the flood security and defences. These aspects of stopping flooding were poorly managed by local councils and/or the government as the dikes that were in place where very old and hadn't yet been tested to their full potential. This could suggest that in the future and the planning of regeneration and rebuilding of the coastline towns and cities that where heavily affected by the Typhoon can be better made and managed by the locals. This also has the potential to make another job sector of employment for the flood defence systems or even more employment opportunities for the people that are helping to rebuild Osaka or other neighbouring cities from the ground up as nearly everything was destroyed. With this the government needs to become more aware of the materials that are going to withhold and stay standing if there was ever an extreme weather event of this magnitude ever again.

Also, they could explore the opportunity to rebuild homes and businesses on 'stilts', this is because they have a record of the amount of water that has the potential to flood these locations meaning that if these 'stilts' where introduced they could be built, for example, 3.5 metres above the land height, further reducing impacts on the infrastructure that they are going to have to rebuild. Japan could take inspiration from a lot of their neighbouring countries that are more often affected by these extreme weather events such as the Philippines as they were affected heavily by Typhoon Haiyan in 2013 which made it so they had to rebuild their infrastructure and defences to try and attempt to withhold the next storm to come. However, there is a major difference between Japan and the Philippines being that Japan isn't a third world country, which further implies that Japan has the money and resources available to make their defences and defensive strategies a lot better than their neighbouring countries.

One thing that went well was the death and injury toll for such an extreme weather event was considerably low. This suggests that even though the Typhoon alert was six hours before the actual event hit mainland, a lot of the population got to a place in which was very safe and got them out of danger or harm's way.

With Japan being a first world country, it is expected that the vast majority of the people have access to cars or transport of some sort. Thus meaning that some of the security measures that had been put in place could be considered as successful as throughout the whole weather event only 13 people had died and around 800 people had been injured, and with Osaka alone having a population of around 2.69 million people alone it could have been considered successful. However, the amount of damage in costs was where Japan was most shocked as around 22 thousand homes were destroyed meaning a heavy investment was needed for the rebuilding process and a lot of money was going to be sent out in the ways of insurance as a lot of the home and business owners had some form of insurance in case of something like this extreme weather event happening.

(Geosciences, 2018)

Conclusion

To conclude I believe that Typhoon Jebi was poorly managed and put across to the public and especially the coastal communities of Japan which is the most important aspect of an extreme weather event such as a Typhoon. I say this because people's lives will be at risk and getting them to a safe place where there is shelter somewhere to stay and have a meal and keeping them alive is more important than money will ever be. With this, the Japanese government should have sent an alert out as soon as they had heard about the formation of Typhoon Jebi in the ocean as a precaution of public safety, because if the Typhoon had travelled more quickly to the heavily affected locations, or before they had anticipated it to have got there by, it could have been more detrimental and devastating than it had been already.

Furthermore, I also believe that the government and local councils should invest more heavily in flood defences and storm surge defences more as it will be able to minimise the impacts and risks onto people and also buildings and other forms of infrastructure. This is a longer-term investment but it is for the better as they know now that there is a huge risk in concern to an extreme weather event. I say this because if they invest in these now and implement them properly and effectively, they only have to manage them and won't have to reimplement them unless when tests are ran they fail. This then means that with a high upfront cost and very little future costs people can be considered safer.

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2019 Indian flooding

Adam Mayes

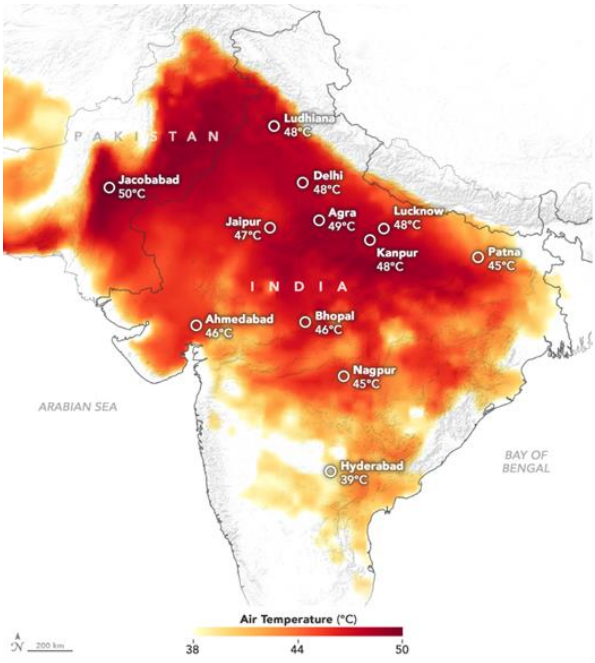


Figure 1 showing the Indian heatwave in June 2019 (Earth Observatory)

Authoritative account.

In the summer months of 2019, some of the western states of India suffered from heavy flooding. This flooding was caused by extremely heavy rainfall predominantly in 4 regions which were Kerala, Karnataka, Maharashtra and Gujarat. Kerala was possibly the region that was hit the hardest and it is still recovering from record breaking floods it experienced in 2018. Each of these regions was affected differently by the flooding but in total over a million people were evacuated and more than 200 people were killed making this a very significant event.

The flooding occurred in the monsoon season in the month of August, in recent years India has experienced heavier rainfall and more extreme weather in the monsoon season and 2019 has been one of the worst years for this extreme weather. This excessive rainfall put pressure on water levels in water sources like rivers and reservoirs. 2019's monsoon season in India has been one of its worse and has resulted in thousands of deaths and over 2 million people displaced, the season also lasted until the beginning of October (Patel, 2019) which is a month later than usual, this only added to the problems by prolonging the period of rainfall. Figure 2 and 3 show the same section of the river Ganges in India a year apart, figure 2 is a satellite image from the 2nd of October 2018 and figure 3 is from the 7th of October 2019.

Regions affected.

Kerala.

Kerala is an Indian state on the tropical southwest coast of the country, well known for its sandy beaches but in the past two years has seen some of the worst flooding in its history. In 2018 it had 'the flood of a century' where over 400 people died (Taylor, 2018), and the estimated cost of the damage was over $5 billion, and the state was still recovering from this devastating event. The flooding experienced in 2019 was not as extreme but still caused substantial economic damage. It is hard to determine when the flooding in Kerala started as there were multiple accounts of flooding throughout the monsoon season, but it appears that some of the heaviest flooding happened started around the 8th of August and lasted for an estimated 10 days. This flooding had a substantial impact on the region with an estimated 121 deaths and over 280,000 people evacuated and put into relief camps of which there over 1500. Some districts in Kerala recorded 300mm of rainfall in 24 hours and over 450mm in 6 days, for the whole month of august Kerala received a record breaking 951.4mm, the previous highest was 821.9mm which was recorded last year (Surya, 2019). The airport was also damaged causing major disruption (Thakur, 2019) and to try and combat the flooding, flood gates across the state were opened to try and disperse some of the water.

Karnataka.

Karnataka is a state that sits on the south west coast of India and sits next to Kerala although it is considerably larger. This was another state which endured heavy flooding, the flooding in Karnataka started earlier than in Kerala, around the 6th of August. Again, the flooding was caused by excessive rain, one of the repercussions of this caused water levels to rise in the river Krishna which is the 4th largest river in India and flows through Karnataka. The constant rains have led to huge losses of property and crops for farmers residing in the downstream of the Krishna river basin. India's Central Water commission (CWC) reported that 11 dams and barrages in the region were approaching maximum capacity and would soon need to be released (Kapil, 2019) . This flooding resulted in over 60 people losing their lives and over 400,000 people being displaced (the Guardian, 2019).

Maharashtra.

Maharashtra is a state on the western coast of India that also stretches a considerable distance inland, it is one of the most populous states in India and contains the megacity; Mumbai, the population of the city of Mumbai is over 12 million and the population of the

greater metropolitan area of Mumbai is estimated to be over 23 million. This shows that flooding in Maharashtra could have an even more pronounced effect due to the highly urbanised nature of the area, Maharashtra is the most heavily industrialised state in the country and is the largest contributor to the Indian economy, this makes trying to reduce the effect that flooding has on the region vitally important as to minimalize the economic impacts. The flooding caused by heavy monsoon season rain in Maharashtra occurred in early August and had a significant impact, over 400,000 people were displaced and at least 35 people have lost their lives. The regions that were it the hardest in Maharashtra were Kolhapur and Sangli, 28 villages in Kolhapur and 18 villages in Sangli were completely flooded and were only accessible by boat and the Mumbai Benglauru National Highway was also closed after a landslide affected the area resulting in an estimated 18,000 stranded vehicles (Aggarwal, 2019) . The CWC stated that rivers in the region including the Krishna were at record levels.

Gujarat.

Gujarat is also another state on the west coast of India that has been heavily affected by the excessive rainfall during the monsoon season which has seen the western coast of India severely affected by flooding. Flooding in Gujarat started slightly earlier compared to the other regions that have been discussed, the flooding in Gujarat started on the 1st of august of this year, some regions in the state recorded over 400mm of rain in a 24-hour period. The city of Vadodara experienced especially heavy rainfall and suffered from extreme flooding due to the heavy rainfall and the Vishwamitri river breaking its banks and water entering the city.

Technical interpretation.

The monsoon season in Asia is one of the most important weather events in the world because it has such significant environmental, economic and social impacts. It has huge impacts on the food and water security of a large part of one of the most populous areas on earth and this in turn has great influence of the economic wellbeing of the region (Gadgil, 2006) . The socio-economic impact of this weather event makes the task of trying to predict the weather event of critical importance, but it proves to be a very difficult task. Although the summer monsoon is very consistent in the fact it happens around the same time every year, trying to predict the severity of it and the average amount of rainfall is extremely complex and can be hard to get an accurate figure. The Indian summer monsoon is often only seen as the wet period in the summer months, but it is actually a full cycle which consists of those wetter summer months but also a dry winter, this is why areas are so dependent on the precipitation that nourishes so many people because the months prior to this are often much hotter and drier and can result in drought, the heatwave that India was experiencing in the months leading up to the summer monsoon season can be seen in figure 3.

The monsoon season has always been associated with strong winds and this is for good reason because one of the drivers behind the change in the weather in the season is to do with the reversal of the wind direction, the Indian monsoon season is represented by the largest seasonal reversal of winds, this change in wind direction is caused by the seasonal migration of the intertropical convergence zone (ITCZ) and the changes in precipitation are also linked to the ITCZ due to the migration of the 'rain band' (Goswami and Chakravorty, 2017) . The ITCZ is a band of clouds that contain water that stretches around the globe which is located near the equator, this area exists because of the convergence of the trade winds from the Northern and the Southern hemisphere and at the point where they meet the air is forced upwards and the moisture cools and condenses forming the rain band and the ITCZ (Weather.gov, 2019) . The strength of the monsoon season can also be related to solar forcing and global temperatures, when looking at the monsoon over a long periods of time variations are seen to follow changes in solar forcing and temperature (Cheng et al., 2016). There is also another school of thought when it comes to looking at how monsoons occur and what drives them and this is the more traditional theory that the primary cause of monsoons was the differential heating between the land and the ocean that was caused by the seasonal march of the sun. this difference in heating between the land and the ocean would cause atmospheric differences and changes in pressure. This initial principle was put forward by (Halley, 1687) and is still considered the primary driver of the monsoon season in many papers and textbooks. Since this idea was suggested it has been built on by other authors and researchers, e.g. (Meehl, 1992) highlighted the role of topographic features such as the Tibetan plateau in enhancing the effect of differential heating. The greenhouse effect is also having an impact on this process due to surface temperatures rising around the globe but with the land warming more intensely than the oceans (Lau and Kim, 2017). This then means the difference in temperature between the land and the ocean becomes closer and this has resulted in increased precipitation during the summer monsoon season (Jin and Wang, 2017).

Conclusion

The Indian monsoon season is one of the most important global weather events that takes place and it has numerous impacts that affect the global climate, the socioeconomic conditions of multiple countries, the safety of over a billion people in its catchment. Although people in India and other Asian countries rely on the monsoon to provide much needed rain, there is a worrying trend that has seen this year and

the year before that become some of the most devastating years ever for flooding. This trend should be looked at with caution and adaptation and mitigation techniques should be considered because the areas that have been hit with flooding in the past couple of years and vulnerable and certainly need protecting from future events. With climate change and temperature rise on a steady increase year by year I can only see these events getting more intense and causing more damage. I believe the role of trying to track and predict the monsoon season also has an important role because the more accurate these predictions are the more preparation can be done the less damage will be caused to the land and less lives will be affected.

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Indo-Pakistani Heatwave and Drought: May – June 2019

Rebecca Neish



Figure 1. Satellite images of Chembarambakkam reservoir, from 01/01/19 and 15/06/19 respectively (United States Geographical Survey, 2019).

Authoritative Account

Background

Heatwaves and droughts occur annually in the Indo-Pakistani area, however the intensity and length of 2019's May-June heatwave greatly exacerbated this year's annual drought. India's dry season usually lasts the entirety of May, with monsoon rains and weather expected to start this year on 01/06 but did not occur until more than a week later. A combination of an unusually dry, pre-monsoon season starting in May and the delayed monsoon season saw India and Pakistan suffering from an extreme dry heat.

Temperature highs during this heatwave were found in Churu, India, where temperatures reached 50.8°C – almost beating India's record of 51°C from 2016 – and 51°C in Jacobabad, Pakistan on 02/06 (BBC, 2019). Both of these locations can be seen in Figure 1. During early June the Indian Meteorological Department (IMD) issued a severe heat warning for the state of Rajasthan, where Churu is located, stating that "extreme care [is] needed for vulnerable people", however in this instance it did not just include the elderly, very young, and the sick, but also people without access to air-conditioning units and people without sufficient economic stability to take time off work (Kahn, 2019).

Primary Impacts and Responses

This extreme heat was a threat in of itself, with at least 1500 cases of heat-related illnesses reported country-wide (TWC India Edit Team, 2019), with 184 confirmed fatalities in the Eastern Indian state of Bihar (Al Jazeera, 2019), as well as dozens reported from various of the other 23 states affected by this heatwave. Notable fatalities include: the deaths of 4 elderly passengers of the Kerala Express at Jhansi, India, on 10/06, while they travelled in non-AC sleeper coaches (Chauhan, 2019); and the shocking deaths of 5 infants in an ICU of a hospital in Sahiwal, Pakistan, after AC units broke down during the night of 01/06 (Ahmed, 2019). These confirmed numbers are thought be far less than the actual number of cases of heat-related illnesses experienced.

In an attempt to reduce the effects of the heatwave, authorities in the Gaya district imposed curfew-like restrictions during midday when the heat was most extreme, with construction work, outdoor labour, and outdoor activities such as cultural gatherings, banned between 11am and 4pm (Al Jazeera, 2019). The National Disaster Management Authority (NDMA) also advised reducing 8 hour work days by 20%, which was implemented for government workers, however privately-employed workers had no such protection (Srivastava & Nagaraj, 2019). Additionally, the Bihar government decided to close all schools, although this closure only occurred for two days, from 20/06 to 22/06 (India.com News Desk, 2019).

Secondary Impacts and Responses

A massive impact of this heatwave was widespread drought conditions, which posed a secondary threat. Chennai, the capital of the Eastern state of Tamil Nadu and the sixth largest city in India with a

population of 7 million, was one of the worst hit by drought. Chembarambakkam reservoir and the 3 smaller reservoirs that provided the city with water were almost completely dried up, resulting in an acute water shortage. A comparison of standard water levels and the reduced water levels of the Chembarambakkam reservoir can be seen in Figure 2.

The Government was forced to start chartering tankers to bring water into the city, however with both the high demand for water and the inconvenience of transporting it, water was barely being supplied every other day, with citizens forced to queue for hours in the sweltering heat (Yeung, Regan, & Gupta, 2019). Similarly, in the Indian state of Uttar Pradesh, the rivers and reservoirs were practically empty, and citizens had resorted to digging holes in the riverbed in the hopes ground water would ooze up, while others were forced to walk kilometres for water with no guarantee they would manage to get any, as in these Northern states pumps cease to function if the ground water level dips below 300 feet, which occurred in multiple areas (Chauhan, 2019).

Water tensions were at an all-time high, with violence breaking out between neighbourhoods and water tankers being hijacked. One fight that broke out at a tanker filler station near Ranchi, India on 07/06, resulting in 6 people being stabbed, similar conflicts occurred in the state of Madhya Pradesh on 05/06 resulted in 2 men and the tanker driver being seriously injured, and a fight in the Southern state of Tamil Nadu on 07/06 resulted in one fatality (Janjevic, 2019).

To combat both the water scarcity and extreme temperatures, large groups made their way to hill stations – high altitude villages – as these areas have both reduced temperatures and more water, however these settlements are not designed to receive such large influxes of people. Nainital, India, saw 15,000-20,000 tourists arrive during the heatwave, while the settlement only has a capacity of 8,000 rooms, and Mussoorie, India, has only a 2,000 room capacity but over 190,000 tourists arrived and/or passed through during the heatwave (Chauhan, 2019). This put major pressure on road and water infrastructures, further impacting both these hill station's capacity to handle the heatwave, but the surrounding lower altitude areas that had found themselves dependent on these hill station areas for water.

Tertiary impacts

A major tertiary impact was the arrest of at least 550 citizens on 19/06 in Coimbatore, India, for protesting with their empty water containers in front of the local government's headquarters (Yeung & Gupta, 2019), many of whom blamed both the local and national government for exacerbating the drought through both the decades of poor management of water sources and excessive ground water drilling (Yeung, Regan, & Gupta, 2019), and their minimal action taken during the heatwave.

Technical Report

Climate Discrepancies and Soil Moisture

A pre-monsoon dry period occurs annually, however not only was 2019's far more intense but far longer, occurring for over a month from mid-May to mid-June. Multiple factors contributed to the heatwave; an unfortunate combination of climate change, hot and dry winds blowing in from the Northwest (Tech2 News Staff, 2019), and depleted soil moisture from both decades of ground water drilling and below average rainfall during 2018's monsoon season (Srivastava & Nagaraj, 2019), exacerbated and intensified the pre-monsoon dry period.

Since 2015 India has seen an increase in tree-cover, as efforts have been made to undo the mass deforestation that was occurring well into the 21st century (Kumari, et al., 2019), with India being ranked 10th worldwide for forest loss in 2009 (Gore, 2009). This moisture depleted soil, and the continued effects of previous deforestation has seen a reduction in evapotranspiration of water from the soil into the air, causing reduced humidity and cloud cover (TWC India Edit Team, 2019), thus increasing atmospheric temperatures and resulting in a hotter, drier climate that has further exacerbated the annual Indo-Pakistani pre-monsoon dry season.

El Niño Modoki

This dry period was then extended even further due to the monsoon season's delayed arrival, thought to have been influenced by climate change, but it has also been suggested that it was influenced by a Central Pacific (CP) El Niño event, also known as an El Niño Modoki event. The warming event of El Niño, and its companion cooling event of La Niña, is caused by natural changes in the interactions between the atmosphere and the ocean (National Oceanic and Atmospheric Administration, 2015). During a standard El Niño event the Eastern Pacific Ocean is warmer than the West or central areas, whereas during a CP El Niño event, the central Pacific is warmest, as shown in Figure 3. While it is not yet clear what the exact mechanics are, previous studies have suggested correlations between anomalies in the Indian ocean and El Niño Modoki events, with the timings of monsoons and the severity of India's annual heatwaves (Rohini, Rajeevan, & Mukhopadhay, 2019).

Conclusions

Vulnerability

A key way to mitigate and adapt to hazards and disasters is to understand both how large the

vulnerable population is and what makes them vulnerable. The elderly, very young, and sick are vulnerable in any society, but more complex economic factors influence the vulnerability of the Indian population. In India, around 70% of rural households are still dependent on agriculture for their livelihood, and 82% of these households are practicing subsistence farming (FAO, 2018), more than that however, 60% of this agriculture is almost entirely rain fed and thus requires the monsoon season to ensure crop success (Kahn, 2019). This makes a very large proportion of these rural agricultural populations very vulnerable to changes in rainfall and temperature.

Employment and living conditions also play a major role in vulnerability in India. In large cities, around 60% of the population live in informal and/or unauthorised settlements i.e. slums, which have no running water, no AC, and very poor ventilation (Yeung & Gupta, 2019), resulting in large proportions of urban populations also being very vulnerable to extreme temperatures. It was also unfortunate timing, as recent long spells of unemployment and general economic instability, meant people were either unwilling or unable to take time off work or temporarily pause looking for employment (Srivastava & Nagaraj, 2019), resulting in large populations with no choice but to still go out and work in these extreme temperatures.

Responses, adaptation, and mitigation

The actions taken by the authorities, such as enforcing curfews and trying to provide water through tankers, were good ideas, however as proven by continued deaths, illnesses, and water shortages, the execution of these ideas was arguably not effective. Combined with public response at the time in the form of protests by citizens outside of government buildings, it is not difficult to believe that the authorities' actions failed to mitigate the impacts and that longer-term, more deep-rooted issues regarding water management were also an influencing factor of the severity of the drought.

Ideally the way to adapt to heatwaves and droughts in the Indo-Pakistani area, especially as they are annual and predicted to be getting more extreme, is to tackle deeper economic and social issues, particularly in terms of reducing the vulnerability of the population. More economically questionable actions could also increase water security, such as reducing and/or reorganizing India's production of water-intensive crops, such as sugar cane, rice, and cotton (WWF, 2013). However short-term solutions might include: continued and increased afforestation, year-round water use reduction schemes, and improved and increased water recycling.

Implications and final thoughts

Heatwaves in India occur annually, however the increased severity of them of them in recent years, has greater and more concerning implications in terms of climate change. It is possible that we have already left it too late to significantly reduce or stall the increasing severity of these heatwaves. Indo-Pakistani social and economic losses could prove devastating to both domestic and international society. Undoubtedly, in this case, inaction will guarantee failure.

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Pingdi Landslide 23rd July 2019

Harry McClean

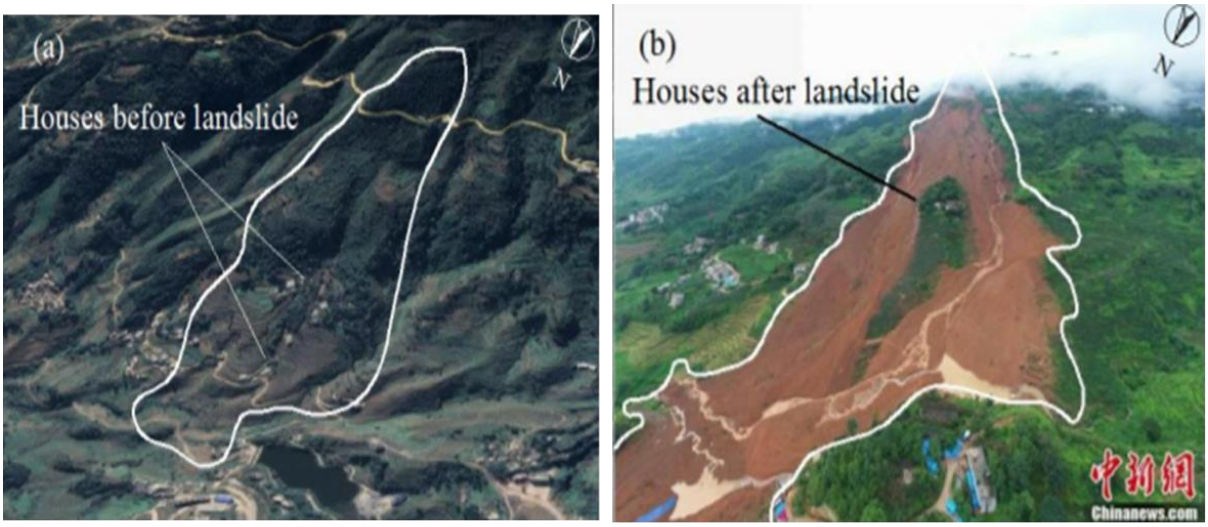


Figure1, 3D images from Google Earth of Pingdi before and after the landslide occurred. (Source: http://gz.people.com.cn/n2/2019/0724/c194849-33174976-7.html)

Case Study account

On the 23rd July 2019, a small mountainous village called Pingdi (104º40'E 26º15'N) in the Shuicheng County of the Guizhou Province. Was hit by a large landslide causing widespread disruption throughout the region and immediate devastation to the village.

The scale of the landslide saw around 2 million m³ of soil and rock move down the mountain from its peak some 500m above the village. The occurrence is largely down to the region being on the end of weeklong heavy rain fall.The duration of the landslide is estimated to have lasted for around 60 seconds, clearly demonstrating the sheer size and scale; to be able to move such a volume of earth in a very short time period. In its torrent the landslide also damaged electricity poles and as a result cut power off to around 2000 homes further demonstrating the damage that Pingdi suffered during the event.

The mountain in question lies above the village leaving the local residents in a vulnerable position. As a result, this left an overall death toll at 36 as reported by Al Jazeera. It's believed that the timing of the landslide fell at a time many residents were at work outside of the village, preventing further deaths.The article was published five days after the disaster had occurred giving time to emergency services to evaluate the facts of the disaster. Al Jazeera was the first news platform to provide a final death toll and the organisation had obtained facts from the state run news agency Xinhua News.

Due to the mountainous topography of Pingdi and the surrounding land, it becomes incredibly susceptible to flooding and landslides, as a result of ground becoming saturated and very soft. As you can see from figure 1 below it outlines the land which was affected by the landslide. The top image shows the area before the landslide's occurrence illustrating where some of the houses were/are situated on the hillside. We can begin to make an inference on the highlighted houses. With the location they are built in and the cheap materials that they'll be constructed from showing the vulnerability of these houses in a landslide event. Then moving to a shot post landslide which clearly shows these houses have largely been submerged or moved by the slide as expected from the prior image. This then begins to raise the question of whether safety of the villagers was sacrificed for the housing needs and demand that follows. This then allows us to ask whether the severity of this event could have been alleviated through stricter regulations.

The location of the landslide is believed to have occurred at a highway construction site that was high up in the mountains. Part of the mentioned highway can be seen in figure 1, running high across the hillside above where the landslide started on its path of destruction. This can also help to provide an explanation for the landslide's occurrence, with disturbance to the saturated land during construction making it even weaker after the heavy rain had hit the region. Therefore. more susceptible to give way and cause a landslide event. As it did once the ground reached a level of saturation that was no longer physically viable to contain. Flooding in the region has been rife due to the extensive monsoons. Meaning control over floods has proved challenging. As a result, this has seen more disasters occurring in

regions that have already been heavily hit by rainwaters.

Following on from the point made earlier, agriculture is one of the main industries in the region and through its need for pastural and arable land. It sees residencies being built on the land of no use to farming. Often land in a vulnerable location. As a result, over 20 houses from the village were lost and buried within the mud. (Global news).

The recovery operation saw Beijing pledge $4.4 million (30 million yuan) for disaster relief. President Xi Jinping pledged to fully support the recovery mission as reported by the South China Morning Post. Saying he "ordered local officials to improve monitoring and early warning systems". This could be used to support the earlier point raised about whether measures in place were of an adequate standard.

During the rescue operations more than 800 rescuers, 20 diggers and 100 vehicles were sent to help with recovery as reported by state broadcaster China Central Television (CCTV). The president also insisted rescue work should be conducted in a scientific manner and monitor for potentially risk of secondary disasters occurring. (Liqiang, Hou. 2019). It's clear to see the concern over secondary hazards. This concern should of come as the land became saturated allowing evacuations to take place. The positioning of debris meant surface run off began to accumulate in certain regions forming barrier lakes. These then presented the growing risk of localised flooding and other secondary threats should these 'lakes' burst as a result of the runoff and high risk of debris flow in certain points in the landslides. This saw a suspension to rescue operations on the 25th July in certain points amid fears of more movement. (Yan, T et al. 2019). Managers were now beginning to put human safety first over the looming risk of further disasters.

Cross referencing

If we begin to fact check and cross-reference the articles used in the chapter a pattern emerges. All of them follow relatively realistic facts. However, this appears to because all international news formats reporting the incidence are only able to get hold of what the Chinese State has released.

Xinhua News Agency is the official State run news agency in china. Strict laws over media show mean it can be difficult for western media to gain an insight into affairs.

TRT world, Al Jazeera and Global News are a Turkish, Qatari and Canadian media platform and all use the information that has been released by Xinhua News.

Only one of the articles didn't reference information sourced from Xinhua News Agency and that was China Daily. A newspaper still owned by the publicity department of the government showing the information contained in the article is State release. They reference 'CCTV' which is an abbreviation for China Central Television. Showing the tight control over release of information by the government. This thought can be built on by looking back what was reported by the South China Morning Post about the president Xi Jinping's speech. Who ordered local officials to improve monitoring. Which could be inferred as them not wanting negative press to be released or other countries to find out about inadequate measures in place that could have alleviated the impacts of such disaster. Which may have also change perceptions on the country.

Newspaper Facts

- TRTworld (Turkish): 20 deaths 25 people still missing. 21 houses disrupted. Claim facts obtained from state media release. Xinhua News Agency26th July
- Al Jazeera(Qatar): 36 dead. 15 missing. 28th July. Still obtained information from Xinhua News Agency.
- Global News (Canadian): 20 dead. 'about two dozen' missing. Same Xinhua reference
- South China Morning Post: . 13 dead. Dozens missing. 21 house buried .24th July. Earliest article. Could be locality. Still references information from Xinhua News Agency
- China Daily: 26 dead. 21 houses under rubble. 27th July. No reference of Xinhua News however do reference CCTV.

Technical interpretation

Landslides in china are constantly becoming more of a destructive hazard to populations located in and around mountainous regions. Susceptibility can be seen in Figure 3 around Southern China. Awareness in literature is rising with it being recorded landslides being ranked second in terms of their destructive nature behind earthquakes for threats towards mountainous regions in china. (Li et al. 1999).

With the affected Guizhou region home to Pingdi being one of the most at risk areas across the South of China. Records show that the region experiences heavy continental monsoon rainfall between the months of May to September. This then sees landslides occur frequently during this time, as a result of the high instability within the land. (Huang, R & Li, W. 2011). So, the timing of heavy rainfall in the build up to the landslide in Pingdi means extreme precipitation levels can be accounted for causing the event. As the ground becomes increasingly saturated the weight of soil increases and as a result sees a rise in the sliding force making the ground more susceptible to moving. Landslides then occur when the sliding force exceeds that of the sliding resistance. (Tao, Yan et al. 2019). As witnessed in Pingdi on the 23rd July.

Figure 2 shows the different forms that landslides can take through varying factors. By looking at the top half of the diagram in the higher mountainous region. It provides a basic illustration of what occurred in Pingdi. With the landslide starting in the higher regions relatively shallow in depth occurring through saturated soils and higher gravitational force. Gaining speed moving downhill whilst increasing in size.

This thought is supported by the level of rainfall in which Pingdi and its surrounding land received being a level that was above the global thresholds for landslide occurrence. Globally its common to see translational landslides occur after a period of heavy rainfall.

Relating back to Pingdi, as the rain filtered through from the mountain top it flows through causing high hydrostatic and uplift pressures along the sliding plane. (Huang, R. 2012). Once this then reaches a certain level movement will occur. Obviously, the volume of water moving through relates to the amount of earth being moved. As seen with the 2million m^3 of soil moved by the rain received in Pingdi. Demonstrating the size of landslide. Relating back to the science behind translational landslides and their occurrence.

In addition, an interpretation can also be introduced to look at moving away from the natural threats of the hazard. But beginning to look at the measures in place to prepare the region against such events. Adequate preparation could see better management of landslides in the region. Leading to a reduced future threat to local residents and infrastructure.

Conclusion

As mentioned in section one, after the disaster occurred President Xi Jinping ordered local officials to improve monitoring and warning systems. Illustrating they were inadequate to start with highlighting the vulnerability of not just Pingdi but other villages that find themselves situated in similar landscape. residents can be seen to be living with restricted capacity to cope and prepare for potential hazards. Therefore, if these systems were better prior to the disaster more could have been done to restrict the impacts in which the landslide caused on the Tuesday evening in the Shuicheng County. There is also a train of thought surrounding vulnerability of the response groups. By having restricted equipment and technologies available to them their response won't be as effective as one with a more substantial resource range. Following this, measures have been set up since the early 1990s surrounding mapping landslides and the high risk areas. Making prediction 'easier'. It has allowed warnings to go out when weather forecasts predict a serious chance of a landslide.

The vulnerability of populations must also be considered expanding population and urbanisation can lead to a lack of control towards land-use, destabilising the land. But also as towns in these mountainous regions expand they spread further into hazardous terrain. (Nadim et al. 2006). Demonstrating that this expansion around high risk areas can present more potentially risk that come with a landslide such as damage to infrastructure which in turn can put more people at risk during an event. (Lin, et al. 2017). In addition the outward sprawl of communities into hazardous terrain places them at greater risk in future events. However, as raised it can be seen that as countries become better equipped they can prepare and protect populations better than what has been seen previously.

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Brahmaputra River Flooding, Bangladesh - July 2019

Danyal Mahmood

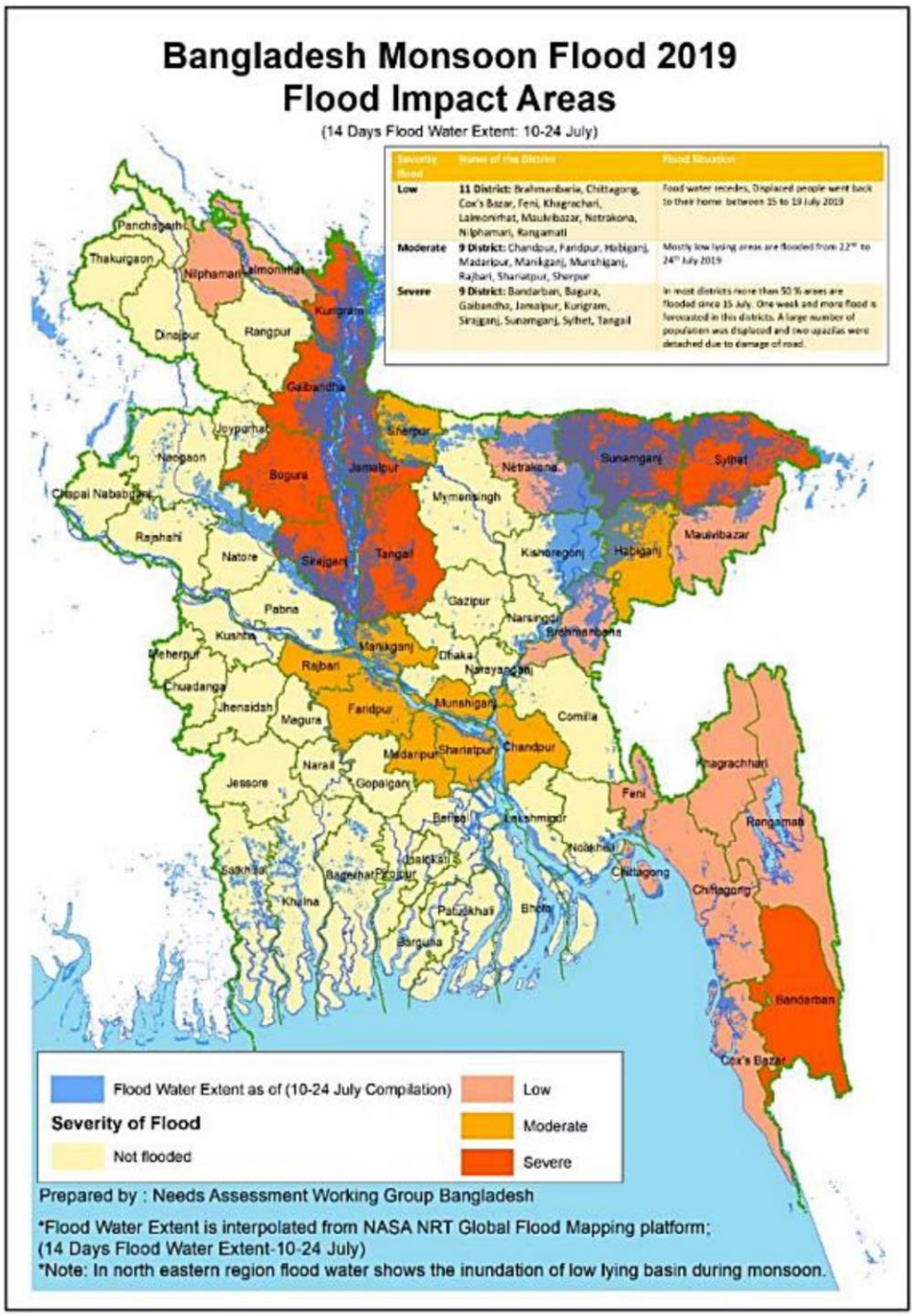


Figure 2 - Flood Risk Map of flooding in Bangladesh, July 2019. It illustrates the most severely affected areas in Red and moderately affected areas in amber. (Sourced from; UN Resident Coordinator for Bangladesh, 2019).

Background Information

Heavy monsoon rainfall has caused intense river flooding in Bangladesh from 9th July to 24th July 2019 (CARE, 2019). According to Al Jazeera (2019) high levels of precipitation fell in a short amount of time causing the Brahmaputra River to swell, resulting in the bursting of its banks, leading to river flooding. The time period between the 9th and 24th of July bought landslides and river flooding through many parts of southern Asia including Bangladesh, India, china and Nepal (BBC, 2019). The Brahmaputra river basin flows across the Himalayas and through Bangladesh into the Bay of Bengal (See figure 1 below).

It is apparent that these floods were the worst floods in years whereby they submerged villages under water (Al Jazeera, 2019). There have been a range of articles and humanitarian response reports that were published during the unfolding of the monsoon rainfall event in July 2019. As a result of this specific event taking place over a fortnight there are some discrepancies and differences in the statistics and facts, these have been triangulated below.

Location of Event

The monsoon rainfall of July 2019 impacted countries across south Asia with Bangladesh being impacted significantly. Namely, the nine most impacted areas within Bangladesh were Kurigram, Jamalpur, Gaibandha, Sylhet, Sirajganj, Tangail, Sunamganj, Bogra and Bandarban (CARE, 2019). These areas are situated in the North of Bangladesh where the Brahmaputra river flows into Bangladesh. According to Shahid (2011) the levels of annual and pre monsoon rainfall trends show an increase in

the amount of precipitation, implying that the rivers were already of increased river discharge. This is likely to cause greater intensity flooding during the monsoon season.

Event and impacts

The event of the monsoon rainfall caused significant river flooding of the Brahmaputra River impacting upon many areas of Bangladesh from the 9th – 24th July 2019 (CARE, 2019). Outlined below is a series of events and impacts that have occurred in this time period. Through the occurrence of the river flooding there were frequent updates by United Nations, Bangladesh providing statistics on the event itself and ways in which the government and NGO's have or are to respond to this specific natural disaster. In July 2019, 800mm of rain fell in Sylhet and up to 1000mm in Cox's Bazar causing severe disruption to livelihoods (Climates to travel, 2019). The monsoon floods threatened the world's largest refugee camp at Cox's Bazar where 4000 families 3 were displaced and put into temporary accommodation (Wright & Saeed, 2019). It is reported that 60,000 children are unable to attend schools due to being submerged under water and this has also led to the difficulty of access to aid. Cox's Bazar is in the south east of the country (see figure 2, below). A total of 427 educational institutes were damaged in this flooding event (CARE, 2019). According to UNICEF Bangladesh (2019a) 700,000 children were put at danger. As of 21st July, four million people had been affected by the monsoon rainfall and 187,000 people were displaced (UN Office for the Coordination of Humanitarian Affairs, 2019) (Al Jazeera, 2019). Consequently, as a result of the river flooding, millions of people were put at risk with respects to food insecurity, clean water scarcity and the spread of disease (Al Jazeera, 2019). The post emergency response article published by CARE (2019) outlines that the northern area of Bangladesh was significantly impacted upon by the high levels of monsoon rainfall. Additionally, the report states that the July 2019 floods were the worst since the flooding that occurred in 2017, affecting 7.6 million people across 28 districts. Many of the impacts in northern Bangladesh were worsened as a result of the prolonged impact of the 2017 flooding; making some people, especially women and children more susceptible and vulnerable to disease (UNICEF Bangladesh, 2019b).

As of the 20th July there were 60 reported deaths as a direct result of the flooding (Working Group Bangladesh CARE, 2019). It is reported that the total deaths caused between the 9th – 24th July 2019 monsoon flooding was 119 fatalities with counts including disease related deaths and snake bites. In addition, approximately 287,000 people were displaced from their homes across 21 districts in the region. (Concern Worldwide US, 2019) (Relief Web, 2019). There was major damage to over 66,641 km of roads, 1,275 bridges and culverts and 1515 km of river embankments due to the river flooding. By the 29th July 2019 239,387 people were still living in shelters (UN Resident Coordinator for Bangladesh, 2019) (Shelter Cluster, 2019).

Response

There have been many responses towards this natural disaster of the river flooding of the Brahmaputra River basin in the north of Bangladesh as well as the south east. Aid was provided through both governmental and non-governmental organisations including Islamic Relief, UNICEF and Oxfam. The government has provided 10,500 tents and 13300 tonnes of rice to the locals and those impacted directly. Aid was also provided in cash sums to help rebuild damaged infrastructure and the government invested 20 million Bangladeshi Taka to help with medication, sanitation, food and help to rebuild infrastructures (UN Resident Coordinator for Bangladesh, 2019).

On the 30th July 2019 an Emergency appeal was launched by the International Federation of Red Cross and Red Crescent Societies (IFRC) to raise 7 million Swiss Francs (IFRC, 2019). The money raised will allow to provide emergency response efforts in the short, mid and long term. Many countries across the world have also identified most affected areas and provided support in terms of temporary shelter and monies to allow sanitation and healthcare to the most vulnerable (World Vision, 2019) (see figure 3, below). 130 trained aid workers were deployed to the most affected areas (World Vision, 2019). The humanitarian response and recovery plan (Shelter Cluster, 2019) states two phases in all its recovery and response efforts. The first phase in all instances consists of proving first-hand aid and phase two identifies ways in which preparedness can help mitigate future events similar to the monsoon rainfall and river flooding of July 2019.

TECHNICAL INTERPRETATION

The Brahmaputra river basin hosts a population of 130 million inhabitants whereby people are dependent on it as a water source. With an increase in the levels of river discharge due to high volumes of rainfall in the monsoon season this can lead to the spread of disease causing many health issues and further impacts including a lack of medical attention and availability of medication to eradicate this (Yang, Wi, Ray, Brown & Khalil, 2016). Definably, a monsoon is seasonally reversing winds, caused by seasonal variation in the annual temperature across areas of large land bringing with it, rainfall as a result of changes in pressure (McGuffie, 2011). Monsoons vary across the world dependent on the specific conditions it is occurring in.

The land of Bangladesh is predominantly low lying and therefore incurs a greater flood risk than other south Asian countries. There are three main river basins that flow through Bangladesh and they are the Brahmaputra, Ganges and Meghna (Yang, Ray, Brown, Khalid & Winston, 2015). In accordance to Yang et al (2016) it is predicted that there is likely to be increased levels of river discharge with the changing climate and could prove vital for planning in future flooding events in Bangladesh.

According to Mirza (2002) 80 percent of the annual rainfall of Bangladesh falls in the monsoon season putting significant pressure on the peak discharge capacity of the three rivers. It is also stated that this has a significant impact on the locals, both socially and economically, which is detrimental to the already low per capita income. Ahmed (2001) indicates that substantial levels of flooding causes damage to the agricultural land and crop yield in Bangladesh impacting on both people and the economy in terms of food insecurity and the lack of product sales. There have been similar disasters to the one that occurred in July 2019 such as the Brahmaputra river flooding in monsoon season, 2017. According to the Bangladesh Red Crescent Society (2017) the 2017 monsoon floods affected 3.9 million people and destroyed 309,542 hectares of agricultural land. There were 56 reported deaths and 250,000 people were impacted upon in Sylhet alone. A third of Bangladesh was submerged under water with a total of 142 deaths in the country, as a result of the flooding (George, 2017). This event also impacted upon the national religious holiday of Eid (George, 2017).

Monsoon river flooding occurs annually in Bangladesh, with intense rainfall comes increased river discharge and slow decrease in the river discharge of the three main river basins, the Ganges, Brahmaputra and Meghna (Jakobsen, Hoque, Paudyal & Bhuiyan, 2005). Jakobsen et al (2005) imply that the synchronisation of the main three river basins increases the river discharge rate being one of the main factors that causes the river flooding in Bangladesh. According to Ahasan, Chowdhary and Quadir (2010) the annual rainfall in Bangladesh is 2456.38mm and 1769.14mm of it falls in the monsoon season from June to September. This data has been collated and averaged from the rainfall between 1961 to 2010. This indicates that the level of rainfall falling in the monsoon season is considerably higher than in other months.

The lowest levels of rainfall occur in the central western area of Bangladesh and the highest levels of rainfall occur in the south east and north east parts of the country (Ahasan et al, 2010). Figure 4 (below) illustrates the average summer monsoon rainfall which supports the idea of high levels of monsoon rainfall occurring in the north east and south east of Bangladesh. This article also states that the levels of precipitation are increasing by 5-6mm per year in the north west of Bangladesh and 3-4mm per year in the south east of Bangladesh. This is in the same areas that have been impacted upon in the July 2019 monsoon rainfall and river flooding where areas in the north east including Netrakona, Sunamganj and Sylhet were impacted significantly by river flooding as a result of the heavy rainfall. Similarly, Rangamati, Feni and Cox's Bazar located in the south east were also impacted upon significantly by the July 2019 monsoon rainfall. This indicates that the trend illustrated by Ahasan et al (2010) is significantly supported.

CONCLUSION

The communities within Bangladesh were impacted greatly by the floods as a result of the monsoon rainfall of July 2019. Many people were affected, and millions were displaced as a result. With the low capita of Bangladesh, the country was still recovering from the 2017 monsoon flooding which also had detrimental effects on the population of Bangladesh. It can be concluded that the monsoon flooding is

an annual event that occurs over the monsoon months in Bangladesh. The effects vary from year to year dependent on the previous weather conditions prior to the monsoon season and dependent on the river levels. The impact severity also depends on the levels of rainfall that occur during the monsoon season and the rate it falls at.

The response was implemented from a range of organisations including governmental and non-governmental organisations. Aid was provided in two phases one in the short term and one in the long term. The plans for the humanitarian response and recovery plan will continue up until April 2020. The response both during and after the disaster was implemented immediately to protect and provide for the population affected in the most impacted upon districts across north eastern and south eastern Bangladesh. With respects to future events like the river flooding of the Brahmaputra it is likely that these events will continue yearly, and the response will develop with the

occurrence of more events of this origin. The risk of vulnerability will continue to rise as a result to a constant rainfall period over the monsoon season and therefore continue to put people and infrastructure at risk.

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South-East Asia and Oceania

Typhoon Yutu

George Fountain

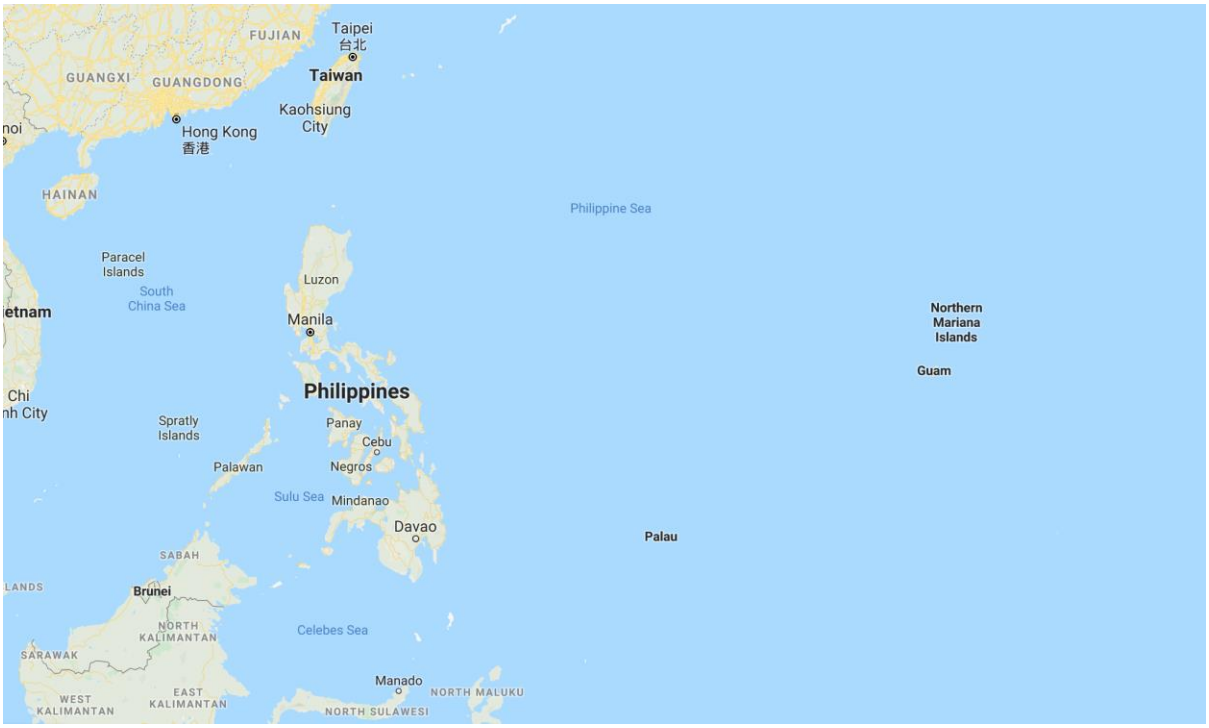


Figure 1: Map displaying the region in which Typhoon Yutu caused major damage (Google Maps, 2019)

Authoritative Account

Typhoon Yutu was first captured by satellite on October 22nd, 2018, over the North-western Pacific Ocean as a tropical depression; rapidly intensifying into a tropical storm (NASA, 2018). NASA (a worldwide trusted organisation) provides a 'Hurricane and Typhoon Updates' page for an in-depth timeline of the movements of Typhoon Yutu. Following the original capture of the storm, Yutu moved North over the Pacific Ocean, passing over the Northern Mariana Islands between the 24th and 26th October – particularly the islands of Saipan and Tinian – where the storm intensified into a category 5 super typhoon. Multiple news sources demonstrate the severity of the category 5 storm; describing winds of between 178-180mph in the eye wall over Tipian – seen in figure 1 (Euginio and Rice, 2018; NASA, 2018; Press and Collman, 2018).

After devastating the Northern Mariana Islands, with peak rainfall figures of 269mm/hour in the eye wall of the storm, The National Weather Service in Guam stated that the storm was the worst to hit any region of the United States in 2018 (NASA, 2018). Typhoon Yutu proceeded to then move further North towards the Philippines, where it provided heavy rainfall (178mm/hour) and weaker wind speeds (103.5 mph) over the Philippine island of Luzon, then back into the North-Western Pacific Ocean on October 31st. Early warning protocols were put in place in South East China and Hong Kong, however Yutu weakened rapidly and faded as it passed over the Pacific Ocean; updated as a weak tropical depression on November 2nd, 2018 (NASA, 2018). Figure 2 (Google Maps, 2019) shows the region in which Typhoon Yutu caused devastation, with arrows indicating the approximate path the storm took.

Yutu's Impacts

Having been described 'by meteorologists' as the strongest storm of 2018, and one of the most intense to hit United States territory (Dwyer,2018), Yutu was predicted to cause catastrophic destruction to the homes and livelihoods of the approximate 50,000 inhabitants of the Northern Mariana Islands. However, these statements cannot be taken as hard evidence due to the vague reference to 'meteorologists' that Dwyer uses in the article rather than specific names and dates for these statements, as well as any records of previous history of storms in the region. Consequently, Eugenio and Rice (Pacific Daily News) also reported the storm to be the strongest to hit U.S territory, providing the 'National Oceanic and Atmospheric Administration' as a reference to the statement; providing the reports with increased scientific backing and trustworthiness (Euginio and Rice, 2018).

Saipan and Tinian – Northern Mariana Islands

Infrastructural damage was described to have been the most significant, with the capital city Saipan hit with

devastation to schools; resulting in the displacement of hundreds of students (Quintans, Hobbs, Belway, 2019). Furthermore, Saipan's international airport was severely damaged, with figure 3 displaying only a small amount of the devastation caused. The Collapse and closure of Saipan airport caused major disruption to the island's tourism industry, with over 1,800 South Korean tourists and 1,500 Chinese tourists trapped on the island due to the closure; leaving them without power and a low amount of basic supplies (BBC News, 2018). Hundreds of power poles were downed, as well as significant damage to transformers and conductors during the storm (Chiu, Mooney and Eilperin, 2018), leaving not only the airport without power, but the whole island. As well was extensive damage to critical power supplies in Saipan, a significant number of houses were ripped apart by the storm. Due to the use of tin roofs, and wood for structure, Yutu's high velocity winds reduced many houses to nothing but heaps of tin and wood spread amongst other debris – with a resident of Saipan reportedly saying "if it wasn't made of concrete, It's probably gone" (Chiu, Mooney and Eilperin, 2018). The magnitude of Yutu's impact became evermore evident through the constant updated stories of destruction and chaos it brought, especially through reports of the death of a 44-year old woman on Saipan reportedly killed when sheltering in an abandoned building, which consequently collapsed onto her.

Tinian, adjacent to Saipan, was caught in the eye of the storm and was reported to have been damaged equally as heavily, with water shortages and power outages just two of many significant implications caused by Typhoon Yutu (Breslin, 2018). Tinian's Mayor Joey Patrick San Nicolas stressed the extent of the demolition through various news outlets reporting him declaring that the island was without water, both its airport and seaports were inaccessible, whilst also declaring that it could take 'months' to restore power throughout the whole island (Breslin, 2018; New Zealand Radio, 2018). Multiple outlets also reported Tinian's continued struggles with empty stores of water, gas and electricity to be closing in on a humanitarian disaster.

The Philippines

Having been hit by Typhoon Yutu after the Northern Mariana Islands, as well as the storm weakening in terms of wind speed and rainfall figures, The Philippines were surprisingly impacted substantially. Wind and rain did not directly impact The Philippines as it did to Saipan and Tinian, but the destruction it led to was much more fatal and devastating than that of Typhoon Yutu's peak strength. Due to the heavy rainfall brought by Typhoon Yutu, this led to the eventual triggering of landslides in the mountainous region of Cordillera, North Philippines. Natonin region was reportedly the worst hit area, with the death toll rising to 18 as of 15th November,2018, with up to 10 other bodies missing (CNN Philippines, 2018). Other reports suggest 16 bodies were found, with another 12 reportedly missing (Romana, 2018). Not only was the death toll high in comparison to the Mariana Islands, the agricultural damage was distressing with a reported total value of approximately $34.2 million in crop damage; covering over 90,000 hectares (Romana, 2018). Not only is this significant in terms of economic cost, but this is equally as damaging in terms of social cost, as the agricultural sector in the Philippines is responsible for approximately 25% of the labour force throughout the islands (The World Bank, 2018); therefore having an enormous impact socially for workers and subsequently, their families.

Technical Interpretation

Typhoons often form over ocean waters with a relatively warm surface temperature of 26 Degrees Celsius or above; these waters are most common in the tropics due to the solar energy per unit area being at its greatest in these regions (Trenberth,2005). They develop when an area of low pressure and thunderstorms interact – a tropical disturbance. As the surface water evaporates and condenses to form more rain clouds in the storm, the storm itself becomes larger and strengthens into eventual violent storms. Due to the Coriolis effect and convergent winds blowing in the direction of the storm, the storm rotates (Holden, 2018; Clements and Casani, 2016); therefore, creating a devastatingly large storm. Yutu was classified as a typhoon due to the wind speeds generated, as well as the location of the storm (Clements and Casani, 2016). Although hurricanes, tropical cyclones and typhoons all have similar characteristics, the location and wind speeds have an impact on the catergorisation and name of the storms: Yutu was a typhoon due to the wind speeds exceeding 74mph, as well as the location of the storm being in the Northwestern Pacific Ocean. The categorisation of a category 5 'super' typhoon is due to the winds exceeding 134mph (Clements and Casani, 2016), or 118mph (190kmph), as per Abdullah et al's 'six categories of tropical storms' (Abdullah et al., 2015).

Provided the context in relation to the formation and characteristics of tropical storms and typhoons, it can be deduced that Typhoon Yutu was a relatively normal occurrence for this region of the world, where the sea surface temperatures are over the boundaries required for these types of storms to converge. Due to the Western Pacific Ocean being the 'busiest' location for tropical cyclones on Earth, the region has been named 'Typhoon Alley' by many news outlets and articles (Belles, 2018; AFP, 2014). Storms, such as Typhoon Yutu, have become a norm amongst these islands, with more than 20 tropical storms and typhoons supposedly are born in the Pacific Ocean each year (AFP, 2014). Typhoon Mangkhut hit similar regions to Typhoon Yutu, only one month previous to the emergence of Yutu – causing a much larger

devastation than Yutu due to the fact that Mangkhut had already caused region-wide damage and destruction, as well as forced evacuations of local people and tourists already, thus had not yet recovered. The Philippines were hit significantly by Typhoon Mangkhut (Ellis-Peterson, 2018), whereas the Northern Mariana Islands had only recently recovered from Typhoon Souledor (Wong and Cruz, 2018), which occurred over 3 years previous to Yutu. Due to the frequency of tropical storms in these regions each year, the recovery process cannot be thorough enough for a successful recovery.

Although it is thought to be within the norms for this location within the Western Pacific Ocean to be hit with Typhoons every year, articles suggest that climate change may also be having an impact on the frequencies and intensities of these tropical storms. Holden discusses this in great detail, whilst referencing that although the Intergovernmental Panel and Climate Change (IPCC) seem reluctant to express whether climate change is causing stronger storms, a significant amount of other scientific literature says otherwise (Holden, 2018). Holden refers to the fact that the mechanism that is driving the generation of stronger typhoons is the higher ocean temperatures – referring to Bagtasa and Emanuel stating this to be a major factor due to the energies provided for tropical storms by warmer oceans (Bagtasa, 2017; Emanuel, 2018). The widespread literature Indicating that climate change is having an impact on the strengths of tropical storms, highlights that Typhoon Yutu may not in fact have been a typical storm in the past, however, with the rising sea surface temperatures due to climate change, it poses the question: are storms of category 5 intensity going to become even more common in years to come, with the occurrence of smaller, less devastating storms potentially becoming less frequent? Further consideration should be put into this by the IPCC particularly.

Conclusion

Responses

Both the Northern Mariana Islands and the Philippines were similarly vulnerable to the destruction of Typhoon Yutu. Due to the fact that tropical storms alike Yutu are common in this region of the world, it may be expected that these island nations are well prepared for such events, however this is not usually the case. The responses to the carnage that Typhoon Yutu brought were relatively poor in relation to time. The preparations and responses were put in place relatively quickly, with emergency shelters set up and filled, temporary school shelters built – with 66 in Saipan (Quintans, 2019). Aid was however difficult to distribute rapidly due to the inaccessibility of the islands, with major ports and roads, as well as various other infrastructure, being heavily damaged or destroyed (Chiu, Mooney, Eilperin, 2018).

Vulnerability

The vulnerability of the South East Asia region is high due to it constituting of many small islands that are exposed to the ocean at all angles. Storms can encompass these full islands and cause havoc, whilst the effects of climate change are not heading the destruction levels through the increased frequency of these storms magnifying the vulnerabilities. Furthermore, island nations tend to have one or two main exports in terms of crops or tourism. Agricultural industries tend to use coastal areas for farming practices; removing natural storm buffers (such as mangrove forests) to accommodate agriculture. These industries are easily wiped out by intense storms and storm surges due to this, thus, escalating the vulnerabilities of these nations through removing their base economic incomes and livelihoods; therefore, hindering their recovery efforts with a lack of available income (Wisner, 2014).

Typhoon Yutu is a common natural hazard occurrence at this time of the year, substantial amounts of literature state that these storms will become more frequent and intense due to climate change, therefore, responses and infrastructure require significant improvements and tourists and locals should all be educated about the risks and best evacuation strategies that are in place.

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Kyushu Island Floods – August 2019

James Thompson



Figure 1 shows the flooding of homes and infrastructure in Takeo, Saga prefecture during the floods of August 2019. (BBC News. 2019).

Case study

Saga prefecture contains modern cities combined with historic landmarks such as Karatsu and Saga. (Japan-guide.com. 2019). To the North and to the East of Saga are mountainous areas, meaning that the rainfall from storm events that lands on the south and west side of the mountains will head towards Saga, encouraging the risk of a flood event. Due to the low lying land Saga is also known as a potential city that could be at severe risk if a tsunami were to occur on Japan's West coast. Japans soil is also very weak due to the volcanic layers and tectonic plates that make it hard for the soil to consolidate. This unconsolidated land makes is very susceptible to landslide when heavy rain occurs.

Between the 48 hours from 5:00pm on Monday 26th August and 5:00pm Wednesday 28th August 427mm of rain fell on Saga, Kyushu Island, in the South-West of Japan, this being more than twice its average rainfall for the entire month of August. Areas of the Island were inundated with up to four inches or standing water in just one hour, with one man telling Reuters "I woke up and the water was ankle-deep in my house, which has never happened before." The Japanese Meteorological agency (JMA) recorder hourly rainfall in Saga city and Shiroishi at 110mm per hour. Saga resident Takaaki Matsuo said the usual 5-minute commute to the train station took him an hour with the knee high water level making it difficult to walk. (StraisTimes. 2019)

Eco watch and NHK reported that over 900,000 people were ordered to leave their homes with another one million people advised to leave their homes by Japanese authorities. Japans military, the Ground Self-Defence Force, deployed around 100 troops for aiding in disaster relief at the request of Saga prefecture. Resident also voiced their concerns on twitter with one person posting "The first floor of our house is flooded and a total wreck, so we're here on the second flood, awaiting rescue." They then continued with tweeting "We can see the firemen out there moving around, but our street is such a mess they don't seem to want to come in." Evidence of this can be seen in figure 1with the flooding of homes, cars and transport infrastructure.

Just a month before in July over a million people were ordered to evacuate their homes due to a single months' worth of rain falling in one day, killing one woman and forcing the government to deploy 14,000 soldiers from the Japanese defence force to assist emergency responders. (CNN. 2019).

Light consistent rain began to fall on Monday 26th August, followed by much heavier rain on the Tuesday and Wednesday. The constant rain falling on already saturated ground made it very difficult for water to drain away.

The Kyushu Island floods caused the deaths of 3 people, two victims were elderly, one aged 96, and it has also been reported that two of the deaths were caused by vehicles being washed away in the strong flood water according to Reuters.

The Fire and Disaster management agency also reported that the flooding had caused a leakage of toxic materials at a steel works in Takeo city. This could potentially have long term environmental impacts on the surrounding wildlife. It is predicted that over 50,000 litres of oil used to cool iron was washed away from the local ironworks plant in Omachi, Saga prefecture that is run by Saga Tekkohsho Co. The managing director of the steelworks, Ken Taromaru, apologised to residents and claimed the torrential rain suffered in the area was beyond their worst-case scenario. This came as little comfort to rice farmer Kenji Kishikawa who said he had lost everything. "The soils is contaminated and some of my farm machinery was damaged as well." He told the Japan times. There are also claims that the was not enough preparation for emergencies including oil fences and absorption mats. (Kyodo. 2019)

Kyushu Island was also affected by the floods economically as two factory works had to close temporarily. Toyota Motor Corp, that builds Lexus cars had to suspend manufacture on the Wednesday evening. This is not the only manufacturing plant that temporarily closed as Daihatsu Motor also had to stop work.

One of the major transport hubs in Saga, Japan Rail Saga Station, was also under water. Flooding of the station again had secondary impacts of surrounding the movement of people around the province but could have also had an impact on the temporary supply of goods.

Approximately 70% of Japans land consists of hills and mountains leading to many homes being built on steep slopes or the flood plains that sit immediately in front of them. In North-West Kyushu, where the majority of the flooding took place, there is a lot of low-lying land at the base of mountains as seen in figure 2. With the rainfall rapidly coming off the mountains the river levels were quick to rise resulting in 10 river locations being at their highest alert showing a severe risk that the rivers were near bank full.

The nature of Japans topography combined with the torrential rainfall caused fears over landslides occurring. One landslide did occur in the city of Takeo in Saga Prefecture.

ON the 27th August authorities issued emergency alerts warning of the possibility of mudslides flooding and swollen rivers in Fukuoka, Saga and Nagasaki. The authorities initially raised the warning at a level 5, the highest level, however this was later downgraded to a level 4.

Technical Interpretation

One of the major causes of flooding in North-West Kyushu is due to the topography of the area. Large parts of the land in North-West Kyushu is near horizontal compared to central, near vertical mountainous areas with some slope angles of 86°. This causes volumes of water to rapidly leave the mountainous areas and get to large, low-lying urban areas to the North-West. The South of Kyushu Island very rarely floods even though monthly rainfall in the South is nearly double that of the average rainfall in the North during the wet season from June to August. The flash flood risk assessment for Kyushu Island from 2018 stated that precipitation does not exceed 400mm/month, however the precipitation at the end of August 2019 reached 427mm in a 48-hour period. This shows that the area hadn't received this level of precipitation before. The geology of North-West Kyushu also makes the area much more at risk from flooding due the largely impermeable nature of the soil. Due to the low permeable soil surface run-off increases and lag time decreases, and the rivers fill much quicker. The Largest River on Kyushu Island is the Chikugo-Gawa river measuring 113km. The river has 28 basins and more than 300 sub-basins, meaning the water from precipitation is very likely to find its way into the Chikugo-Gawa that eventually flows through Saga. The Saga prefecture is one of the most urbanised in Kyushu, again increasing surface run-off. The flash flood risk assessment for Kyushu Island states that there is higher risk of flash flooding in the North-West due to increase surface run-off due to urbanisation and the low infiltration rates of the soil. (Shehata, M., & Mizunaga, H. 2018).

Flooding is intimately related to and run off. The level of precipitation that was experienced in the Saga prefecture was at a level that had not been experienced before, leading to a lack of preparation for a flood event of this magnitude and therefore resulting in events such as the oil leaking from the ironworks. As seen in figure 3, the number of people killed or affected by flooding along with economic loss is greatest in Asia thus reflecting the amount of the population living along rivers and on the floodplains. Human activities increase both the magnitude and frequency of flood events in urban drainage basins. (Keller, E. A., & DeVecchio, D. E. 2016).

Land in Kyushu is also likely to still have been saturated from previous rain not only in August but also in July. In July more than a million people on the Kyushu Island were ordered to evacuate after the entire expected rainfall for one-month worth of rain

fell in a single day, killing one woman and leading to deployment of 14,000 staff from the Japanese Defence Forces to assist emergency responders.

The landslide in Takeo was caused due to the heavy consistent rainfall and Japanese topography. The instability of the soil occurs when force exerted on the slope exceeds the resistance of the slope. Pressure will have been applied upon through the slope through porewater pressure where pressure is exerted by water through voids in the soil structure. The earth flow was caused through loading of weight due to the mass of the water and was triggered by an increase in pore pressure. The location and topography of Japan also has an influence on the landslide. Areas most at risk from landslides are seismically active areas as the soil is often unstable and unconsolidated. Takeo is also located in a mountainous area of the Saga prefecture which gives the slope a large gradient therefore the soil has less friction in comparison to a horizontal surface. Adverse meteorology in Kyushu can also lead to landslides with increased precipitation increasing the risk of a landslide occurring.

Conclusion of vulnerability and risk

North-West Kyushu was always at risk from flooding due to its low elevation and vast floodplains surrounded by steep mountainous terrain as outlined by the flash flood risk assessment of 2018 (Shehata, M., & Mizunaga, H. 2018). However, the results from the risk assessment did not predict the amount of rainfall that occurred and therefore the flooding was worse than the risk assessment predicted it to be. With two large floods occurring in the space of two moths it shows how North-West Kyushu is susceptible to flooding but also shows how the returning frequency of the floods can be increasing, potentially due to urbanisation in the area. Consistent flooding of the area makes residents more vulnerable to the effects of flooding whether it be water damage to the home, damage to transport infrastructure or landslides. The flash flood risk assessment used previous weather patterns to predict and model where a flood event could occur. However due to the unprecedented level of precipitation it was not predicted a flood this large could occur in the area which also gives potential reasoning as to how the ironworks were not prepared to cope with the level of water it received and therefore, leaked oil into the Saga prefecture.

Vulnerability can be defined as ‘the characteristics of a person or group and their situation which influences their capacity to anticipate, cope with, resist and recover from the impact of a natural hazard’. Those that are most vulnerable to loss of life from flooding appear to be the elderly with two out of the three deaths in the august floods being elderly people, one of them aged 96. The elderly are the most vulnerable due to their lack of being able to cope with the physical effects of flooding.

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Japan, Kyushu Island city floods – July 2019

Holly Thompson

5-Level Warning System			
Warning Level	*Action to take*	*Information provided by local government*	*Wearther alerts issued by JMA*
5	People must take measures to protect lives	Disaster information	Early warning infromation
4	All residents must evacuate	Evacuation order / instruction	Landslide alert information etc.
3	Elderly people must evacuate	Evacuation preparation information	Rain / flood / storm surge warnings etc.
2	You should check evacuation behaviors	Advisories	Rain / flood / storm surge advisories etc.
1	You should stay on alert for disasters	Early warning infromation	-

Figure 1 - 5 level flood disaster warning system. Source: NHK WORLD News (2019)

Introduction:

Kyushu, meaning nine provinces, is located southwest of the main Japanese island of Honshu, and is Japans third largest island. (Japan-Guide.com, 2019). Figure 1 below is a map of Kyushu island which can be seen in relation to Japans main island Honshu, in the top right.

The flood event:

A weather system known as the "Meiyu front" caused the flooding of the Kyushu Island which occurred late June/ early July of 2019. This system is known to have formed mid to late spring time, continuing through into the summer. The Meiyu front plays a key role in the weather and climate across a large part of Asia, as it brings warm, moist air from the Bay of Bengal and the South Bay of China. The system ended over south Kyushu, which caused intense rainfall. (JBA Risk Management, 2019). It was stated by Ogura. J & Stambaugh. A – CNN (2019), that up to a months' worth of rain fell in just one day. Reports from Japans meteorological survey suggest that up to 1000mm of rain fell in parts of Kyushu Island between the 28th of June and the 3rd of July 2019, and this is was likely to continue over the following days. (The Japan Times, 2019).

In just 24 hours, some locations within the prefectures of Miyazaki, Kumamoto and Kagoshima had reports of over 230mm of rain, and Ebino City, located in the Miyazaki Prefecture – as can be seen in figure 2 below, saw a staggering 381mm of rainfall in just 24 hours (Floodlist, 2019).

The rivers in Miyazaki and Kagoshima in particular were found to have been above the danger level in 8 different locations due to the intense rainfall (Floodlist, 2019).

*Impacts***:**

The flood event had a number of effects on a number of different areas, including the damage to around 60 homes in the Kumomoto and Kagoshima prefectures, and unfortunately, a death in Kagoshima city due to a landslide triggered by the intense rainfall (Floodlist, 2019). It was said that the landslide occurred behind the woman's home. She was vulnerable and in her 70s, and the landslide buried her up to her neck in mud (Japan Times, 2019). Figure 3 is an image of homes buried in floodwaters and mud in the Kumomoto Prefecture. Following a different landslide caused by the heavy downpour, travel between the Kumomoto and Kagoshima train stations was halted by the Kyushu Shinkansen, temporarily cutting off these areas from one another (Japan Times, 2019).In a residential area in Kirishima, three elderly people became stranded by the floodwaters and had to be rescued by boat (Japan Times, 2019).

Responses:

Following the flood events that occurred in July 2018, known as the country's "worst flooding disaster in decades" (BBC, 2019), which left over 200 people

dead in 15 prefectures, a new 5 tier heavy rain disaster warning system was launched this year, as seen in figure 4 below, and put into use (The Straits Times, 2019). A level 5 warning is when the flood itself strikes, level 4 is when evacuation orders are made, and level 3 involves getting residents of the area ready to evacuate in case of the disaster striking. (The Straits Times, 2019). On the 3rd of July, it was stated by Prime Minister Abe, that firefighters, police and the Japanese Coast guard were on high alert, and up to 14,000 initial response personnel of the Self Defence Forces, were ready for rapid deployment, whilst the government were going to maintain high levels of vigilance. Locals were told to "stay alert" and "follow the evacuation advisory to be issued by local governments to take necessary steps in advance in order to save lives" (Floodlist, 2019). Over 1 million people on the island of Kyushu were ordered to evacuate their homes and seek safety – this included the entire populations of Kagoshima city, Aira, and Kirishima, and a further 930,000 on the south of Kyushu Island were advised to leave their homes (BBC, 2019).

Technical Interpretation:

Stationary weather fronts:

The Meiyu front, which is what caused the weather events and flooding of Kyushu Island, is known to be an almost stationary front (Ninomiya, K & Shibagaki, Y, 2007). Stationary fronts occur when either a cold or warm front halts in its movement, and neither of the air masses have the energy to move through one another. Even though they may appear to be stable, air is actually moving around quite a lot higher up within the atmosphere. The weather brought by a stationary front is typically that similar to what a warm front may bring, such as showers and cloudiness, however, they may occasionally provoke much more serious weather events such as heavy showers and thunderstorms, resulting in the flooding of areas, such as Kyushu Island. These more severe weather events are sometimes associated with a powerful belt of strong winds called Derecho winds. (Sciencing, 2019). Figure 5 below is an example of a stationary front, where warm and cold air meet, but do not have the power to overtake one another (not to be confused with an occluded front, where cold air overtakes warm air, figure 6.)

Flooding:

Flooding is an extremely common occurrence throughout the world, and around 72% of the earth's surface is covered with submerged soils and sediments. – No continent, apart from Antarctica is free of flooding (Bozzano, G. Luisa, 2012), and flooding in urban areas has grown to be an inevitable problem in a number of cities worldwide (Ole. M. et al, 2001).

Flooding occurs when land that is usually dry becomes inundated with water, and there are a number of different ways this can happen, such as prolonged or excessive rainfall, climate change – affecting sea level and the melting of glacial ice, and the rupturing of levees and dams. (Nunez, C. 2019). It has been said that "more rain and raging rivers" is "the new norm" in Japan (Martin. A, 2015), and that over the last century, the number of days experiencing heavy rainfall and the number of days experiencing no rainfall at all, has increased, and there has been an increase in the intensity and frequency of extreme weather events, such as heavy rain (WWF, 2008).

Climate change and increased rainfall:

With climate change comes an increased concentration of greenhouses gases in our atmosphere, which consequently increases the amount of downwelling infrared radiation, causing heating at the earth's surface, increasing rates of evaporation, and therefore a much higher atmospheric moisture content. (Trenberth, E.K, 1999) In correspondence with this, weather systems such as thunderstorms and cyclones will have more moisture to feed off of, resulting in much more intense storms.

Flooding of Kyushu Island:

Due to climate change, the island of Kyushu now experiences higher levels of rainfall yearly than it did in the past, providing the perfect recipe to flooding. Generally, flooding occurs when a rivers discharge has reached bank full, and the river spills over and onto the floodplain (CGP, 2009), and as was mentioned earlier, the rivers in Miyazaki and Kagoshima were found to be above danger level, due to this intense rainfall (Floodlist, 2019). Prolonged rainfall also leads to the ground becoming increasingly saturated, meaning that any further rainfall becomes virtually impossible to be infiltrated, increasing amounts of surface runoff on the land, and increasing the amount of discharge running into rivers. (CGP, 2009)

A number of different physical characteristics to an area play a role in the risk of flooding. The amount of vegetation within the drainage basin – the less vegetation there is, the less water gets intercepted by the uptake of water via roots, meaning an increase in surface runoff. Another characteristic is how permeable/impermeable the ground is – more impermeable grounds, such as clay soils, allow less infiltration and do not hold much ground water, leading again to a higher amount of surface water runoff. Steep slopes allow water to run into the river faster than shallow slopes, again increasing discharge entering a river. (CGP, 2009).

Landslides caused by flooding:

One of the impacts of the Kyushu floods of 2019 was landslides, which unfortunately took the life of an elderly woman in Kagoshima.

A landslide is defined by the movement of mass amounts of rock, artificial fill, earth and debris down a slope, under the force of gravity (Recare, 2018). In most cases, landslides are triggered by intense rainfall, and there is a clear relationship between rainfall and landslides in a number of countries. An example of an area in which 90% of all landslides that occur are caused by rainfall is Hong Kong – these occur at least once every two years (Brand, E.W. et al, n.d.). In the case of heavy rainfall such as that that occurred on the island of Kyushu, soil and rock slopes become weakened by saturation, resulting in slope failure (Facts and Details, 2012).

Conclusion:

To begin with, reflecting on the floods that occurred on the island of Kyushu just a year earlier, it seems that a lot more had been done in both preparation and response to the flood event. In the flood that took place in 2018, over 200 people lost their lives in 15 prefectures, and in response to that, a new 5 level warning system was rightly put in place, which resulted in only one reported death – a massive drop from the year previous.

However, one death is one too many, and still, more could have been done to prevent this tragedy. It must be taken into account that this was an elderly person – reflecting back on the 5 level warning system, warning level 3 states that elderly people must evacuate. Clearly, with the nearly 200 less deaths, this warning system is mostly a success, but it must be remembered that not every elderly person is able to just leave – they may not be physically able, have relatives who can help them, or maybe officials didn't carry out the warning system orders correctly in this particular area of Kagoshima city - this woman may have been forgotten.

With a lack of detailed research into the flood that happened a year previously, it would be difficult to compare any more aspects of the 2019 flooding to this, but it is clear that with knowledge of previous events, the government did all they could to stay vigilant and keep locals updated, and they made sure they had response units and the Self Defence Forces on hand ready for rapid deployment when needed. It was wise of them to evacuate over 1 million people, which they may not have done in time if it wasn't for the new 5 level warning system.

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Tropical Cyclone Penny – The Solomon Islands, 2019

Frankie Sheard

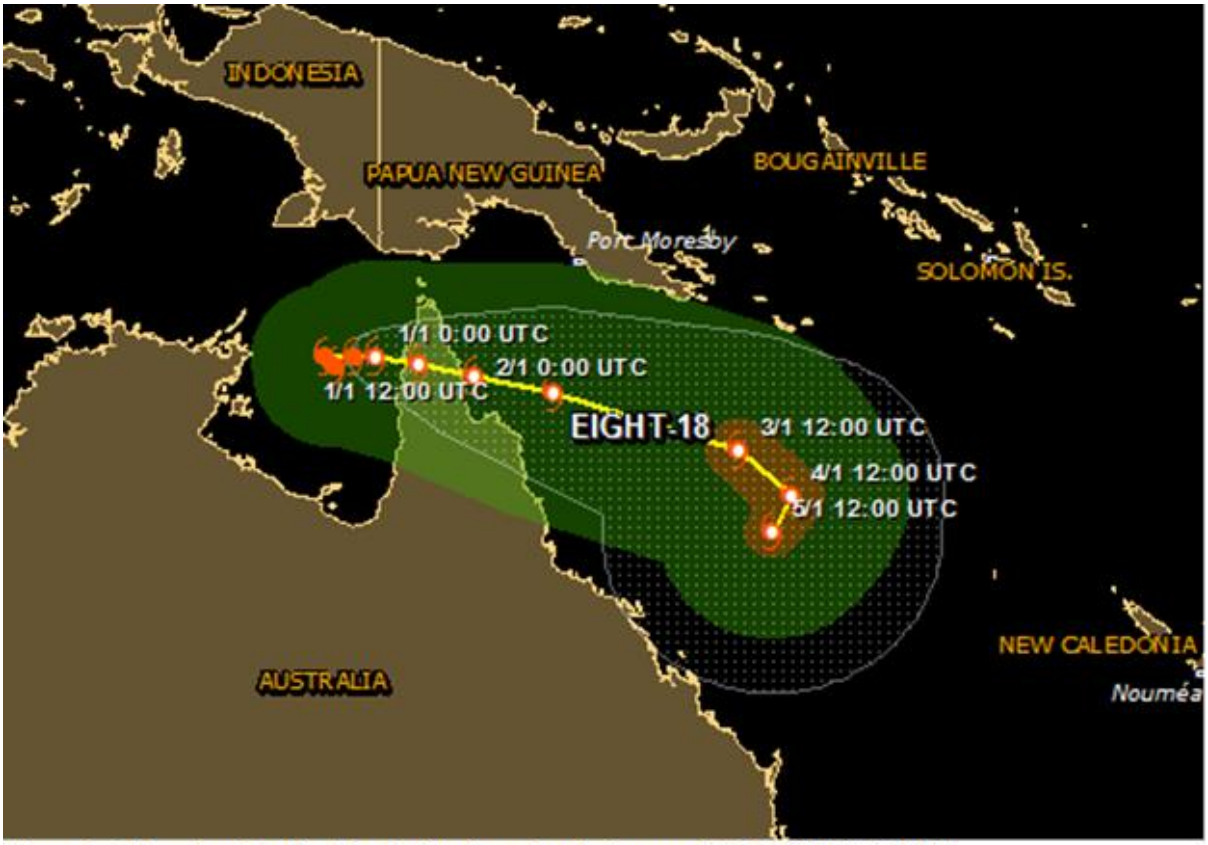


Figure 1 - Map showing the Tropical Cyclone Track. Source: GDACS (GDACS, 2019)

Account of the Event

Tropical cyclones are storm events that form when there are specific conditions that create a tropical low-pressure weather system (Vatrotos, Krapivin & Soldatov, 2019), the warm body of water and air causes air to rise due to the pressure difference; the pressure difference causes rotation of the evaporated water and air which picks up more speed and winds are generated (Stillman, 2014). Cyclones affect more than 50 countries and approximately half of the world's populations, with their strong winds, intense rainfall and flooding (Vatrotos, Krapivin & Soldatov, 2019).

One such cyclone event that caused damage to thousands of people was included Storm Penny. Tropical Cyclone Penny was a storm event that strengthens into a tropical storm in late December 2018, and lasted 3 days, affecting the Pacific Ocean Islands with heavy rainfall, severe flooding and related diseases from the standing water that resulted (Gutro, 2019). The affected islands included The Solomon Islands and Fiji (IFRC, 2019), as well as Australia and Papua New Guinea.

On 27th December 2018, the Pacific Islands began to experience high levels of rain (Floodlist News, 2019), by the 29th December the tropical cyclone was tracked by both the Fiji Meteorological Services and the Solomon Islands Meteorological Services (SIMS), and identified a tropical disturbance located 926km east of the Solomon Islands and announced an early warning so that the islands could prepare (IFRC, 2019). Their predictions for preparation included strong winds and heavy rainfall resulting in flash flooding.

The Solomon Islands is a country that is made up of over 900 small islands, 6 of which are the major ones, with a population of around 550,000 (The Commonwealth, 2005). Many of the inhabitants of the Solomon Islands travel between the islands in small handmade boats which makes the people and economy vulnerable when access between islands is limited.

The impacts of the storm were strong winds and heavy rain, which resulted in flash flooding that affected several islands that make up the Solomon Islands and islands of Fiji. In total, the Floodlist News (2019) said that over 22,000 people were affected by

the flooding that was the result of Tropical Cyclone Penny. The ECHO daily flash from the European Commission, announced that the Solomon Islands' Red Cross Society reported 827 people being affected with 174 homes destroyed on 5th January 2019. (European Civil Protection and Humanitarian Aid Operations, 2019). By 6th January 2019, the National Emergency Operations Centre (NEOC) estimated that 23,708 people and 4,480 households had been affected (Floodlist News, 2019). The Global Disaster Alert and Coordination System (GDACS) predicted that Tropical Cyclone Penny to have a GDACS score of 0.5 on a green alert, and that it would have a low humanitarian score as there were no people in an area of a Category 1 or higher cyclone (GDACS, 2019).

The weather station located in Honiara, the capital city of the Solomon Islands, recorded 350mm of rain over a time frame of 3 days from 27th December 2018 (Floodlist News, 2019). The average precipitation for the months of December and January is between 235-280mm over 20 days in the month (Climates to Travel, n.d.). These figures show how the precipitation associated with Tropical Cyclone Penny led to some areas of the Solomon Islands being flooded continuously for 6 days straight (Floodlist News, 2019); for the islands of Malaita and Guadalcanal, the heavy rainfall caused rivers to burst their banks and flood villages located nearby.

Although the Solomon Island Government announced that no external support was needed (European Civil Protection and Humanitarian Aid Operations, 2019), the Disaster Management Office did require the distribution of food supplies, health and sanitation packs, as the flooding created a risk of water and mosquito borne diseases and to support the evacuations that took place in Honiara (Floodlist News, 2019). Tropical Cyclone Penny travelled along its path south towards Queensland, in the north west of Australia, this path can be seen in Figure 2 . The Australian Bureau of Meteorology (BOM) released warnings of heavy rainfall and flooding, particularly to the coastal towns (GDACS, 2019). On making land in Australia, Tropical Cyclone Penny resulted in intense rainfall and flooding, which resulted in one woman missing and one man having lost his life (The Guardian, 2019).

Technical Interpretation of Tropical Cyclones in the Solomon Islands

The Solomon Islands is a nation that experiences tropical cyclones frequently (Maru, Shibata & Ito, 2018). Scientists have found that in recent years, rising sea temperatures have resulted in the increased frequency on tropical cyclones that have been taking place over the Pacific Islands. The location of the Solomon Islands means that it experiences the trade winds from the southern hemisphere, these trade winds generate waves that swell from tropical storms (Australian Government & Australian Aid, 2014). Climate data on the Solomon Islands has shown an increase in temperature at night and the frequency of cooler days and nights have reduced. This data reflects the global trends that are being a result of climate change. Cyclone season in the Solomon Islands is between the months of November and April, with 29 cyclones per decade being experienced (Australian Government & Australian Aid, 2014). In more recent years, 27% of the cyclones that occurred between 1981-82 and 2010-11 seasons were classed at Category 3 or higher tropical storms (Australian Government & Australian Aid, 2014). The Solomon Islands' poor economy means that it is reliant on external organisations, bodies and National Government Organisations (NGO) in the provision of aid and guidance regarding disaster resilience activities, such as the facilitating community-led disaster evacuation simulations and the prevention of disease amongst many others (Reid, 2018).

The Solomon Islands, due to its location experience several tropical low-pressure systems yearly, these mostly occur when there is an equatorial trough (Solomon Islands Government, 2015). With the Solomon Islands being in the middle of the Pacific Ocean, for the most part, tropical cyclones that affect the country are normally in their early stages of development, and therefore have a smaller impact compared to other countries. Normally, within one year the Solomon Islands experience between 1 and 2 cyclones, with the damage to the country being caused through the strong winds to infrastructure, crops and the water supply (Solomon Island Government, 2015). Other risks include the associated flooding that can negatively damage the livelihoods of residents due to damage to the crops and businesses. This makes Tropical Cyclone Penny be at a level of destruction that is not uncommon to the Solomon Islands. The damage of Cyclone Penny was mostly disruption and displacement, without loss of life, therefore this tropical cyclone was a relatively small natural disaster but had a high cost to a less developed country where they are less financially able to recover.

Natural Hazards and the Solomon Islands

The Solomon Islands are in an area of the world where there are several natural hazards experienced frequently, which means that the country is economically vulnerable to the high volume of hazards where the economy is heavily reliant on the agricultural industry (GDFRR, 2016b). In recognition of the Solomon Islands vulnerability, the United Nations as part of the Sustainable Development Goals and the Committee for Development, created a Vulnerability Profile for the Solomon Islands. This profile outlined that the Solomon Islands have been affected by 71 natural disasters in the part 90 years (as of March 2018) and affected more than 430,000 inhabitants (UN Committee for Development, 2018).

These statistics do, however, highlight that earthquakes have been the most detrimental to the country, followed by flooding (UN Committee for Development, 2018). Therefore, although the tropical cyclones that affect the Solomon Islands may not have the most impact, when experiencing cyclones on top of other disasters, greater pressure is put on the country as a whole.

Vulnerability, Responses and Adaptability of the Solomon Islands

The vulnerability and response of the Solomon Islands to Tropical Cyclones

The Solomon Islands are made up of hundreds of small islands that are scattered, and the residents travel between them for work and supplies using their handmade boats (Maru, Shibata & Ito, 2018). As a result, these factors leave the Solomon Islands vulnerable to the effects of tropical cyclones when access to nearby islands become limited. The islands consist mostly of rural areas with approximately 80% of the population living in these areas (GFDRR, 2016a), the industry of the Solomon Islands mainly consists of agriculture of items including timber, fish, cocoa and palm oil (GFDRR, 2016a). This makes the country vulnerable as a tropical cyclone can severely impact productivity with little financial alternatives to support farmers when this happens.

There are many concerns in the Solomon Islands related to land degradation and deforestation, which are exacerbated by impacts of tropical cyclones. Weakened soils are vulnerable to erosion by the flood waters that form as a result of the high precipitation levels during a tropical cyclone event (GFDRR, 2016a). Flooding and high-water levels also impact the Solomon Islands populations more than other countries, due to high poverty rates and a large majority of the population living within 1.5 kilometres of the coastlines (GFDRR, 2016a). The overall rising sea levels that are associated with climate change also contributes to the detrimental impact on agriculture, which in turn leads to widespread malnutrition and loss of income as 75% of the population are involved in the agricultural and farming industry (Reid, 2018). Further concerns are related to the effects of climate change which result in warming of ocean temperatures, which contributes to the increased frequency of tropical cyclones forming (Centre for Climate and Energy Solutions, 2017). Climate change and the changes to the thermodynamics in the atmosphere in accordance with the climate models (Knutson & Tuleya, 2004; Oouchi, 2006) suggests that there will be an increased frequency of cyclones that are classed in the upper limits of the cyclone intensities (Knutson, McBridge, et al; 2010). Which means that the cyclones that occur have the potential to be more severe and cause higher damage and impacts on communities globally and in the Solomon Islands.

The Solomon Islands is a country that is vulnerable to a range of natural hazards, including cyclones, they Islands are predicted to have losses of $20 million on average per year from the damages from cyclones and earthquakes alone (GDFR, 2016b). The economy of the Solomon Islands makes it one of the poorest countries in the Pacific, with the frequent natural disasters resulting in a vicious cycle of the economy struggling to cope with the financial pressures (Reid, 2018). For the Solomon Government to become more resistant to the inevitable effects of cyclones and natural disasters, more financial investment needs to be applied to research and monitoring, whilst adapting infrastructure to be more resistant to cyclone damage. The Solomon Islands Governments made efforts to improve their resilience to natural hazards, with the goal of reducing the risk of natural hazards and climate change through creating a National Disaster Risk Management Plan (GDRFF, 2016b). The plan is designed to identify the risks to the country in terms of climate change and increased frequency of natural hazards, through mitigating the effects and distributing information on the risks, as well as improving the emergency communications and monitoring (GDFRR, 2016b).

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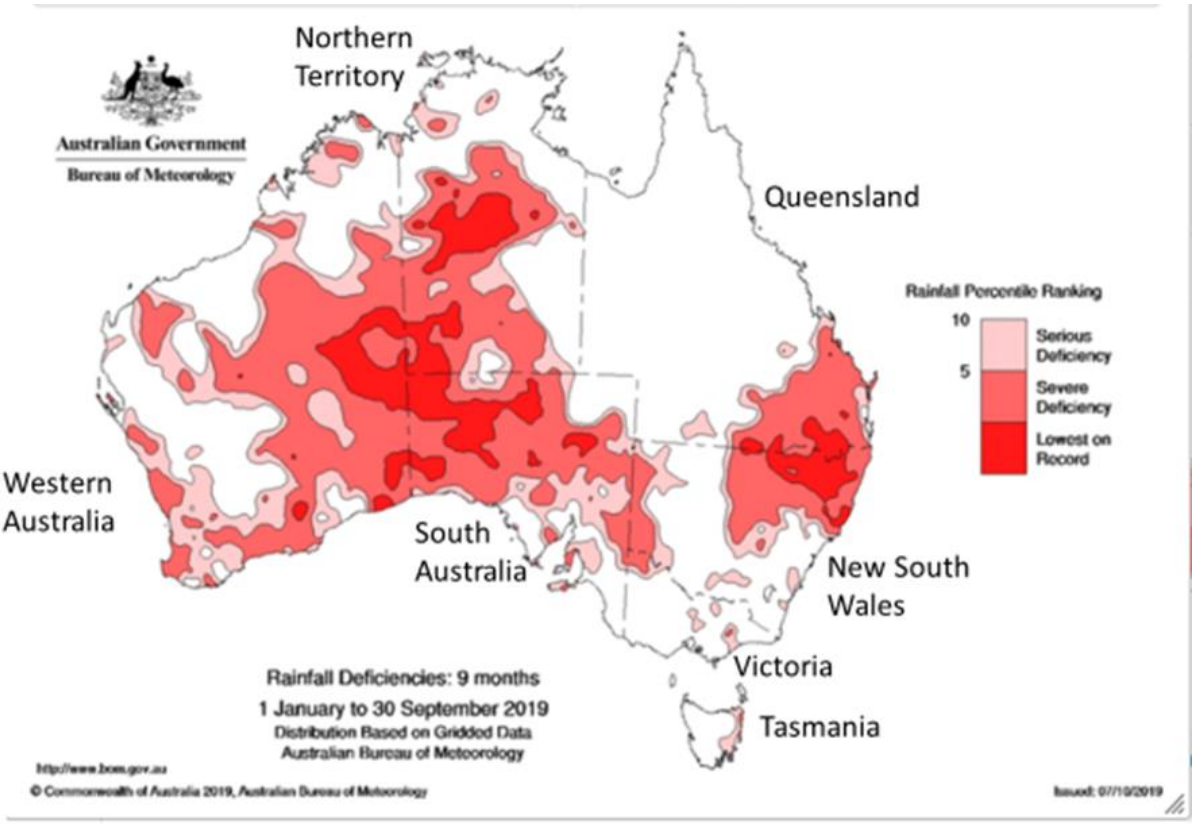
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Drought in Australia, update for September 2019

Evie Whattam



Authoritative account

Overview of September 2019 drought, Australia

Drought and the effects can be classified into hydrological, meteorological, agricultural and socioeconomic [Mishra & Singh; Thomas cited Van Dijk, Beck, Crosbie, de jeu, Liu, Podger, Timbal & Viney, 2013). This chapter emphasises meteorological drought involving prolonged rain deficit caused by climatic parameter's ; hydrological drought concentrating on reduced rainfall relating to diminished waterflow, increasing water scarcity creating socio- economic difficulties; and the agricultural element comprising of reduced soil moisture and the ripple effects, (National Drought Mitigation Centre: University of Nebraska, 2019).

Locations of drought in Australia

The Australian Government Bureau of Meteorology (BoM) characterised drought as rainfall deficits for a duration of three months or more below the 10th percentile on record, (Australian Government Bureau of Meteorology (BoM), 2006). Australia has experienced prolonged drought into September 2019. Areas subject include large amounts of New South Wales (NSW) except coastal regions; vast parts of Queensland excluding some South western areas, the northern Peninsula and the Gulf Coast, most of Victoria except Gippsland and expanses in the South West; proportions of Tasmania; the Northern Territory; the Southern part of Western Australia; and large quantities of the west, east and north of South Australia, (Australian Government: BoM, 2019a). Figure 1 below displays these regions of Australia that experienced rainfall deficit for September, (Australian Government: BoM, 2019 a).

Context of the September 2019 meteorological drought:

Drought for many regions of Australia has been ongoing since 2017, including NSW, Queensland and South Australian zones of the Murray- Darling Basin (MDB), (Australia Government: BoM, 2019 a). Drought has been severe in the north zones of the MDB, Northern parts of NSW and southern Queensland. The first nine months of 2019 alone, rainfall deficiencies increased in south east Queensland, north eastern NSW, farming areas of South Australia, the south coast of Western Australia and the South West Land division, (Australia Government: BoM, 2019a). Figure 2 shows the areas that experienced rainfall deficits from January 1st, 2019 to September 30th, 2019, (Australia Government: BoM, 2019a). Ongoing rain deficit has been exacerbated by a high diurnal temperature range that is associated with absence of cloud cover

promoting sun exposure, low humidity and a soil moisture reducing latent heat capacity. For September, the nation experienced the 9th lowest record of rainfall and a national mean temperature of 1.19 degrees Celsius (°C) above the average, (Australia Government: Bureau of Meteorology (BoM), 2019b)

Furthermore, September 2019 soil moisture deciles in the root zone remained below average for much of Australia as seen in figure 3. Dry soils have been influential in extending dry period to September, (Australia Government: Bureau of Meteorology (BoM), 2019c). As seen in figure 3, soil moisture continued to be extremely low in the Murray- Darling Basin that spans 77, 000 km from Queensland, to NSW also to the Australian capital territory, then into Victoria and into South Australia, (Australia Government: BoM, 2019c & Australia Government: Murray Darling Basin Authority, 2019).

Hydrological drought overview:

This drought has been one of the most severe on record for Australia causing water shortages in Southern Queensland and a large proportion of NSW. This has resulted in some dams within western NSW drying out amplified by low rainfall levels in the early winter months recorded in the lowest 10% (Davies, Smee & Allam, 2019).

Record-low levels recorded in rainfall has dramatically reduced water supply within the MDB, (Australia Government: BoM, 2019a). The parched soils absorbed a large proportion of the little rainfall there in September resulting in inadequate runoff and few inflows (Australian Government BoM, 2019a & Australian Government Bureau of Meteorology (BoM), 2019d). By end of September 2019 the main storages for the north basin were 8% of capacity representing 0.5% reduction from August. Figure 4 shows low water storage for major towns along the basin, (Australian Government BoM, 2019d).

Pre-summer 2018 saw the mass death of fish in the lower part of the basin due to low river flows caused by drought conditions, high temperatures and over-extraction of water (Davies, Smee & Allam, 2019 & Cox, 2019). Resulting, in September 2019, with the NSW government introducing a $10 million rescue package to relocate fish and mitigate drought implications, (Davies, 2019).

Hydrological drought, New South wales:

Moreover, lack of water availability has been considerable for NSW. Substantial proportions of the Macquarie River dried out and water storage for the Macquarie valley were at 11% on 6th September. In Namoi to the North East of the state, the storage was at 1.5% and the Sydney, Warrangamba Dam storage was below 50% for the first time in more than 10 years (Cox, 2019 & The University of Sydney, 2019). Additionally, water supplies for some towns including Dubbo and Tamworth as Cobar, Nyngan and Manilla were reduced,(WaterNSW, 2019). Figure 5 shows the locations of the river, dams and towns mentioned, (Google, 2019a)

Prolonged drought into September resulted in NSW's north-western towns including Dubbo, Armidale and Tamworth being projected to run out of drinking water by 2020. Consequently, the government has provided local councils with day zero dates in relation to no water, (Barrett, 2019). Figure 6 shows the towns dubbed for day zero, (Google, 2019b)

For the town of Dubbo with a population of 40,000, on 14th September 2019, the Burrendong dam located on the Macquarie river was at 4.5% of its total capacity and was still falling due to high temperatures in this area. This is having colossal economic implications for Dubbo as water shortages have meant crops are unable to flourish and as result a reduction in the sale of stock, (Davies, Smee & Allam, 2019). This farming economic crisis is not unique to this town as the central bank announced the drought is stunting Australia's economic growth. Farm production is set to reduce by 5% to A$59 by 2020 stated by (ABARES cited in Barrett, 2019). Additionally, farmers have been paying double for transition drinking water to their farms particularly in NSW, (Barrett, 2019).

Dubbo council has been preparing to release plans to extend dates of day zero by drilling underground to tap reservoirs, (Barrett, 2019). Bores are to be sunk underground in a $30m governmental program, however there are concerns over whether adequate quality and quantity of water will be attained, (Davies, Smee & Allam, 2019).

For north-eastern areas of NSW and southeast coastal areas of Queensland, September has had the highest Forest Fire Danger Index (FFDI) value for 2019. Fire danger ratings have been inevitable with drought conditions apparent. On 6th September, strong west-north westerly winds created disastrous fire conditions in the Granite Belt districts of Queensland and the Maranoa, Warrego and Darling Downs as well as North Eastern areas of NSW, (Australia Government Bureau of Meteorology (BoM), 2019e). Figure 7 shows the wildfire location risks.

Technical interpretation of the event related to climate variability

Australia's climate is variable temporally and spatially with high interdecadal variability (Gallant et al. 2007 cited in Cai, Purich, Cowan, Van Rensch, & Weller, 2014). Australian annual climate change, particularly rainfall patterns are primarily associated to the Indian Ocean Dipole (IOD) and El Nino and La Nino cycles in the Pacific Ocean, (Nicholls et al ; Ashok et al; Hendon et al; Risbey; Ummenhofer cited in Cai, Purich, Cowan, Van Rensch, & Weller, 2014 & Australia Government Bureau of Meteorology (BoM), 2018).

IOD involves prolonged changes in the difference between surface sea temperatures in the eastern Indian ocean and the tropical western Ocean, apparent during the winter months. Such phenomenon has three phases; positive negative and neutral, (Australia Government Bureau of Meteorology (BoM), 2019f). Positive IOD is associated with Australian drought conditions as wind patterns change allowing a temperature gradient across the tropical Indian ocean seeing warmer waters in the west and cooler in the east. This results in less atmospheric moisture for northwest Australia. This varies the weather system track to the West of Australia leading to higher temperatures for two thirds of southern Australia and reduced rainfall in winter and spring for south eastern and central Australia, (Australia Government BoM, 2019f).

El Nino and La Nina are part of a natural phenomenon called the El Nino- southern Oscillation (ENSO). Australian El Nino is associated to drought meaning limited rainfall, hotter temperatures, an alteration in extreme temperatures, less tropical cyclones, delayed monsoon onset and a rise in bush fires for southeast Australia, (Australia Government Bureau of Meteorology (BoM), 2014).

Climate change and natural climate variability:

The warming trend associated to climate change has increased average air temperatures and amplified natural drivers, explaining drought, (Australia Government BoM, 2018). Since 1910, Australia has warmed by approximately 1 °C with most warming since 1950, (Australia Government BoM, 2018 & Chiew, Hughes, Newton, Schuster, Tait, & Whetton, 2014). Figure 8 shows the rise in Australian air temperature since 1910, (Australia Government BoM, 2018). Temperature growth means an increase in intense heat incidents and increased drought situations throughout low rainfall events, (Australia Government BoM, 2018). Since 2005, Australia has encountered 8 out of 10 of the hottest years recorded, (Australia Government BoM, 2018). Low rainfall events associated to climate change are apparent with changes in seasonal rainfall, for example reduced cool season rainfall in Southern Australia and increased warm season rainfall for Northern Australia, (Stemp-Morlock, 2007 & Climate Council, 2018).

The warming has resulted in an increase in the frequency and intensity of El Nina over La Nina events for the nation., (Stemp-Morlock, 2007). Research supports this trend for positive IOD phases as temperatures continue rising reducing rainfall for South Eastern Australia, (Australia Government, BoM, 2019f). Australia is distinctively vulnerable to climate change due to the proportion of small land mass to ocean and as a result El Nino and IOD events as sea surface temperatures are more intense. Also, South Eastern states for examples NSW, drought conditions are exacerbated by increased urbanised water extraction, (Stemp-Morlock, 2007).

Climate change and the Millennium drought:

Evidential fluctuations in natural climate variability relating to climate change can be seen with the Millennium drought that impacted eastern Australia from 1996 to 2009, (Stemp-Morlock, 2007). Anomalies in precipitation were associated with natural sea surface temperature (SST) forcing in close connection to EL Nino. Causing two thirds of deficits for eastern Australia. Climate change may exacerbate deficits further with subtropical drying and storm track shifts poleward and intensified surface drying from increased evaporative demand, (Stemp-Morlock, 2007).

Climate variability and prolonged drought:

For 2018-2019 Australia's climate has been influenced by a positive Indian Ocean Dipole (IOD) exercising drying influence. The continued IOD is unusual for Australia with the last continuous positive IOD's seen in 1982-1983 according to BoM. This is most likely due to the influence of climate change and its asserting influence on air and SST. For 2017, there was not a positive IOD, however conditions Indian Ocean conditions still meant limited rainfall for Australia. In association, humidity has been low exacerbating potential evaporation. Also, in terms of ENSO, conditions were neutral exerting little change on global and Australian climate, although a La Nina cycle is needed to break such an intense drought, (Australia Government, BoM, 2019e).

Climate variability update September 2019:

For the 17th September 2019, ENSO remained neutral for Australia however IOD continued controlling Australia's climate. A moderate to strong positive IOD remained distinguished by warm waters to the west and cooler water northwest of Australia. The IOD index was above threshold mainly from August-September, however the SST and cloud patterns portrayed positive IOD traits since May causing drought conditions. International climate models assessed by the Bureau suggest the positive IOD will continue in spring for the southern hemisphere but naturally breakdown during early summer, (Australian Government Bureau of Meteorology (BoM), 2019g). ENSO however remains neutral in the tropical pacific exerting little influence, (Australian Government BoM, 2019g). A negative Southern Annual Mode (SAM) is expected develop during spring intensifying warm and dry conditions over eastern Australia and wet conditions for Tasmania, (Australian Government: Department of Agriculture (ABARES), 2019). A negative SAM involves the equatorward growth of the belt of potent westerly winds. An alteration in such winds creates low pressure and storm systems for Southern Australia (Australian Government Bureau of Meteorology (BoM), 2019h).

Concluding section:

Assessing Australia's vulnerability:

Physically, Australia is vulnerable to drought as 70% of landmass is distinguished as arid, rainfall varies more temporally and spatially in comparison to other countries (Nicholls et al cited in Chiew et al 2014). Climate change is intensifying natural climate cycles as seen, (Chiew et al 2014). Such constraints aggravated by the social- economic factors, including urbanisation and population increase (ABS, 2008, 2013 cited in Chiew et al 2014) also increase in over 65's, (ABS; SNZ, cited in Chiew et al 2014) which has been event in South Eastern Australia.

Policy addressing drought vulnerability:

Previously drought and water management were inefficient, (Edwards et al cited in Kiem, 2013). Consequently, strategies have been altered and drought scale and water policy has been addressed by debate and numerous revisions in relation to the MDB plan involving the distribution of water between a combination of stakeholders, (Murray- Darling Basin Authority cited in Kiem, 2013).

However, plans may be inadequate for farming communities with changes in farm expansion and trade, a growth in the uncertainty of crop selection and investment and reduction in farm succession. These are due to combined failures in policy decisions, agricultural markets, trade and the drying environment, (Kiem, 2013). Evidence of this in relation to drought can be seen with a recent stock sale decrease and importation of water for NSW previously mentioned, (Davies, Smee & Allam, 2019 & Barrett, 2010)

Future risks from droughts:

As expressed, Australia is experiencing climate change impacts on current weather systems, with projections suggesting drought events are likely to be amplified in the future for southern Australia, (Climate Council, 2018). Resulting in increased water scarcity for agriculture, the urban environment as seen in Dubbo and ecosystems in southern Australia. In conjunction, policy concerned with short-term drought is expected to be impractical without the mitigation of climate change questioning the countries preparedness, (Climate Council, 2018).

Previously seen, the Millennium drought that associated with climate change experienced severe conditions in the MDB where river systems and ecosystems as well as dryland agriculture were affected [Leblanc et al cited Van Dijk et, 2013). Socio-economically, drought created water restrictions, electricity price growth and bushfires seen in 2003 and 2009 are likely to continue as policy efficiency and drought episodes worsen for much of Eastern Australia, (Van Dijk et al 2013).

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Indonesian Tsunami December 2018

Matthew Smith

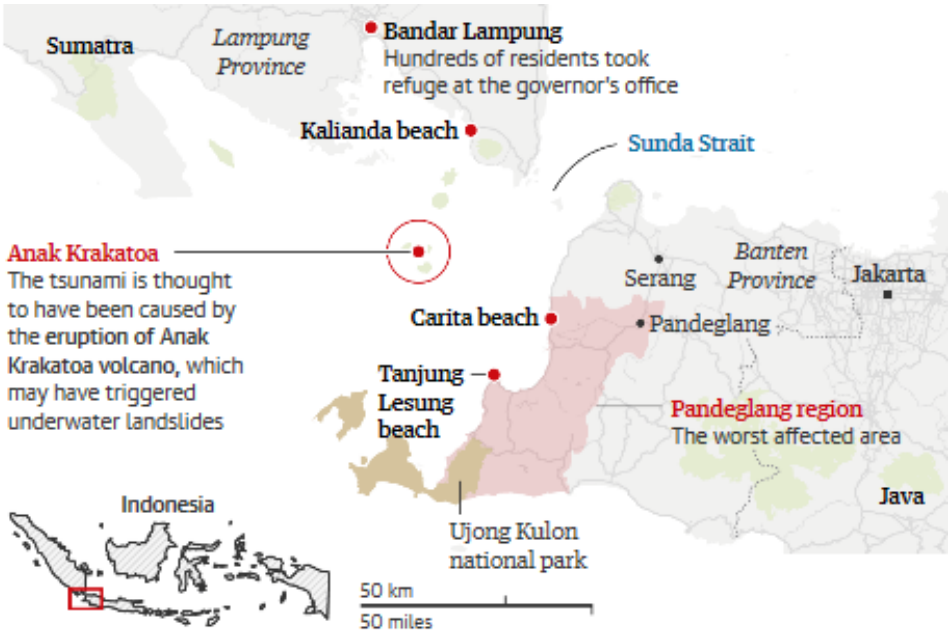


Figure 1 Map showing Anak Krakatoa where the tsunami originated (Martin and Zhou,2018a)

Authoritative Account

Background

Indonesia is located in the southeast of Asia with the Indian and Pacific Ocean lying either side of it. Figure 1 shows a map of Indonesia and highlights the area which has been impacted by the recent tsunami event. The country is made up of 17,508 islands which makes it the largest archipelago in the world. There are 5 major islands and about 30 smaller groups (Embassyofindonesia.org, 2019). Therefore, the country has 54,716 kilometres of coastline (Hays,2019). A large amount of this land is low lying and not much higher than sea level which makes it vulnerable to high tide and especially vulnerable if a tsunami was to occur. Indonesia sits on the ring of fire which is prone to earthquakes, volcanic eruptions and tsunamis (Zhou, 2019). A lot of this low-lying land is used for agriculture with approximately 90% of Indonesia's population engaged in it. This agriculture along with increasing tourist popularity has led to a steady rising economy since the early 2000's and in 2018 the GDP per capita amounted to 3,870.56 U.S. dollars ("Indonesia - Gross domestic product (GDP) per capita 2024 | Statista", 2019).

However, this isn't a true reflection of Indonesia with most of the wealth staying at the top. Out of the population of around 264million, about 25.9 million of these people are still currently below the poverty line and from data collected in March 2018 approximately 20.19% of the population is vulnerable to falling into poverty ("Overview", 2019). Therefore, meaning that a large majority of the population live in regions with inadequate infrastructure to cope with any form of disaster.To achieve a factual account of this event, the grey literature used consisted of non-governmental organisations and international newspapers were found by inputting 'Indonesia, tsunami, December 2018' into the search engine of google. This helped find key sources which were mainly found via relief web.

Event

On the 22nd December 2018 a large chunk of the Anak Krakatoa volcanic island collapsed into the ocean, causing a tsunami that swept across Indonesia's Sunda Strait (United Nations OOSA, 2019). At 21:27 hours local time the coast around the Sunda Strait and Carita Beach in the Bantem province in Indonesia were hit with a tsunami. The tsunami has been recorded four times in four different locations with its height ranging between 30 and 90 centimetres. The highest wave which stood at 90cm hit the Serang Subdistrict which is a part of the Sunda Strait (International Federation of Red Cross and Red Crescent Societies, 2018). The event was made worse by the fact that there was no warning for people that a tsunami was on its way. This is because the detectors that they have available are for earthquakes and there wasn't an earthquake prior to the event due to the way it occurred. Therefore, the sirens didn't go off. A 56-year-old local described his version of events; "I

didn't see the waves, I just heard a sound: 'Uuuuuuurg'. There was no sign of it coming, and I fell. Stalls were swept away, people were running, the water chased me" (Fullerton, 2018). Another local Azki Kurniawan, 16, said he was undergoing vocational training with a group of 30 other students at Patra Comfort Hotel when people when "Suddenly a one-metre (3.3-foot) wave hit me, I was afraid I would die." He said (Ellis-Petersen, Perraudin and Farrer, 2019). This showing that there was no time for the locals to prepare for the event and that they were let down by a lack of equipment and preparation from the government so that people could have been aware of the incoming tsunami.

Indonesia was not the only place to be hit by the tsunami as a Sri Lanka has also been affected. On the 24th December 2018 it was reported that in Indonesia alone 281 people had been killed, 1016 people injured, 57 people missing, and 11700 people had been displaced (OCHA, 2018a). Kathy Mueller from the International Federation of the Red Cross predicted that "The situation, and death toll, will remain fluid over the next days and even weeks" (Martin & Zhou, 2018b). This was proved to be correct as on the 28th December 2018 these numbers had increased with the number of fatalities now at 426, the number of injuries had also increased to 7702 people with 40386 people displaced by the tsunami (OCHA, 2018b). based on the official statistics the final report from BNPB the tsunami caused 437 deaths, 14059 injuries and 16 are still missing. The amount of people displaced has gone down to 16198 people. In terms of damages the final reports are that 1614 houses are severely damaged, 527 houses partly damaged and 97 houses lightly damaged. These figures include 97 hotels. In addition, 510 boats have been severely damaged (International Federation of Red Cross and Red Crescent Societies, 2018a).

Response and Potential Impacts

The international medical corps is working with a local aid organization to provide emergency healthcare through mobile medical clinics in the Banten Province. They were also waiting on the government of Indonesia's request to deploy health personal, additional staff or medical relief materials if necessary ("Indonesia Tsunami December 2018 | International Medical Corps", 2019).There are also support workers from An immediate response to the tsunami was made harder due to the flooding and heavy rainfall at the time the tsunami occurred. The impacts that the tsunami has had on the affected areas is that key roads and access routes to the coastal areas are flooded or damaged from the high volume of water. This is highly significant as any sort of aid or response is restricted due to certain areas being inaccessible. The damage caused to buildings means that peoples basic needs of shelter is not being met. Therefore, temporary shelter is a priority. As well as this food and clean water will be required to be provided as it is more than likely that this is of short supply due to the damages the water has caused to houses and other buildings. A potential impact of not having clean, fresh water readily available to drink is that there is possibility for diseases, such as cholera and diarrhoea, caused by contaminated water. Therefore, it is essential that clean water is also provided as the spread of disease could become a whole new disaster. The rebuilding of the affected areas in Indonesia are going to be a long and difficult process. This is going to be enhanced by the resources which the country possesses. As already stated, Indonesia is a poor country and is going to have to rely heavily on donations and charities such as the red cross and the international medical corps to recover from this disaster.

Technical Assessment

Regularity of Tsunamis in this region?

Indonesia is located at the junction of four major lithospheric plates: Eurasia, Indo-Australia, the Pacific, and the Philippine plates whose inter plate fault zones exhibit volcanism and frequent earthquakes (Hamilton, 1979). In the west of Indonesia where this has occurred the oceanic lithosphere of the Indo-Australian plate subducts beneath the Eurasian plate which forms a convergent plate boundary (Brune et al., 2010). A convergent plate boundary is where 2 plates come together resulting in one of the plates going underneath the other in a process called subduction. The older plate is more likely to subduct due to its greater density and the impact of gravity. As the subducting plate, which in this case is the Indo-Australian plate, is forced deeper towards the mantle it begins to melt. As a result of the melting, magma chambers are produced (King, 2019). On this plate boundary a chain of volcanoes has formed with Krakatoa being one of them.

What Caused the Tsunami?

This makes the area vulnerable to events like this due to its location near to the convergent plate boundary. The cause of this tsunami is most likely to have been caused by undersea landslides from the collapse of a volcanic chamber. This would have been caused by the ongoing eruption of Anak Krakatau volcano which is in the Sunda Strait. The volcano in question for causing the Tsunami had been undergoing a stuttering eruption since the 18th June 2018. Tsunamis that have been generated by volcanic eruptions have caused about 25% of all deaths associated with volcano activity which suggests that the tsunami which is a biproduct of the volcano is the most dangerous to human life (Prasetya, 1998). Assumptions have been made that the cause of the tsunami was volcanic activity, like the movement of magma underground or the collapse of volcanic chambers which have formed from the melting of the Indo-Austrailian plate into the

mantle. Prior to the event regular earthquake frequency waves were not detected. However low frequency signals were detected which support the assumption an underwater landslide triggered by volcanic activity was the cause of the tsunami (Wei-Haas, 2019).

The collapse of a volcanic chamber causes the landslide resulting in a tsunami due to the water surface displacement. The water will drop to fill the crater that has been left from the collapse. This changes the level of pressure in the water and as the water surface realigns itself the water level rises once more as it evens itself out. This shift in water depth creates waves going from the point of the surface above the collapse. The first wave created is the largest and this is followed by multiple smaller waves (Paris, 2015). Figure 3 shows where the volcano erupted and where the landslides will have occurred making this the point at where the tsunami first formed.

Comparison to a past event

However, this is not the first time that this volcano has caused a tsunami in the region. In 1883 one of the deadliest eruptions of modern-day history occurred. It was estimated that the resulting tsunami caused more than 36,000 deaths. This eruption affected climate and caused temperatures to drop all over the world. (Bagley, 2019) This event does have similarities to the December 2018 Tsunami in the way that it occurred as a result of an underwater volcano due to the subduction of the indo-Australian tectonic plate as it moves north towards mainland Asia. Even though both tsunamis were caused by the same volcano, what caused the wave was different. The most recent tsunami was caused by the collapse of a volcanic chamber. However, in 1883 it has been concluded that after using numerical simulations to investigate three major mechanisms for tsunami generation; caldera collapse, phreatomagnetic explosion and pyroclastic flow, that a high quantity of pyroclastic flow entering the sea is the most plausible mechanism of the 1883 Krakatoa tsunami (Maeno and Imamura, 2011). Therefore, showing that different mechanisms resulted in each of the tsunamis.

Conclusion

The response to the event from the medical corps and red cross foundation were successful as they got to the affected areas as quickly as possible in the search for the dead and injured. Without there help the number of fatalities would have been higher than the 437 deaths reported. The donations from foreign countries have helped with the rebuild. One of the largest donations has come from CAFOD who joined forces with the Disaster Emergency Committee by raising £23 million from UK donations alone (Cafod.org.uk, 2019). This money goes towards food, clear up of debris and shelter. This enabled the response to start almost immediately after the event. However compared to if this event was to occur in a more developed country, as already stated a high amount of Indonesians are poor with a poor infrastructure, the overall amount of damage would be less and the response would be more effective due to the better equipment the more developed countries have. Also, the damage would be on a smaller scale as the housing would be able to withstand the water more due to its higher quality. Indonesia are still vulnerable to tsunami events like this because of its location and the tectonic activity surrounding it. Indonesia also has a lot of low-lying land which is used for its agriculture which has been previously stated means that the water can flow more freely with little resistance than it can in other countries and cause damage on a wider scale. Also, the Anak Krakatoa volcano that triggered this tsunami is still active meaning that another could be caused at any time. Another tsunami would have a more devastating effect now due to the damage that is still present. Therefore, Indonesia is still vulnerable to tsunamis and is not in a strong place to prepare for another disaster as it is still in a process of recovery.

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Indonesia Earthquake - April 2019

Jagoda Sokolowska

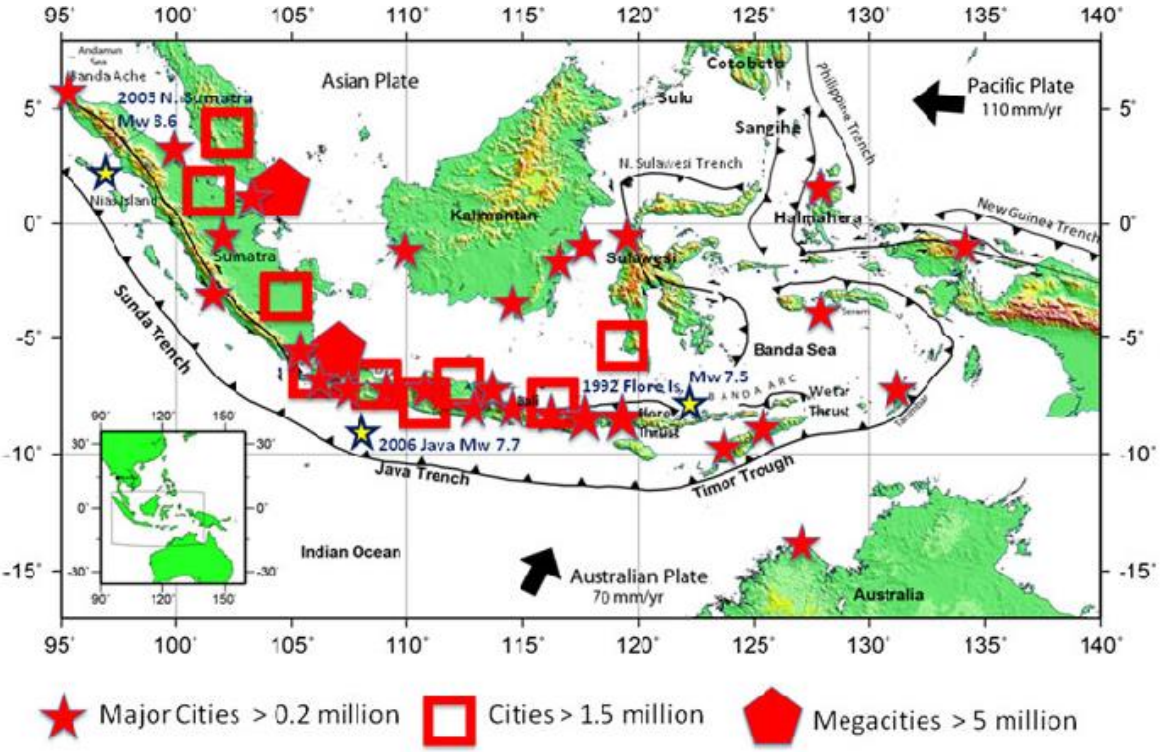


Figure 2 – Placement of cities and major plate boundaries in the Indonesia region (Harris and Yung-Chun Liu, 2013)

Introduction

The Sulawesi earthquake, which happened in April 2019, was a natural disaster that had great impacts on the country of Indonesia. The effects of what was a relatively light earthquake were exacerbated by the previous year's Palu disaster, in which a series of earthquakes and a resulting tsunami killed hundreds (BBC News, 2018). The disaster left behind a population that was particularly vulnerable to new hazards, with many people who had been displaced still not living in appropriate long-term housing (Japantimes, 2019). As a result, the April 2019 Sulawesi earthquake was felt to a far stronger degree than what would otherwise have been expected. The 2019 Sulawesi earthquake therefore brings into question the ideas of how past disasters result in preconditioning and also the importance of a countries ability to recover rapidly from natural hazards as a factor that exacerbates the effects of future issues; suggesting that where effects could otherwise be minimised, they are intensified by the state of the people, perhaps providing an explanation as to why this relatively small earthquake had such noticeable impacts for Indonesia.

Background

Indonesia is particularly prone to natural hazards. Situated within the 'ring of fire', the country's tectonic structure means that it is vulnerable to both earthquakes and volcanic eruptions (Pambudi, 2017). Consequently, Indonesia is often subjected to widespread destruction, negatively affecting both the standards of life and economic growth in the area. This has been shown through historical economic and political patterns that are presented to be influenced through environmental factors by the natural disasters within Southeast Asia (Henley and Schulte Nordholt, 2015).

The Natural Hazard

At 6:40pm on the 12 April 2019, a 6.9 magnitude earthquake hit near Sulawesi Island. The earthquake hit at a depth of 10km, the epicentre being at sea

87km west of Kep.Bangggai (AHA Centre, 2019). Felt as 'strong and long lasting' (Sky News, 2019), the earthquake terrified residents across different areas, such as Palu and Mandado, with an estimated exposed population of 165,000 (AHA Centre, 2019). The shake map in Figure 1 shows the areas most

affected by the earthquake tremors, where Matindok – located along the east coast of Sulawesi – is presented to have the highest levels of perceived shaking and potential damage, at a Modified Mercalli Intensity Scale (MMI) of VI.

The earthquake was followed by two aftershocks of magnitudes 5.0 at 7:03pm and 5.2 at 7:12pm. There was also a tsunami warning soon following the first hit, where people on the coast were ordered to go to higher ground (South China Morning Post, 2019) and residents were advised to evacuate after the earthquake was declared to be of tsunami potential (CBS News, 2019). One person was killed while trying to flee (the Guardian, 2019). The tsunami warning was shortly lifted, and did not occur (South China Morning Post, 2019).

Whilst the earthquake in itself was not extremely damaging to stable infrastructure and did not injure large numbers of people, it was particularly frightening to those it affected due to the disasters of the prior year – in September 2018, Palu was affected by a magnitude 7.5 earthquake, liquefaction as well as a tsunami that destroyed the capital, and killed over 2000 people (Worldvision, 2018). This left thousands of people displaced, and homes destroyed, many of which had not yet recovered (Japantimes, 2019). These people were more vulnerable to the impacts of the Sulawesi 2019 earthquake, and also more likely to suffer emotionally, particularly if they had lost family or friends in the 2018 events. This was seen to a large extent by the panic that arose within what was only a few seconds of shaking, as people ran into the streets (USA Today, 2019).

Over half of Indonesia's population lives in cities (The World Bank, 2019). Due to the aforementioned disadvantages associated with natural hazards in the area, large percentages of these people live in slums and short-term, poor quality and ill-maintained infrastructure, which makes the area less resilient to damage and increases the vulnerability of its residents (Prasad et al, 2009). This means that more homes are more likely to be destroyed in the event of a natural hazard, causing for further strains on rehousing programmes.

Technical interpretation

Development

Natural hazards have put limits on the economic growth of the countries most at risk. Budgets cannot be used purely for development, as the presence of a disaster redirects it to emergency response and, in the longer term, rebuild of the affected areas. In addition to the redirection of economic budgets, large scale natural hazards, such as earthquakes, halt work in city centres, reducing industrial and commercial activities (Shaw, 2016). This results in a slower rate of development and economic growth as countries are regularly set back by the damage these events cause, and the time it takes to rebuild infrastructure and deal with losses. As a consequence, one could argue countries prone to natural disasters – such as Indonesia – to be disadvantaged in their ability to thrive in development when compared to locations not affected by Natural Hazards to the same extent: for example, the United Kingdom.

Occurrence of Earthquakes in South East Asia

As Indonesia lays within the pacific ring of fire, it interacts with three major plates: the Indian-Australian, Philippine and Sunda. These collide with each other causing a number of thrust and strike-slip faults along their boundaries. These can be seen below in Figure 2, which highlights the proximity of densely populated cities and these major plate boundaries. Due to the speed at which plate movement takes place, and the placement of the triple junction, there is also a complex deforming zone where micro block rotations take place. These happen as a result of changes in boundary conditions around different parts of Sulawesi and are suggested to cause clockwise tectonic rotation in the north, and anticlockwise tectonic rotation in southern areas. Sulawesi is an example of a location where crustal block rotation takes place as opposed to mountain building (Soquet et al, 2006).

The type of boundary which caused the Sulawesi earthquakes – strike slip – is one that is often thought as unlikely to be associated with tsunami generation. Nevertheless, data shows these faults to be able to form tsunamis though tectonic seafloor uplift of echelon step-overs as well as underwater landslides (Legg et al, 2003), which is thought to have been the case for Sulawesi tsunamis in the past (The Guardian, 2018).

Assessment of Impact and Preparedness

One of the main impacts of the earthquake appeared to be emotional and psychological distress to the residents of the Sulawesi area, who would have been afraid that this incident could be as disastrous as that in September 2018. It is particularly difficult to prepare for these types of impacts, as earthquake related trauma (such as losing family and friends or being displaced) is associated with post-traumatic stress disorder and other psychiatric symptoms (Punamäki and Sezgin, 2012). Once the earthquake has occurred and people experience losses and distress, it is difficult to prevent fears of these incidents happening again in such a large population.

The other main impact of the earthquake was its damage to inadequately built and designed structures (Channel News Asia, 2019). This was a large issue due to the living conditions for many people being extremely poor following previous earthquake events. People were more vulnerable as a result of their displacement, and the inability for them to be re-homed in the time between the two events showed the limits to Indonesia's preparation for future events in

regard to housing and infrastructure support. These conditions also made it difficult to assess the damages to infrastructure, because, as was mentioned previously, hundreds of people had continued to live in poor quality short term for many months prior to the earthquake.

Whilst both these issues present Indonesia to have a lack of preparation and as having exacerbated the impacts though pre-existing conditions in Sulawesi, there are also signs of preparation and plans of actions. For example, the declaration of a tsunami warning shows signs of preparation. Past experiences with tsunami events, such as the catastrophic tsunami of 2004 (Goh et al, 2014) have encouraged for the implementation of an effective tsunami warning, which is important because the levels of destruction caused by tsunamis in the past suggest that the proper and effective use of a tsunami warning could be key to saving many lives in the future. Nevertheless, whilst the warning was put into place, it was shortly cancelled as the water level was calculated to be less than half a meter (Channel News Asia, 2019). The fact that people were evacuated although a tsunami did not occur could bring around distrust in the population and people may not want to leave in the future in the belief that this may be another precaution without a hazard, potentially causing upcoming problems.

Furthermore, following the 2018 events, detailed plans of action were designed to allow Indonesia to recover from the disaster; the plans were called 'Wahana Wisi', or 'World Vision'. Nevertheless, they were scheduled to be ongoing until September 2020, which shows a disadvantage for prevention planning and limits preparedness, as priorities are focusing on recovery and maintenance of shelter, sanitation and water (World Vision, 2019) as opposed to finding techniques that will defend the location from such severe earthquake impacts in the future; hence the nature of the effects in the April 2019 earthquake.

There does not appear to be a separate plan of action for the April 2012 earthquake, which is understandable considering the extent to which the World Vision plan is being implemented. This means that it is applicable to the April events, though support of recovery and rehabilitation, as well as disaster risk education programmes (World Vision, 2019).

Conclusions

The Sulawesi earthquake of April 2019 was of light to moderate intensity across the region, which – situated within the ring of fire – is prone to such occurrences. Nevertheless, there were a variety of negative impacts that affected the people of Indonesia, particularly in more vulnerable regions that had been affected by other destructive events of a similar nature in the recent past.

Taking all of this into consideration, it seems apparent that the April 2019 earthquake that hit Sulawesi was more damaging as a result of the pre-existing conditions for people in the area. The inability to adequately prepare exacerbated problems such as poor infrastructure quality and mental health impacts within the population and came as consequence to the extent of time it was taking for Indonesia to recover from the 2018 earthquakes, landslides and tsunami events.

The degree to which unresolved problems from prior events extended the degree of problems in Sulawesi thus highlights the importance of aiding the recovery process in countries that experience regular destructive natural hazards, particularly when these countries are less economically developed.

Nevertheless, Indonesia appears to be planning and taking steps towards recovery and risk prevention through the World Vision response, which is shown to have brought many ongoing benefits to the Sulawesi area. The response techniques outlined in this plan would also be beneficial in the future, were similar events to take place, although this could potentially put a strain on the Vision economically.

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Mt. Ulawun Eruption, June 2019

Kieran Woolford



Figure 1 - Location Map for Mt. Ulawun Eruption (Google Earth, 2015).

Authoritative Account of the Event

Background

Located on the Island of New Britain, Papua New Guinea, Mount Ulawun sits at a staggering 2,334m making it the largest volcano in the Bismarck Arc; this volcano is further classified as a stratovolcano. On June 26th Mt. Ulawun erupted displacing thousands across West and East New Britain, Papua New Guinea (ECHO,2019a; RNZ,2019a; IFRC 2019). Reports suggest that at around 22:00 UTC on June 25th, lava began to flow down the sides of the volcano which furthermore emitted magmatic gas and ash (RNZ,2019a; ECHO,2019a). Ulawun is part of a group known as the 'Decade Volcanos', this was coined by the IVACEI (International Association of Volcanology and the Chemistry of the Earth's Interior) to direct attention and encourage a range of research and awareness activities to better enhance the understanding of the volcano and the hazard's that is poses (Wired, 2009). By better understanding the range of volcanic hazards Mt. Ulawun presents it is hoped that the severity of potential disasters can be decreased.

To achieve a factual account of the event, the grey literature search consisted of using well-known non – governmental organisations and local newspapers that were found using google searches with key terms 'Ulawun, June 2019, Volcano, Eruption'. These helped return the most useful sources, mainly highlighting Radio New Zealand (RNZ) and a UN source found via relief web.

Eruption Timeline

Initial eruption began on June 25th as a large column of black smoke rose, and lava spewed from the crater. Satellite images (Figure 2.1) helped show the eruption plume reach estimated heights of 15km (ABC, 2019). An ash cloud (Figure. 2.2) subsequently formed and spread across the western and southern parts of New Britain, as well as heading towards to Solomon Islands. Pyroclastic flows were spotted on the northside of Ulawun and it was unclear how far debris went down the slope or if road access was restricted (UN Office of the Resident Co-ordinator, 2019; Global Volcanism Program, 2019a) but it was later reported that lava had cut off the New Britain Highway in three different locations (ABC, 2019; RNZ,2019b).

Steve Saunders, of the nearby Rabaul Volcano Observatory (RVO) spoke saying "There's some force behind it", he later added that the volcano was still steadily erupting on Wednesday evening (June 26th) into the early hours of Thursday morning (June 27th)

(RNZ, 2019a). After increased activity from the weeks leading up to the event, the local population were alerted to the danger since ash plumes discovered using satellite data collected by the Darwin VAAC (volcanic ash advisory centre) resulted in inhabitants close to the volcano to be evacuated – meaning that the eruption thankfully occurred with zero casualties (IFRC, 2019;RNZ 2019a). Further evidence of activity leading up to the eruption was through the analysis of RSAM (Real-time Seismic Amplitude Measurement) values. Between June 24-25th June RSAM values steadily increased, values then sharply rose in the early hours of the 26th June. These values reflect an overall increase in seismicity, dominated by volcanic tremors (Global Volcanism Program, 2019a).

Effect upon the population

Officials were sent out to assist with evacuation efforts of the thousands still situated close to the base of Ulawun, however many villagers had begun to leave home themselves. Individuals such as Christopher Lagisa, a resident, wrote in a message he had been shepherding people to a local church tirelessly. He also said, "around 3,000 people were gathered at the church hall with vehicles working flat out to move people to Kabaya Community" these numbers have not yet been confirmed by officials (RNZ, 2019a).

As of the 27th June, 6,871 people were confirmed to have left their homes in West New Britain and are in 2 care centres south of Ulamona according to the National Disaster Centre (NDC).Informal displacement sites could have possibly been set up at this time however it was roughly estimated by disaster authorities that around 4,000 in East New Britain and 12,000 in West New Britain have been affected by the eruption (UN Office of the Resident Co-ordinator, 2019a). The RVO reported on the same day that the eruption was powerful but brief, which led to thoughts that overall volcanic activity was subsiding (Global Volcanism Program, 2019a). In total, low volumes of ash were dispersed west and southwest of Ulawun, mainly along coastal areas as a result of wind patterns. The Pacific Disaster Centre reported that before 28th June the ash cloud is expected to dissipate meaning the alert level is most likely to be reduced from 2 to 1 due to observations from the observatory (UN Office of the Resident Co-ordinator, 2019a; ECHO 2019b;Global Volcanism Program, 2019b).

Economic and Environmental Effects

Due to the ash cloud, Air Niugini who runs flights internal and external to Papua New Guinea had cancelled flights to Hoskins Airport, which serves Kimbe, the capital of West New Britain (RNZ, 2019b).The ash not only brought disruption to flights; villages and plantations surrounding Mt. Ulawun have been coated in ash (Figure 3) meaning crops have failed and water sources for the villages have been contaminated, adding to the evacuation crisis as remaining at home was no longer viable(RNZ, 2019c). A crop; palm oil trees – are vital to the local economy which further compounded the misery of those already affected as they had lost a huge asset to them financially. All communities within a 20km radius of the volcano were reported to relocate at the designated safe zone (UN Office of the Resident Co-ordinator, 2019b). Francis Maneke stated that "the displaced people desperately now need supplies, however with the airport closed the only access is via dirt road meaning relief will be slow to arrive" (RNZ, 2019c). As the 28th June, authorities had now declared a provincial state of emergency, air quality assessments were carried out to see whether Hoskins could be reopened to alleviate pressure regarding transportation of supplies to care centres, which was then of upmost importance. (ECHO, 2019b; UN Office of the Resident Co-ordinator, 2019b).

Aftermath and the on-going situation

Around 5,000 displaced people were able to move back home by July 31st, most of these local workers at the palm oil plantation, however there were still around 8,000 left in temporary accommodation. Tarpaulins provided by disaster relief agencies such as the Red Cross accounted for 75% of the type of shelter (figure 4), with unoccupied buildings or tents making up the rest (RNZ, 2019d; UN 2019c). 13,250 people were now in 9 care centres, with the WHO reporting that clean water was hard to come by and there was limited food supply with the possibility for vector borne diseases to spread endangering public health (WHO,2019; ECHO,2019). Mr Maneke, the W.N.B governor stated that those in temporary accommodation would most likely have to wait for their villages to be rebuilt and ultimately wait until the volcano stabilises (RNZ, 2019d).

Technical Assessment

Formation and recent volcanic activity

Ulawun is classified as a stratovolcano, a type of volcano characterised by having steep profiles and periodic eruptions that are often explosive. The steepness of stratovolcanoes is constructed by layers of debris which includes ash, pumice and solidified lava, in the case of Mt. Ulawun such debris would have been accumulated from events such as those in 1978, 1980, 1985, 2000 (Volcano Discovery,2019a) and a plethora of minor ones every other year or so. This demonstrates that Ulawun is an active volcanic zone, where eruptions are common. Ulawun also makes up part of the Bismarck Arc, a volcanic arc extending roughly 1000km from the Schouten Islands in the west to Rabaul in the east. This arc is extremely hazardous due to multiple volcanically active centres including Ulawun but also Manam and Bam. (Johnson, R. W. et.al, 1972). More than half of all volcanoes worldwide consist of basalt, with Ulawun

consisting of basaltic and andesitic rock, this volcano would additionally be described as polygenetic meaning it erupts repeatedly meaning there is a large and persistent magma supply rate (Walker, G. P., & Sigurdsson. H, 2000), further adding to the hazardousness of Ulawun. The Bismarck Arc would have formed above a subduction zone (ITA, 2019) on an oceanic-continental convergence boundary. This means that the Solomon Sea plate would subduct underneath the South Bismarck Plate therefore creating active volcanos and a zone of melting (Johnson, R. W.,1976).

Activity before the June 2019 eruption was rather minimal. The last notable event was in 2010 when ash eruptions reached 3.7km, similarly to this in 2006 ash eruptions reached 4.6km in altitude (Volcano Discovery, 2019b). These events were brief and there is little evidence to confirm whether this caused significant issues for the local population. In terms of scale, the September 2000 eruptions draws on some likenesses to the 2019 eruption. Build up to the eruption was rapid with a sub-Plinian type explosion which resulted in an ash cloud reaching heights of between 12-15km in altitude (Volcano Discovery, 2019b). These events happen follow a pattern of every 15-20 years or so, meaning the 2019 event was unexpected in relation to the relative normalities of Ulawun's eruptions.

Type of Eruption

Ulawun 2019 would be categorised as a sub-Plinian eruption, these are uncommon in wide regards to global eruptions, with Ulawun 2019 being the first sub-Plinian eruption since Calbuco, Chile 2015 (Volcano Discovery, 2019a). Features of a sub-Plinian eruption are that they are marked with large columns of ash, evidenced with the 15km plume confirmed by satellite images at Ulawun. They are also short and brief but often moderately explosive (in terms of other types of explosions, see figure 5) – ejecting large amounts of debris. Pyroclastic flows are often seen as a result of such an eruption, these flows are compositions of hot gas and volcanic material (tephra) that can travel quickly away from the volcano (Sheridan, M. F.,1979).

The reason why Ulawun's eruption was explosive lies within the viscosity of the magma within the volcano, with increased levels of viscosity there is also increased explosivity (Pyle, D. M., 2015). Since Ulawun is basaltic-andesitic, the silica content (SiO_2) would be roughly 53-57% meaning the magma composition would be intermediate. The amount of dissolved gas within magma equates to how explosive an eruption would be, with higher viscosity magmas - the more explosive eruptions would be as dissolved gas within the magma cannot easily escape (Walker, G. P.,1973) , subsequently causing a build-up of pressure and more force behind an eventual eruption. The 2019 eruption of Ulawun is a clear example of a moderate viscosity composition of magma meaning the eruption style was sub-Plinian. Stratovolcanoes however can see large variations in eruptions styles (as shown before with the recent history of eruptions at Ulawun), this is due to changing magma compositions as a result of melting of crust. At Ulawun, this change develops when the oceanic plate is forced under the continental plate which consequently melts and becomes magma that will then rise (Hofmann, A. W.,1988) (See figure 6).

Critical Comment

To summarise, Mt. Ulawun's eruptions has shown how vulnerable the population of the local area are to such an event. Vulnerability can be described as "the characteristics of a person or group and their situation which influences their capacity to anticipate, cope with, resist and recover from the impact of a natural hazard" (Blaikie. Et.al., 2005). The population at Ulawun live in unsafe conditions, as the physical environment is extremely hazardous due to the active volcano. Also, the local economy is poor, mainly occupied by farmers working their palm oil crops – which takes up 5.3% of total exports (OEC, 2019). The island has limited access to infrastructure also, roads are minimal with dirt roads used across the island apart from Hoskins airport. Early warning systems around Ulawun that are run by the RVO however hugely help reduce the vulnerability as these warnings allow the inhabitants of nearby towns and villages to evacuate before the hazard occurs, reducing the overall risk.

Assessing future potential risk means encompassing the overall hazard with the vulnerability of the population; which is quite high. If an event like the 2019 eruption would occur again it would further affect the economy as ashfall would yet again destroy crops and furthermore force people from their houses. With thousands still living in temporary housing their ability to resist another event will be largely minimal, increasing the chance for loss of life to occur. Aid will most likely make up for the fact the population has a very low capacity to cope however this aid may be delayed, seen during the 2019 eruption, as key infrastructures are likely to be over-bared or interrupted due to the hazard type.

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The Tsuruoka Earthquake, Japan, 2019

James Watford



Figure 1 - Photo showing the epicentre of the Tsuruoka Earthquake (Earthquake Track, 2019

Case Study Introduction

At 10:22 pm on the 18th of June 2019 an earthquake hit the region of Tsuruoka, Yagamata in Japan. The purpose of this case study examination is the collate an accurate understanding of the event. This will be done by sifting through the many contemporary reports and critically evaluating them, allowing for a more cohesive narrative. The case study will also provide an opportunity to look at the technical aspect of the event as well such as the mechanisms and theoretical concepts of past earthquakes, relating them to this event.

Authoritative Account of the Event

The Tsuruoka Earthquake: The Physical Facts

The earthquake, like all natural hazards in the modern age, was subject to a plethora of different web and newspaper articles reporting the happenings of the event. To find out the earthquakes impacts on people and the environment, we first need to begin with looking at the region in which this earthquake hit. It hit the Hokuriku region of Japan as seen in Figure 1 below.

Hokuriku is on the Western Coast of Japan and the earthquake hit 2 main cities in the region, those being Yagamata and Tsuruoka. As seen on Figure 2, the epicentre was just off the coast of Tsuruoka, the city that was affected by the event the most. Due to the epicentre being in the ocean, a tsunami would have been a realistic possibility. The Japan Times among other reputable sources reported there was indeed a tsunami warning. The tsunami was predicted to be up to 1 metre however luckily it only topped out at a modest 10 centimetres (The Japan Times, 2019).

It was however the quake itself that cause most of the damage and injuries. 6.7 on the Richter Scale in the magnitude reported by various online news articles such as The Japan Times (The Japan Times, 2019) and South China Morning Post (South China Morning Post, 2019). The USGS on the other hand reports the magnitude at 6.4 (USGS, 2019). The reason for conflicting reports is not entirely clear, however it could be due to these reports being released in such close proximity to the event it can be attributed to the lack of concrete facts being available at that stage.

According to USGS the epicentre was 31.3 km from Tsuruoka and 45 km from Sakata (USGS, 2019). Tsuruoka has a population of 99820 while Sakata's is 100446. This therefore shows that these cities have a high population density with many potential people at risk.

The Tsuruoka Earthquake: The Impacts

One of the most eye-catching realities of natural hazards is that they can have a devastating effect on human life and is one of the reasons why they are so heavily reported on in modern society. The loss of life can often be tragic, and this is down to many things such as low wealth and preparedness as well as a lack of knowledge of the lethality of these events. Japan, however, does not have such problems as it is one of the most knowledgeable and prepared countries when it comes to mitigating the affects of earthquakes. Due to their wealth they have implemented several earthquake prevention techniques which are sure to have contributed to this earthquake resulting in 0 (zero) deaths (Kyodo News, 2019). According to Kyodo News there were 30 injuries however The Japan Times (The Japan Times, 2019) and South China Morning Post (South China Morning Post, 2019) report at least 26. Injuries were mainly down to rubble and falling debris due to structural weaknesses. Kyodo News reports that "a man in his 30s in Tsubame…fell and broke a bone, while a high school student in Yuzawa…broke her ankle when she lost her balance" (Kyodo News, 2019). This shows that the injuries weren't of an extreme level and were only minor with all the people injured expected to make a full recovery. Other social impacts included "over 9,200 houses in Niigata and Yagamata prefectures were hit by power outages" (Kyodo News, 2019) and Kyodo News reported that shelters were used for those who could not find it during the event (Kyodo News, 2019). An example of this is 200 people including children and the elderly took shelter in a gym hall of a local school, seen on Figure 3.

People aren't the only thing to be affected by earthquakes as infrastructure can also be affected. Powerful earthquakes can tear through weak structures and so it is important to have earthquake-proof buildings as to prevent the quake from causing

lots of lasting damage. Japan are one of the front-runners in earthquake proof buildings and as such the damages to buildings weren't nearly as large as they could have been had the earthquake hit a country less infrastructurally prepared.

Some examples of earthquake proof buildings in Japan are the Mori Tower in Tokyo that has implemented reinforced steel piping as well as a "motion absorbing technology called oil dampers" (What's Next, 2017) which allow shock absorbers to counterbalance the shaking and as such reduce the damage the earthquake can cause. Another example of earthquake proof design is fa-bo, located in Noma City. It has been fitted with "1031 braided carbon fibre rods" which are connected to the ground (What's Next, 2017) as seen on Figure 5. There are an additional 2,778 rods inside the building, and it all contributes to the building being more stable to protect against earthquakes (What's Next, 2017).

Technical Interpretation of The Tsuruoka Earthquake

Earthquakes are created by tectonic plates colliding together and as such only occur on plate boundaries. Figure 6 shows that the 2 plate boundaries that collided to make the Tsuruoka earthquake were the Amur Plate and the Okhotsk Plate. These 2 plates are part of the Eurasian and The North American Plates, the 2 large tectonic plates within this area. The Okhotsk Plate and Amur Plate are on a boundary known as a convergent boundary. Also known as a convergent margin, it is "A junction between two lithospheric plates that are moving towards each other" (Park & Allaby, 2017) or converging. This forces one plate to subduct under the other [subduction] and this sharp release of tension is what causes the earthquake.

Therefore, the earthquake occurred by the Okhotsk plate converging on the Amur Plate (Hoppe, 2019) which created the tension, which when released caused the quake. The tension eventually breaks the rock creating seismic waves. Earthquakes generate 2 types of seismic waves, those being P and S waves (Rennie & Law, 2019). P waves are sent first and are longitudinal or back and forth movements (Rennie & Law, 2019). S waves are sent afterwards and cause "rock particles to move back and forth perpendicularly to their direction of propagation" (Rennie & Law, 2019). Most of the damage is instigated by the S waves and so detecting the first signal of the P wave has become vital in sending out alarms to the general public that the S wave and the most damaging part of the earthquake is on its way.

The Pacific Ring of Fire

The fault line on which the Tsuruoka Earthquake occurred is located along the Pacific Ring of Fire. This is "A volcanic zone around the edges of the Pacific Ocean, along a series if subduction zones of convergent plate boundaries" (Park & Allaby, 2017). The tectonic activity in this area is among the highest in the world and goes a long way to explain why the earthquake would take place here. The layout of the Pacific Ring of Fire can be seen on Figure 7.

While the Ring of Fire as its name suggests is referring to the volcanic activity that occurs along this belt earthquakes also occur along it as the Ring of Fire is along plate boundaries. Most of the world's strongest earthquakes occur along this belt (The Editors of Encyclopaedia Britannica, 2019). This is important in the context of the case study as it shows that they are up against statistically the strongest and potentially the most devastating earthquakes on planet earth. In many ways it makes their ability to mitigate the impacts of these potentially catastrophic events more impressive. Other countries along this belt such as Indonesia have a really tough time facing many of the same events and hazard intensity that Japan do which allows for a good comparison between each countries' mitigation successfulness.

Past Earthquake Events

With the location of the Tsuruoka Earthquake being located in the Pacific Ring of Fire there are an abundance of previous tectonic events to call back on. An earthquake involving the exact same plate boundaries occurred on 24th May 2013. This is known as the largest deep earthquake recorded as of 2013 and had a magnitude of 8.3 (Ye, Lay, Kanamori & Koper, 2013). The impacts of this earthquake pale in comparison to even the 2019 Tsuruoka Earthquake. Because the earthquake was instigated at such a low depth the intensity was rather low however it was felt over a vast area with the aftershock being felt in Moscow (RT, 2013).

This shows there are a variety of earthquakes in this region and they can vary from deep earthquakes with low intensity and a wide affected area to a more concentrated shallow, higher intensity earthquake.

Conclusion

The Tsuruoka Earthquake in many ways is a mark of just how far Japan have come in Earthquake damage mitigation and prevention. The knowledge of the hazard along with significant preparedness has allowed Japan to effectively deal with a significantly sized earthquake and come out the other side of the event with 0 causalities and a controllable and relatively insignificant amount of damage. It cements Japan as being the worldwide leader in terms of understanding and implementing what is necessary to deal with potential catastrophic events. It also allows their methods of earthquake production to be studied and passed on to other areas that are affected by large and frequent earthquakes. However, there is a caveat to this sentiment. Japan's earthquake management is as good as it is partly because of the wealth and infrastructure that already exists within the country.

Therefore, while their techniques of hazard prevention such as earthquake proof buildings and advanced monitoring systems may be extremely useful, implementing them in lower income countries affected by earthquakes can prove very difficult. The infrastructure is often not there to support such developments and as such means these events can cause catastrophic results. An example of this would be the Haiti Earthquake in 2010 where the earthquake hit an extremely vulnerable location and had dramatic effects with the official death toll being over 200,000. The effects of this event are still be felt to this day such was the difference in preparedness between Japan and Haiti. Then a situation can develop where the wealthier country continually improves its hazard monitoring and protection while the lesser income country stagnates. Therefore, in summary, I believe Japan can be used as a case study in how to effectively nullify the impacts of earthquakes however their strategies should be modified to appropriately suit the country's capacity to accommodate this change.

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Mount Agung Eruption

Connor Ward

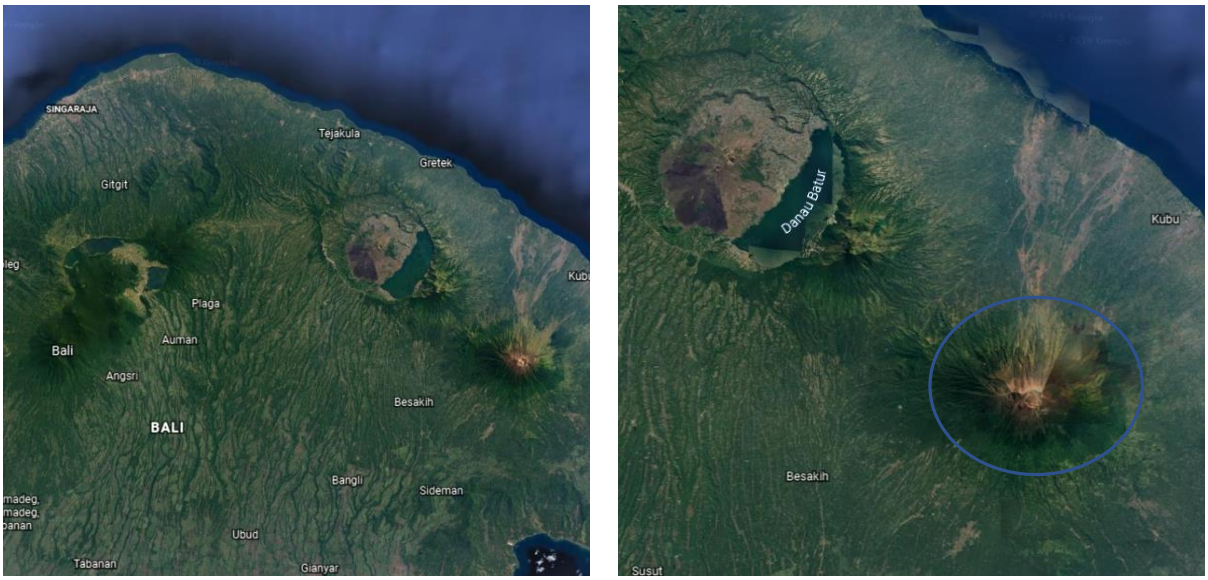


Figure 1: This figure shows Mount Agung and its location in Bali, Indonesia. The current size of Mount Agung's crater is approximately 800m. (Google Maps, 2019)

Introduction:

This chapter will focus on the eruption of Mount Agung, with focus on the timeline of events from the October 2018 through to September. The primary focus of displaying the events in order of occurrence will aim to supply a holistic view as every eruption event will be in this chapter. This will be followed by an academic explanation of the events that occurred, drawing upon previous eruptions and literature to comment critically on the vulnerability of those effected and potential future risks rising as a result of future Mount Agung eruptions.

Background

Mount Agung is a stratovolcano found in Bali, Indonesia. As an active stratovolcano Agung has a has a rich history of eruptions dating back to 1843, with eruption events including the 1963-64 eruption. This eruption event is one of Indonesia's worse volcanic eruptions to date. Mount Agung shown in figure 1 is a typical symmetrical stratovolcano with 3000m steep sides cone-based shape (King, H.M.,2019).

Figure 1.0 Shows Mount Agungs location in Bali and surrounding features. The volcanos steep sides are a result of recurrent eruptions of lava and pyroclastic flows which build up gradually. This process eventually made the volcano the highest point of elevation in Bali. (Park, C., & Allaby, M.,2013)

Eruption Timeline

Within recent times, Mount Agung has been erupting continually since 2017. However, within the dates specified earlier, December 2018 saw the first major volcanic activity of interest. This involved volcanic ash and white smoke sent 700 meters into the air (NCAN, 2018). This ash and smoke littered the neighbouring villages however, no evacuation began as no eruption of lava occurred. Despite this fact many scholars and government organisations such as the World Meteorological Organization regard the eruption of Mount Agung to be continual from 25/11/17 (WMO, 2017). This highlights a discrepancy between news sources report on the volcanic event and academics.

Following the activity of December 2018, the new year bought more volcanic action. This consisted of ash plumes because of further eruption. These ash plumes were difficult to record due to visibility surrounding Agung being poor. As a result of this episode significant secondary impacts occurred. These impacts involved waterways connected to Bali's Mount Agung potentially becoming contaminated. This means that locals must find other sources of water as ingestion could prove fatal. Furthermore, livestock and vegetation became affected via direct falling of ash upon them or pollution from the waterway. (TST, 2019)

The idea of vegetation becoming affected by Mount Agung's eruption studied in Sutomo and Wahab's 2019. The paper states that the amount of vegetation

has increased since Agung's earlier eruptions. However, the rate of succession has been slower than other volcanos studied within the paper. The volcano saw an increase of 1km2 of vegetation, this can explain the volcano outputting material which could aid growth once levels of the substance are not at extreme levels. This supports the idea of the volcano affect the local ecosystem as mentioned in the earlier paragraph.

Mount Agung continued to spew columns of volcanic ash into February and March 2019. This ash proved more problematic on a global scale rather than a local one. This refers to the ash plume actively rising to flight levels used by the international airport close by. This ash plume however, despite the warnings, never caused a problem to airports functionality as the levels of ash were not of significant levels to cause damage. (Erviani, N.K, 2019)

To protect further damage to locals and the environment surrounding Mount Agung the Centre for Volcanology and Geological Hazard Mitigation (PVMBG) issued an 3rd level alert. This alert called for an exclusion around the volcano of 4km. Despite this zone set out by PVMBG, many locals outside the zone also evacuated with those from the zone (Syahbana et al, 2019). This is because they believed they were in danger and feared the sounds of the volcano. This highlights how locals are inexperienced and lack critical information of how to respond appropriately to the potential future eruptions.

The last major volcanic explosion event occurred in June 2019; material expelled from the volcanic event ended up 700m from the crater. This was accompanied by an ash plume which reached 30,000 ft into the air. After the 10-minute eruption an earthquake swarm occurred which in turn inflated the area surrounding the epicentre due to the plates surrounding rising upwards. (Szeglat, M., 2019). These earthquakes and eruptions may have also affected the local airways as the plume reached flight height. Also, the earthquake could have caused other secondary impacts such as landslides or mudslides however, none were recorded.

The effect of Mount Agung's eruption on global climate is well documented. This is because volcanos cause the Earth to cool down. This is due to the sulphur dioxide distributed by the volcano. The gas emitted is known to block radiation from the sun. From Agung's 1963 eruption global temperatures saw an average 0.3-degree decrease (McGowan, 2017). This is a small decrease, however, could have devastating effects both locally and global. The eruptions also contribute to global warming as carbon dioxide is released. The earlier data collected shows how the eruptions of 2018-19 could have a significant effect on the environment.

Furthermore, climate effect changes because of volcanic dust were studied in 1963. The data is still relevant today as the study found that the dust released from the volcano is and has changed the climate systems of the world thousands of miles away (Moreno, Sanduleak and Stock, 1965). This further supports the idea of volcanos being a key factor in a changing climate and show how anthropogenic causes are not fully to blame for the rising carbon dioxide levels and global warming.

In comparison, Iceland's Eyjafjallajökull eruption also showed comparable results to that of Mount Agung. For example, the effect of ash and tephra which can contaminate farming supplies. This was seen in both Iceland and Bali. Oroian's 2010 paper "Eyjafjallajökull Volcano Eruption – A Brief Approach" highlights how Eyjafjallajökull could potentially affect the climate globally. This shows that the volcanic eruptions can affect the climate and through the triangulation of sources can confirmed to be true.

Technical Interpretation

Mount Agung's characteristic shape and size is a result of its location on the Ring of Fire. The Ring of Fire or the circum-Pacific seismic belt is found along the Pacific Ocean is a horseshoe shaped area of seismic activity and volcanic eruptions. The seismic belt is synonymous with earthquakes as 81% of the earths largest earthquakes occur within this 25,000-mile area (USGS, 2014). The circum-Pacific belt, a consequence of plate tectonics involves movement of plates in the earth's lithosphere. These movements are what caused Mount to erupt during the period of investigation within this chapter.

The earths lithosphere consists of two distinct types of lithosphere, including the oceanic lithosphere which is created at ocean ridges. The ocean ridges are caused as two plate boundaries move apart causing magma to rise and create new rock. The second type is continental lithosphere which is significantly thicker than oceanic (Fowler, 2012). Similarly, ocean trenches also found in the Pacific Ocean and the Ring of Fire are created when one tectonic plate is pushed beneath another (Elsasser, Huene, Scholl and Ridlon, 1968). These can cause earthquakes to form and volcanos to form at the seabed and eventually over time on land.

There is multiple different process which cause the movements of the Earths lithosphere. However, scholars and scientist agree on 3 main forces causing the movement of these plates. These are Convection Currents, Ridge Push and Slab Pull. The first force convection currents, involves heat transferring between mantle and crustal rocks with both viscous and non-viscous rocks (Schubert, Turcotte & Olson, 2001). This means that once the rocks rise from continual heating, they eventually cool down causing these convection currents.

In terms of slab pull, many mathematical calculations are involved in the movement of slab pull on a plate. Simply, slab pull is the subduction of the plate due to the plate becoming cold or denser. The density of the rock then becomes denser than that of the mantle below forcing the plate downwards. This plate then forces the warmer plate further along to also be forced down causing a mid ocean ridge to be created (Lallemand, Heuret & Boutelier, 2005).

In the case of Mount Agung it sits upon The Australia Plate, which is moving at 6 centimetres per annum due to the previously mentioned forces combined. (Wilson, 2009). This plate then collides with the Sundra plate at a convergent plate boundary (tectonic plate subduction add diagram to explain). This in turn creates a rise of magma and rock and therefore creates volcanic structures such as Mount Agung.

Furthermore, Earthquakes are also a common occurrence on these fault lines. As an addition to a volcanic eruption, earthquakes can also occur within them. These occur in volcanic swarms described below and major earthquake events which occur. These events are caused when the plates connecting slip and strike against each other causing a rupture and a release of the tension between the rocks underground (Ohnaka, 2013). There is also conviction to believe that a release of pressure does not solve the issue of over pressurised rock. This is because the pressure just shifts further down fault. Nelson, 2015 text suggest collision of plates can occur without causing an earthquake. This is known as Fault Creep and means some areas can receive a larger earthquake once an earthquake even has occurred (Wilson, 2009).

Earthquake swarms were also seen at Mount Agung and are defined by a series of smaller, shallower earthquakes. These differ to larger earthquakes as typically larger quakes just involve one event or movement. These swarms are believed to be caused because of smaller fractures within the rock being created rather than one main fracture (Miller, 2013).

Conclusion

Balinese people's faith could enhance their vulnerability. This is because many of Bali's residents are of Hindu faith and believe Mount Agung is a home for the gods. This meant that during the period of the volcanos eruptions they believed the gods to be angry and upset. In turn they made offerings and prayers to calm the gods and beg for forgiveness (Muthia, 2017). This means that the Balinese people lack knowledge, this could make them more vulnerable to an eruption. However, the issue is more diverse. As religion forms a part of many Balinese people's life, disrupting what they believe to be a god could cause national upset. This means a compromise between Geographers and locals to enable the vulnerability of the local population to diminish.

The impact of ash interfering with airports in and around Bali could also heighten the Balinese people's risk to this natural hazard. The closure of Ngurah Rai International Airport also grounded 59,000 passengers (Today, 2017), worsening the demand for fresh food and water. Furthermore, government officials urged locals to go to emergency centres which will also cause high demand of resources. This means that aid given to Bali in the form air such as Food and Water will also not be received. The point pollution of water sources and food further increases the lack of supplies. This shows that Bali is more vulnerable to ash and tephra from the volcano rather than the eruption itself and better practices and sources of supplies are needed if a future event were to occur. A future event could also include a serious earthquake or tsunami due to Bali's location on the ring of fire. If measures are made to prevent the damage of an eruption, another natural hazard event could have serious effects. For example, an earthquake could destroy aid given for the volcanic eruption meaning conditions could be worse than before.

In conclusion the people of Bali are vulnerable to volcanic eruptions due to the lack of information and geographic location. The island is vulnerable due to airport closure during these events. This means that upgrades must be made to Bali's infrastructure to ensure future events are not so devastating. Furthermore, tourism on the island took a sharp decline during the eruption period. Tourism in Bali is estimated to contribute 3.2% of Bali's economy by 2025. This could further damage Bali's economy if money that would normally be relied upon is not received.

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Cyclone “USMAN” 2018

Paul Turnbull

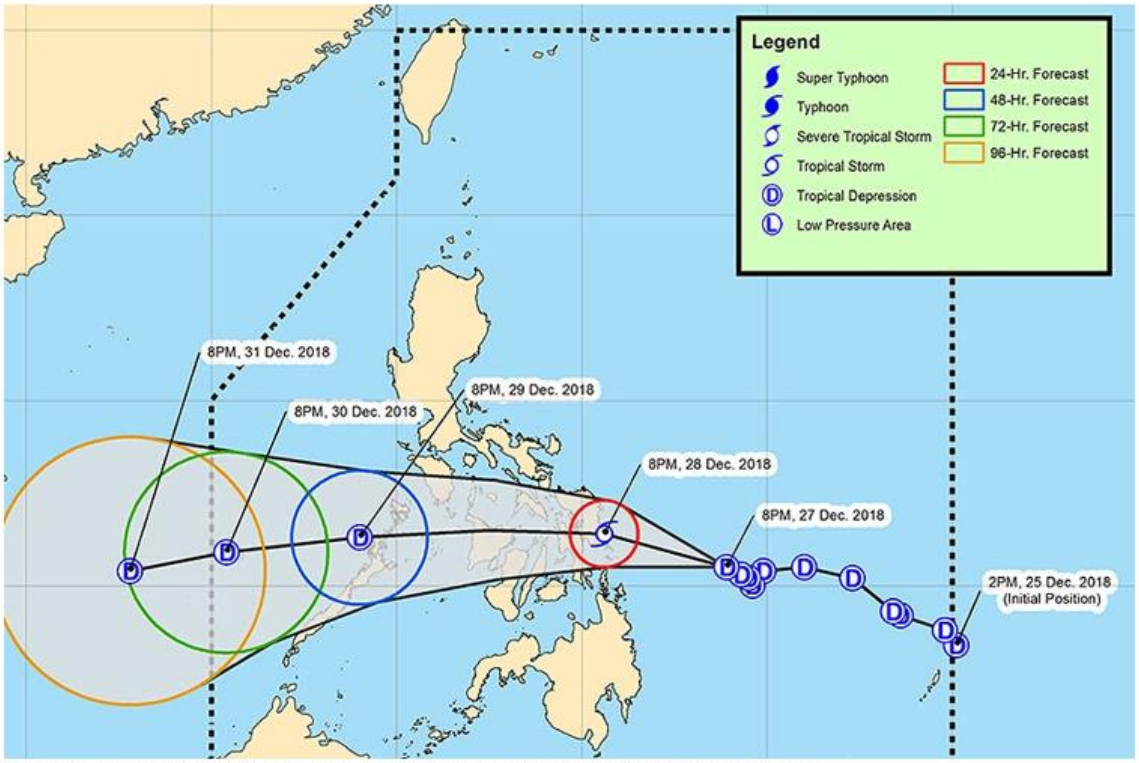


Figure 1- A map to show the origin and path of Cyclone (ABS-CBN News, 2018)¶

Authoritative Account:

Introduction

On average, the Philippines experience 20 tropical cyclones a year, with roughly 10 becoming typhoons, of which 5 will have the capability to develop into destructive ones (Cruz, 2016), which as a result kill hundreds of people and leave millions in a constant cycle of debt (The Guardian, 2018). As stated in a Time Magazine article from 2013, the Philippines is "the most exposed country in the world to tropical storms" due to there being more than 7000 islands, making the coastlines susceptible to storm surges (Brown, 2013).

The effects of such events are amplified by the fact that the Philippines is one of the poorest countries in the world, which in 2018 had a GDP per capita of $3,022 (Trading Economics, 2019). Meaning, a large majority of the population live in regions with inadequate infrastructure in place to cope with such events. Gathering accurate information for Cyclone “USMAN” was made difficult due to a lack of academic material, however by using google and key terms for searches allowed for an accurate representation of the event to be formulated. This was possible as information gathered was cross referenced to see any correlations in reports to allow for this study to occur, with the most accurate sources coming from ReliefWeb.

Cyclone “USMAN”

On 25th December 2018, a Tropical Depression, which was subsequently named Cyclone USMAN by locals, began to form North of the Island of Palau in the North Pacific sea. It then started to slowly move West into Philippine waters at a speed of around 10km/h as seen in Figure 1 (ABS-CBN News, 2018). This was the 21st and last Philippine tropical cyclone that occurred in the 2018 season. At this point, the Tropical Depression had wind speeds of up to 55km/h towards the centre with a pressure of 1002 hPa, and gusts of up to 65 km/h (Jalad, 2019). Although, due to a cold surge, these wind speeds were prevented from intensifying any further meaning the cyclone had at this point reached its peak intensity (PAGASA, 2019).

A few days passed, and on 28th December, “USMAN” was moving erratically across the Philippine sea. However, the heading of the cyclone was relatively consistent, going in a Westerly direction towards Eastern Samar, whilst still maintaining its peak intensity from the previous days (Jalad, 2019). Tropical Cyclone Warning Signal 1 (TCWS □1) was raised over several provinces around the Philippines, meaning that winds of 30km/h to 60km/h were expected to hit these areas in the following 36 hours (PAGASA, 2019). This is the lowest of 5 warning signals that could have potentially been raised for an incoming Tropical Depression, with the highest being TCWS □5 which

refers to winds greater than 220km/h expected in a 12-hour period. The following day, the Tropical Depression made landfall in the region of Eastern Samar, close to the city of Borongan, where it weakened into a Low-Pressure Area (Jalad, 2019). As a result of this Tropical Cyclone Warning Signals were lifted across the region, causing most of the population to remain in their homes and implement little to no preparatory action for the potential imminent threat. However, even though the warning signals were lifted, sustained heavy rainfall still hit many regions across the Philippines such as the “Bicol Region, Eastern Visayas and portions of MIMAROPA and CALABARZON” (PAGASA, 2019). From the 30th December, USMAN began to weaken further as it travelled Westwards, whilst still causing heavy rainfalls in its path, where it eventually dissipated into a minor depression over the South China Sea.

Flooding

Due to the interaction between wind flows from the Low-Pressure Area and the cyclonic circulation created by the Tropical Depression, a prolonged period of intense rainfall created widespread flooding across the south of Luzon. As the rainfall hit, the island of Luzon increased the percentage of potential damage as it is the largest and most populated islands within the Philippines (Britannica, 2019). It was recorded at 11 rain gauges in the Bicol region, Southern part of Luzon, that at least 250mm of rain fell in a 2-day period, with the highest recorded in the same time period being 573.2mm in Daet, Camarines. The highest accumulative in a 24-hour period was documented on 28th December 2018 in Catarman, Northern Samar, the third largest Philippine island, with a recording of 438mm (PAGASA, 2019). This large amount rain resulted in extensive flooding across the region, evident in Figure 2, damaging an array of infrastructures as well as injuring and displacing a large amount of the population.

Landslides

Subsequently, this huge input of water into the countries’ landscape led to some areas having unstable ground which triggered a wide range of landslides across the country. These landslides caused the most damage during the event, as many people’s houses collapsed as a result, which in some cases led to injuries and fatalities (BBC, 2018). Furthermore, a range of infrastructures were damaged due to landfall, such as some roads and bridges, which is evident in Figure 3. As previously stated, the Philippines is one of the world’s poorest countries, meaning that the housing quality isn’t to a high standard, which as a result increases the likelihood of these buildings collapsing in such an event.

Impacts

Overall, 238,100 families and 1,015,958 people were affected by the event across 14 provinces of the Philippines. A total of 156 fatalities were recorded, with 26 people accounted as missing and 105 injured. Many of these fatalities were as a result of houses collapsing due to landslides. Accumulatively, 36,890 houses were damaged, 4,132 of which were destroyed with the rest partially affected. 163 road sections were damaged as a result of “USMAN” as well as 5 bridges. The total damage cost from this event was estimated to be PHP 5.4 billion ($106,677,324), with PHP 1.9 billion in agricultural damage and PHP 3.5 billion in infrastructure (PAGASA, 2019; Jalad, 2019).

Responses

An immediate response to the event was the deployment of rescue teams to search for missing people across the regions. These teams included army troops and volunteers with rubber boats to enable them to rescue families in the flood waters (Deutsche Welle, 2018). Additionally, a total of 802 evacuation shelters were set up to support families and individuals affected by the event. It was recorded that 1,196 families received aid including sleeping mats, blankets, and mosquito nets. Alongside this, 4 water tankers were mobilized that provided 747,000 litres of water to the affected. Furthermore, 15,111 individuals were served with hot meals (ReliefWeb, 2019).

Some long-term responses include, a standby fund of PHP 3million ($59,404.76) which is available for food and aid if needed. Quick response teams are on standby in conjunction with continuous monitoring of weather conditions, as well as prepositioned equipment that is on standby in case of a likely future hazard (Jalad, 2019).

Analysis:

Regularity of Cyclones in the Western Pacific

As previously stated, the Philippines experiences roughly 20 tropical cyclones a year, which is a significant amount compared to other regions across the world (Cruz, 2016). The regularity of these tropical cyclones making landfall in this region, as well as their intensity, can be linked to recent changes in the oceanic and atmospheric environments within the North-western Pacific. One of the changes in question are that these sea-surface temperatures in the North-western Pacific have notably warmed between the period of 1979 – 2010, along with a weak cooling in the tropical Central and Eastern Pacific (Park D. S., 2013; Park D. S., 2014)

Furthermore, the increased effect of the Walker circulation has also helped to intensify these cyclones. The Walker circulation also known as the Walker cell, refers to air flow in the tropics within the troposphere, where parcels of air flow in a closed circulation. They do this in zonal and vertical directions. Subsequently, these are caused by differences in heat distribution between the ocean and land, meaning that the increase

in sea surface temperatures directly affect this process and further intensify it (Zhang, 2011). These changes may be a direct result of manmade global warming; however, this is not certain yet as the 40-year cycle is a fairly short time period to determine whether it is due to human interference, or a natural cycle. The increased sea-surface temperature, and enhanced effect of the Walker circulation, increases the regularity and intensification of these cyclones making landfall, as the warmer coastal seas provide more energy to developing storms, allowing for increased wind speeds to occur at a more rapid rate (Mei, 2016).

Reasoning for the increased amount of rainfall

One of the main characteristics of a tropical cyclone is they tend to bring torrential rains into the affected area when they make landfall (Chen, 2006), however when the storm weakens into a low-pressure area, the intensity of the rainfall decreases as a result. Although, it is possible in some cases that the remnants of the storm are revitalised. Subsequently, producing an increased amount of rainfall compared to when it made landfall previously, as if the storm has gained new energy from the land, which occurred with Cyclone “USMAN”. This phenomenon is recognized as “rainfall reinforcement associated with landfalling tropical cyclones” (Dong, 2010). These events often occur under complicated atmospheric environments, as evident in the Philippines region, making the prediction of RRLTC difficult, posing a challenge to forecasting, consequently having a substantial effect in relation to Cyclone “USMAN” as the unpredicted heavy rainfalls led to large areas across the Philippines becoming flooded.

Reasoning for Landslides across the Philippines

The Philippines has a well recorded history of deadly landslides occurring across the country, such as of the most destructive landslide events to occur in the world. This disaster occurred in 2006 on Leyte Island with an estimated death toll of just over 1000 people (Evans S. G., 2006). The large amount of activity is due to a mixture of natural factors affecting the grounds’ stability across the region. One of which is the fact that the Philippines is set upon an active tectonic zone, meaning the islands experience tectonic movement frequently, which ultimately will loosen the ground beneath them. Partnering this with the extensive tropical weathering taking place all year round furthermore disrupting the rugged topography helps to cause landslides (Evans S. G., 2007). So, during heavy rainfall events, such as Cyclone “USMAN”, a large amount of the previously stable natural slopes become unstable and fail due to the infiltration of water leading to soil saturation. The slope ultimately fails due to an increase of negative pore-water pressure, which as result, decreases the shear strength of the soil due to the pore space being filled by excess water (Tsaparas, 2002).

Critical Comment

In conclusion, Cyclone “USMAN” highlighted the vulnerability of the local population within the Philippines due to the economic state of the country, as a large majority of the population have low quality housing and poor infrastructure in place to help mitigate some of the hazard’s impacts. However, the responses to Cyclone “USMAN” highlighted the preparedness of the country to such hazards, as rescue teams and emergency aid was sent to the affected areas immediately. Although, even though some warning signals were raised early in the event, a potential lack of monitoring allowed for these to be lifted shortly after even though there was still a threat present. So, this indicates a need for improvement on warning systems and monitoring technology. These improvements can be completed to a high degree by following the Sendai Framework for Disaster Risk Reduction, and the subsequent four priorities (UNDRR, 2019). This partnered with the relaxed mentality from the local population, as many failed to prepare to the necessary standard as it was a holiday period (The Guardian, 2018), which allowed for the impacts from the hazard to become intensified and more deadly as a result.

Future risks from similar events may only increase due to the rising regularity and exacerbation of such weather events as a result of climate change affecting both the temperatures and air circulations in and around this region of the world. This poses a large threat to the Philippines in the future as the economy may not be able to cope with such events occurring on a regular basis. Furthermore, this puts the population at severe risk of harm due to a lack of preparedness and aid available to them, during such an event.

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Mt. Manam Volcano - June 2019

Lewis Sullivan

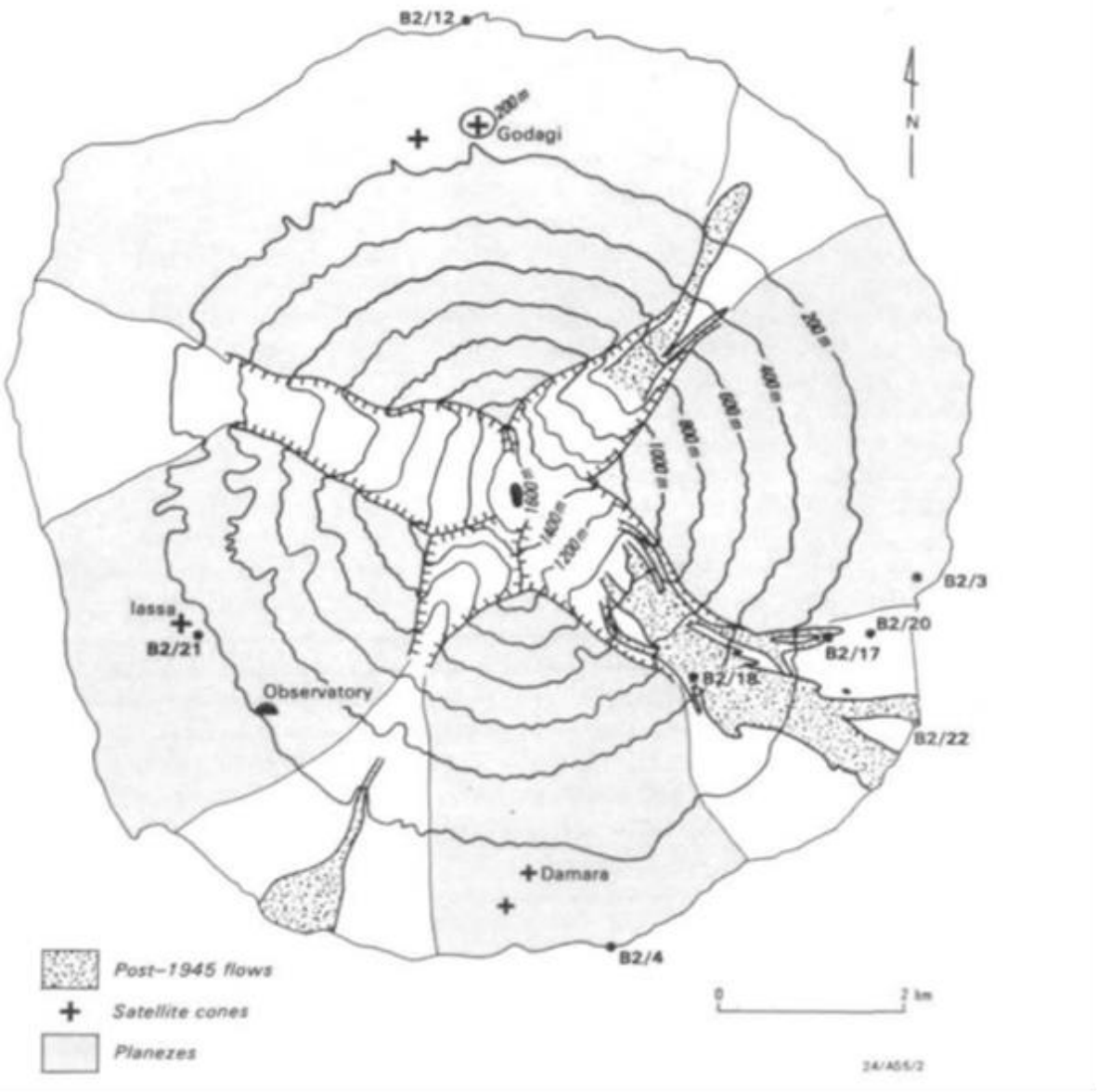


Figure 2 showing the topography of Manam and the volcanological features (Johnson, 1985).

Introduction

The Mt. Manam volcano has a long reputation of frequent and ongoing eruptive periods. This case study is regarding the eruption that initially took place on the 28th of June 2019 with the aftermath continuing into early July. It is of the upmost importance to analyse natural hazards such as this in order to globally educate and ensure the safety of communities. Leading to self-sufficient durable solutions catered to specific areas.

Background

The island of Manam is a conical volcanic island that is approximately 12-km in diameter and situated 13 km off the coast of northern Papua New Guinea; the Madang Province (Connell, Lutkehaus, 2017). Mt Manam is a basaltic-andesitic stratovolcano and is part of the Bismarck volcanic arc, a notoriously hazardous sequence of volcanoes, stretching around 1000km in distance "Manam is one of a chain of active volcanoes, situated on the "ring of fire" that

extends along the north coast of New Guinea" (IOM, 2016: Johnson, et al, 1972). Life on the very active island is difficult for the local residents as the volcano has produced 45 Holocene eruptive periods, with the most recent period commencing 29th June 2014 (Volcano discovery, 2019). The island has a problem with population displacement after extensive volcanic activity, making it hard to keep a track of. For example, in 2005 alone approximately 9000 people were evacuated from their homes (IOM, 2016). With no evacuation or resettlement plans in place, this has resulted in social and economical issues. Leading to tension amongst landowners and locals (IOM, 2016).

Disaster

Volcanic activity was initially recorded on the 27 June when Real-time Seismic-Amplitude Measurement (RSAM) values shot up from 540 to 1400+ (Global Volcanism Program, 2019). The next update in situation came the following day 28th June, when satellite images from The Darwin VAAC recorded an eruption plume at approximately 6:20am. This was around the same time that locals reported the beginning of the eruption (Global Volcanism Program, 2019; International Federation of Red Cross and Red Crescent Societies, 2019). Furthermore, on 29 June 2019, around the time of 7:45am, Mt. Manam continued to erupt and emit volcanic ash. This emission dispersed into the atmosphere, reaching heights of 15,000 feet and sent a surge of superheated pyroclastic flows down the northeast and western edges of the volcano (International Federation of Red Cross and Red Crescent Societies, 2019; OCHA, 2019a).

This eruptive period that started on the 28th June continued into July when the activity of the volcano persisted. At around 11:40am on the 12th July another volcanic ash plume swept over Manam, this time reaching heights of approximately 12,000 feet as stated from Darwin, Australia, Volcanic Ash Advisory (OCHA, 2019a). Volcanic activity continued 7 other times from the 12th July with the most recent being on 4th October. Ash plumes rising in some cases to 14,000 feet in this eruptive period, nearly as high as the initial eruption on the 28th.

Aftermath

The aftermath following this included a total of 7 separate areas directly affected by the pyroclastic flows and ashfall. These areas consisted of the villages of Bokure, Budua, Dangale, Dugulava, Madauri, Waia and Yassa. This amounted to a total of 3775 effected people from 755 households, all of which were directly relocated to various care centres (OCHA, 2019a). The situation was a struggle for locals after the first initial eruption on June 28th, food and water was very scarce, with the only sources remaining unsafe to consume. It was estimated from a flash report issued July 12th that 1410 people from the seven villages stated previously remain affected and situated at various care centres (OCHA, 2019a). Another big issue regarding the eruption was the disturbance in flights from surrounding airports. All flights were either rerouted or cancelled causing a disruption to the general public flying anywhere near the eruption (Global Volcanism Program, 2019). The aftermath of the eruption has led to a very vulnerable population of people, evidence suggests that Manam is a very low-income area that relies heavily on agriculture. As the area is a highly active zone for eruptions the high risk of eruption prolongs the displaced periods. This means that farmers and landowners not only have their land constantly effected, they are burdened with the lack of infrastructure and cannot rebuild or begin to resume normal life.

Response

There were high levels of displacement caused by the volcanic activity, this meant that locals were forced out of there homes in search of urgent refuge. The main response to the influx of displacement was an urgent demand for food and water for the locals situated in the various care centres. However, when this was identified by provincial disaster authorities, nearly a week passed since any action was actually taken. The National Disaster Centre stated they had released resources to provincial authorities on the 4th of July, 6 days after the urgent demand. Furthermore, as reported on the 12th July 1410 people from the 7 villages were estimated to still be in need of aid. United Nations Office of the Resident Co-ordinator in Papua New Guinea stated that there was no clean water available in the surrounding areas for the use within the care centres. (OCHA, 2019a). Due to the ongoing eruption, a defence naval barge departed on the 15th July with supplies for the thousands still forced to live in care centres. They arrived with 470 litres of water, 450 blankets, 350 kitchen sets, tents, solar lights, 70 hygiene kits, clothes and many more relief items in aid of the individuals (OCHA, 2019a). Furthermore, the instillation of water purification units were initiated. Medicals from the defence force provided vital check-ups and necessary education on awareness to those vulnerable and likely to be in similar situations in the future (OCHA, 2019a).

Technical Analysis

Mt. Manam is identified as a stratovolcano, situated approximately 2800m – 3000m above the Bismarck Sea (McKee, 1981). The slopes of most stratovolcanoes will rarely exceed the angle of repose for fragmental material at approximately 30-35 degrees (Global Volcanism Programme, 2019). Other characteristics of Manam include the 4 large valleys descending down the lower slopes from the summit. Spaced around 90 degrees from one another, they are commonly known as the 'avalanche valleys' as pyroclastic flows are typically channelled inside them

(Volcano Discovery, 2019). These characteristics of Manam demonstrate how hazardous the volcano is. The height, partnered with how small this island is (12km in diameter) and how active it is, highlight how much destruction the events will cause compared the many other areas that are faced with the same natural hazard. The volcano is located at the sub-ducting plate boundaries where the Pacific Plate sinks beneath the Indo-Australian Plate. Typically, the explosive eruptions that occur at Manam are particularly violent, suggesting the large discharge of volatiles from conduit magma (Johnson, 1985). These volcanos are the most common type found around the world (NASA, 2019: Wood, 1978). Stratovolcano such as Mt. Manams morphology are made up of layered slow lava flows and pyroclastic deposits, these deposits result from continuous eruptive periods. The formation comes primarily due to the rise of magma from the asthenosphere. This then reaches the Earth's surface through the pre-existing fractures and faults due to the lithostatic pressure pushing up the magmatic melt (Nechayev, 2015).

Assessment of response

Volcanic activity is a hazard in which results in many environmental, social and economical issues that an area has to be well prepared for. An example of response to such hazardous events is the case of Manam's neighbouring stratovolcano Ulawun. The volcano is located on the island of New Britain, Papua New Guinea. An eruption occurred a few days prior to Manam on the 26th June, the initial response to the hazard was rapid and thorough. Firstly, within one day, the response sub-committee of the National Disaster Committee called an emergency meeting to plan and discuss a strategy for response. Throughout this, the National Disaster centres emergency operations centre stayed active and if needed, had two helicopters on standby as well as emergency funding for shelter and food to aid displaced people. Finally, the National Disaster Centre set up plans to warn residents of any "no-go" zones around the volcano to avoid any further risk of hazard (OCHA, 2019b). As stated previously this was the response 24 hours after the eruption, compared to Manam's response that initiated a week after the event, the timings are very contrasting. Manam island is very active in regard to eruptions, this may have had a negative impact, resulting in a slow response. As volcanic activity is so common, some eruptions do not pose as much of a threat as others. The eruption on June 28th possibly wasn't identified to be as hazardous as it in fact turned out to be. Therefore, is would not be unreasonable to assume that authorities didn't accurately monitor and predict the extent of the ongoing issue. These timing issues, paired with the fact that many response teams and aid may have been dispatched to Ulawun just 2 days prior, result in a big strain on resources. In addition, another factor may be down to lack of funding to disaster teams and schemes "the Manam Restoration Authority (MRA) has no money to implement any restoration programme, according to chairman Ken Fairweather." This partnered with the fact that 10,000 people continue to live in the care centres in Papua New Guinea currently from eruptions as far back as 2004, mean that the government is already very behind in efforts of response. In essence playing catch up with themselves. (Elapa, 2019).

Conclusions

Upon reflection of the report, Manam is an island that has had 45 Holocene eruptive periods beginning as far back as the 1600's (Global Volcanism Programme, 2019). Therefore, this is an ongoing issue that the population of Manam will be continue to be burdened with. This is an example that shows the vulnerability of Manam and how fragile the local population is. As stated previously it appears that it stems from the fact that the infrastructure is damaged by the economical struggle the area is faced with. Addressing the failures of previous restoration programmes and tackling the problem of thousands of previously displaced people is the best place to start. Similarly, to Ulawun, a simple and effective strategy is to implement "no go" zones and relocating people to safer areas of the island, as oppose to relocating them to the narrow northern costal strips in the Madang Province. This will prevent the conflicts with local people over the use of various resources and overtime stop the complex and difficult political issue of resettlement they are faced with (IOM, 2016). The Madang Province government need to facilitate these local Manam communities themselves, in order to find a long durable solution and in turn not be forced to reply on as much aid from elsewhere.

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Wildfires in Australia

Rebecca Stockdale

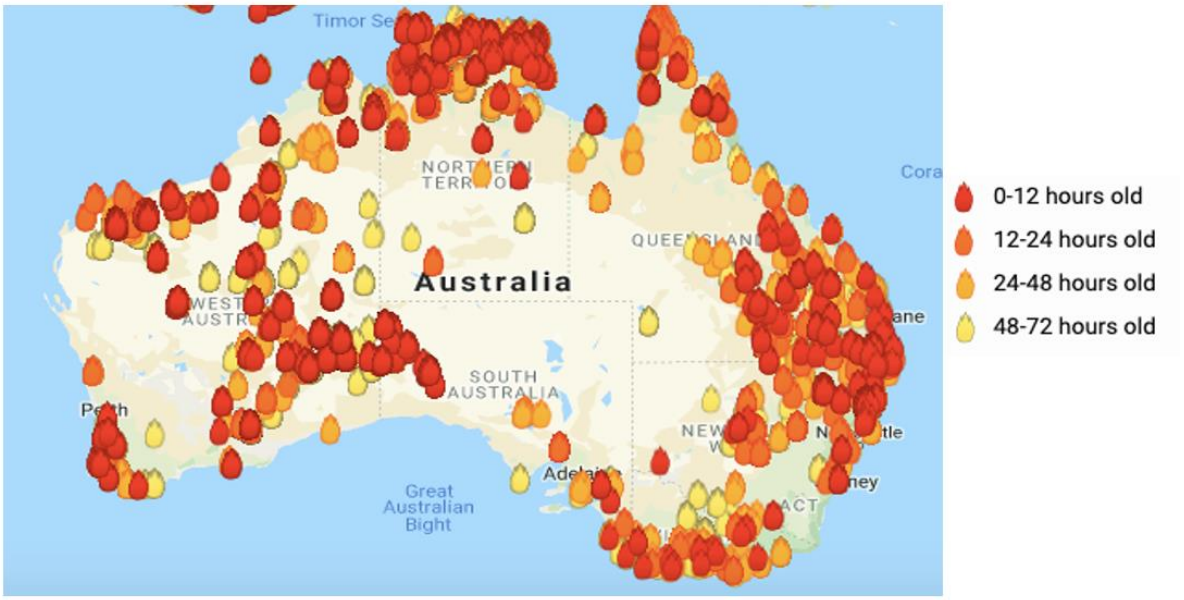


Figure 1: A map of Australia showing the spread of wildfires across the country and the number of hours they have been burning for. (*Government of Western Australia, 2019*)

Background

Australia has been enduring both extreme and dangerous conditions throughout the last year as wildfire conditions are reaching alarming levels. Spread over vast areas, consuming large amounts of fuel and advancing faster than they can be managed the country has been struggling to get the situation under control. The North, East and South-East coats have been hit particularly harshly with the states of Queensland and New South Wales being two of the worst affected places. There has been well over 200 fires estimated to be burning with no signs of rain to help ease the situation. Recent reports state that around 2.5 million acres have burned, and more than 400 structures have been lost. Six people are said to have lost their lives in the blazes, which is proclaimed to be a relatively low number when compared to how far the fires have spread and the scale of the environmental damage. (Leonard, D. 2019).

New South Wales has unfortunately been one of the most critically affected areas, with an area significantly larger than suburban Sydney destroyed in a short period of time. All six of the deaths sadly occurred in this area as firefighters battled to control a fire front about 6000km long, equivalent to a return trip between Sydney and Perth. (Morton, A et al. 2019). New South Wales' Rural Fire Service stated that the number of firefighters working tirelessly throughout day and night to try and contain the fires was over 630, estimating that without any significant rain the fires could continue to burn for 6 to 8 weeks. In Sydney, fires have reached the suburbs and there is a thick layer of smoke hanging across whole of the city, with flame retardant having to be dropped in the northern suburbs as the closest bushfires approached within 15km of the centre. Daily life has become disrupted as more than 600 schools have been closed across the state. Residents are being urged to stay away from bushland and keep up to date with official reports and warnings as the fires show no reprieve. ("Australian bushfires reach Sydney's suburbs" 2019)

In Queensland, the situation is despairingly similar, with the number of homes lost reaching double figures and around 180,000ha burned. Officials say the intense blaze marks the worst start to the fire season on record for the state of Queensland. Fires have already torn through rainforest areas in the South-East, which had become an easy target after drying out in the months of little rainfall that had preceded it. Winds of up to 50mph have been met with hot and dry weather resulting in threatening conditions needing upwards of twenty fire crews to fight the blazes in one go. (Australian Associated

Press, 2019 & Morton et al, 2019).

As can be seen in Figure 1 above, which was taken at the end of September 2019, the majority of wildfires are burning from the North coast round to the East, spreading through the two states of Queensland and New South Wales. The figure illustrates the extremely high number of individual fires burning across the

vast area demonstrating that it is not a simple job for fire crews as they have to tackle multiple fires of different sizes across Australia's unforgiving terrain.

Wildfire Safety

After the devastating Black Saturday bushfires that occurred in Australia back in 2009, killing a total of 173 people, Australian officials produced a new policy to be followed in times of wildfire urgency, in the hopes of preventing a situation like this from ever happening again. The policy, known as 'Prepare, Stay and Defend, or Leave Early' is based on the principle that a well-prepared and well-defended home can be one of the safest places to reside during a wildfire. Alternatively, if these methods are unable to be adopted, the policy suggests leaving early to prevent being trapped if trying to evacuate at a later time. However, further reports suggest that although these guidelines may be suitable during less severe fires, the best advice is to leave before a fire threatens. This comes after many people had been caught by surprise waiting for an official warning or other sign of danger as well as being unaware of a fire's location, speed, and intensity. (Leonard, D. 2019).

A second step towards safer guidelines after the 2009 tragedy was the development of a national agreement establishing a new framework for wildfire warnings, one that would be linked to the Fire Danger Rating. This fire warning comes into action as soon as a fire on the ground is discovered, with three levels of warnings depending on location, speed and the Fire Danger Rating for that day. The first is an Advice level which is issued for fires that don't yet pose a threat but require close monitoring. The second is a Watch and Act notice meaning a fire is spreading and residents should either prepare to leave or leave immediately. The highest alert is an Emergency Warning which warns residents to leave immediately. News reports suggest that there have been more than 10 of these alerts issued in a single day throughout the worst parts of the 2019 bushfires and it is believed that these improved warning systems have played a key role in saving lives during outbreaks of the fast-moving fires, ultimately keeping the death toll significantly lower than it was back in 2009. (Leonard, D. 2019).

Wildfire development

There are several ways in which wildfires can be ignited, both naturally and by human causes. The most common natural cause is lightning, estimated to start the majority of wildfires across Australia. Typical hot and dry weather conditions mean fuel is easily ignited and burning conditions are exacerbated creating a force unstoppable without the aid of natural heavy rainfall. Unfortunately, a second way wildfires are commonly started is through deliberate arson. Other human causes are accidental burning from campfires, cigarettes and BBQ's, as well as agricultural practices. It is thought that the brunt of the deadly fires burning in Australia were started through natural causes, however throughout the burning police forces have been undertaking investigations into cases of what they believe to be deliberate arson. An arrest was made on a young volunteer firefighter spotted lighting fires in a remote area before later returning to respond to the fire as part of his duties, in what has been described as an "ultimate betrayal". (Australia bushfires: Firefighter accused of arson... 2019)

Conditions in Australia

Over the past few years Australia has been suffering from one of the severest droughts on record, with some parts of the East Coast of Australia experiencing two years of below average rainfall conditions. Statistically, when comparing to other 35-month periods commencing in January, the period from January 2017 to November 2019 has been the driest on record. Averages of both of the Murry-Darling Basin and the state of New South Wales came in at 36% below levels recorded in previous years. New South Wales received over 100mm less rainfall than the last recorded dry period, which ended in November 1902 during what was named the Federation Drought. (Bureau of Meteorology, 2019). As this is a long running drought, it has allowed the build-up of adverse conditions that are not only detrimental to human wellbeing but also to environmental conditions. With no rainfall and no surplus moisture for vegetation, landscapes have dried out drastically creating the perfect conditions for wildfire spread. Wildfires rely on three components to burn – oxygen, heat and fuel, aptly named the heat triangle. Limited moisture contributes specifically to the fuel aspect of the heat triangle, as dry vegetation is a fuel source that allows fire to rapidly gain energy and accelerate across large areas of land in short periods of time. Although fires burn through many different fuel sources, it is grasses, shrubs and forests that burn in the highest quantities. Grasses are lightweight and ignite easily, creating flames between 1 and 4m, whereas shrubs are denser but create a much more intense burn due to a higher oil content. These two types of fuel contribute to the beginning stage of forest fires – 'litter' layers on forest floors made up of leaves, twigs and small plants set alight first, known as a surface fire. From here, 'ladder' fuels, such as short trees and shrubs are ignited causing the fire to gain both energy and height. The final stage, known as a crown fire, occurs when ladder fuels set alight the branches of taller trees. Crown fires are the largest and most dangerous fires as they are the hardest to control. The drought conditions have affected the fuel available at each stage of this burning process by drying it out and making it more susceptible to fire sources, such as lightning, as well as making it easier to catch light from fire already burning. These reasons are why drought has become

one of the main contributors to Australia's devastating wildfires being experienced today. (Randall, 2004).

In Australia, 17% of the total land area is made up of forests, a figure of 134 million hectares. Out of this total forest area, 39% is located in Queensland and a further 15% located in New South Wales. The two areas combined make up 72.2 million hectares of land, accounting for over half of the total sum of forests within the country. Forests in Australia are split up into three different categories; 'Native forests' make up the majority of the land at 98%, with the remaining proportion being split between 'Commercial plantations' and 'Other forests'. Native forests are dominated by eucalyptus, reaching 77% coverage, a species that has a high oil content when compared to other plant species found within Australia's forests. (Australian Government, 2018). This widespread coverage of woodland coupled with the composition of species found within explains why the fires burning across Australia are so severe. The high oil content in the eucalyptus plants will be resulting in extremely intense burns and the large volume of forest land found within Queensland and New South Wales will mean they are burning in high quantities. These two factors paired with the drought conditions explain why the battle that firefighters are undertaking to try and protect the two large states is such a large one.

Characteristics of wildfires

Wildfires can occur across the country at any time of year, however peak activity levels vary across the country with the changes in seasonal weather patterns. In the Southeast of Australia, the main wildfire season is throughout summer and autumn due to the drying out of grass and forest fuels. During late spring and early summer vegetation contains some moisture but fires can still occur on hot days with strong winds. The greatest threat to the North and East Coasts, where Queensland and New South Wales are situated is from spring to mid-summer. This occurs after the dry winter when deep low-pressure systems near Tasmania bring strong, hot and dry, westerly winds to the coastal districts. The end of the fire season is determined by the arrival of moister conditions making potential fuel less flammable. (Bureau of Meteorology, 2017).

As seen in Figure 2, the graph shows that Northern Australia is most commonly hit by wildfires through winter and spring with the South being affected during summer. The East coast, where the majority of fires are spread between has the longest ranging fire season as it receives influencing weather from both the North and the South. Figure 2, along with the information presented above contradicts the situation in Australia at present as the fire seasons have reached peak levels many months before they usually occur. This would suggest that there are external factors beginning to influence the wildfire seasons and the usual global weather patterns used to predict them may be changing.

Impacts and Responses

Being a well-developed country with capital available to access facilities, produce warning systems and fund firefighters Australia has previously managed to control the yearly fires with relative success. With fires usually following a season and peaking at specific times it is easier to plan and provide enough resources for the times of highest risk. However, the out of character circumstances seen in the last year and beyond has resulted in unseasonal fires and left resources under great strain. The sheer number and strength of the fires has left firefighters constantly battling flames without breaks to try and protect local wildlife, houses and most importantly human life. Volunteer crews have been a necessity in the struggle meaning some individuals have not had the experience required to fight fires of this great scale. Although the country is somewhat struggling to reduce the fires burning, several response measures have been put in place. The warning systems described above are helping to keep local populations safe and keep the damage occurring mainly restricted to the environment. Charities such as the Australian Koala Foundation have been set up to help the multiple species struggling to escape the blazes, as they are being wiped out in large numbers due to their habitats being destroyed. In terms of the human population, it is still unclear as to how Australia will respond to help those communities devastated by the fires as at present the focus is still on trying to stop the catastrophic blazes.

Future Impacts

The severity of Bushfires may only get worse, as the effects of gradual climate change make slight alterations to the influencing factors in the burning of wildfires. Although it cannot directly start more fires, climate change is influencing both the frequency and severity of wildfire conditions in Australia. Temperature and environmental moisture fluctuations, weather patterns and fuel conditions are all factors influenced by a warming climate that can exacerbate the conditions of natural fires. Evidence for this has been observed in Southern and Eastern Australia where the fire season has started much earlier than usual. There have also been more severe conditions experienced during summer, and the dangerous weather conditions often noted in spring have begun significantly earlier than previous years. In northern Australia where there is the highest amount of fire activity during the dry season, there has been an increased level of monsoonal rainfall resulting in a surge in the growth of fuel sources in recent decades, ultimately increasing the risk level of wildfires in this area. (Karoly, D et al, 2001).

In conclusion, in line with the evidence of the conditions in Australia at present and the nature of the wildfires, it would appear that if the state of the climate continues to worsen, primarily due to human use and consumption, these 'abnormal' fires could sadly become a common occurrence for Australia.

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Typhoon Faxai:

Ned Ward

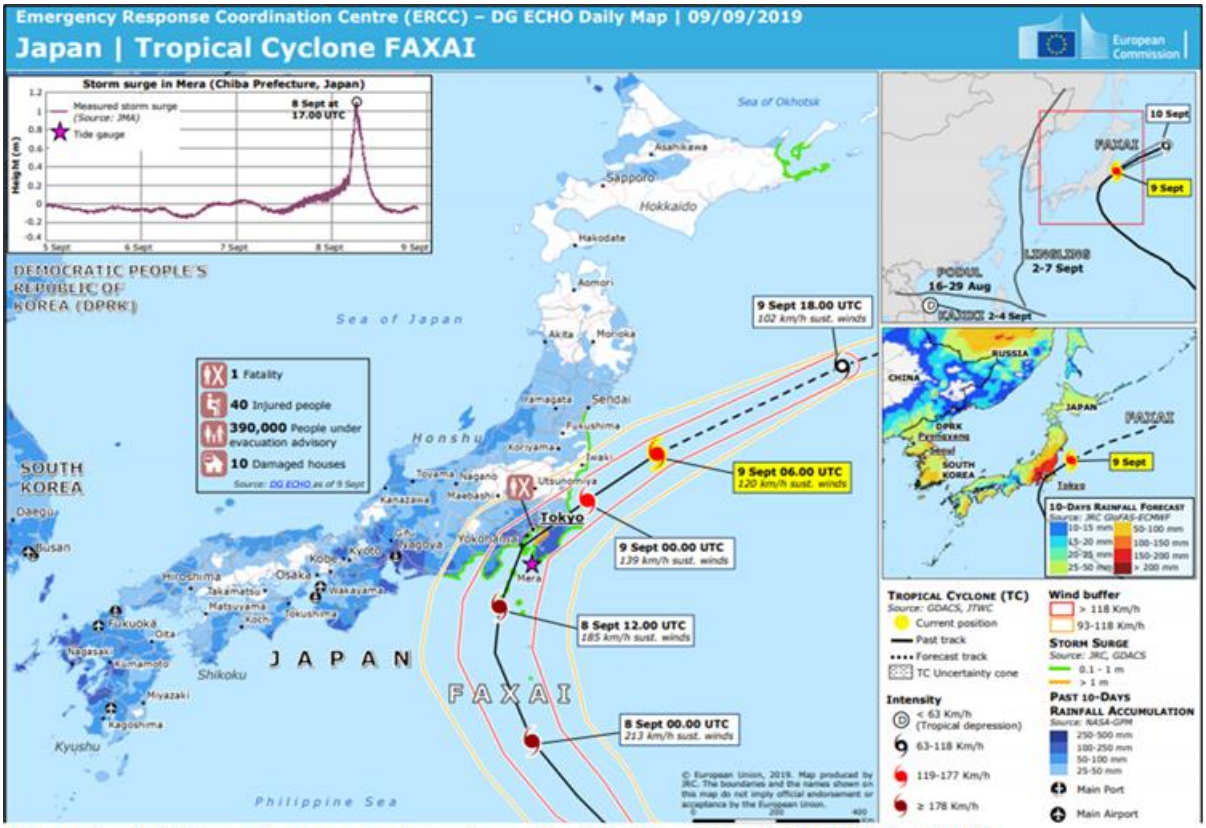


Figure 4: An informative map to show the path of Typhoon Faxai (Reliefweb, 2019)

Introduction

Cyclones, hurricanes and typhoons are different names for the weather phenomenon: tropical cyclones. 'Tropical cyclone' is the generic name that meteorologists use which refers to a rotating, organised system of clouds and thunderstorms that have a closed, low level circulation and develop over either tropical or subtropical waters. Tropical depressions are the weakest tropical cyclone, however they become tropical storms if maximum sustained winds reach 39mph. If maximum sustained winds increase to over 74 mph, then it can be categorised as a hurricane, typhoon, or tropical cyclone. The geographical location and severity of a cyclone determines the name of the tropical cyclone. The term hurricane is used in the North Atlantic, central North Pacific, and eastern North Pacific. Whereas they are called typhoons in the Northwest Pacific. Lastly, in the South Pacific and Indian Ocean, they are referred to as tropical cyclones. (NOAA, 2019)

Typhoon Faxai made landfall in the Kanto region of Japan in the early hours of September 9th, 2019 at 5am. The location of the main affected areas can be seen in figure 1. The typhoon was the largest to hit Tokyo in a decade. Damaging wind speeds reaching up to 216km/h were recorded, resulting in substantial structural damage, and record rainfall of 430mm fell within 12 hours. (Tokyo Weekender, 2019) There was a total number of 3 fatalities as a result of the typhoon. Since Japan began maintaining records, Faxai was the ninth to have made landfall in this area of Japan, with the previous typhoon occurring in 2016, known as typhoon Mindulle. (Reliefweb, 2019)

Meteorological Background

Figure 2 shows satellite images of typhoon Faxai on the 8th and 9th September. The path of typhoon Faxai can be seen in figure 3, where it formed as a weak tropical depression on the 1st of September 2019. As Faxai's journey progressed, its storm category increased, with the storm reaching typhoon status on September 6th and further intensifying into a category 4 storm on September 7th, just south of Japan. The typhoon then weakened slightly to a category 3 storm, before making a short-term landfall over the Miura Peninsula, Kanagawa Prefecture in the Kanto region of Japan, in the early hours of September 9th. The centre of the typhoon later moved northeast across Tokyo Bay, making a second landfall over the city of Chiba, 20 miles east of Tokyo (Risk management

solutions, 2019; Weather Underground, 2019). Typhoon Faxai turned north east where it began to quickly weaken and finally fizzled out and ended over the Pacific on September 9th (Reliefweb, 2019).

The Effects of the Typhoon

Typhoon Faxai affected areas such as Chiba Prefecture, Tokyo and Kyonan, which can be seen in figure 1. Faxai was one of the strongest typhoons to hit the Japanese capital in a decade and caused a path of destruction throughout its journey with The Japanese Meteorological Agency (JMA) announcing high waves, heavy rain and storm warnings for south-eastern Japan. These resulted in damages to property, infrastructure, travel destruction and deaths (Belles, 2019). This path of damage can be seen in figure 4. Media reports have stated that there was a total of three fatalities as a result of the typhoon, with 1 death in Tokyo, a second in Otaki Town and a third in Kanagawa Prefecture. There was also 50 people injured (Reliefweb, 2019). The area in which Faxai made landfall is rarely impacted by such intense storms. Although Typhoons affect Japan yearly, the storms rarely make it as far north as Tokyo, with Faxai being the ninth typhoon to make landfall in Chiba Prefecture since Japan began keeping records. It was also the first since 2016 (Victor, 2019).

Faxai resulted in evacuation warnings, with 5,000 people in Chiba and nearby Kanagawa prefecture being instructed to evacuate. Authorities also declared a non-compulsory evacuation warning to over 390,000 people as rain and wind achieved record strengths, with winds intermittently strong enough to shake buildings. The risk of landslides was another factor resulting in the evacuation warnings (McCurry, 2019; KYODO, 2019). Further issues as a result of the typhoon included several water purification plants having no power, which resulted in approximately 16,700 households were left without water (KYODO, 2019).

Power Outages:

Destructive wind speeds of up to 216km/h were recorded, which produced substantial structural damage, including causing electricity poles to snap and towers to fall over. This resulted in 930,000 households to experience power outages. (KYODO, 2019; Reliefweb, 2019; AIR Worldwide, 2019). These power blackouts were also a result of two steel towers in Kimitsu in Chiba collapsing, shown in figure 5 which was estimated to have caused 100,000 households to have no electricity. In Japan, it is required by the industry ministry that these steel towers ought to withstand 144km/h winds, however they collapsed due to the typhoon having maximum wind speeds of 207km/h (greater than normal expectations) in Chiba's Chuo Ward. A Sony Corporation factory that manufactures the PlayStation 4 was also affected by the blackouts, resulting in the factory to close. (KYODO, 2019). Faxai was also connected to a fire at Japan's biggest floating solar power plant, which is located on the Yamakura Dam in Chiba prefecture. The power plant stretches across 44 acres and generates up to 13.7 megawatt of energy. However, some of its panels caught fire as a result of the typhoons powerful winds pushing the solar panels on top of each other. This resulted in them to overheat as energy from the sun began to hit the solar plant (Chappell, 2019).

Transport Issues:

Typhoon Faxai prompted mass transport disruption, causing problems for the morning commute in Tokyo on the 9th September. Japan prepared for the typhoon by cancelling and delaying main train lines, with 2.7 million passengers on Tokyo's JR East (East Japan Railway) being affected. (Chappell, 2019; McCurry, 2019). JR East's 5 bullet trains ran at reduced speeds, whilst strong winds forced Central Japan railway to suspend the Tokaido bullet train which connects Tokyo with Odawara city. Most train services train services did not resume until the following day. Before the typhoon even made landfall, it caused travel disruption with roughly 100 bullet trains that connect Tokyo with central and western Japanese cities being cancelled on the 8th September, as well as ferry services in Tokyo Bay. Other travel disruption included, over 100 flights being cancelled as the typhoon hit Tokyo and its neighbouring prefectures, with an approximate 13,000 people left stranded at the Japanese capital's international airport. (McCurry, 2019).

Technical Interpretation

How do Tropical Cyclones Form?

Tropical cyclones can occur in seven ocean basins: Tropical Atlantic, Northeast Pacific, Northwest Pacific (where typhoon Faxai occurred), Southwest Indian, North Indian, Southeast Indian, and South Pacific. This can be seen in figure 6. The intensity of the tropical cyclones is a result of several processes which include tropical cyclone dynamics, dynamics, upper ocean interaction, and atmospheric circulation. (Goni et.al 2009).

The Northwest Pacific basin, where Faxai occurred, is known to be the most active basin out of the seven, with cyclones forming throughout the year. Once the cyclones have formed, they commonly move north/northwest, where the countries that are regularly impacted by typhoons include, the Philippines, Southeast Asia including China, Taiwan and Japan in this basin. The peak frequency of tropical cyclones within the Northwest Pacific basin occurs during the months from July to November. (Roy and Kovordányi 2012). For tropical cyclones to form, they require heat and moisture, therefore they form over warm tropical or subtropical ocean water with sea surface temperatures of at least 26°C. The meteorological growth starts with a low-pressure disturbance such as

a vortex near the Inter-Tropical Convergence Zone. As the surface pressure falls, it creates a circular area with around a 30km radius and strong in blowing winds. This disturbance can them create a hurricane if specific environmental conditions are met. The rising air must be warmer than the surrounding air masses up to 10– 12 km above sea level. There must also be high atmospheric humidity up to about 6 km. For the low-pressure system to gain rotation, the typhoon needs velocity. Therefore, it cannot develop within 5° latitude of the equator so that the low-pressure system can be sustained through the Coriolis force and the airflow converging on a low is deflected to create a spiral structure. Cyclones need to form in air currents that have weak vertical wind shear as this reduces vortex development. Most cyclones occur after monsoon season (late summer to autumn) because this is when sea-surface temperatures are at their highest. Lastly, along with the developing surface low, an area of comparatively high pressure must happen on top of the developing storm. (Smith 2013).

Forecasting Techniques

Accurate tropical cyclone forecasts are extremely important as it helps to determine where and when the damage may be expected, ensuring that preparations such as evacuations are made to reduce the loss of lives and economic loss. However, when it comes to forecasting tropical cyclones, there are numerous challenges, for example, tracking the path of the typhoon, predicting wind intensity, precipitation and duration of the typhoon, and predicting storm surges and coastal floods. Over recent years, advances in numerical weather prediction computer models and forecasting the initial development of tropical cyclones has improved significantly. In the 1960's, the TIROS weather satellite was launched, providing television pictures from space, and satellite coverage was adequate to detect the formations of all tropical cyclones around the world. In the Northwest Pacific basin, forecasting duties are shared between China, Thailand, Korea, Japan, the Philippines, and Hong Kong (Elsberry 2014). The main forecasting techniques used in the Northwest Pacific basin include, statistical forecasting techniques, satellite image-based techniques and numerical and ensemble forecasting. (Roy and Kovordányi 2012).

Tropical Cyclones and Climate Change

Numerous studies have discovered an increasing trend in intense typhoon frequencies in the Northwest Pacific. Figure 7 shows the percentage increase 1980 to 2016 in the number of tropical storms worldwide depending on their strength. As the ocean becomes increasingly warmer, this results in surface water to have much more energy to convert to hurricane winds. This is likely increasing the amount and intensity of typhoons in the Northwest Pacific, impacting areas like Japan such as Typhoon Faxai. (Kang and Elsner 2016). In the northwest Pacific basin, there is emerging evidence for a detectable poleward shift in the latitude of maximum intensity of tropical cyclones, with a tentative link to anthropogenic warming. Because of the steady warming of Northwest Pacific during the past few decades, the area that is favourable for tropical cyclone development has increased, and its northern boundary is shifting poleward. Consequently, tropical cyclones in this basin are more likely to begin weakening at higher latitudes, which further leads to their lifetime maximum intensity location shifting poleward. It also extends the region favourable for tropical cyclones development to higher latitudes. (Song and Klotzbach 2018).

Conclusion

It is evident that Japan and other areas within the Northwest Pacific basin are vulnerable to typhoons, with the Northwest Pacific basin known to be the most active basin out of the seven, where cyclones form throughout the year. Typhoon Faxai occurred in the beginning of September 2019, which is consistent with the peak frequency of tropical cyclones within this basin, which occurs during the months from July to November. This therefore indicates that Japan is highly vulnerable to typhoons, consequently Japan has preparations and responses in place to mitigate the impacts from typhoons, for example the Japanese Meteorological Agency (JMA) can forecast the rainfall and wind intensity, as well as issuing storm warnings and evacuation warnings. Japan also ensures that all residents know what to do in an event of a typhoon. (Roy and Kovordányi 2012).

Due to Japans vulnerability to typhoons, there is a strong future risk as intense typhoon frequencies are increasing, with one factor been due to climate change. As the Northwest Pacific Ocean warms, this causes surface water to have much more energy to convert to hurricane winds, resulting in tropical cyclone development to increase. The area in which Faxai made landfall is rarely impacted by such intense storms. Although Typhoons affect Japan yearly, the storms rarely make it as far north as Tokyo. Typhoons in this area of Japan are likely to become more common due to climate change and the northern boundary shifting poleward. (Kang and Elsner 2016; Song and Klotzbach 2018).

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Sunda Strait Tsunami, Indonesia

Ella Warburton



Figure 1 - Aerial picture showing the vegetation damage caused by the tsunami at Ujong Kulon National Park, photo from Muhari et al. (2019)

Event Account

Indonesia is a very tectonically active area as it sits on the plate boundary of the Indo-Australian, Eurasian, and Philippine plates. It is also within the Pacific Ring of Fire. This means it's an area with a high level of earthquakes, volcanic eruptions, and tsunamis. Anak Krakatoa is a volcano that sits between the larger islands of Sumatra and Java, as can be seen in figure 1. On the 22nd December 2018 the volcano Anak Krakatoa erupted for 2 minutes and 12 seconds and shot an ash cloud 1,300ft into the air (Russell, 2018). The eruption caused the island to partially collapse into the sea and caused tsunami.

There was little to no warning of the tsunami, this was a result of the source of the waves. Earthquakes are the most common trigger for tsunamis, however volcanic eruptions, landslides, and any other event that can cause a displacement of the water can also cause them.

Tsunamis are far easier to predict when an earthquake causes them, as the monitoring systems are more effective. There is less of a consensus in the scientific community around how to monitor volcanoes for potential tsunami events, as early warning centres do not often consider this cause (Walter et al., 2019). This tsunami and many around Indonesia are very localised and would require thousands of buoys in order to cover all the at risk areas (The Guardian, 2018).

In September 2018 a tsunami hit Palu, there was warning for this one as an earthquake caused it. Warnings were sent out via text to warn residents, however the tsunami turned out to be a lot bigger than expected and resulted in over 2000 deaths (Omira, Dogan, Hidayat et al., 2019). The lack of organisation and inability to communicate with the citizens seems prevalent in Indonesia as it is underfunded and has very complex plate boundaries underlying the country. There is also no consensus among the scientific community on what signals act as good warnings for collapses on volcanic islands.

Immediate impact

The tsunami took around 30 minutes to strike the shore, which hit at 21:30 during a local holiday (Wei-Haas, 2018). One of the worst hit areas was the Pandelang area in Java, as shown in figure 1.

Originally, the death toll was reported to be around 222 by the BBC, National Geographic and the Guardian (BBC News, 2018b) (Wei-Haas, 2018) (The Guardian, 2018). A few days later the death toll had risen to 429 (Antara News, 2018). Roads and bridges, which were already in bad condition, were damaged making villages and areas inaccessible (Watts and Sentana, 2018). This made finding out the true damage and impact of the event difficult to assess quickly. Most sources after around the 26th December state around 1000 buildings and structures have been damaged including: houses, hotels, shops, and stalls. This means people have been left homeless and some have lost their livelihood, through their homes and shops being destroyed as well as possessions such as boats.

The tsunami hit a beach where a local band were playing sweeping away the stage and killing their bass player and manager as well as people in the crowd (The Guardian, 2018). Many of the people found dead were tourists on holiday (Watts and Sentana, 2018). It occurred during a long holiday so the holiday resorts were packed with people (Rudianto, 2018).

Loss of coastal vegetation often occurs during tsunamis as the waves carry away trees and anything it it's path. This can be observed on the three islands surround Anak Krakatoa. Loss of vegetation can be seen along the coast of the Ujong Kulon park to the south of the volcano, as is shown in figure 2. Coastal forest was swept away up to 800m inland, this area is uninhabited and the vegetation is over 100 years old. The national park is designated to conserve the rhinoceroses (Muhari et al., 2019).

The extreme damage to the surrounding three islands that are close to Anak Krakatoa indicates that they may have reduced the tsunami amplitude thus reducing the extent of the damage by the time it hit the shoreline where people and infrastructure was (Muhari et al., 2019).

Locals and tourists were warned to stay away from the coastline until at least Christmas day (3 days after the event) in case of further waves (Hodgkin, 2018). This resulted in people being displaced from their homes for an extended period of time. There was debate about the future risk of tsunamis from this source. Richard Teeuw from Portsmouth University said that the likelihood of further tsunamis would remain high whilst Anak Krakatoa is still active due to the risk of more landslides (Al Jazeera, 2018). However in the past year there have been no further waves since the initial one; and no further landslides.

Technical Analysis

Geological History

Indonesia is a very tectonically active area as it lies on the conjunction of three tectonic plates. The Indo-Australian and Philippine plates are subducting under the Eurasian plate at 90mm and 75mm per year (Omira, Dogan, Hidayat et al., 2019).

Anak Krakatoa is located on the ring of fire surrounding the Pacific Ocean. It is also one of the 127 volcanoes in the archipelago forming Indonesia. Anak Krakatoa was formed following the largest recorded volcanic eruption in history. In 1883 Krakatoa erupted, the volcano hadn't erupted for a long time as a plug had formed preventing the lava from escaping (The Eruption of Krakatoa, 1888). It erupted so violently that only one third of the volcano was left; the rest had been erupted and submerged into the sea (Schröder, 2013). The collapse formed a caldera, which the other 3 islands in the area are part of. Anak Krakatoa (or "Child of Krakatoa") emerged in the middle of the caldera over 40 years later, around 1928 (Walter et al., 2019). The volcano is very active and has been growing in height for close to a century, and was standing at 340m. This followed the collapse of the South Western flank of the cone (Amos, 2018a).

Prior to the Eruption

The volcano was experiencing its greatest eruptive phase in 20 years resulting in an increase in the islands surface area leading up the eruption. Most of these eruptions had little to no impact on the surrounding population, as they did not cause a landslide and tsunami. There had been concerns from the scientific community previous to the eruption that a landslide could cause a tsunami as the southwest flank of the volcano was growing towards the deep caldera basin. This deformation had been noticed but was not closely monitored for risk of collapse (Walter et al., 2019).

In 2012 a group simulated a tsunami caused by the collapse of the south-westerly flank. Figure 3 shows the path and the timing predicted within this simulation. It shows that it would take around 30 minutes to reach the shoreline of Java. This is accurate to what actually occurred 6 years later. Although this had been simulated, the volcano was still not monitored for signs this event actually occurring. This meant no warning was issued when the event actually occurred.

The Eruption

When Anak Krakatoa erupted and caused the tsunami, the eruption lasted over 2 minutes. The ash cloud went 1,300ft into the air (Russell, 2018). The volcano was initially 340m above sea level and after the eruption was reduced to 110m, less than a third of the size (Amos, 2018b). Such a huge amount of debris collapsing into the sea caused massive displacement of the water. The eruption and then subsequent landslide can be seen in the seismic data shown in figure 4 below.

As can be seen, the earthquake occurs around 2 minutes before the flank collapses into the sea. The mass of land entering and moving in the sea causes a

displacement of water. The tsunamis effects were exacerbated by the heavy wind and rain as well as the high tide (Watts and Sentana, 2018).

The "run-up" of a tsunami is the used to describe the maximum height of the seawater above the sea level prior to the event; this is directly linked to how far inland the wave travels (Lin, Ikuta, Rao, 2012). The tsunami had run-up values higher than 30m at the islands surrounding Anak Krakatoa like Rakata, this can be seen by the limit of the destruction of the trees. By the time the wave reached the populated island of Java and Sumatra the run-up had reduced.

Early Warning Systems

Even with the knowledge that it could happen again, Indonesia has no early warning system for underwater landslides or volcanic eruption. On top of this its early warning system for tsunamis hasn't been operational since 2012. After the 2004 Boxing Day tsunami, Indonesia was donated 21 buoys, which can dispatch advanced warnings using data gathered. These are no longer operational due to vandalism and theft, and any replacements were delayed due to lack of funding (BBC News, 2018a).

The system that is used is Indonesia's meteorological and geophysics agency (BMKG), which use a modelling system based on earthquake depth and magnitude. This is less accurate than the buoys would be and also does not allow for volcanic causes.

Conclusion

Anak Krakatoa erupting, for the most part, doesn't affect any people living in this region. The islands immediately surrounding the volcano are uninhabited and the larger islands are far enough away that it doesn't really affecting the population. The danger comes in when a landslide is a possibility; there was a level of awareness that a collapse was going to occur as Giachetti et al. simulated this event occurring in 2012. Unfortunately the Indonesian government does not have the funding to monitor and prepare for all the natural hazard events that could occur in this area.

The area that was hit contained a number of hotels and resorts for tourists. It is often the case that tourists aren't aware of the risks or the emergency procedures for how to act if an event like this does occur. They are far more likely to rely on sirens and warning systems like this rather than pay attention to natural signs such as the tide rushing out (Hall et al., 2019). Education could be used to help tourists reach safety in the future.

There is very little information on the long-term impacts of the event. There are plenty of articles within 10 days of the tsunami occurring and academic article about the mechanics of the tsunami starting. There is however, very little to no information beyond the first 10 days on the impact of the tsunami of the locals and the tourists.

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River Flooding: Townsville, Australia, 2019

Adam Thorne

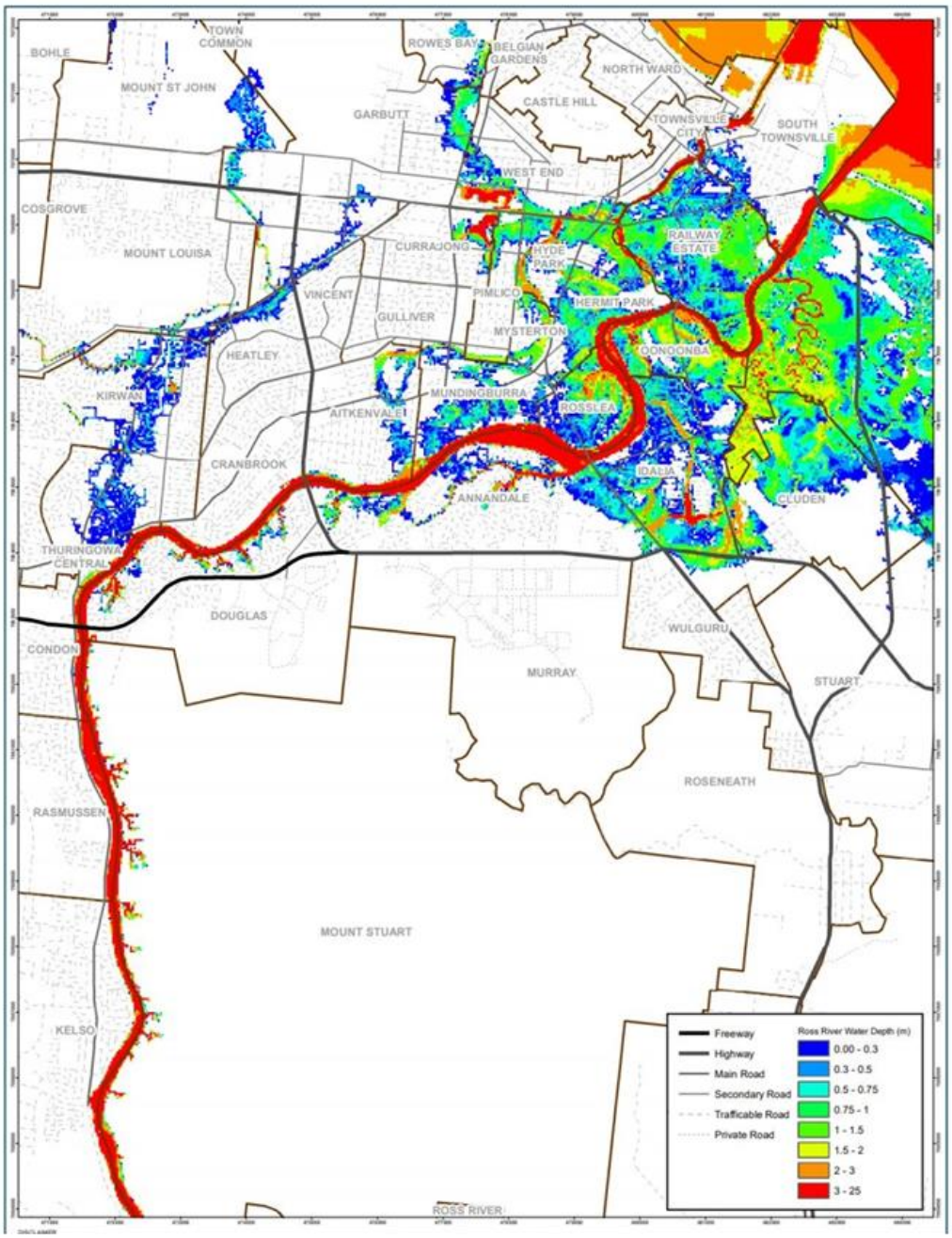


Figure 1.2 - Effects of flooding downstream after opening of the dam

City of Townsville, (2019)

Introduction

Riverine floods are considered one of the most frequent natural disasters, which cause considerable damage both material and environmental. (Buldakova, E, et al. (2016)) During the months of January and February 2019, Townsville a City located in the Australian state of Queensland (See Figure 1.0), the most flood-prone state in Australia (Insurance Council of Australia (2019) experienced unprecedented heavy rains and major flooding. More than 100 million hectares of land was damaged, with areas located in North and North West Queensland most affected. This report highlights the 2019 Floods in Queensland, Australia by examining the factors which contributed

to the event, their subsequent impacts and the management strategies undertaken to alleviate the situation.

Authoritative Account

Monsoon

The initial cause of the River Ross flooding began on the 26th January 2019, as an active monsoonal trough and slow-moving low-pressure system from tropical cyclone Riley, brought heavy and prolonged rainfall over Australia's Western coast. Reports by (Gissing, A, et al, 2019) explained that the area of low-pressure was centred over the Gulf of Carpentaria, drawing rain in from the Coral Sea which eventually intensified inland. Within a few days, the monsoonal trough began moving slowly south over Queensland, until eventually maintaining its position over areas around Townsville by the 28th January.

Intense Rainfall

The system of persistent heavy rainfall in the Townsville Region occurred between the 28th January and 8th February (See Figure 1.1) and lasted for over a week. Dr Richard Wardle from the Bureau of Metrology said, "The summer annual rainfall for Townsville was 1.1 metres", however, several areas in the Ross Catchment had already received two or three times that. (Australian Associated Press (1st February 2019)) According to the Bureau of Meteorology (BOM) the Townsville Rainfall Gauging Station measured total rainfall at 1,391mm from the 27th January to 8th February. (JBA Risk Management (7th February 2019)) These levels exceeded the previous record of 871mm which was set in January 1998. Bureau of Meteorology (BOM) noted that 370mm of rainfall fell within 24 hours at Paluma. (Floodlist News (31st January 2019) The series of frequent intensive rainfall events resulted in increased ground saturation causing watercourses to swell and some flash flooding, with initial flood depths around 30cm in the worst affected areas. (Gissing, A et al, (2019) However, as the rainfall intensified concern grew in areas located outside Townsville, as further rainfall fell in the upper Ross Catchment.

Water Levels in the Ross Dam

The Ross River Dam has an upstream catchment area of 760 km2 and is situated 9km upstream of the City of Townsville. As the torrential rain continued, upper catchment areas above the Ross Dam received large volumes of water, which caused smaller tributary rivers to swell. As upstream river levels began to rise, the water began to drain down into Lake Ross which contributed to the rising water levels. A report by (BMT in Environmental), reported that the dam peaked at 248% capacity with a record supply level of 43.03m AHD. As there was still a chance for heavy rainfall to continue local authorities made the decision to open the spillway gates to their full setting reported CNN Affiliate 9 News. (Griffiths, J. (4th February 2019)).

According to Smee, B (2019), the decision to open the floodgates was based on a 2012 one in 100-year flood model, delaying the levels in the Ross Dam until they reached 43m, would result in less than 100 properties downstream to be affected. (Bailey W.G, et al, (2012) However, it was not taken into consideration that in an extreme one in 1000-year flood, the model predicated that delaying the floodgate opening could be six times as damaging downstream. (Smee, B (2019) Monitoring by the Bureau of Meteorology (BOM) recorded the height of the Ross Dam as 42.99m on the 3rd February, which prompted the Townsville Government to open the floodgates fully on the Sunday night. Once the floodgates had been opened approximately 1.900 m3 of water per second exited the Ross Dam, causing rising river levels downstream.

According to Annastacia Palaszczuk, from the Queensland Premier, opening of the dam was in line with the current management plan. (Guardian Staff and Agencies (3rd February 2019)) However, the mayor of Townsville Jenny Hill said that dam release would "exceed what was allowed under Townsville's Emergency Action Plan", but authorities had no choice to try and alleviate the situation or face catastrophic dam collapse. (Guardian Staff and Agencies (4th February 2019)

Ross River Flooding

Once the Ross Dam had been fully opened (See Figure 1.2) downstream observations at the Black Weir on the 4th February, noted rising river levels recording just below the moderate flood level of 2.50m. Local spokesman Bruce Gunn said, "High velocity flows and unprecedented areas of flooding would occur". (Guardian Staff and Agencies. (3rd February 2019)) Emergency flood alerts were issued in Black River, Bluewater, Beach Holm, Yabulu and Toolakea all areas situated around Townsville as rising water levels in these areas were causing flash flooding. (Norton, F, et al (2019) (City of Townsville (1st February 2019)) Many low-lying suburbs located in close proximity to the Ross River were the first to be affected, prompting people to evacuate. Some residents living in Wulguru, a suburb in the City of Townsville also reported a landslip that occurred in several back gardens, leaving behind tonnes of mud and rock. (Griffiths, J. (2019)

Impacts on Townsville

The impacts of the floods in Townsville was widespread, as many homes and businesses were significantly damaged. Queensland authorities said, the city was entering "Unprecedented Territory" as record flood levels were recorded in the region. (Henriques-Gomes, L. (2019) According to (Gissing, A et al, (2019), the highest flood depths recorded were up to 1.6m. Hundreds of residents were displaced

from their homes, with close to 1,471 properties uninhabitable, one local resident even said she, "felt like a first-world refugee." (Wainwright, S. (9th August 2019) It was also reported that two fatalities had occurred during the peak of the flooding, from people entering floodwaters and at least 19 people were trapped as rescue crews worked to find flood victims. (BBC, News. (5th February 2019) As flood waters griped the city, authorities warned residents of the dangers of the floodwaters, after locals reported signs of crocodiles and snakes roaming in the streets and some people's gardens. (BBC, News. (4th February 2019))

Technical Interpretation

Extremely Arid Summer

Climate conditions in the Townsville Region were abnormal in the months leading up to the event. In early January 2019, a blocking high-pressure system formed in the Tasman Sea, resulting in sustained drought conditions, potentially delaying the monsoon. (Gissing, A, et al, (2019)) Bureau of Meteorology (BOM) reported that early January 2019, was the fourth warmest on record for Australia, with temperatures above average for most of the country (See Figure 2.0) Areas in the Gulf and Northwest Queensland prior to the heavy rainfall had the worst drought conditions, which had a significant effect on ground conditions, leading to overland flow and flash floods once the monsoon trough arrived.

Climate Drivers

On an inter-annual time scale, the El Nino-Southern Oscillation (ENSO) is a key driver in controlling Northern Australia's climate variability, with heavy rainfall occurring during November to April. (Ghelani, R et al. (2017) However, on an intra-seasonal time scale, the Madden-Julian Oscillation (MJO) brings significant levels of monsoonal rainfall which varies from persistent heavy downpours to sporadic showers. This tropical wave was active over the area of Queensland during late January 2019, which could have contributed to the development of the monsoonal trough and heavy rainfall.

Period of Intense Rainfall

Initially, the Townsville flooding occurred when a tropical cyclone Riley, developed a monsoonal trough and slow-moving low-pressure system, brought intense persistent rainfall over the Townsville Region. Although the rainfall associated with the monsoonal trough was unusual in its presence, this type of seasonal weather pattern is associated to Northern Australia. At the regional scale, Northern Queensland is influenced by the monsoonal ascent to the East and the southward convergence zone over Indonesia, which draws moisture in from the Coral Sea (Robertson, A. et al, (2006) resulting in two seasons 'The Wet and The Dry'. (Lee, D et al. (1984) Convergence zones along the monsoonal trough are not uncommon in Northern Australia during December to March, however, the convergence zone which formed over Queensland in January 2019 was extremely rare, remaining stationary for more than a week. One explanation for the stationary convergence zone is atmospheric circulation change, caused by the increase in anthropogenic warming. (Kossin, J et al. (2018) As the Earth warms the strength of summertime tropical circulation becomes weakened which results in the speeds of tropical cyclones to decrease. According to Kossin, J et al. (2018), over the period 1949-2016 the speeds of tropical cyclones has decreased by 10% which is likely to have caused intensified local rainfall in some regions. In particular, land areas of Australia have seen circulation slowdowns of 19%, this factor combined with an intra-seasonal Madden-Julian Oscillation (MJO) which brought monsoonal conditions, could have caused the period of intense rainfall. In contrast, studies by Walsh, K. J., & Ryan, B. F. (2000) suggest that under enhanced greenhouse conditions tropical cyclone intensities have increased by 10-20%, corresponding to a 15-25% increase in wind circulation, going against what Kossin J et al. (2018) initially reported.

Ross Dam Hazard

An overview of dam-based impacts on river systems, shows that catchments which have been altered by impoundments and diversions can be both enhanced or severely affected. (Nilsson, C., et al (2005)) Introduction of the Ross River Dam has modified the catchment, resulting in managed flow regulation, whereby a volume of water is retained e.g. from over-land flow, stored and released at regular intervals back into the river system. A major issue, with the Ross Dam, which potentially contributed to the January 2019 Townsville flooding was the mismanagement of the dam in delaying the floodgate opening until the levels reached 43m. (Bailey W.G, et al, (2012) Essentially, the Townsville City Council developed hydrological models for upstream and downstream of the dam, but calibrated them to the previous 2010, 2009, 2007 and 1998 floods. (Bailey W.G, et al, (2012) The poor management in water regulation and out-dated records resulted in a poor decision to suddenly open the floodgates, creating essentially a dam-induced flood further downstream. (Petts, G. E. (1984)) However, 'What if the dam wasn't there?'. A study by Poff, N. L., & Hart, D. D. (2002) found that rivers without dam's have unaltered flow regimes and therefore can better withstand persistent rainfall. In contrast to this a study by Palmer and Jaycock, (1998) revealed that a flood in 1946, before the construction of the Ross River Dam, is believed to be the worst in Townsville's history. Therefore, even though the dam was opened it did potentially reduce the impacts on Townsville and mismanagement was a leading cause of the flooding.

Conclusion

Vulnerability

Townsville is a coastal city situated on Australia's North Eastern Coastline, between Cape York and Brisbane, which means it is susceptible to flooding and storm surge inundation. (Franklin, R. C., et al (2014)) The main characteristics of vulnerability for Townsville is its typography and population. A large majority of Townsville's suburban areas are built on swampland floodplains. During flooding, access to major roads and evacuation routes are restricted in some areas when flood waters reach >300mm, resulting in reduced access to emergency facilities and delayed responses of emergency services. (Townsville Flood Hazard Assessment Study, (2005) In contrast to this, Townsville is one of the most densely populated and urbanized cities in Northern Queensland, which enhances it vulnerability causing congestion and limiting escape routes in times of disaster.

Future Risk

The effects of climate change are been experienced in Australia as higher temperatures and frequent extreme floods are becoming more prominent. (Keogh, D. U., et al (2011)) Warnings have been issued in Townsville that bigger floods are likely to occur in the near future. Climatological research highlights that in Queensland, tropical cyclones are projected to rise, resulting in higher average temperatures and changes in rainfall variability. (Towers, C. (1998)) Subsequently, leading to ground moisture depletion and flash flooding across the region.

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2019 Japan Heat Wave

Adam Flavell



Figure five: Photograph showing paper fans featuring heat countermeasures in preparation for the upcoming Tokyo 2020 Olympic and Paralympic Games (Sim, 2019)

What happened

From July 29th to August 4th 2019 a prolonged period of slow-moving high pressure within the atmosphere trapped Japan in a 'dome' of increasingly hot air, causing a heat wave. Periods of high temperature are classed as a heat wave when the temperature is at least 5 degrees Celsius (°C) hotter than the average maximum temperature of that particular region for 5 days or longer (The Lancet, 2018). A number of regions in Japan were impacted by this, with temperatures ranging from 34 to 39 °C across the country (Sim, 2019; Itoi & Shimbun, 2019). Figure one displays the regions impacted during the heat wave, including Tokyo; Hirakata city; Kanagawa; Saitama; Chiba; Tajimi city; Kyoto city; Hatoyama town; Osaka; Nagoya; Hiroshima; Fukuoka; and Hokkaido.

How it happened

Extreme weather conditions occur in Japan due to its location in the zone of mid-latitudinal westerlies and in monsoon Asia between the Eurasian Continent and the Pacific Ocean. As a result, there is often a high level of activity in the atmosphere, causing conditions that are ideal for severe localised rains, extreme temperatures and heat waves (Sasaki & Yamakawa, 2007). The weather conditions during the weeks leading up the heat wave resulted in cloudy and rainy periods, which lasted from early June to late July. This rainy period is known as the 'Baiu' in Japan and occurs every year due to a stationary front. This front is formed when a warm maritime tropical air mass meets a cooler, polar maritime air mass. Characterised by warmer temperatures and substantial precipitation, the warmer tropical air mass meets the cooler, polar air mass which brings cool and moist air (Scha et zl, 2019).

In late July the Baiu ended. When it ended, a subtropical ridge of warm 25 air moved in from the Pacific and extended north westward around Japan, bringing hot and sunny conditions to the country. This is known as the North Pacific High and it sat over Japan from late July to mid-September (Nippon, 2019).As the National Weather Service (2019) states, heat waves form under high pressure. In the days leading to the heat wave, high atmospheric pressures above Japan caused the air to subside (sink) towards the surface. This subsiding created a 'dome', as seen in figure two, which capped the atmosphere. This dome helped to reduce the levels of convection, so warmer air couldn't rise, trapping the heat at the surface. This resulted in little to no formation of convective clouds. This meant that there was a

continual build-up of heat at the surface, generating the heat wave.

The impacts

Heat waves have impacts on a number of factors, varying from human health, socio-economic, environmental and economic (Cecinati, Matthews, Natarajan, McCullen & Coley, 2019). This heat wave resulted in the death of 57 people, with 18,347 needing hospital treatment. Of the 57 fatalities, 45 were the result of heatstroke alone. 729 of those hospitalised suffered severe symptoms and required over 3weeks of medical care as inpatients (Denyer, 2019; Kyodo news, 2019; McCarthy & Gralki, 2019). Of all those effected by the heat wave, those that were aged 65 or older accounted for 54.3 percent of the total (Itoi & Shimbun, 2019; Kyodo news, 2019; Hayashida, Shimizu & Yokota, 2019; McCarthy & Gralki,2019). The number of people hospitalised during the heat wave was the second highest number of people hospitalised due to heat-related illnesses since heat-related records began in 2008 (Perper, 2019; Kyodo news, 2019). Along with a lack of nurses in larger cities, this influx of heat-related hospital admissions placed massive burdens on hospitals throughout the country, resulting in increased waiting times and the potential for increased fatalities (Hayashida et al., 2019; Ng et al., 2013).

What is heat stroke?

Heat stroke is caused by an extreme elevation of body temperature. When a sustained temperature rise occurs, the body can suffer from circulatory collapse, central nervous system damage, loss of consciousness, and death, unless effective intervention is immediately accessible. (Porta, 2018; Shibolet, Lancaster & Danon, 1976).

Who was at most risk?

There are numerous factors that exacerbate the impacts that heat waves have. The age, health, socioeconomic status, behaviour of individuals and living conditions are all said to have varying levels of causation (Hales, Edwards & Kovats, 2019).While nobody of any age is considered immune from the risks presented by heat waves, research and statistics from previous heatwaves has shown that people aged 65 years and older, as well as younger children are particularly vulnerable to heat-related illness. Individuals suffering pre-existing medical conditions, especially cardiovascular and respiratory conditions, along with those of low socio economicstatus (low education, low income, and social isolation) are also particularly vulnerable to extreme heat conditions. (Hayashida et al., 2019; NHS, 2018).

Behaviour of individuals

The behaviour of individuals can also increase the risks of heat stroke. The types of clothing individuals wear can either help to mitigate the symptoms or make the symptoms worse. Lighter clothing such as shorts and t-shirts help to reduce the symptoms. Also, in Japan young children are often left in motor vehicles with no cool air being provided. Overexertion during exercise is also linked to heat strokes (Hales et al., 2019). As seen in figure three, these contributing factors are well known.

Living conditions

The living conditions of an individual can also result in an increased risk of heat stroke. Access to air conditioning units is said to mitigate the effects of heat strokes, by aiding the body to cool down. Kovats& Hajat (2008) suggest that a range of adaptations need to be introduced, such as improvements to housing, including the installation of air conditioning units to reduce health impacts caused by extreme heat. Despite the current knowledge around the impacts and methods of mitigating heat waves, there is a high level of certainty that increases in the frequency and intensity of heat waves will increase the number of additional deaths due to extreme weather (Hales et al., 2019).

Current strategies and methods in place to combat heat waves

The current strategies that are in place to help alleviate the impacts of heat waves in Japan mainly consist of early warning systems, such as text alerts and weather forecasts; educational programs to help promote awareness and prevention of heat-related disorders; long-term urban planning; and landscape improvements to reduce heat exposure (Ng et al., 2013). One example of current urban planning in Japan is seen in figure four, which shows one of the many mist towers located in regions of Japan. These towers spray cool water into public spaces, aiding the body to cool down and reducing the symptoms of heatstroke. These strategies are useful in large, open public spaces and to those who have access to technology and education. However, with the vast majority of the most vulnerable to heat being either elderly, young, dependent on others for care, or a mix of all three, more has to be done in order to help reduce the impacts and lower the number of hospital admissions and fatalities.

Past heat waves in Japan

Deadly heat waves like what occurred this year are becoming an annual occurrence in Japan. A similar event occurred last year between July 14 and July 24, 2018. Last summer, 65 people died of heat-related medical conditions in one week and temperatures set new records (Davidson, 2019). In the same week, more than 22,000 people were taken to hospital with heat stroke, with half of those hospitalised again over the age of 65. In total 138 people died, with 71,266 requiring hospitalisation (Osbourne, 2018; The Japan Times, 2018; The Star, 2018). The city of Kumagaya reported a temperature of 41.1 °C, the highest ever recorded in Japan (BBC, 2018; The Star, 2018).

Motoaki Takekawa, a spokesman for the Japan Meteorological Agency stated that japan was ‘observing unprecedented levels of heat in some areas’ and that the 2018 heat wave was ‘a threat to life’ and was recognised as a natural disaster (BBC, 2018). The price of electricity also surged during this heat wave, as increased air conditioning usage drove prices on the Japan Electric Power Exchange up to their highest in five years (Osborne, 2018). This heat wave that occurred in 2018 was deadlier than the 2019 event. However, it can be said that they were both similar in scale, formation and time of occurrence. This signifies the idea that heatwaves are not entirely random in occurrence and are actually seasonal and quite predictable.

Concerns over climate change

Concerns that climate change will increase the prevalence and the severity of heat waves have never been so prevalent (Kovats & Hajat, 2008; Hales et al., 2019). With significant warming occurring in most regions in the last 25 years, climate change is likely to be accompanied by an increase in the frequency and intensity of heat waves. This, along with warmer summers and milder winters has the potential to increase the impacts on human health (Hales et al., 2019). As mentioned by Im, Pal & Eltahir (2017), previous research has shown that temperatures of 35 °C are already considered as the upper limit of heat that humans can survive. They predict that under the ‘business-as-usual’ scenario of future greenhouse gas emissions, the temperatures reached in a number of regions w 126 ill exceed this 35 °C limit, suggesting that with climate change the number of fatalities will increase during heat wave events.

Potential future risks

Future concerns in Japan

Preparing for natural disasters is part of Japanese culture. Japan is undoubtably one of the most prepared countries for natural disasters. Their ability to anticipate, respond to and recover from a wide variety of disasters is unlike anywhere else (Sasaki & Yamakawa, 2007). However, with the 2020 summer Olympics being held in Japan, there are fears that the potential future weather conditions could impact tens of thousands. Taking place between late July and early August, it is a proven period of extreme weather conditions. As mentioned, just last year the heat caused the government to declare a natural disaster (Wharton, 2018; BBC, 2018). It has been questioned why Japanese authorities have not considered to move the date of the Olympics to cooler periods. However, pressures from organisations such as sports broadcasters and Olympic sponsors make such a move more difficult, as well as less profitable (Denyer, 2019). Instead, it seems that event organisers for the Tokyo Olympics are attempting to tackle the main health impact of heatwaves - heat strokes. There are plans to increase the access to cool drinking water; create facilities which are properly air conditioned; and improve the accessibility to portable cooling aids and products such as ice packs and sun cream (Denyer, 2019). Attempts to reduce the impacts during the Olympics has also led to some altered schedules for a variety of events. Some now have earlier start times, and others later in the afternoon to alleviate concerns about the heat. For example, the men’s and women’s marathons are now due to start at 6 a.m (Denyer, 2019). Authorities are also promoting plans to designate public facilities, shops and other places as "temporary rest areas" where people can take breaks from the heat (Davidson, 2019). The Japanese government have also looked to implement a number of preparatory recommendations and guidelines, though the distribution of educational literature, social media posts and blogs. Examples of the sort of information given can be seen in figure five. There is also a number of online applications in which the Japan Meteorological Agency (2019) has made available. Their website provides an online service 152 that alerts populations about any forecasted extreme weather conditions, such as heatwaves. It is available to anyone via the website, continually updated and can be read in a number of languages. Kovats & Hajat (2008) suggest that improving the care of the elderly and the vulnerable will also help to lessen the impacts of future heat waves.

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The Flooding of Sihanoukville, Cambodia 2019

Matthew Ward



The flooded streets of Sihanoukville showing cars emerged in the flood waters. (Cambodia News English, 2019).

Introduction

Urbanisation has a major influence on flooding and with a growing global urban population, this causes many cities around the world to be at risk. Schneider et al (2015) states that Southeast Asia is one of the fastest urbanising regions in the world, with a predicted increase of around 1 billion people by 2050. The growth and development experienced within these cities creates an interference with the natural flow of water, therefore putting large areas of wealth and population at risk (Pervin et al, 2019).

Sihanoukville, also known as 'Kampong Som' is a coastal city and the capital of the Sihanoukville Province in South-West Cambodia. The city, which has an estimated population of 150,000 (Bernstein, 2019), has seen a major growth in development, especially from China with three-quarters of the approved foreign direct investment (FDI) originating from here (The World Bank Group, 2019). This investment is part of China's Belt and Road initiative, seeing the port of Sihanoukville become connected through roads and railways to other major economic regions of Asia such as Hong Kong (Research Society of Pakistan, 2013). However, with recent flooding on both a local and provincial scale, this has caused many residents and news outlets to turn to the development from China as one of the prime causes of this flooding.

Authoritative account of the event

Monsoon Season

Monsoon season within Cambodia lasts between May and October bringing with it each year significant rainfall causing floods to be a reoccurring hazard to the region. Heavy rains and strong winds as a result of tropical storm Lekima (hitting the Philippines and the Eastern Coast of China) and the South Asian Monsoon (SAM), hit coastal provinces of Cambodia (Agenzia Info Salesiana, 2019). According to the Ministry of Water Resources and Meteorology, the main causes of the flood was as a result of this heavy rainfall from the monsoon and rising water levels of the Mekong river (Fresh News Asia, 2019).

The Disaster

The first accounts suggest that the flooding had begun on the 2nd of August 2019 when photos and videos throughout Facebook and Twitter began to emerge showing streets and cars submerged under water (figure 2). Further photos and videos began to appear throughout social media and on August 3rd 2019 Cambodia's main news outlet Khmer released the first article about the flood. The article states that the governor of the province, Kuoch Chamroeun, had called an immediate suspension for all fishermen to stop activities out at sea and warned tourists to be extra careful when visiting (Sokheam, 2019).

The weather only worsened with winds of up to 15-20 mps and further rainfall hitting the region over the next several days as a result of tropical storm Lekima and the southwest monsoon (Agenzia Info Salesiana,

2019). Dine with Locals (2019) reported that although this region is used to flooding and heavy rainfall, the sheer amount of rain this year had been concerning, leading many residents and local authorities to claim this to be the worst flooding to ever hit the province (Vichar, 2019). Around 270 mm of rain had fallen in the 24-hour period between the 8th and 9th of august, which is nearly double that of the previous heaviest rainfall in over 30 years (Vichar, 2019). It is reported that throughout the week, over 2,700mm of rain fell with an average of 165mm daily (Sokhean, 2019).

The Ministry of Water Resources and Meteorology released a statement urging residents and tourists to prepare for a serious natural event. On the night of August 8th, Mr Panetto went to check on the condition of the Don Bosco Technical School and Children Fund Centre (Agenzia Info Salesiana, 2019). What he first saw was the houses of the resident teachers (located on the ground floor) destroyed, meaning they would have nowhere to live. Welding, mechanical, and electrical machinery within the school had also been damaged which would cost the school thousands to replace.

As torrential rainfall continued across the province over the coming weeks, Cambodia News English (2019) and Vichar (2019) reported that the nearby Kbal Chhay Dam had overflowed, leading to large power outages and the closure of National Road 4. As a result, the armed forces had been called in to help rescue people and help with the evacuation and clean up processes. Kheang Phearum, the provincial spokesperson stated that the flooding that affected the region was as a result of extreme rainfall, poor waste management, and construction that disregarded regulations (Meta, 2019, Sohhean, 2019). Many residents, some of whom owned private property had been found guilty of illegally filling in streams and lakes.

Aftermath

As a result of 'the worst flood to ever hit Sihanoukville' (Vichar, 2019), the city was left in a horrendous state. It had left many homes, streets, and offices underwater leading to many residents having nowhere to live along with the loss of jobs (Sokheam, 2019). According to Sihanoukville provincial officials the flooding affected 1,736 families, leaving 937 houses with severe water damage, and over 450 evacuations (Carruthers & Yon, 2019). The flood had also claimed the lives of 3 construction workers after the collapse of a wall in the city (Vichar, 2019). National roads 3 and 4 suffered serious damages due to the overflow of the Kbal Chahay Dam.

In September 2019, heavy rainfall and strong winds battered the province once again, leading to further flooding of the province. This led to further deaths and destruction to the city which had only recently experienced a similar situation (Chakrya, 2019). Many residents and the media turned to Chinese development as one of the key reasons for the flooding. Carruthers & Yon (2019) state that in recent years Sihanoukville has seen a huge increase in development as part of the Chinese president, Xi Jinpning's, Belt and Road initiative. According to Meta (2019) the amount of development has risen from 50 new projects being accepted between 2005-2016 to 40 within the first 3 months of 2019. Although there has been a rapid amount of development recently, there has however been a lack of development in water management infrastructure and an increase of development in marshlands which would once absorb much of the rainfall (Carruthers & Yon, 2019).

Technical Interpretation of events

Changes within the monsoon season

The SAM brings a highly vital source of water for agriculture, hydroelectric power, and for basic human needs, but heavy rainfall of up to 630mm can also bring intense and prolonged flooding (Singhm and Xiaosheng, 2019). According to Singhm and Xiaosheng, (2019), there has been major increases in both mean rainfall and maximum intensity within Cambodia between 1951-2014, with coastal regions seeing the largest increase (figure 3). However, not all regions have received increases with Cruz, Narisma, Villafuerte, Cheng Chua, and Olaguera (2012) finding that there has been a decreasing trend in monsoonal associated rainfall between 1961 and 2010 within the Philippines.

A study conducted by Bryan, Hughen, Karnauskas & Farrar (2019) investigated the ratio of barium-calcium particles that are transported and deposited within corals by the winds from the SAM. The study showed increased concentrations within the coral and a rise in the intensity of the SAM during the late 19th Century as global temperatures increased. This therefore suggests that as temperatures increase so does monsoonal activity causing climate change to be a huge factor in past and future monsoons.

The effects of urbanisation on flooding

There have been many studies looking into the effect's urbanisation has on flood risk throughout the world, with Wheater & Evans (2009) calling it a key driver for increasing flood risk. The first affect that is identified is that of increased runoff and a reduced storage capacity of water. Miller & Hess (2017) investigated the effects of urbanisation on flood risk within Swindon, UK and found that areas of increased urbanisation had higher runoff rates, leading to higher peak flows. This is down to an increase in impermeable surfaces reducing the water storage capacity and therefore allowing rainfall to reach rivers much quicker. Within Sihanoukville there has been a huge loss of natural drainage systems of fields (Buhler, 2019) and an increase in deforestation

making the region more vulnerable to natural disasters such as flooding (Po & Heng, 2019).

Another significant factor of urbanisation that has an impact on flooding is population growth. A growth in population will lead to the development of new homes and other facilities, putting huge pressures and strain on current urban drainage systems. It is therefore key that cities are either improving current drainage systems or investing in new systems to combat the increasing pressures with Wheater & Evans (2009) stating that without mitigation, flood risk will only increase. Additionally, urbanisation can lead to a higher population density within a city therefore increasing the amount of people who are exposed to the natural disaster (Scaparra, Ngo, Dang, & Tran, 2019).

The role of increased investment and development from China

The flow of investments from China has seen a considerable increase within recent years and a shift from the capital city Phnom Penh to the coastal port of Sihanoukville. As a coastal city, the area is highly attractive for tourism and with the Sihanoukville Special Economic Zone, this offers cheap labour and investment-friendly laws (Buhler, 2019). Po & Heng (2019) state that China invested over US$1 billion each year consecutively between the years of 2013 and 2017 making China the country's largest foreign direct investor.

For Sihanoukville, development not only focused on the expansion of the port, to accommodate larger ships or the addition of the express way to the capital city (Leng, 2019), but had a strong focus on casinos, real estate, and resorts. Such investment has led to a large migration of Chinese residents (78,000) to the city a long with over 120,000 Chinese tourists (Po & Heng, 2019). This rapid increase in development has led to increased urbanisation and population increase putting huge pressures on current drainage systems within a relatively short amount of time.

One of the major issues surrounding the development is the impact on drainage systems. Many of the natural drainage areas such as rice fields are commonly replaced by roads and buildings (Buhler, 2019), therefore reducing the amount natural stores of water which would have taken pressure off the rivers. An example of such development is that of the Golden Silver Golf resort, located within Ream National Park, in which large areas of forestry has had to be removed to welcome this tourist destination (Po & Heng, 2019). Current drainage systems and waste management have received a lack of focus on with Kowattanawaranon (2019) arguing that this is as a result of weak law enforcement. It is clear to see that development within Sihanoukville has increased rapidly in recent years with many environmental factors lacking attention within the already flood risked region.

Conclusion

The flooding of Sihanoukville in August 2019 has brought devastation throughout the city, affecting over 1,700 families and the death of 3 construction workers. Homes and businesses such as the Don Bosco Technical School and Children Fund Centre was also affected leading to the loss of jobs and impacting the education of the students. The flooding has been called 'the worst flood to hit Sihanoukville' by many news outlets with many blaming the recent surge in investment and development from China as the key reason for this.

Development from China has come in the form of Casinos, Property, Resorts, and Roads as part of the Belt and Road initiative. This has led to a flood of migrants from China increasing population and population density. A lack of attention to urban drainage and sewage has been one of the largest issues as well as building on flood plains, putting pressure on current and natural drainage systems. However, a change within the monsoon season is causing increased intensity and percentage of rainfall which looks to further increase into the future. Therefore, it is key for new developments to focus on both natural and urban drainage systems in order to mitigate and adapt to the intensifying monsoon events that will continue to hit the region in the future.

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The Americas

The 2019 Amazon Rainforest Fires

Emma Whiteley

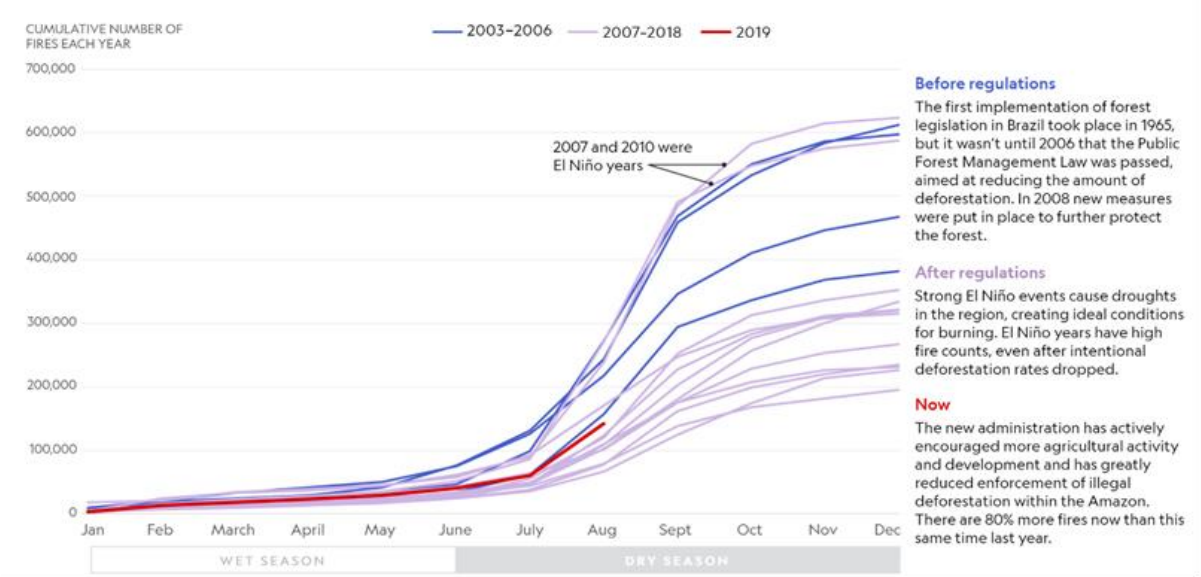


Figure 3: Cumulative number of fires each year

Source: (Borunda, 2019)

Background

The Amazon Rainforest is burning faster than ever before, with more than seventy-four thousand fires being recorded in brazil so far in 2019. Ten thousand of these were new fires which have started since the end of October 2019 (Woodward & Johnsen, 2019). This shows an 83 percent increase in the number of wildfires recorded in the Amazon Rainforest in 2019 compared to 2018.

Brazil's neighbouring countries, Bolivia and Paraguay, have also found it difficult to manage the fires that have cleared large amounts of woods and fields (Weston, 2019). According to a George Mason University environmental scientist, Thomas Lovejoy, almost 20 percent of the Amazon has already been destroyed due to the scale of these fires. The Amazon shrunk by 519 square miles in month of July, which is more than twice the size of Tokyo. This is monitored by the Deter B satellite system, which started in 2015 (Watts, 2019).

Why is the Amazon burning so badly?

Scientists and environmentalists have said that the fires in the Amazon have started due to the deliberate burning of land to clear space for crops and livestock for farmers. Researchers have estimated that at least 99% of forest fires are caused by farmers clearing land in this way (Woodward & Johnsen, 2019). According to Ricardo Salles, Brazil's Minister of the Environment, dry weather, wind and heat caused the fires to spread so vastly (Calma, 2019). However, there are many conflicting views as to how the fires started and have become so intense. Mikaela Weisse, who tracks deforestation and fires for the World Resources Institute, told Vice "The important thing to know about the Amazon is that few fires occur there naturally, pretty much everything is started by humans" (Woodward & Johnsen, 2019).

Where are the fires located?

Figure 2 below shows the fires detected by satellite in the 48 hours leading up to August 23rd, 2019. Most of the fires were seen in the South of the Amazon basin, with them spreading into Brazil, Bolivia and Colombia. This shows how severe the fires are as this satellite image was only taken in the first 48 hours of the fires burning, and there are still fires burning there now.

The wildfires are widespread across South America, with some areas where only a small number of fires are present. This could support the theory that farmers are purposely setting the land on fire due to the fact that the fires are located in multiple smaller areas.

Why has there been so much conflict regarding the cause of the wildfires?

The Amazon Rainforest is known as the "lungs of the Earth", according to news coverage such as Sky News, and presidents such as Emmanuel Macron of France the National Geographic (National Geographic, 2019). However, despite the Amazon being the largest existing rainforest in the world, sources such as the National Geographic (National

Geographic, 2019), state that several scientists do not believe that this statement is true. Scientific research has found that it is likely that the Amazon's net contribution of Oxygen to the planet is little more than zero. Despite the different opinions on whether we rely on the Amazon for our planet's oxygen levels, the wildfires have led to further economic, social and environmental issues. The Amazon is also one of Earth's largest carbon sinks, reducing the intensity of climate change.

What is different about the Amazon wildfires to other wildfires of 2019?

On the 13th of July 2019, the isle of Sardinia, one of the twenty regions of Italy, faced intense wildfires. Over 800 hectares of land was burnt leading to an evacuation of between 69 and 84 people (Copernicus, 2019). This is a lot less than the 519 square miles of land which was destroyed in the Amazon wildfires in the same month. This could be due to the fact that Brazil's sudden increase in demand for meat from 27kg in 1961, to 98kg in 2013, led farmers to purposely burn more land than the farmers in Italy as Europe's demand for meat hasn't seen such a dramatic increase in recent years (Ritchie, 2019).

How are NGOs involved in the fires?

There are many theories as to why the fires started in the Amazon. Brazil's president Jair Bolsonaro initially accused non-governmental organisations of starting the fires, without giving any evidence. It has also been considered that anti-governmental groups (environmentalists) have been purposely setting fire to the forests in order to discredit the Government. These groups have alledgedly set the forests on fire to raise awareness to gain support for protecting and conserving our rainforests (Yune, 2019).

How do weather systems impact on the current Amazon fires?

After some thought, Jair Bolsonaro then stated that the fires were a result of dryer-than-average weather, despite wildfires as big as this not being a natural part of the Amazon rainforest ecosystem (Woodward & Johnsen, 2019). The graph below in figure 3 shows the cumulative number of fires each year in the Amazon, showing that the numbers are much higher in the dry seasons (June – December). He also pointed to the fact that it's a time of year when farmers purposefully use fire to clear land — a seasonal cycle called "queimada."

As CNN meteorologist Haley Brink explained in the network's report, "farmers wait for the dry season and they start burning and clearing the areas so that their cattle can graze. That's what we're suspecting is going on down there" (Woodward & Johnsen, 2019). However, there is a small chance that the fires started naturally, as this happens when dehydrated timber hits flashpoint and releases a volatile gas that combusts when in contact with oxygen, starting a fire (Palliser 2012).

Is the global increase in demand for meat a factor in the current fires??

A reason why the wildfires are so vast has been put down to the large increase in meat being eaten by the human population. The increase in the demand for meat, particularly beef, has caused a need for more space for cattle grazing and crops to be grown for cattle to feed on. This increase is shown below in figure 4, where it is evident that Brazil is one of the biggest meat eating regions in the world, potentially increasing deforestation of the Amazon for cattle. This means that farmers will be more inclined to burn parts of the forest floor as a fast way to generate more space. "Humans are driving these fires, either in a very direct sense or a global sense by changing the ecosystem so much," according to Ruth DeFries, an ecology professor at Columbia University (Woodward & Johnsen, 2019).This shows an increase in Brazil's meat consumption from 27kg in 1961, to 98kg in 2013. This could be why the scale of the fires in 2019 were a lot worse than those in previous years as shown previously in figure 1.

Were the areas impacted by the fires prepared?

Many newspapers and people from around the world wrote on social media about how urgently we need to respond to the Amazon wildfires. One celebrity lawyer and journalist, Shannon Sims, tweeted "Just a little alert to the world: the sky randomly turned dark today in São Paulo, and meteorologists believe it's smoke from the fires burning *thousands* of kilometres away, in Rondônia or Paraguay. Imagine how much has to be burning to create that much smoke! SOS" (Dunne, 2019). This alerted those who use social media, and as it was celebrities voicing their concerns, people took the fires more seriously than if they heard it elsewhere. Pages were then created to raise funds to help go towards equipment used by the emergency services to stop the fires burning. The World Wildlife Fund (WWF) work closely with the Amazon, increasing people's commitment towards conservation and helping to reverse climate change. The WWF also support communities within the Amazon to defend themselves against the dangers of the Amazon (World Wildlife Fund, 2019). This response to the wildfires can help residents of the Amazon get their lives back to normal and help rebuild communities.

What is the current and future impact of these Amazon fires?

Around 34 million people live in the Amazon, including over 385 groups of indigenous, according to World Wildlife Funds (Doheny, 2019). The fires are destroying homes, making residents homeless, and a worst-case scenario would be that they lose their lives or are seriously injured in the fires. Alarming quantities of carbon has been pumped into the atmosphere, potentially increasing the risk of climate change, and causing breathing difficulties for humans

(Yeung, 2019). At the same time, millions of trees are being destroyed by the fires, meaning that the carbon intake is also reduced. Species' habitats have disappeared due to the rapid deforestation, making plants and animals extremely vulnerable. The Amazon fires have led to air traffic congestion, especially over countries like Bolivia, where air traffic was diverted and headlights were being used at only 3pm every day of the fires, due to the smoke (Doheny, 2019).

EU-Mercosur Agreement

Ratification of Brazil's biggest ever trade deal with the European union (EU-Mercosur agreement) may be complicated if EU legislators say that Brazil is not committed to slowing down deforestation, as they agreed in the Paris climate agreement (Watts, 2019). This deal will decrease the cost of exporting agricultural products, especially beef, for Brazilian farmers, which is why the deal is important. There is a concern however, that farming is one of the main reasons for the deforestation of the Amazon, along with the wildfires. According to The Guardian, negotiations for the Eu-Mercosur deal took almost two decades to be agreed, which is why the economic issues are being prioritised over the environmental concerns at present.

Health Impacts

Children's breathing problems have increased in Brazil, due to the smoke from the Amazon fires (Yeung, 2019). The fires are releasing dangerous greenhouse gases like nitrous oxide, carbon monoxide and fine particulate matter (PM2.5). PM2.5 particles can get stuck in people's lungs, causing respiratory problems, and in the long term, heart attacks (Yeung, 2019).

Flora and Fauna

Pets are at risk as residents have struggled to safely evacuate them from homes, along with the wildlife in the Amazon rainforest. Even if the animals survive the fires, their food chain will be affected as plant and smaller animal populations decrease, causing a gap in the food chain. Dr Carmenta warns, "It's not only about those immediate losses of flora and fauna," she adds, "but also the relationships, the identities, the attachments that people have to their homes and to their landscapes, which are eroded and become unrecognisable as fires pass through." Faced with displacement and starvation, many people's lives are at risk.

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Heatwave, The East Coast, United States of America, July 2019

Lily Currie

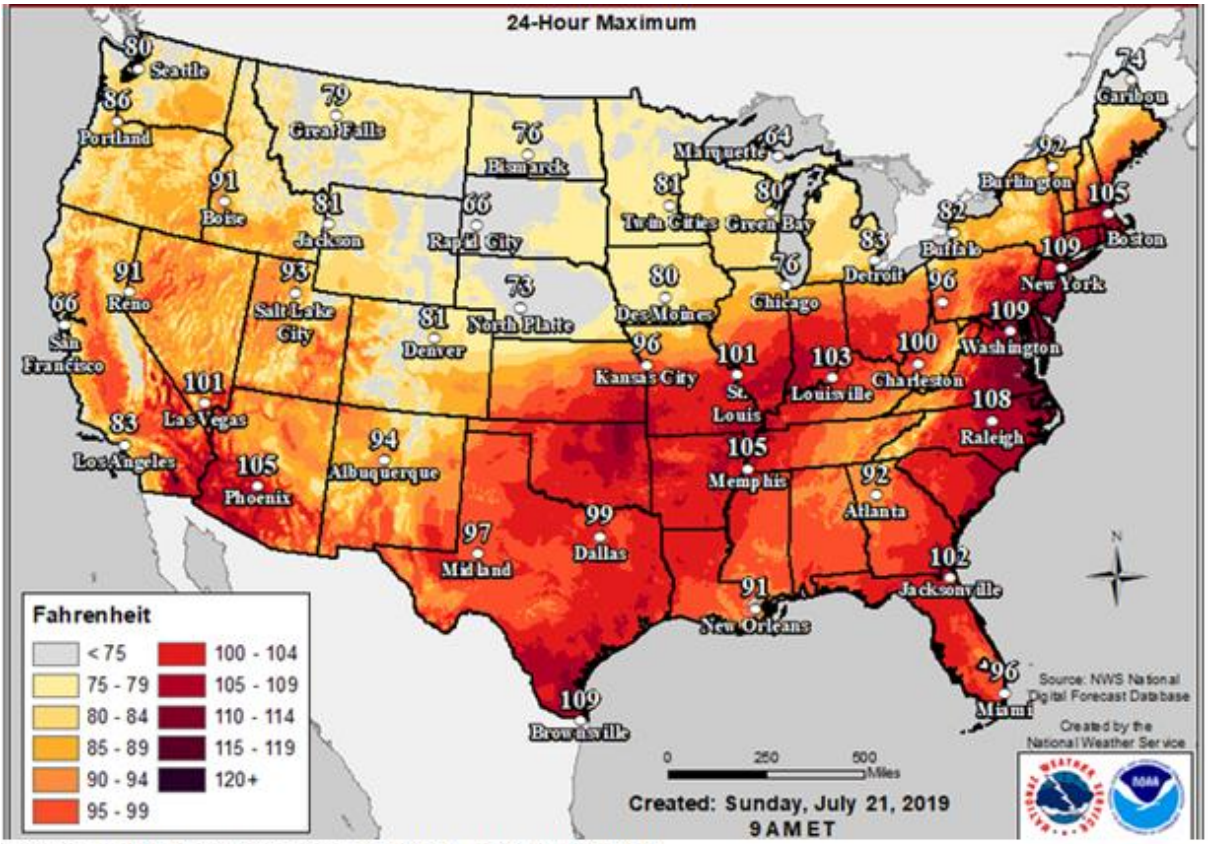


Figure 1: Heat index forecast, USA, 21st July 2019

Reference: National Weather Service (2019)

Introduction

Heatwaves are one of the most impactful aspects of the climate. A heatwave is defined as a prolonged period of abnormally high surface temperatures in comparison to average temperatures (Rafferty, 2018). Heatwaves can be accompanied with either very high or low humidity levels, both of which can cause problems such as droughts. There is evidence that shows global warming is leading to heatwaves increasing in both intensity and frequency and therefore causing an increase in impact (Mora et al., 2017). The human impacts caused by heatwaves are often unacknowledged, between 1989- 2018 there was an average of 123 heat related deaths annually in the United States of America (National Weather Service, 2019) (Figure 1), this is more deaths than caused by any other severe weather event (Abbott,2014).

Case study

The heatwave occurred between the Friday 19th and Sunday 21st July, 2019, affecting over 180 million people, and directly killing seven across the eastern coast and Midwest of the USA (BBC, 2019). Temperatures reached 97°f, however the maximum heat index, which combines relative humidity and air temperature providing an idea of what the temperature feels like (Figure 2), reached 111°f (National Weather Service, 2019) (Kaufman, 2019) (Figure 3). The effects of the heatwave were exacerbated by particularly high pressure humidity levels caused by hurricane Barry that hit the east coast on the 16th July 2019.

New York Mayor de Blasio declared a local emergency, and took several steps to attempt to minimise the impacts the heatwave would have on the community. He transformed public buildings such as libraries into cooling centres, these centres are air conditioned and provide water, restrooms and medical services if necessary. These centres to help vulnerable members of the community such as the homeless whom have nowhere to take shelter. Other actions that were put into place included; opening pools free of charge, extending sprinkler operating hours in parks and adding mist caps to fire hydrants (DeAngelis, 2019). Without these actions, the death toll would have been higher, especially amongst vulnerable people.

Several other activities were cancelled over the weekend for the safety of both those attending and working at the events. The New York triathlon was scheduled to go ahead on Sunday 21st July, however it was cancelled after Mayor de Blasio urged the organisers to prioritise the safety of all 4,000 people involved in the event (Allentuck, 2019). OZY Fest, a two-day festival of "live music, conversation, comedy and food" in Central park was also cancelled despite organisers already having cooling plans in action including, free water, shaded areas, misting fans and sunscreen available (Ries, 2019).

Health impacts

The heatwave caused both direct and indirect health effects to the population. Direct effects include heat exhaustion and heatstroke, which can lead to organ failure and even death. The seven reported deaths were due to heatstroke, and effected the vulnerable and exercising outdoors (Nirappil, Tan & Stark, 2019). However, the actual number of deaths caused by the heatwave is unknown, higher due to the heat causing an excess of natural deaths.

The severity of the health impacts caused by the heatwave does not only depend on the heatwave itself but also on the vulnerability of the affected population (Figure 4). In the context of this heatwave the vulnerable included, young and elderly, chronically ill, pregnant, socially marginalised and tourists as they may be less acclimatised (WMO & WHO, 2015). In an attempt to minimise the health impacts, a care home in New Jersey undertook a mass evacuation of all residents when air conditioning broke, relocating to a nearby school (McCormick, 2019).

During the heatwave the night time temperatures did not drop below 83°f, therefore little cooling or relief is provided (Irfan, 2019). This causes people to feel uncomfortable but also further exaggerates ongoing illnesses and increases the indirect mortality caused by the heatwave.

Levels of air pollution are also exacerbated during the heatwave due to high pressure, low wind speeds and low precipitation causing air pollution to stagnate, and ground level ozone levels to increase in turn producing smog (Peterson et al, 2013). These conditions are more intense in cities like New York due to structure and density. The increased levels of air pollution cause problems for people with respiratory conditions and further increases demand on health services.

Transport

On Friday 19st July, during the evening rush hour, over a third of the New York subway system was closed, leaving people out in the heat, struggling to get home. The closure was due to previously planned work but did not help local residents as many of them had to walk home in the high temperatures. There was also delays to regional rail travel as train ran at reduced speed to prevent the tracks buckling under heat related stress, this happens because the tracks expand under high temperatures (Spector, 2019), whilst this prevented damage to the train tracks it caused delays to many users.

Roads buckled in both Kansas and South Dakota. This occurred on a major interstate leading to long queues of traffic and people being stuck in hot cars, many without practical resources (Stanglin, 2019). Roads buckle under high temperatures due to the materials in the road expanding.

The Grid – Electricity Use

Rising temperatures cause demand for water and electricity to grow as people attempt to keep cool, this puts pressure on the grid to keep up with demand, as well as the increase temperatures causing damage to the overhead lines. On Sunday evening 50,000 in the Brooklyn and Queens districts of New York faced a power outage due to overhead lines being in danger of overloading as a result of the heat (Watkins & Southall, 2019). This power outage caused a range of problems for the local population including, air conditioning and fans being off and cooling centres being down, causing health problems for people.

Technical interpretations

Heatwaves can be easier to plan for as they are seasonal and not spasmodic, however, air temperature alone is not an adequate, as other conditions influence the body's ability to cope with heat. For example, high humidity limits the cooling evaporation of perspiration. There is not one single definition used but there is a range of terms that are commonly used (Table 1). Although now scientists have started using the Heat Wave Magnitude Index (HWMI), that uses a range of factors to produce a single comparable number, it is not commonly used, do if not being used to its potential ability.

Heat island effect

Whilst the heatwave affected the whole eastern coast and Midwest of USA, it was the big cities, especially New York that seen the most severe effects, this is due to urban heat island effect (Figure 5). This is caused by a combination of factors, including building materials often retaining heat well, and large volumes of transport activity. The heat island effect exaggerates the impacts of the heatwave, as well as occurring in high density areas, that often feel the impacts more due poor air quality and lack of greenspace (Campbell, Remenyi, White & Johnston, 2018).

Climate change

Climate change is altering the mean global temperature and variance distribution, resulting in higher frequency and intensity of heatwaves, it has been described as 'the biggest global health threat of the 21st Century', putting the 'lives and wellbeing of billions of people at increased risk' (Costello, Grant &

Horton, 2008). Climate change experts cannot relate climate change to a specific heatwave, however are can say it is increasing the likelihood of heatwaves occurring.

This is important because, heatwaves are associated with a range of adverse consequences including increased mortality and lower crop yields, therefore if the chance of heatwave frequency and intensity is increasing, actions need to be taken to minimise the consequences in the future.

Previous heatwaves

Whilst previous heatwaves are useful for leaning about the impacts of a heatwave and are useful for creating action plans for future heatwaves, the hottest five years on record have all been since 2010 (United States Agency for International Development, 2019), therefore previous heatwaves can only provide a limited amount of information as the frequency and intensity of heatwaves in changing.

Over the 40 years' heatwaves have been two of the top ten most deadly disasters (Figure 6).

The European heatwave of 2003, affecting France, Germany, Portugal, Spain Romania and the United Kingdom lasted through out august and killed 70,000 people. The intensity and long duration of this heat wave caused many environmental and human impacts, including droughts and forest fires. Governments had to ask for aid and make changes to working hours to reduce the impacts on the population.

As a result of this disaster both the UK and French governments have made changes to reduce the impacts of future heatwaves. The UK has a heat-heath watch that gives advanced warnings of hot weather and the French government has made efforts to improve its prevention, surveillance and alert system for people such as the elderly living alone (Met Office, n.d.).

In 2010 a heatwave hit Russia killing 56,000 people the Heat Wave Magnitude Index (HWMI), which merges several climate-related measurements of intense heat events into a single number, therefore making events comparable, indicated that this was one of the most extreme heatwaves due to a range of factors including, intensity and duration (Hoag, 2014).

Conclusion

Heatwaves may not appear to provide great damage to natural, social and physical assets, I think this report has demonstrated the great deal of stress put upon the local population. I think that a lot of work needs to be done my governments to help educate the public about extreme heat events and take steps to help reduce climate change. To conclude I think that this heatwave caused greater damage than what was advertised on local news outlets because of the wide range of secondary impacts and also because people underestimate the damage that heatwaves can cause, especially to the vulnerable members of the population.

Assessment of impact and preparedness

Heatwaves need to be prepared for in a different approach than other natural hazards, as defences cannot simply be built, instead a wide range of subtle measures and education is needed in order for the local population to be prepared. I think to an extent this was done well, as minimisation actions such as opening cooling centres were in place, however I think more in terms of education needs to be done as people were not conserving electricity, causing to power outages and still doing sports outdoors, leading to heat exhaustion. I think New York Mayor de Blasio, reacted well to the emergency and took reasonable steps to try and keep his citizens safe.

Whist the impact of the heatwave was large, affecting over 180 million people, including many vulnerable members of the population, the impact would have been much greater if the heatwave occurred in a less developed country than the USA. This is because the USA has good infrastructure, abundance of water available, advanced healthcare system and wide spread use of air conditioning systems, whereas less developed countries often lack these, which would increase the number of direct fatalities.

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Flash Flooding in Texas, 2019

Kirsten Berry

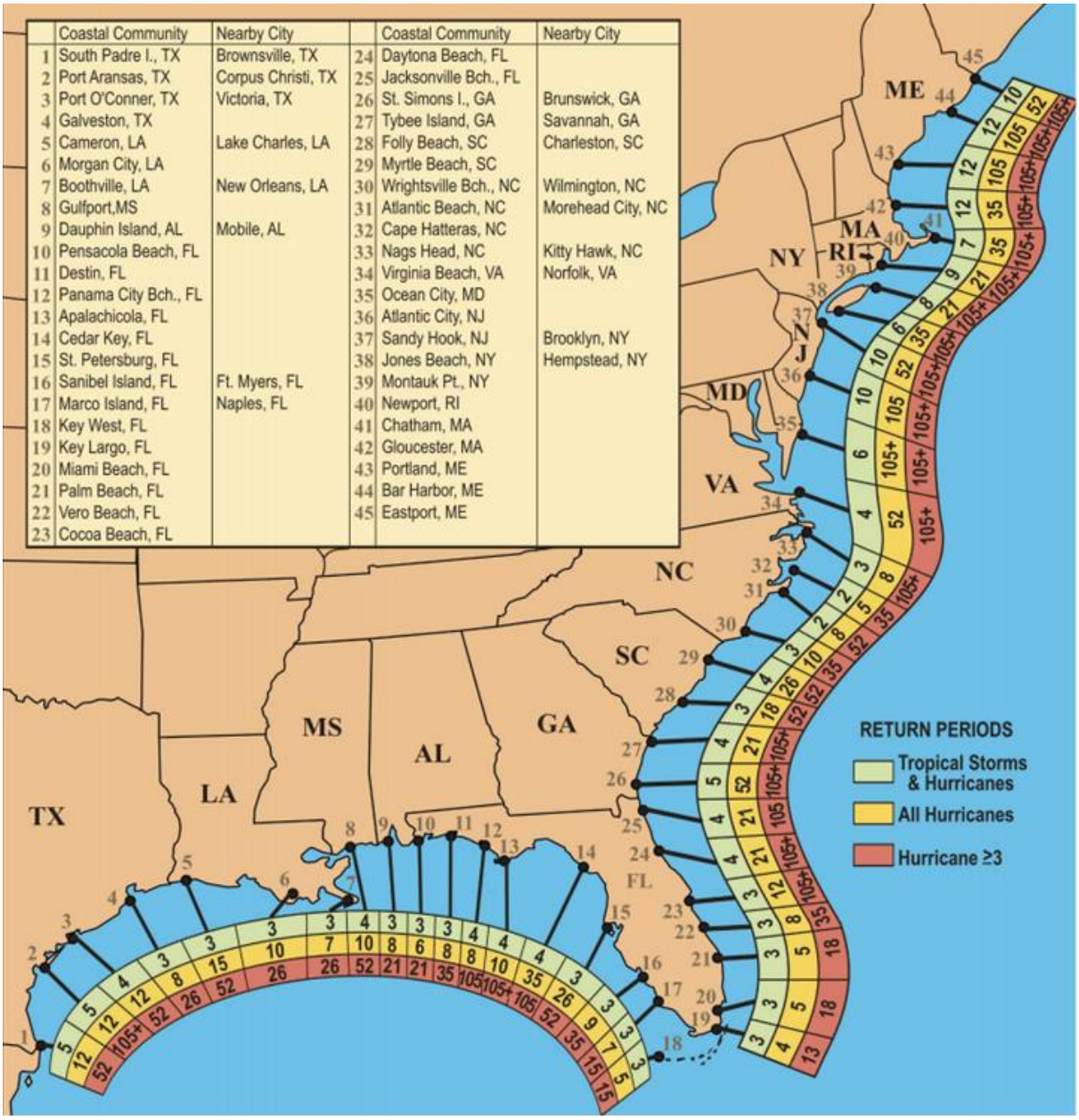


Figure 3.1.- Average return period for tropical storms and hurricanes along the southeast coast of the US (Keim & Muller, 2006)

Account of Hazard

The account of the hazard has been generated using a grey literature search (as opposed to using academic sources) under the search terms "Tropical Storm Imelda," on Google and Google News, receiving around 625,000 and 42,900 search results.

Introduction

Flash flooding is a global issue caused by an influx of rain over a short period of time. It is too sudden for the ground and drainage systems to cope with, especially in urban environments which is a concern alongside concentrated populations. In some instances, tropical storms may be the cause, such as the case of Tropical Storm Imelda in southeast Texas on the 19th-21st of September 2019 (Doswell, 2015; Met Office, n.d.).

Tropical Storm Imelda, Southeast Texas

Monitoring of the tropical depression began on the 14th of September 2019 as it was located 1000 miles to the east of the Lesser Antilles (NOAA, 2019 c).

When it reached the coast of Texas (see Figure 1.1.) at around 13:30 on the 17th of September, the depression developed into a tropical storm (whereby it was named Imelda) drawing in moisture from the Gulf of Mexico (12 News Now, 2019). Warnings of flash floods were issued in Houston at 17:00 with the threat expecting to have developed further within the subsequent few hours as a result of the unstable atmospheric conditions (NOAA, 2019 b).

Tropical Storm Imelda largely impacted 13 southeast Texas counties which were all said to be in a "state of disaster" ensuing the event, according to Governor Greg Abbott (Byrne, 2019, para. 22; Floodlist, 2019). Concerns were raised regarding the impacts of the street flooding and drainage because of the quantity of impermeable surfaces. This included densely populated Houston which is the fourth largest city in the US (CBS Evening News, 2019; Jeffrey 2019).

Heavy Rain and Flash Flooding

On September 17th, the storm was predicted to cause direct impacts until the 19th (see Figure 1.2.) (CBS Evening News, 2019; Terry, 2019) as it travelled from Freeport towards Tennessee Valley. Reduced moisture supply and high pressure were the predicted causes of the storm's dissolution (Floodlist, 2019).

At 23:00 on the 17th of September, the storm was located 10 miles northwest of Houston travelling at 7mph with sustained winds of 35mph (CBS News, 2019). The National Weather Service (NWS) of Houston issued warnings via Twitter for residents to remain in shelter, contact the emergency services if necessary and not to venture onto any roads (NWS Houston, 2019 a). Concerns regarding the levee at Green Pond Gulley (which holds nearly 4,600-5,600 acres of water) breaking, despite repairs and improvements made following Hurricane Harvey in 2017, resulted in the evacuation of residents (Bain, 2019; Jefferson County Sheriff's Office- Texas, 2019; Koop, 2019).

By September 19th, the consequent flooding was classified as a 1 in 500-year event as approximately 25 inches fell in 12 hours (Miller, 2019) with some areas receiving around 4-8 inches an hour (12 News Now, 2019); Houston received 2-3 inches per hour (Floodlist, 2019). It was later decided after a 72-hour period of storm flooding that it was a 1-in-1000-year flood (Aon, 2019; Houston Properties, 2019). However, this was dependent upon the geographical location as the areas were all impacted differently (Figure 1.3.); most counties experienced around 40 inches of rain and flash flooding, making it the "seventh-wettest tropical cyclone in US history" (Jeffrey, 2019; NWS Houston, 2019 b; "Tropical Storm Imelda," 2019, para. 6; Wagner et al., 2019). The highest level of flooding occurred in Hampshire whereby one location received 43.39 inches of water with the 19th of September recorded as the 5th wettest day in Houston (Aon, 2019; Byrne, 2019). However, Floodlist (2019) and National Weather Service (NWS) Houston (2019 b) claim that Fannet received the highest level of 43.15 inches, deeming it Texas' 4th wettest cyclone. Space City Weathering (2019) on the 17th of September ranked the event as a Stage 2 (flash flooding) or Stage 3 (significant flash flooding), with a later decision labelling it as a Stage 3 event (Balke, 2019).

Impacts

Difficulties with coping with the immediate impacts were generated because of the lack of preparedness resulting from the sudden turn of and extremity of events (12 News Now, 2019). This was emphasised by the lack of places for the water to go as the drainage systems across the counties could not cope (ABC News, 2019; Bain, 2019). Real estate agent, Wolff, added that there is not a drainage system that can handle 6 inches of rain in an hour (Jeffrey, 2019). Additionally, the ground was dry prior to the extreme rainfall (CBS Evening News, 2019) which may have contributed to the intensity of the impacts as runoff would have been exacerbated (Miller, 2014). Further issues were also caused as some rivers' banks broke resulting in minor to major river flooding across a few locations (Floodlist, 2019).

The storm dissipated on September 21st as it moved inland with the impacts and nature of the storm compared to that of Hurricane Harvey (ABC News, 2019). Despite the intensity of Harvey ranking worse than Imelda, interviews with the Sheriff in Vidor and Winnie (southeast Texas) claimed that Imelda was more severe since homes and businesses that were not flooded during Harvey were during Imelda (Byrne, 2019; NOAA, 2019 a; Wager et al., 2019). The saturated ground resulted in the potential of further flash floods after the event (NCEP, 2019).

Impacts of the storm include the death of five people as well as over 1000 calls to the emergency services (Byrne, 2019; Jeffrey, 2019; Mansoor, 2019; "Tropical Storm Imelda" in The Guardian, 2019). Flights out of George Bush Intercontinental Airport were temporarily cancelled (Houston Bush Airport, 2019; Mansoor, 2019; Wagner et al., 2019). Damage occurred to houses (however, this was not always structural), as well as to eight bridges as a result of barges that had broken away from their mooring (Byrne, 2019). There was further damage to vehicles and agricultural land, with an estimated total damage of around $2 billion (Aon, 2019).

Technical Interpretation

Tropical storms develop close to the equator in tropical regions (see Figure 2.1.) whereby the ocean temperature is around 26-27oC near the surface; convection currents cause the rising of warm, moist air. As energy is released, a large low-pressure centre is formed. The mass of circulating winds is caused by the Coriolis effect; in the Northern Hemisphere the

rotational direction is anticlockwise. They are defined by wind speed (18-32 m/s), air pressure and damage caused (McAdie et al., 2009; Pérez-PerazaIgor & Libin, 2012; Smith, 2006).

Tropical Storms in the Gulf of Mexico

Tropical storms that impact south-eastern US develop in the Gulf of Mexico (see Figure 1.1.) and western Caribbean. The coastal landmass of Central America lessens the intensity of the storms because of the reduced moisture supply but are given the potential to intensify again as they reach the Gulf of Mexico (Maloney & Hartmann, 2000; Pérez-PerazaIgor & Libin, 2012). This is attributed to numerous regional, seasonal and climatological factors (Schumacher & Johnson, 2006) and may be further enhanced by the location and orientation of the coastline (McAdie et al., 2009). A paper by Van Oldenborgh et al. (2017) regarding Hurricane Harvey stated that the increased winds and moisture content within the Gulf of Mexico created a moisture flux and therefore caused the extreme rainfall that made landfall; this was likely a result of the geographic location and also a likely contributor to the intensity of Imelda.

Intraseasonal and Interannual Variations

The Madden-Julian Oscillation (MJO) is a tropical weather pattern that consists of the movement of tropical winds that propagate eastward. The MJO is an intraseasonal movement that occurs every 30 to 60 days, the consequences of which are intensified alongside the Northern Hemisphere summer season, creating the Atlantic hurricane season which falls between May and November every year. Links have been made between wind patterns within the Gulf of Mexico and the genesis of tropical storms despite it being topographically separated from the strongest of the MJO winds (Camargo & Wing, 2016; Gottschalck, 2014). Maloney & Hartmann (2000) claim that tropical storms in the Gulf of Mexico are not just a result of the regional contributors but are "modulated by the MJO" (p.2003). This is supported by Sobel & Maloney (2000), Aiyyer & Molinari (2008) and Martin & Schumacher (2011) who found consistencies amongst the movement and genesis of the storms as well as precipitation patterns. Changes may also be attributed to El Niño/Southern Oscillation (ENSO) and the North Atlantic Oscillation (NAO) which cause interannual precipitation variations alongside sea surface temperature changes (Kim et al., 2009; Martin & Schumacher, 2011) thus potentially influencing the aforementioned. The increase in ocean temperatures along the coast of Texas may also be attributed to climate change, resulting in the likelihood of two-day rainfall events becoming nearly 2.6 times more likely (Masters, 2019).

Physiography and Flash Flooding

The geomorphology of Texas creates orographic rainfall which contributes to the intensity of precipitation impacts thereafter. This has resulted in 'Flash Flood Alley' which is orientated north to south across central Texas with the assumptions that the Balcones Escarpment serves as a 'barrier' for the moist air masses, thus resulting in frequent flash flooding. Furl et al. (2015) uses the example of the flash flooding proceeding Tropical Storm Hermine as being orographically induced (despite the orography being more impactful in central Texas as opposed to the similar southeast routes of Hermine and Imelda); they regarded their location studied as being a regional flood microcosm. However, rainfall from tropical storms is not homogenous and so it is difficult to predict as there are numerous factors to consider (Trepanier & Tucker, 2018).

Additionally, urbanisation has influenced the effects and likelihood of such events with a study of Houston by Khan (2005) stating that there was an increase in impervious surfaces and a decrease in vegetation further enhancing chances of flash flooding and its impacts. However, improvements in mitigation techniques following Hurricane Harvey may have helped alleviate, but this will be location and situation dependent meaning that wider urban and climatic factors need to be considered when addressing flood events and their potential impacts (Zhang et al., 2018).

Conclusion

Vulnerability of Flooding

The vulnerability of tropical storms and extreme rainfall in Texas differs across the state with the southeast coast being the most susceptible with shorter return periods compared to the locations that are further south along the coastline (see Figure 3.1.) or situated inland. Southeast Texas is also more socially and economically vulnerable because of the dense population within Houston and its surrounding areas (Trepanier & Tucker, 2018). A study by Collins et al. found that the impacts following Hurricane Harvey were socially disparate, relating to ethnicity and socioeconomic status, despite the Environmental Protection Agency's 'environmental justice' definition (2019, para. 2). Problems generated revolved around mitigation (heightening the exposure of certain areas where there was less investment), water-based amenities, self-protection (e.g. flood-proofing homes), distance to floodplains, perception of flooding, and insurance (Brody et al., 2018). This may have been less severe for Imelda as improvements were made as a result of Harvey's impacts.

Potential Future Risks

The geographical location of Texas has generated a history of tropical storms and other related events with 38% of tropical cyclones recorded between 1851-2006 reaching the coast of the US or making landfall (McAdie, et al., 2009). Keim and Muller (2006) claimed that the return period of tropical storms and hurricanes in Galveston (point 4 in Figure

3.1.) is 3, 8 and 26 years which is considerably more frequent than other locations, particularly those along the northeast coast of the US (as mentioned in Figure 3.1.). However, the occurrence and intensity of tropical storms are only expected to worsen alongside climate change, particularly with the warming of oceans (Elsner, 2006; Wang et al., 2018) and with recent rapid urbanisation increasing the occurrence and impacts of flash floods, as well as damage to assets. A summary of 2019 Atlantic Hurricane events by Masters (2019) supports this.

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Hurricane Dorian, The Bahamas

Emma Holden

Figure 3 – The devastating impacts of Hurricane Dorian: before and after (Lai, Watkins, Singhvi, Love, & Patel, 2019).



This case study is based on a review of available research sources between 1/10/18 and 30/09/19. In total 49 different sources were returned from a range of reputable news articles, social media and in some instances journal articles. In an attempt to provide the most accurate account of the event, careful attention has been paid to the reliability of the news articles referenced and the date in which the information was published, in order to locate the most up-to-date figures (i.e. death toll).

Authoritative Account

Introduction

On September 1st, 2019 the Bahamas (see figure 1) was hit by the strongest hurricane the country has ever experienced (Mercy Corps, 2019) with wind speeds of up to 185mph (Ostrowski, 2019; Jenner, 2019; Masters, 2019). When Hurricane Dorian made landfall, it was considered to be a category 5 hurricane, according to the 'Saffir-Simpson Hurricane Wind Scale' (CBSnews, 2019), making it the largest storm of its kind, on record, for over 80 years (Le Page, 2019). To provide some context, Hurricane Dorian was equal in strength to the Labour Day hurricane of 1935; 'the worst Atlantic storm to make landfall ever recorded' (Economist, 2019).

The Event

Hurricane Dorian devastated the Islands of the Bahamas, in particular both the Grand Abaco Island; including prosperous regions such as Man-O-War Cay and Elbow City, and Marsh Harbour where it wiped out entire shanty-towns (e.g. Pigeon Pea), as well as the Grand Bahama Island, where approximately 60% of the island was inundated (Economist, 2019). The National Hurricane Centre were documenting and reporting on the journey of Hurricane Dorian before it made landfall in the Bahamas. At approximately 11am EDT (Eastern Daylight Time) on September 1st, they issued a warning on their twitter account that urged people to take immediate cover, it read: "TAKE COVER NOW! THIS IS AN EXTREMELY DANGEROUS AND LIFE-THREATENING SITUATION. Move immediately to the safe room in your shelter" (Twitter, 2019). Figure 2 depicts the journey that Hurricane Dorian embarked on from August 31st through to September 5th.

After making landfall, it hovered above the Bahamas for over 48 hours, '15 of those hours were at Category 5 intensity' (Resnick, 2019), where it decimated parts of the archipelago, often moving at just 1 mph (Mercy Corps, 2019). Not only did this result in copious amounts of wind damage, it also caused a 'sea surge' that was approximately 26 feet tall in places (Economist, 2019), that was responsible for washing people out to sea, cutting off the power/

communications and, to quote Health Minister Duane Sands, creating "20 feet of ocean" in people backyards (McDonald & Fieser, 2019). To think that 80% of the Bahamas 'is less the 32 feet above sea level' (McDonald & Fieser, 2019), the impacts of a 20-26ft sea surge are incomprehensible. In addition to the coastal flooding, circa 2ft of rain fell during the time Hurricane Dorian camped out over the Bahamas (Resnick, 2019), which is a lot in itself.

Aftermath: Social, Environmental and Economic Impacts

By 30th September, 2019, almost a month after Hurricane Dorian hit, the death toll was estimated to have reached 58 people (USAID, 2019; ReliefWeb, 2019), however, Fitzpatrick (2019), a healthcare writer for Forbes magazine, suggested that Bahamians who know the Abaco Islands and the surrounding areas better than anyone have stated that this estimate is severely miscalculated. Marsh Harbour was home to undocumented personnel and Haitian refugees, both of which were underserved and cannot be accurately accounted for (Ma, Frias, & McFall-Johnsen, 2019). Irrespective of this, officials have stated that there are still approximately 600 people missing (Chavez & Thornton, 2019).

Given the severity of the event (see figure 3), the aid, both internationally and locally, came in thick and fast. Organisations, countries, charities and individuals have recognised the devastation that Hurricane Dorian imposed on the Bahamas and are doing everything they can to help out. The National Emergency Management Agency based in the Bahamas has been working alongside the US Coast Guard to rescue people, and has so far recovered 295 since Dorian struck (VOA, 2019). Alongside this, the UK sent a team of 'Department for International Development' (DFID) humanitarian experts into the Bahamas, aboard the Royal Fleet Auxiliary (RFA) ship Mounts Bay to supply 'water carriers, hygiene kits and shelter kits' (GOV, 2019) as well as food and other basic resources (see figure 4). On board they also had equipment capable of turning 'sea water into drinking water' which they can then distribute amongst the local people (Chavez & Thornton, 2019). The RFA Mounts Bay team is working in unison with the Royal Bahamas Defence Force to deliver the supplies efficiently to the most vulnerable (GOV, 2019). The UK also deployed The Royal Navy to aid in the evacuation of residents to nearby Island Nassau (BBC, 2019). Cruise liners did their part; 'The Royal Caribbean and Walt Disney cruise lines…are instead using ships to deliver food, water, flashlights and other vital aid' (VOA, 2019). Airbnb is running their 'Open Homes Programme' which enables people to post if they have any spare rooms/space for people to live temporarily while they figure out how to rebuild their own homes (BBC, 2019).

The BBC (2019) stated that 'The International Red Cross fears 45% of homes on Grand Bahama and the Abacos – approximately 13,000 properties – have been severely damaged or destroyed' as a result of the storm. Tens of thousands of people remain homeless. Sadye Francis, director of a non-profit organisation 'One Eleuthera' said "some people will have nowhere to go" (Bryant, 2019). Manuel Moreno González (2019), an author for UNICEF, described the damage that he could see flying over the Abacos Islands; "Only a few buildings still stood in a sea of debris, where twisted metal and broken wood littered the landscape, boats and cars were scattered around, and buildings were knocked off their foundations'. In possibly the worst hit area, Marsh Harbour (see figure 5), '90% of infrastructure is damaged or destroyed' (BBC, 2019). A local resident emphasised the difficulty of trying to obtain essential resources; "We've had to funnel gasoline out of destroyed cars to get injured people back and forth" (BBC, 2019).

The impacts of Hurricane Dorian are predicted to cost insurance companies anywhere in the region on $1.5 billion to $3 billion (Fitzgerald, 2019). The UN agency has been allocated a budget of $5.4m (£4.3m) to conduct a 'three-month emergency operation' to try and minimise the short-term impacts. In terms of long-term impacts, the economy will suffer dramatically due to the lack of tourists holidaying in the Bahamas as a result of the damage inflicted on the Islands by the hurricane. "The Bahamas are heavily reliant on tourism, so any small decline in visitor arrivals will have a relatively big negative economic impact" - Carolin Lusby, a University professor specialising in the industry of tourism and travel (Sampson, 2019).

A spokesperson for The Red Cross, Jenelle Eli, said "People are concerned about their next step, but also how they'll earn an income and what their lives will look like in the future" (BBC, 2019). In addition to this, the guardian newspaper (2019) quoted Lisa Head-Rigby, a member of a local hurricane relief organisation, "It's not rebuilding something that was there; we have to start again."

Technical Interpretation

Characteristics of a 'Typical' Hurricane

Depending on the geographical location and severity of a cyclone, it can be referred to as a 'cyclonic storm, tropical depression, hurricane or typhoon' (Harrison, 2019). Keith Smith (2013) defined a tropical cyclone to be 'non-frontal, low pressure, synoptic-scale systems with strongly organized convection that form over warm oceans'. Tropical cyclones with low-intensity are known as 'tropical depressions' and 'tropical storms', however, those with high-intensity are called 'hurricanes' (Keller & DeVecchio, 2014). In order for a tropical cyclone to 'become' a hurricane, it must have sustained wind speeds of >75mph (Boone, 2018).

With reference to the Saffir-Simpson Hurricane Wind Scale, hurricanes are categorised on a scale of 1-5 based on their wind speed (NHC, 2019); see figure 6 for a breakdown of each category with regards to their wind speed and the levels of damage caused.

This particular scale is widely used to provide a more in-depth understanding of the potential damage, e.g. flooding, that is to be expected from hurricanes with different wind speeds, to allow for efficient preparation (Keller & DeVecchio, 2014). Categories 3, 4 and 5 are characterised by having a wind speed of no less than 111 mph and are referred to as 'major hurricanes' (McGuire, Mason, & Kilburn, 2002; NHC, 2019). Major hurricanes, in particular, are renowned for causing a multitude of deaths and vast amounts of disruption. Smith (2013) suggests that category 4/5 hurricanes emit 'more power in one day than the USA uses in a year'.

Detrimental Impacts of Climate Change on Hazard Type

The World Meteorological Organisation describes the climate, in a limited sense, to be "the 'average weather', or more rigorously as the statistical description in terms of the mean and variability of relevant quantities over a period of time." (WMO, 2010). The intensity of the hazards that could occur from a hurricane are dependent on things such as frequency, geographical distribution, size and duration, therefore it is highly important that we are aware of the likelihood of these factors changing as a result of climate change (Emanuel, 1997).

Current research into the climate and the impacts of global warming has identified the possibility of hurricanes and sea level rise becoming more intense (Soloman, et al., 2007). In turn, this will lead to 'increased hurricane flood risk at the coast' meaning coastal flooding during hurricane events will be much more devastating (Mousavi, Irish, Frey, Olivera, & Edge, 2011). A study modelling the 'impact of anthropogenic warming on the frequency of intense Atlantic hurricanes' predicted that by the end of the 21st century, category 4 and 5 storms will have almost doubled in frequency (Bender, et al., 2010). The instrumental climate record shows that tropical oceans have increased in temperature by approximately 0.6□C, 0.5□C of this occurring in the past 50 years (Cazenave & Nerem, 2004; NOAA, 2016). Therefore, it is understandable that there is very little doubt that the most recent hurricane related observations are due to anthropogenic effects (Meehl, et al., 2004).

Comparison to Previous Hurricanes Experienced in The Bahamas

The Atlantic hurricane season of 2018 was the third consecutive season that experienced a 'series of above-average intensity and damaging hurricanes' (Kelleher, 2019). In total, 2 major hurricanes, eight 'normal' hurricanes (category 3 or below) and 15 named storms struck the Atlantic (Kelleher, 2019). In comparison to previous hurricane events, Hurricane Dorian is the second of its kind to make landfall in the Bahamas. The Labour Day hurricane of 1935 (see figure 7) was the first category 5 hurricane to hit the Atlantic on record (Willingham, 2019; Economist, 2019), making Hurricane Dorian the second ever. Prior to Hurricane Dorian, Bahamians had a very casual attitude towards hurricane warnings, however, due to the impact Dorian had on the area, the citizens are likely to take the warnings more seriously in the future (Darville, 2019).

Conclusion

In conclusion, given the scale of Hurricane Dorian, the official death toll is relatively quite low. This could be as a result of the residents knowing the local area really well and being aware of the more effective places to take cover or because there are still 600 people unaccounted for, which ultimately could also have lost their lives. In my opinion, this death toll could have been reduced even further if the local people didn't have such casual attitudes towards events such as hurricanes. Not only are they risking their lives, but as a region, they are going against the international guidelines (the Sendai framework) where it states that the number 1 priority for action against natural disasters is 'understanding disaster risk' (UNDRR, 2015). If the residents don't understand the potential severity of the disaster, they are not likely to abide by the advice given to them, thus making them more vulnerable and open to potential future risks.

In terms of responses to the hurricane, there were some logistical issues which really should have been avoided. Relief workers in the Bahamas found it extremely difficult to coordinate the aid they were receiving from all over the world as it was being sent to different places each time, meaning some areas had too much, and some too little (Smith D. , 2019). In order to avoid this in the wake of future disasters, a more efficient plan needs to be agreed upon and distributed to those who require it (i.e. international aid charities). With regards to efficiency, being aware of the potential challenges of dealing with the aftermath of such an event is of high importance. To highlight this, a ferry that was transporting Bahamians to safety was stopped and those who didn't possess a visa were told to disembark as they could not enter the place they were headed (BBC, 2019). Incidents like this should be considered beforehand and managed appropriately to avoid unnecessary complications.

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Eruptions of Popocatépetl: September 2018 to July 2019

Anna Clarke-Smith



Figure 4 Shows Popocatepetl's 32,000ft ash plume observed during an overflight on 11 June, it was observed to be approximately 350 m wide and intensely degassing.

Introduction

This case study is a review of available sources between the 1st October 2018 and 30th September 2019. Due to the nature of Popocatépetl's current activity, this case study is ongoing and informs the reader about a series of events. Therefore, objective searches were used to gather sources of information, which were limited. Primary sources of literature were gathered via google searches, with the frequent use of Wikipedia pages for background literature. The use of library gateway aided the development of this case study throughout the technical interpretation. In order to gather relevant reports, accounts and data concerning Popocatépetl, the google search 'Eruptions of Popocatépetl 2018-2019' was used. This search brought up 67 reliable results covering relevant media, authority and personal information. This method of finding literature is not usually used when producing an academic report, media reports were relied upon due to the nature of building a timeline from reported accounts entailing facts and figures, which were then triangulated against other reported accounts to build a case study.

Authoritative account

Background of Popocatépetl

At 5,426 meters tall Popocatépetl is the second largest volcano in Mexico after Citlaltépetl which reaches 5,636 meters, making the currently active stratovolcano the 5th highest in North America. Figure 1 shows Popocatépetl is situated in Central Mexico 19.02°N / -98.62°W, lying on the eastern ridge of the Trans-Mexican volcanic belt. Figure 2 demonstrates the scale of Popocatépetl in comparison

to the surrounding high altitude protected Izta-Popo Zoquiapan National Park in which it is situated, as well as Popocatépetl's proximity to Mexico City- which lies 44 miles southeast with a metropolitan population of 21.2 million (2019). Popocatépetl doesn't usually pose a threat to the surrounding areas due to its usual dormant state. However, since October 2018 several chain eruptions have taken place, continuing into 2019.

Timeline of Eruptions from Popocatépetl

A near constant emission of gas and steam with minor ash quantity was typical volcanic activity for Popocatépetl throughout the months of October 2018 to early February 2019. This activity increased on the 15th December 2018 at 18:57 local time, reports of spewing lava, ash and rock were made by locals. However, Mexico's National Centre of Disaster Prevention (CENAPRED) stated the event posed no immediate threat to the surrounding villages at the base of Popocatépetl.

On the 22nd January 2019 21:06 local time, Popocatépetl began spewing ash higher into the air, up to 4 km high, avoiding interfering with commercial airspace in the region (which begins at 18,000 ft). Reports made by local residents of villages near the base of Popocatépetl stated the plumes had generated ash fall onto their communities from September 2018 through to February of 2019, which correlates with ash explosions in Figure 3. Ash emissions in the region were also reported by the Washington Volcanic Ash Advisory Centre (VAAC). Ash explosions and low intensity emissions were both monitored closely by CENAPRED

Wikipedia states as of the 19th March 2019 21:38 local time, fragments of Popocatépetl's dome were projected outwards within a 1 to 1 and a half mile radius. Due to ongoing activity and continuous analysis of seismic activity and sulphur dioxide emissions, Mexico's Scientific Advisory Committee, recommended changing the phase of the Yellow Volcanic Warning Light Phase 2 to Yellow Phase 3 on March 28th 2019, this was put in place as a preventive measure against the observed changes of the volcanos fragile state. Sky News (2019), reported Mexico City was put on alert on the 29th March, after over 200 minor eruptions are recorded within a 24-hour time period.

The minor eruptions caused a thick cloud of ash and smoke, even glowing lava was observed spewing from the crater in the early hours according to many locals interviewed by Phys.org. (2019). CENAPRED again advised people to stay away from Popocatépetl - a 12km restricted zone was implemented surrounding the crater to not only protect climbers conducting research in the region but locals living at the base of the volcano. Mexico's National Disaster Prevention Centre issued an update to the yellow phase 2 warning, increasing it to phase 3, meaning "intermediate to high activity", a precautionary measure taken triggered when the volcano shows "explosions of increasing intensity, expelling incandescent fragments." This was one step shy of a red alert which means a mandatory evacuation of local towns and villages, including south-eastern suburbs of New Mexico.

On June 15th, Blaskovik. T. reported that a volcanic ash cloud rose an estimated 9.8 kilometres (32,000 ft) into the atmosphere as shown in Figure 4, breaching international airspace. This was also recorded by the Global Volcanism Program. (2019). reporting 'a comparably strong vulcanian-type explosion occurred that produced an ash column of 32,000 ft'. VAAS also registered 115 exhalations, accompanied by water vapour, gas and light quantities of ash from the 14th June 2019. Daily averages of explosions and exhalations increased over a two-week period demonstrated in Figure 5, whereby low-pressure emissions of steam and sometimes ash were observed more frequently by CENAPRED and VAAS.

Between June 18th, 2019 and July 25th, Popocatépetl continued to erupt, spewing ash clouds 28,000 ft. upwards, observations as far as 80km northeast of the ash clouds in Xochimilco (a suburb of New Mexico) were made to VAAS (Global Volcanism Program. 2019). On July 25th, Popocatépetl erupted twice prompting VAAS and CENTRPED authorities to warn the public to get ready for an evacuation. CENTRPED's statement recommended people stay away from Popocatépetl due to landslides and danger of fragments of flying rock. One of the explosions emitted so much power that 3,300 ft of debris was launched into the air, with ash travelling in a south-westerly direction.

Technical Interpretation

Causes of volcanic activity

Popocatépetl lies on the Trans-Mexican Volcanic Belt, which makes up a large section of the ring of fire as shown by Figure 6. Spanning 1000km across Central-Southern Mexico, lying on the southern edge of the North American Plate, the volcanic belt is unique; in that it doesn't run parallel to the Middle American Trench. Therefore, the main stratovolcanoes including Popocatépetl are positioned diagonally to the general position of the belt and in zones of subduction which increases their activity; the oceanic plate coverages with the continental Middle-America plate. Martin-Del Pozzo, (2019) identified that increases in seismic events, temperature, sulphate and chloride concentrations in the crater, decreasing of pH as well as rising pCO_2 in the spring water are all indicators given off by Popocatépetl at past events. Long periods of seismic events also increased before many of the eruptions, episodes of pulsing and moderate exploitatively increase, however

Popocatépetl is also prone to having period whereby activity dissipates.

History of past events

Popocatepetl's history shows during the past 23,000 years, eruptions ranging in size and style including massive sector collapses to the crater and Plinian events have occurred. Boudal and Robin, (2019) state the eruptions occurred in four stages, each lasting 1,000 to 2,000 years. Historical activity since the year 1500 consists of nineteen small to moderate eruptions which have been recorded soon after the arrival of the Spanish in 1519. Currently, the fourth period is still active, which explains the similarities in current activity with events from 1500 onwards. In the mid to late first century a violent VEI-6 eruption may have caused the migration of settled civilisations near the base of the volcano according to DNA recovered in the form of bones and teeth. More recently, after lying dormant for the last half of the century, Popocatépetl became active again in 1994, and in 2000 Popocatepetl demonstrated its largest display in over 1,200 years, causing the evacuation of tens of thousands of people by the local government including suburbs of New Mexico City. Plunket, P. and Urunuela, G. (1998). Past events have produced lava flows that have been limited to the summit, however, pyroclastic flows, ash and pumice have had a much larger reach.

Effects of the eruptions

Volcanic activity has produced lash explosions, generating large ash plumes to be projected into the atmosphere as shown in Figure 4. Persistent ash fall across the region is increasing potential health effects including respiratory problems, especially for individuals living with asthma. Over exposure to ash through inhalation and contamination of water sources also increases the chances of contracting Silicosis- caused by the scarring and impairment of the lungs. Ash fall will also damage buildings and vehicles due to its abrasive nature, however, ash plumes from Popocatépetl between 2018-2019 have reached heights over 5km into the air, where they are carried by prevailing southern-westerly winds over the continent, avoiding direct ash fall on surrounding villages and nearby New Mexico City. During periods of explosive activity, higher emissions of sulphur dioxide have been measured, increased levels can have environmental effects such as causing acid rain, a process observed when sulphur is mixed with water and air in the atmosphere- having a detrimental effect by altering the pH of water systems and soils. This causes a potential issue for locals, as both potentially continuous ash and acid rain can accumulate causing changes to their ability to use resources provided by the land.

Coping with an ongoing event

Due to the frequency of events, particularly in the last 20 years and more so between 2018 and 2019, locals' interest and concern regarding volcanos hazards has dissipated. The frequency of small events of ash plumes and explosions combined with a lack of threat from pyroclastic events meant people began to believe volcanic activity was coming to an end. Popocatépetl is located in a densely populated region of Mexico, therefore, to reduce risk to people, resources and infrastructure a network monitoring the volcano using sophisticated equipment has been set up, including visual surveillance, seismic, geodesic and geochemical monitoring. An early warning system CENAPRED is an early warning system, developed to keep the population permanently informed. CENAPRED and VAAS continue to monitor the situation as activity has not been scaled down and the phase remained Yellow.

Erupting in 2018 for the first time since 2000, Popocatépetl produced 3 kilometres of ash into the sky. (Mexico News Daily, 2019). Signs of seismic activity 250-450 metres into the crater have been observed since 2005. This suggested there was potential for significant activity to come in the near future and therefore response planning could be established. Data collected and observations of Popocatépetl are carried out continuously 24/7 by Mexico's branch of CENAPRED - the National Centre of Disaster Prevention in North America and the Washington Volcanic Ash Advisory Centre (VAAS). CENAPRED monitors explosions, crater emissions, lava and gas production, rockfall, landslides and risk to surrounding areas. Whereas VAAS monitors ash emissions, plume height and risks to airspace. protecting local and national civilisation and international airspace. (Global Volcanism Program, 2019). Any changes in activity are assessed and reported to the appropriate authorities at a timely manner according to the severity of event(s) or risk the activity poses. CENAPRED monitoring of Popocatépetl, also continues to allow the coordinated efforts of Popocatépetl Scientific Committee (PSC), who work closely within the local communities to educate the region as well as analyse data for forwards planning and prevention reasons.

Conclusion

Response of impacted communities and authorities

When Popocatépetl exhibits significant eruptive activity, information is fed down from CENAPRED monitoring systems to authorities who issue instructions across the region, given by radio and television. During the yellow phase events through June 2018 people living closest to Popocatépetl were told that they're safe at home, however, should follow stockpiling measures for storing food and water, and taken precautionary measures such as closing windows and covering their mouths and noses when going outside. Evacuation of these zones was not

suggested as a red alter wasn't issued. Prevention Campaigns are conducted by the local government and Civil Protection services across the region, this is to further educate people about evacuation plans and volcano activity awareness specific to their proximity from Popocatépetl.

Future planning

De la Cruz-Reyna & Tilling & Valdés-González, (2019) commented, though Popocatépetl is monitored continuously, a disaster may also occur if society surrounding the volcano in local villages and nearby Mexico City fail to adopt and implement appropriate measures when needed- increasing the risk to individuals, property and infrastructure. This can potentially cause greater harm to the economy and demographic of the region. To tackle future events, emergency plans have been implemented across the region through close interaction between three main entities: The scientists studying Popocatépetl and its potential disaster outcomes; the authorities in charge of public safety and infrastructure; and the affected populace. Working together closely, they have developed risk assessments, evacuation schedules and appropriate preparations for hospitals, medical centres and shelters. Emergency rescue teams are also on call at times of heightened risk to establish damage caused and respond to a disaster event. (Boudal, C. & Robin, C., 2019).

Future risks and future events

Remaining continually active for over 20 years, Popocatépetl has therefore created a long-standing volcanic danger, causing additional difficulties in the management of the volcanic risk. It is unknown how long Popocatépetl will remain in its current active state, as sustained activity makes it particularly difficult to forecast future events and their consequences. Due to persistent low to medium activity, monitoring indicators of such activity becomes increasingly difficult. However, using past indicators and eruptive patterns could help identify a potential timeline, as aforementioned the periods in which Popocatépetl is active can last between 1,000 to 2,000 years. The introduction of CENAPRED has enabled authorities to keep a close eye on activity continuously, enabling any future risks to be identified and plans put into place to prevent disaster from occurring.

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Hurricane Michael

Chama Nkandu

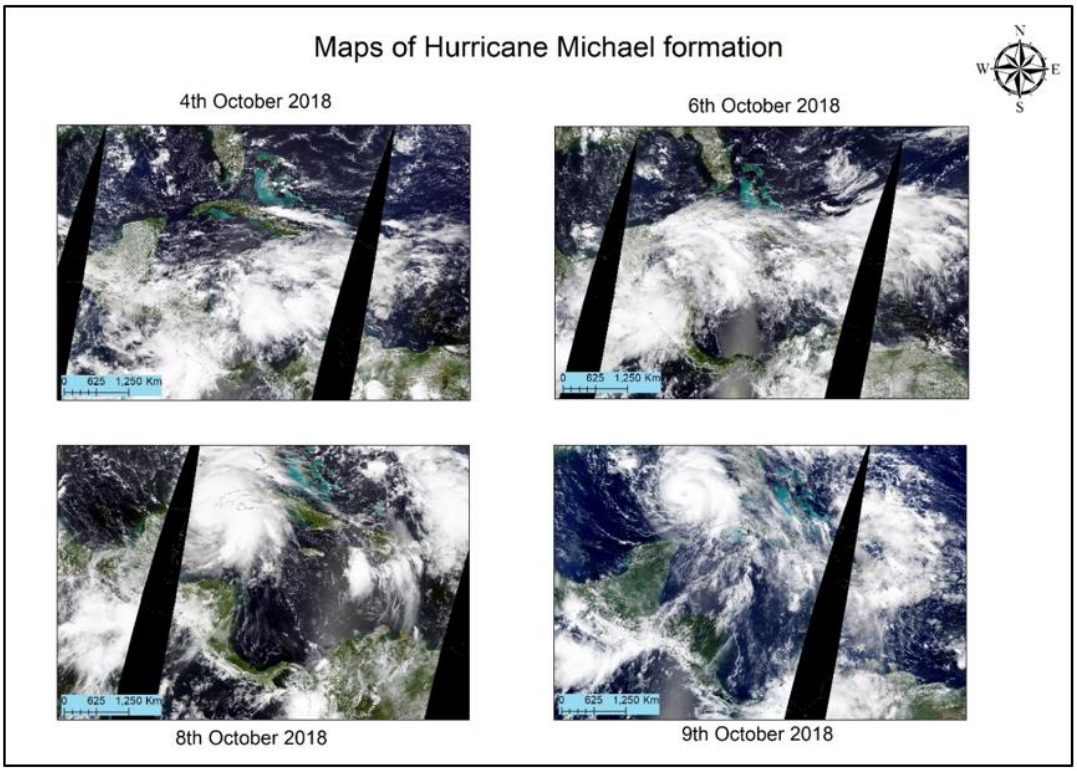


Figure 1: A series of maps put together using NASA Worldview data showing the formation of Hurricane Michael, (NASA, 2019)

Introduction

Hurricane Michael was a devastating hurricane that struck parts of the Caribbean, South-eastern United States and the East Coast of the United States in October 2018. Based on its internal barometric pressure Michael is the 3rd most powerful hurricane to strike the US mainland, putting it behind the "Labor Day" storm in 1935 and Camille in 1969 (Allen & Graham, 2019). The BBC in a news report, "Hurricane Michael upgraded to a Category five storm", (2019) wrote that the hurricane caused damage that totalled up to $25.1 billion (£19.6 billion) and resulted in 74 deaths of which 59 were in the US.

Authoritative account

At first hurricane Michael was just a tropical depression, this is a system that forms when a low-pressure area is accompanied by thunderstorms producing a circular wind flow at a maximum sustained wind speed of below 39 mph ("Hurricane Michael 2018", 2019). The article, "HURRICANE MICHAEL - Timeline, Aftermath & Statistics", (n.d.) describes that from the 1st to 2nd of October 2018, there was a large area of disturbed weather forming around the central and western Caribbean Sea. What had remained of a tropical storm that had just occurred prior, named Storm Kirk, was absorbed into this weather system to form hurricane Michael

Hurricane Michael made landfall at Mexico Beach which suffered devastating storm surge damage, though many of the total casualties were the result of extreme weather brought by the hurricane. In many cases there was damage caused from the heavy rain that Michael produced as it travelled along its course. Coastline cities were hit with severe flooding for example in eastern central America i.e. Honduras, El Salvador and parts of Costa Rica, as well as towns in west Cuba (Wright, 2018). A blog by NASA (Pierce, 2018) reports that the rainfall totalled greater than 10 inches along the track and the heaviest rainfall accumulation occurred just off the Yucatan peninsula where over 20 inches was estimated (Figure 2).

Technical Analysis

Soon after becoming a tropical depression, Michael started to rapidly intensify taking it from a category 1 when it flooded Central America, (Cherelus, 2018) to a category 5 hurricane. Thompson, (2018) explains that low wind shear, warm ocean water and high humidity are what is needed for a hurricane to rapidly

intensify. Wind shear is the difference in wind speeds and sometimes the direction of the wind over a short distance. A low wind shear would mean the hurricane shape is not disturbed and becomes more stable (figure 3).

Therefore, if the wind were to be blowing in many different directions or at different speeds vertically, then hurricane Michael may not have gotten stronger and instead dissipate. Just prior to hurricane Michael's intensification, there was an upper trough, an area of low pressure, which allowed air to exit the top of the hurricane and promotes a convection process due to low vertical wind shear ("Hurricane Michael 2018", n.d.).

With ocean water, it increases the temperature contrast between Earth's surface and cooler layers higher up in the atmosphere (Thompson, 2018). This increases air instability and fuels the convection that drives the storm. In a Spatial analysis done by Trepanier, (2013), Two diagrams showing the spatial analysis of hurricane activity with the use of red numbers to identify the hexagon, (figure 4) demonstrate that in areas of higher sea surface temperature, there is a higher occurrence of hurricanes.

"Hurricane Michael 2018", (n.d.) states that before the formation of Michael, Florida experienced its warmest September on record. "HURRICANE MICHAEL - Timeline, Aftermath & Statistics", (n.d.) also mentioned that the surface temperatures along Michael's path were 0.75-1.5°C warmer than average. This contributed to Michael in intensifying from 35 mph to a 145-mph hurricane within 72 hours.

The final factor that impacts hurricane intensification is the humidity. Due to the heavy rain produced, the humidity was high at the time of the hurricane. Braun, Sippel & Nolan, (2010) deduced that storm size was affected by humidity where higher levels of humidity in the environment led to larger storms, and broader storm-force winds. Hoyos (2006) also found that Higher seasonal average values of humidity are associated with a higher number of category 4-5 hurricanes. A Reduced level of humidity would disturb the convection process of the hurricane (Thompson, 2018), Thus humid air provides the hurricanes with clouds for the storm when they rise.

Conclusion – Impact and Response

Many people were left vulnerable and some worse off than others from the impact of the storms. People with businesses and workplaces that were destroyed would've found it hard to recover because it is their livelihood. It would be difficult for someone like a farmer to find a different means of income to provide for their families consequently leaving them more vulnerable.

Storm surges flooded areas of Coloma which is a small fishing village located on the southern coast of Cuba. Fishermen were trying to salvage what was left of their boats (Vela, 2018). 200.000 people were said to have been left without power for several days in some western provinces (Murcia, 2018), but operations began shortly after the hurricane to recover from the serious damage homes, electric grids and crops by local authorities (Yan, 2018).

In Honduras it was reported that at least 260 homes were damaged, in mostly southern parts of Honduras, and that more than 6,000 people have been impacted by the rain (Tallahassee, 2018). Services like school were suspended until they were able to recover from the flood damage. The president arranged relief efforts, providing food mattresses and other necessary items to families that were most affected by the storm (teleSUR, 2018)

In El Salvador, Storm Michael affected many fruits vegetables and other crops grown by farmers in the eastern areas of the country. As a response, the Ministry of Agriculture and Livestock delivered food packages to farmers who were affected.

Sanchez (2019) wrote that in Bay County, Florida, the report said. More than 45,000 structures were damaged and at Mexico Beach, 1,584 of the town's 1,692 buildings were reported damaged. Numerous charities helped to provide relief such as red cross and Allhandsandhearts.

Many of the places affected by hurricane Michael are still yet to recover. According to CBSnews, (2019), hundreds of people still live in trailer parks and more than 2,400 Bay District school kids are listed as displaced or homeless. A part of the coast east of Panama City earned the nickname 'the forgotten coast' due to being underdeveloped. Most of the residents live in damaged homes and trailers reportedly not suitable for habitation. The majority blame it on the contractors and insurance companies associated with them (Achenbach & Sullivan, 2019).

In the near future, the length of the response to get the communities back onto their feet and provide them with what is necessary would need to be revised. If such a hurricane happened again the communities would be even more vulnerably as many of them already have nothing left.

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Eastern Canada flooding

Luke Owen

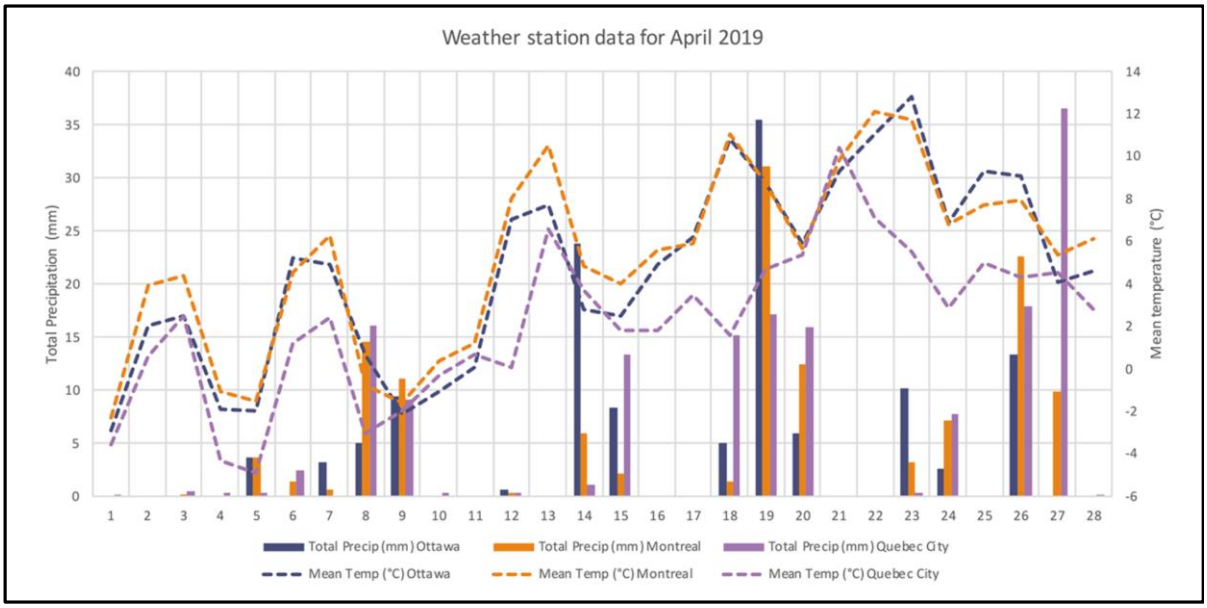


Figure 1. Precipitation data of the main areas effected in the Canadian floods of April 2019 (Government of Canada – Water Office, 2019)

Authoritative Account

During April 2019, Eastern Canadian regions including New Brunswick, Ottawa, Ontario and Quebec were heavily affected by river flooding, along with these areas in the USA, New York was also impacted. The key effected areas are shown in figure 1, indicating the close proximity of the multiple flooding rivers. The highly disruptive floods began on 19th April 2019 and continued until the 27th April 2019. Unfortunately, there was one death contributed to the flooding event with a women being washed off the road in Outaouais due to the high velocity water flow that she experienced (Floodlist.com, 2019; CBC News, 2019).

Causes of Flooding

Although the main cause of the flooding event was the high level of precipitation that was experienced in eastern Canada and north-eastern USA over such an extended period of eight days, the antecedent conditions also played a major factor in what took place. Prior to April 2019, snowmelt from the Laurentian Mountains meant that the ground was saturated and thus soil water capacities were almost at their limits prior to the falling of any precipitation. Therefore, when the high level of rainfall began it was not long before surfaces began to be covered in standing pools of surface water (TheWeatherNetwork.com, 2019). As indicated in figure 2 below the total precipitation values are the main reasoning behind the flood event, with the intermittency of the rainfall across the whole month not allowing time for water levels to decrease back to a standard base level.

Spring snowmelt from the Laurentian Mountains also caused overflow of lakes such as the Lac des Deux Montagnes, along with this rivers in the region including the Ottawa and St Lawrence reached their limit and flooded the surrounding areas (Floodlist.com, 2019; CNN, 2019). The Mattawa region had risen levels contributing to the Ottawa river's flow. Furthermore, the Ottawa river had rising levels of stream flow due to the catchment area of the Abitibi-Timiskaming having several reservoirs contributing to the river, which were being filled rapidly. In the west-central region the basins large surface area caused high volumes of surface run off contributing to existing high-water flows. Usually the reservoirs in the northern section of the watershed would be used to contain water and restrict the flow of the Ottawa, but due to the levels of precipitation and snowmelt being excessively high they filled rapidly and could no longer hold the excess water. Therefore, because these reservoirs would usually prevent the flooding from occurring that could not be the case here.

Effects on Households and Economic Impacts

Within Canada 17,500 households were affected by the flooding event that took place (Statistics Canada, 2019). Quebec experienced the biggest negative impact involving households with 9,800 homes influenced by the flooding according to the Insurance Bureau of Canada (IBC, 2019). These impacts ranged from minor floodwater affects such as water levels

narrowly reaching homes causing gardens to be flooded, or stillwater deposits to form on paths and driveways. This is indicated in figure 3 with the floods shown to have effected a wide range of areas across the region. But, in other more serious cases lower floors of houses were severely damaged from floodwater leading to personal property such as furniture and kitchen equipment to be damaged or destroyed. As well as this flooding of basements was extremely common due to the location of this being at the lowest point within the house and more often than not was positioned below the levels of the garden. Therefore, any surface water that was situated on the gardens surface would have naturally flowed down into the basement causing the flooding issues.

Along with this 6,800 homes in New Brunswick and 2,000 in Ontario were also negatively affected by the floods (TheGuardian, 2019) along with large-scale disruption to transport links being a key negative impact upon local residents' lives. Over 460km of road networks were affected by the flows of water or precipitation that fell. Along with this an estimated $208 million in insurance damage was reported (Floodlist.com, 2019b; CatIQ , 2019). The largest contributing sector to this was home insurance causing damage totaling $160 million. Furthermore, impacts upon businesses amounted to claims totaling $40 million and along with that auto insurance of damaged vehicles cost $10 million.

Response

Within the Canadian state of Ontario, Ottawa Major Jim Watson had to declare a state of emergency, city wide in wake of the flooding that was occurring (Floodlist.com, 2019c; Maharlikanews.com, 2019). In addition to this in the Constance Bay area, to the south of the Ottawa River voluntary evacuations were put in place. According to satellite imagery captured on April 25th, 2019 by Service New Brunswick 16,155 properties in the New Brunswick area had been touched by floodwater in some capacity (Floodlist.com, 2019c).

By the 29th April 2019 over 9,500 residents had been evacuated from Quebec with the aid of 2,000 military personnel deployed from Canadian protection services (Floodlist.com, 2019c; CNN, 2019). In the north-eastern state of America, New York additional troops were deployed to help combat the rising effects of Lake Ontario. The main problems that arose from the flood events within eastern Canada and the north-eastern tip of the USA, were consistent of roofs leaking due to unprecedented volumes of precipitations, that housing structures were not able to withstand. As well as this, overflowing rivers such as the Ottawa river caused damage to roads with vehicles becoming submerged and sewerage becoming backed up, which led to a surplus of negative impacts upon transport infrastructure (IBC, 2019).

Due to the flooding problems the evacuations that took place left many citizens in jeopardy and therefore, by the 30th April 2019 there were 486 households that had registered with the red cross. Of these 433 people were being sheltered (Floodlist.com, 2019c; CTV News, 2019).

Technical Interpretation

Factors Influencing the Flood Event

Flood events that take place in Canada are usually attributed to a variety of factors, these include the volume of precipitation that has fallen within specific catchments. As well as this there are the antecedent conditions that have a large effect upon many aspects of the environment (Burton, 2006). With the uptake of water within soils reducing the surface run off being a key factor, which is detrimentally effected by previous high precipitation weather conditions. This is dependent upon the climate and time of year. In addition to this the rise of urbanisation in Canada (Nirupama, Armenakis & Montpetit, 2014) has meant an increase in the number of impermeable surfaces, (such as rods, pavements and car parks) and thus meant there are less areas that can effectively absorb rainfall and reduce the volume of surface run off.

As described in (Blais, Greshuk & Stadnyk, 2015) the effects of antecedent conditions that can be caused within Canada can have a large impact and causation towards river flooding events. The range of conditions that were present in the 2011 Manitoba floods were parallel to those of the April 2019 floods described above. With precipitation rates 50-100% higher than the previous monthly average, combined with low winter temperatures contributing a significantly higher water content from melting snow pack ice.

The cause of the snowmelt of snowpack's within Eastern Canada was due to the increase in mean daily temperatures across the month of April. With temperatures rising from a low of -5oC on the 5th April 2019 in Quebec to a high of 11oC on April 21st, 2019 (Government of Canada, 2019) which is displayed in figure 4, showing the large temperature scale that was experienced across April 2019. This 16oC increase caused large scale melting of snowpack's resulting in large volumes of water flowing down into the Lac des Deux Montagnes Lake. Which in turn decreased the lakes capacity to hold water that was flowing in from other streams in the region. Therefore, the volume of water needed to fulfill and exceed the storage capacity was lowered and thus vastly increased the likelihood of the lake flooding. This accompanied by the already saturated soils that had limited capacity to hold further volumes of surface water. So, when the high volume of precipitation fell it ran as surface run off into the streams and rivers leading to the Lac des Deux Montagnes where there was nowhere for the excess

water to be held. Thus, leading to the large-scale flooding that was seen.

Why Canada Is Particularly at Risk from Flooding

The majority of major flood events that occur in Canada are that of flash flooding due to Canada's geographical location in retrospect of the polar jet stream, which when is in its active phase causes the buildup of concurrent thunderstorms. This is highlighted in (Kimbell, 2013) where multiple storms conjoined to produce heavy rainfall in Toronto.

In this particular flood event the combination of precipitation which fell over a period of eight days, and the snowmelt which led to saturated soils. Along with overflowing of lakes once precipitation started meant all were contributing factors to the flood event. This shows the impeccably long duration of the flood event when compared to other floods within Canada, which is further supported by the flood in Toronto on July 8th, 2013. This was a one-day event and caused lasting damages of more than $850 million in damages (Toronto Star, 2013).

A further point to be made regarding the similar causes between different flood events arising in Canada are that of the placement of pre-existing natural creeks, that have had pipes for sewerage works to pass through being constructed within them (Young, 2013). This was a prominent problem within Ontario in the 2013 floods and thus will be a prominent factor in why Lake Ontario was largely effected yet again, due to the reduction in water capacity due to the piping.

Conclusion

Overall the impacts caused upon Canada and north-eastern USA, although in relative terms caused large scale impacts upon infrastructure and economic costs, but the threat to life remained low. This is due to Canada's high economic status which allows for fast and effective response, such as the deployment of 2,000 military personnel just in Quebec alone. Therefore, by having such effective response systems as well as the high-quality healthcare a more economically developed country such as themselves can provide, means that the vulnerability to such disasters is lower.

But, due to the topography of Canada providing that of an environment consisting of a large number of lakes, of which settlements have formed, thus leading to an increased level of risk due to the proximity of humans to the potential hazard.

Finally, the risk of flooding occurring again within Canada in the future is highly likely, with the extremity only likely to increase due to a number of interlinking factors. The first of those is the impact of climate change with rising temperatures earlier in the season causing the melting of snowpack's in upland and mountainous areas leading to increased volumes of water in the river networks. Along with this the increase in urbanisation within Canada will further increase the number of impermeable surfaces with a rise in infrastructure such as roads and driveways.

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Ridgecrest, South California July 2019 Earthquakes

Siobhan Patel

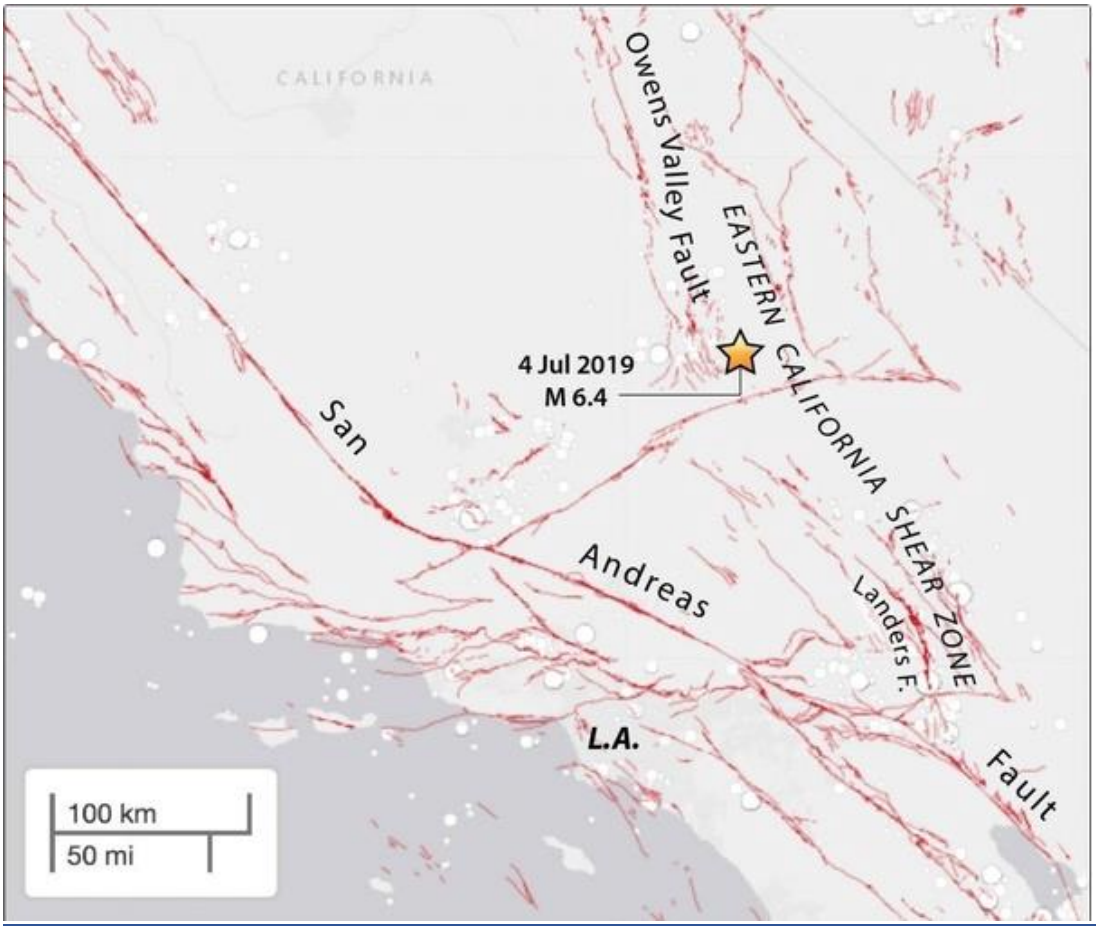


Figure 3: Shows the faults lines located in South California (Retrieved from Dokka, Travis, 1990)

Account of the Event

Introduction

The Ridgecrest Earthquakes was the highest magnitude earthquakes recorded in California in the past twenty years. The event consisted of two main earthquakes, which took place on the 4th and 5th of July 2019. The sequence began with an earthquake, with a magnitude of 6.4, acting as a foreshock to the larger event, which occurred thirty-four hours later. The foreshock which occurred on the 4th of July was located 18km Southwest towards the city of Ridgecrest, South California. Both earthquakes can be seen on figure 1. The first earthquake also had several minor shocks following the event.

On the evening of the 5th of July at 8:19pm the major earthquake commenced hitting the Richter scale at a devasting Mw7.1. Thirty minutes prior to the Mw7.1, a foreshock occurred at Mw5.0, (Epstein, Eunjung cha, 2019). The Mw 7.1 shock fell just northwest of the Mw6.4 foreshock and then ruptured northwest and southeast, causing a horizontal slip of 4.5 meters and a maximum reported vertical separation of 3.7 meters. The effects of the earthquakes crossed over three states in the US impacting California, Nevada and Arizona. With the two earthquakes being the trigger for the recent shocks caused in California, it is vital that the cause of the earthquakes must be identified, in addition to careful regulation amongst the area to prevent further damage.

Preparation

The city of Ridgecrest were left in the dark with the occurrence of the earthquakes as no warning signals were alarmed prior to the event. The yearlong developed app 'ShakeAlertLA' was made in order to notify residence of the state of upcoming natural hazards. As the epicentre was located outside of the city of LA, those who were most effected; the 27,000 residents of Ridgecrest, weren't notified of the high magnitude earthquake, (Burroughs, 2019). The app

developers and seismologist have now recently resolved the issue by having the app available for the entirety of the state of California. This is critical issue which needed to be addressed as it was predicted that the two earthquakes trigger multiple aftershocks for the forthcoming months which has proven to be true, which can be observed currently, (Watkins, 2019).

Damage- 4th of July

With the lack of preparation Ridgecrest had with the earthquakes. The damage was kept to a minimal due to design of the buildings, as majority of the cities buildings were new and therefore shock resistant, however some buildings did sustain serve damage. Furthermore, water, gas and power lines were also broken during the event, which initially left around 6,900 people without power. Two building fires erupted, one of which was a house fire, however majority of the damage was to infrastructure and mobile homes in the city, (Ntczak and Rodgriguez, 2019). Figure 2 shows the impact of the first earthquake on infrastructure in the city, with large fractures within highways across california. Twenty injuries were reported on the evening mainly from broken glass and falling debris. One death was recorded on the 4th due to a man's vehicle collapsing on himself in state of Nevada.

Damage- 5th of July

It was reported that 3000 people were left without power from the immediate effect after the second shock acrocss the rest of Kern county. The governor of Ridgecrest, Gavin Newsom estimated $100 million in economic damages for Ridgecrest alone, (CBCN, 2019), with an overall estimated damage for the combined earthquakes were estimated to total over $5.3 billion. Fortunately no deaths were caused by second earthquake. Ridgecrest also suffered multiple rockslides jamming the roads, making it difficult for the public to travel, including traveling via state route 178 for a temporal time, (Molina, 2019). In addition, fifty homes were destroyed causing emotional trauma on the residents of Ridgecrest.

Response

In response to the events, California's emergency operations centre (CEOC) was activated to its highest level, as well as the state was coordinating mutual aid to first responders. More specifically San Bernardino County received attention from the CEOC, as numerous homes and other structures sustained critical damage. In addition, it was reported on the Friday night following around 200 people stayed in the emergency overnight shelter including the red cross, (McCain, Hayden and Woodyard, 2019). Mayor Peggy Breeden also resorted to distributing two trucks of water to Ridgecrest and the nearby town of Trona for the emergency, (Kim, Lloyd, 2019).

The California National Guard also deployed 200 troops, logistical support and aircraft to be sent to the scene for support to the incident, as well as the entire California Military Department was put on alert as well as the pentagon also being notified, (CNCB, 2019). The damage was minimal in comparison to what would have been expected for such a high magnitude earthquake. The president of the United States, Donald Trump offered long term federal support in order to help rebuild Ridgecrest economy and infrastructures. Motorists were able to travel back on to the roads by the following Sundays as well as power, gas and water returning to homes by the Monday.

Technical Interpretation

Large earthquakes such as the Ridgecrest shocks are shown to cause stress in the ground triggering a new cycle of earthquakes to be released nearby. This is evident how the Mw6.4 leaded to the release of the more destructive Mw7.1 earthquake the following day due to the instability in the surrounding land, (Watkins, 2019). Which is why the epicentres of the two major earthquakes where located near each other.

Tectonic motion occurred between the Pacific-North America plate boundary. Two main fault zones were the contributors towards the shocks. Which included the San Andreas Fault, (SAF) and the Eastern California Shear zone (ECZS). Figure 3 maps the SAF and ECSZ. This was due to the fault lines collapsing. the ECSZ which accounted for 20% of the total relative plate motion, as well as the ECSZ just being located 140 Kilometres to SAF, taking these into factor, the predicted impact of the earthquakes were enviable. It was thought that the sequence was caused by a number of small faults across the ECSZ, (Nyst, 2019).

Figure 1 shows the epicentre of the Mw6.4 and the Mw7.1 earthquake. The blue and white target presents the strike-slip focal mechanism and epicentre of the 4th of July shock. The blue lines illustrate the observed surface ruptures. The red target represents the epicentre of 5th of July earthquake, as well as the red lines showing the surface ruptures of the 5th of July event. When examining the figure, it shows the surface ruptures interject each other as the Mw6.4 earthquake moves westwards, as the latter earthquake moves north-west as well as south-east, reaching the Garlock Fault Zones (GFZ). The release of tension caused by the first earthquake caused the area to be unstable. This shows how the first earthquake weakened the plates, not only causing the second earthquake to occur, but also causing the second earthquake to be more destructive due to the land being more unstable, (Nyst, 2019).

As the latter earthquakes reached the GFZ, this can explain the more recent earthquakes also caused in the area. There has been seven other earthquakes which have happened since the 4th of July, with relatively high magnitudes. This also shows how fault slips which occur in particular zones have a direct effect on other marginalised zones, weakening the area, making the area more susceptible larger and more frequent earthquakes.

History in the area of past events

Earthquakes have been common in area due to the ECSZ. The most recent notable earthquake which occurred before the Ridgecrest sequence happened in 1999 known as the Hector Mine earthquakes located in a remote part of the Mojave desert with a magnitude of 7.4. Similar to the Ridgecrest sequence, the Hector Mine earthquakes also consisted of prior foreshocks hours before the main event, one which had the largest magnitude of 3.4. The Hector mine earthquakes were thought to be caused by the 1992 Landers earthquakes. Recurrence of earthquakes in the Eastern California Shear Zone have been considered to occur in the order of thousands of years sequencing earthquakes to slip every few years due to the fault zones, (Mellors, Sichoix, and Sandwell, 2010). This illustrates how the Ridgecrest earthquakes are a natural occurrence of events which will continue to happen. Past events which also occurred in the area include 1872 Owens Valley earthquake, 1952 Kern County earthquake and 1992 Landers earthquake the 1999 Hector Mine earthquake mentioned already.

Conclusion

Human activity such as mining, formation of artificial lakes, carbon and hydrocarbon stores can contribute to the occurrence of an earthquake. However, the Ridgecrest sequence can be seen as a inevitable natural disaster which strikes the area of California every few decades (on estimate) along the fault lines of the ECSZ and SAF zones. This makes California a vulnerable area susceptible to a sequence of earthquakes. Due to this, preparation is vital to mitigate the damage for before, during and after the event.

Before the Event

Those who suffered the most during the earthquake was those of lower income households who could not afford to replace items they have lost, as well as finding the facilities available for them which the public services offer. Due to this public service announcements of being able to find emergency services and shelters should be promoted in order to decrease the amount of users trying to contact 911, and only used for extreme cases which the event such as injury to a person or missing people. In addition, public funds need to be raised in order to improve on lower income houses to make them more fire resistant. The app developers of 'ShakeAlertLA' have already improved the range of the app by reaching all of the residents of California so they can prepare, however, the app on gives a notification once an earthquake has been detected and not an earthquake prediction app, which could be another recommendation to the state of California to introduce in order to further help prepare residents for upcoming earthquakes.

During the Event

During an event it is important to get those who are most vulnerable to injury and death to safety, this includes children, elderly, disabled, and those of lower income including the homeless. The red cross housed shelter in addition providing emotional support for those in need. Drivers should be warned to move out of traffic in the occurrence of an earthquake.

After the Event

The main problem caused by the earthquakes for majority of residents were the damage to the power, water and gas lines, as example 3000 residents were left without power in kern county. Due to this it is important that a backup system is in place for residents to continue with daily life. However, impressively the damage was limited caused by the July 4th and 5th earthquakes in comparison to the great magnitude. Many of Southern California's buildings withstood the shocks of the earthquakes, as well as the emergency response to the event being outstanding. Sadly one death did occur, with unlucky timing and position as well as a handful of injuries, however compared to prior earthquakes of a similar magnitude such as Ashgabat, Turkmenistan, Oct. 5, 1948, which had an estimated death toll of 110,000 it shows how preventative measures can enormously improve damage control for natural disasters.

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Hurricane Dorian

Joe Sheppard

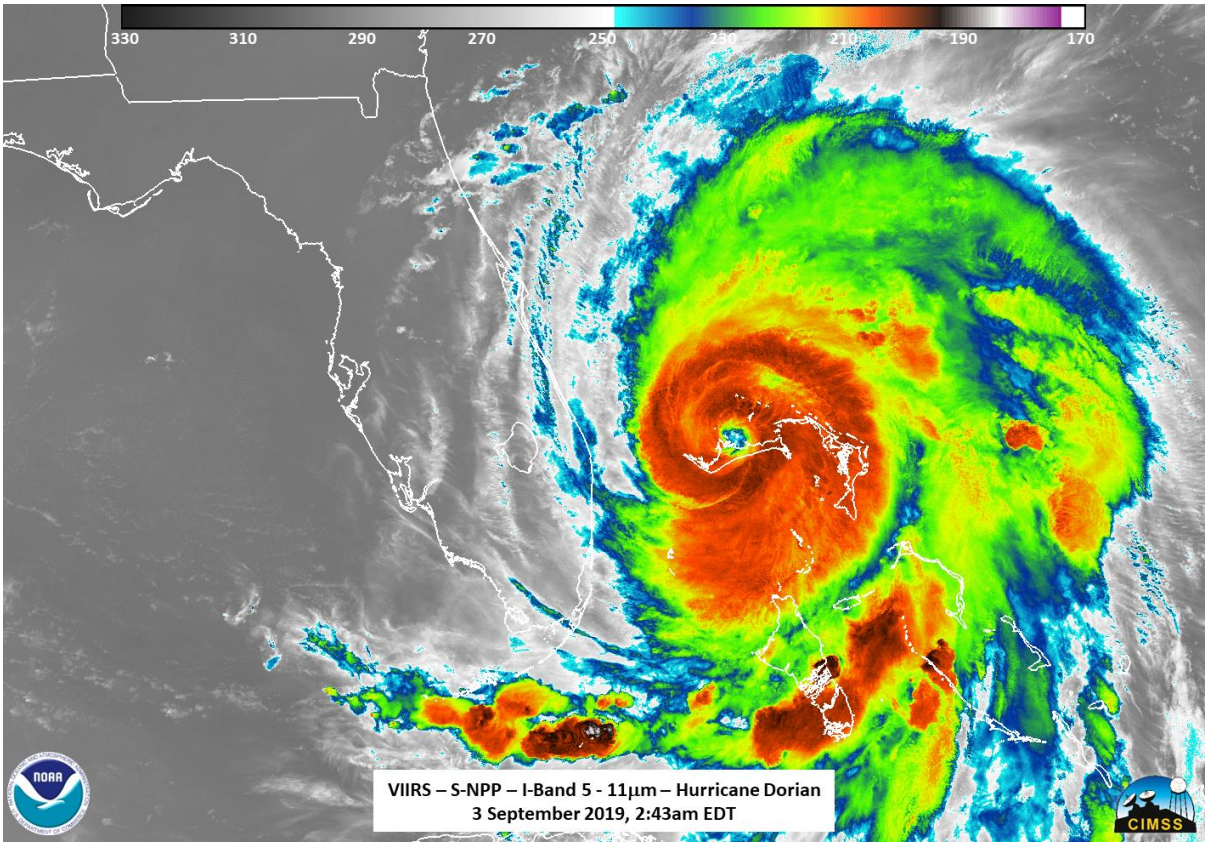


Figure 1 Image taken from National Oceanic and Atmospheric Administration website. 2018.

INTRODUCTION

Hurricane Dorian was one of the most significant Natural disasters to affect the Americas in the past year. The hurricane began forming on the 23rd of August and dissipated on the 10th of September. By definition a hurricane is a tropical cyclone that occurs in the North Atlantic and Northeast Pacific ocean. According to the Royal Meteorological Society a hurricane is a 'storm system rotating around an area of low pressure which produces strong winds and heavy rain' a storm can only be described as a hurricane when its wind speed is over 63 knots, hurricanes tend to be 500miles wide and ten miles high. The brunt of the damage of hurricane Dorian was taken by the Bahamas, however it also reached some of the southern states of The United States of America, including Florida, South Carolina and North Carolina. According to the charitable organisation ShelterBox Dorian began forming on the 23rd of August and had strengthened to a tropical storm on August 28th. BBC news described how The Hurricane reached the Bahamas on the 1st of September at this point being rated as a category 5 hurricane , then moving on to Florida on the 3rd before hitting South Carolina and North Carolina on the 5th and 6th by this point however its severity had been downgraded to a category 2. The Hurricane moved as North as Nova Scotia, Canada affecting the area on the 7th and 8th of September.

IMPACTS

Bahamas

Hurricane Dorian was one of the most significant hurricanes in recent history, in fact according to the Scientific American blog it is tied with the 1935 Labor Day hurricane in the Florida keys as 'the strongest landfalling Atlantic hurricane on record.' This severity is due to the extreme winds and surges caused by the hurricane there are differing reports on the highest wind speed recorded during the storm; the Scientific American reported winds of up to 185mph, however according to the Guardian wind speeds exceeded that reaching 200mph, accompanied by 24ft surges. CNBC explained that these conditions meant the storm was classified as a category 5 hurricane for the duration of the time it was over the Bahamas from the 1st till the 3rd of September, by the time the storm reached North America the conditions weren't quite as severe, and it was downgraded to a Category 2 hurricane.

Figure 1 shows a satellite image that was captured on the 3rd of september as Dorian was battering Grand Bahama the image was retrieved from NOAA's website. The Hurricane caused unimaginable damage to the Carribean island an article from the Guardian described how an estimated 45% of homes in Abaco and Grand Bahama had been destroyed however this percentage could be even higher with Time magazine reporting that it was in fact 60%. The guardian article went on to mention the deputy president of the country revealed "70% of the homes are underwater". The article then described how reports from the UN confirmed 60,000 people on the Island would need food aid, while the Red Cross said 62,000 would need drinking water provided. In a separate article from the Guardian further evidence of the severe damages caused by the hurricane was provided as an apparent 76,000 people in Grand Bahama and Abaco have been left homeless.

Not only were homes destroyed by the storm but there was also a significant loss of life, an article from the Washington Post reported that the death toll from the disaster was officially 58 however with 1300 people still missing the real death toll is suspected to be much. The hurricane also caused severe damage to the natural environment of the Bahamas as according to an article on Gizmodo an Oil Storage facility for the company Equinor was significantly damaged by hurricane Dorian and 1.5 million gallons of oil was spilled.

North America

The effect of the hurricane on North America was considerably less severe than the Bahamas, however there was still significant damage, disruptions and even fatalities caused by the hurricane. Florida was the first part of the USA to be hit by the storm and flooding incurred, according to Spectrum News 13 there was a total of 6 fatalities in Florida linked to the hurricane.

North and South Carolina where the next areas affected being hit by winds of up to 90mph according to the BBC. Extreme rain accompanied the winds with rain being blown sideways according to USA Today. The report went on to mention how some areas of South Carolina 'were under a foot of water' this flooding led to around 250,000 homes and businesses going without power, 440,000 people evacuated coastal areas of the region.

Those that did not evacuate found themselves stuck in the extreme conditions, on Ocracoke Island some people had to resort to climbing into their attics to escape the high water according to the NY Times. 45,000 people on the Island where left without power according to Time Magazine, the article then went on to mention by the time the storm had passed, there had been a reported 13 hurricanes in North Carolina. By the 7th and 8th of September the hurricane made it to Canada, according to NASA Blogs the hurricane caused 400,000 people in Nova Scotia to lose power. This was as a result of the extreme rain and 75mph winds the area was hit by according to Time magazine.

TECHNICAL ASSESSMENT

WHAT CAUSES HURRICANES?

Hurricane Dorian occured due to the same factors and conditions that cause all hurricanes, John T.M (1990) explains how 'the exchange of entropy from the ocean to the atmosphere drives the thermodynamic disequilibrium' then a 'strong atmospheric starting disturbance is required' to initiate the hurricane. The article goes on to describe how the most common atmospheric disturbance that starts hurricanes for the North American continent 'is provided by a macroscale wave' that is created by instabilities in atmospheric flow over sub saharan africa. L. Bengston's (2001) descriptions builds on that describing how air begins to spiral towards the centre of the storm due to friction at the sea surface. Then 'clouds near the centre become organized into spiral rainbands an eventually into an eye wall by the rotation in the vortex' More and more water begins to be extracted from the ocean as winds begin to strengthen. It is clear from this description why hurricanes are such powerful natural disasters that cause so much damage, costing the US 5 billion dollars annually according to Bengston.

In the past few decades there has been a pattern of hurricanes becoming more and more common which is very concerning for the countries being affected by them. In terms of why these hurricanes are becoming more regular there seems to be a common opinion that a main contributor to the higher rate of hurricanes is changing sea surface temperatures. According to Stanley Goldenberg (2001) the main factors in causing more hurricanes are an increase in sea surface temperature along with a decrease in vertical wind shear. The fact increasing sea temperatures has a direct impact on the rate of hurricanes that occur is concerning considering global warming is heating up our oceans meaning this problem is only going to get worse. This idea is supported by a study carried out by Mark Saunders (2008) he described how a '0.5°C increase in sea surface temperatures is associated with a 40% increase in hurricane frequency and activity.'

However the warming sea temperatures don't only affect hurricane frequency, they also affects the intensity and severity of the hurricanes as heat energy from the ocean acts as fuel for the storms. An article written by Kerry Emanuel (2005) describes how a 'global climate model shows a substantial increase in potential intensity with anthropogenic global warming, leading to a prediction that actual storm intensity could increase with time.' Global warming and rising sea temperatures increasing the frequency and intensity of hurricanes in the future could severely

affect the Americas considering the amount of destructive hurricanes it has already experienced.

PREVIOUS EXAMPLES

There are many examples of hurricanes that have hit the Americas in the past and caused as much if not more damage than hurricane Dorian some of the most obvious being hurricane Sandy and hurricane Katrina. A book written by Wayne Nealy (2016) comprehensively covers the subject of hurricanes affecting the Americas and Carribean documenting almost every significant hurricane that has taken place since 1494. One of the more recent hurricanes mentioned in the book is hurricane Gordon, it was a category 1 hurricane that took place in 1994. It affected some similar areas to hurricane Dorian moving in from the Carribean over Florida and then on to North Carolina, despite it only being a category 1 its effects were far more severe than that of hurricane Dorian in terms of death toll with it reaching 1122 in Haiti alone. Another hurricane spoken about in the book was hurricane Andrew, the size of the hurricane and the amount of damage it caused was very similar to hurricane Dorian. Hurricane Andrew was a category 5 and had winds of up to 165mph, its severity made it the fifth most costly hurricane in American history creating 26.5 billion dollars of damage and destroying 80,000 homes. Similarly to Dorian one of the worst affected areas was the Bahamas it then went on to Florida and central Louisiana with a total death toll of 65.

CONCLUSIONS

VULNERABILITY TO HURRICANES

The extensive damage caused to the Bahamas by hurricane Dorian isn't a particularly rare occurrence to islands in the Carribean, over the years there has been a huge amount of destruction caused by hurricanes all over the Carribean due to the vulnerability of the area. Roger.A Pielke (2003) mentioned these vulnerabilities being increased by 'societal and economic factors'. The Bahamas isn't a particularly wealthy country meaning that when a disaster like hurricane Dorian strikes the country it is not necessarily completely prepared to be able to rebuild and repair the damages particularly easily.

Being such a small country means on top of that its emergency services and hospitals may struggle to cope with the scale of the emergency when a hurricane hits. North America struggles less with these issues being such a large and wealthy country, however it does have vulnerabilities. Tim.G Frazier (2010) described how Florida is at risk from sea level rise 'significant portions of the population, economic activity, and critical facilities are in contemporary and future hurricane storm surge hazard zones.' Climate change seeming to be the main cause of North America's vulnerabilities.

PREPARATION MEASURES

There have been efforts in recent years by countries in the Carribean to be more prepared for future hurricanes and other disasters. J.L Poncelet (1996) described how the areas vulnerability to 'catastrophic events' has led to the region moving away from 'an ad hoc response towards institutional preparedness and more recently to disaster preparedness and mitigation.' North America also has a number of hurricane defence measures in place in order to mitigate the amount of damage caused. For example there are building regulations in place in order to ensure that there is a minimal amount of structural damage when a hurricane hits. This was mentioned by G.L Pita (2013) who described the 'wind load provisions' in place in Florida which has 'played a critical role for wind damage mitigation' in the area since it was introduced in 1982. However more could still be done in the most at risk areas of the Americas for hurricane protection considering the predicted increased frequency and severity of hurricanes threatening the region in the future .

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The Midwestern Floods in the US (Iowa)

Laura Layton

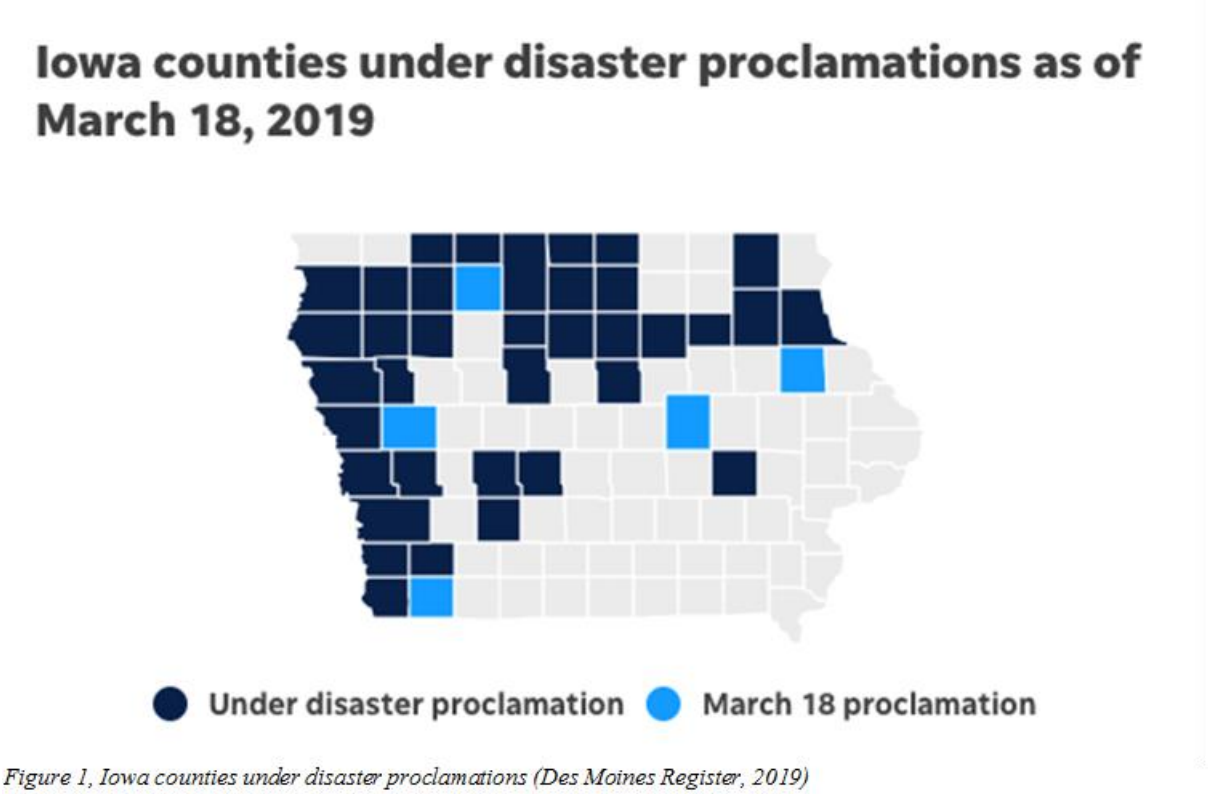


Figure 1, Iowa counties under disaster proclamations (Des Moines Register, 2019)

Authoritative Account

The midwestern region of the United States started experiencing significant flooding around March time of this year along the Missouri River, which is the second longest in the United States, meaning flooding affected multiple states surrounding the river. I will be focusing on the state of Iowa and how the flooding affected the cities and people within the state.

Background of Iowa

The state of Iowa is in the Midwest of the United States and is situated in between the Missouri River to the west and the Mississippi River to the east. Typically, Iowa experiences 50 days of thunderstorms annually, with the most rainfall occurring in the summer months (figure 1).

The Missouri River is the longest river in the United States and is the second longest river in the continent of North America (Encyclopaedia Britannica, 2017). Its formed by the confluence of three rivers located in the Rocky Mountains area of Montana. The river has a length of 3544km and runs through 6 states, including Iowa. The drainage basin of the river covers 1,371,100 square kilometres and the elevation of the river at its source is roughly 14,000ft which is significantly higher than the elevation at its mouth in Missouri, which is 400ft, (World Atlas, 2018).

Preparation

Prior to the floods and during residents were sent flood warnings and regular updates to ensure their safety. In extreme cases, residents were also assisted in evacuation.

The main defences in place in the event of a flood are the levees constructed along both the Mississippi River and the Missouri River. It was reported that prior to the flooding in Hamburg, the residents were attempting to raise $5 million for the necessary repairs to the levee before the storm took place to reduce the impacts of the flooding (Almukhtar et al, 2019). The area is prone to flooding due to being located on the floodplain of the Missouri River. Some minor flooding events in the past had been mitigated by the existing levee in the town, as mentioned above, the residents had attempted to repair this levee prior to the storm but were unsuccessful in raising enough funds. Furthermore, after previous flooding events, levees had been raised around specific buildings such as sewage and water treatment plants to reduce damage.

There were also temporary HESCO flood barriers put in place prior to the flood the help prevent the flood waters from travelling into towns and cities.

Timeline of events

Between the 12th and 15th of March heavy rainfall fell on Iowa and surrounding states around the

Missouri River. The rain fell on layers of deep snowpack which over lied heavily saturated soils beneath, this combined to create perfect flooding conditions.

On March 13th, the river spilled over levees near the town of Hornick, causing the area to be evacuated (Nozicka, 2019). Western Iowa, which borders with Missouri River was most severely impacted, 30 levees had been breached by the river and caused towns and highways to flood, preventing people in the area from evacuating, (Norvell, 2019). Furthermore, Bartlett city was shown via satellite image to be completely underwater.

By the 14th of March, the Missouri River and its tributaries had begun to flood western Iowa, causing nine state parks within the state to close. According to the Department of Natural Resources, 31 people were rescued as well as 17 dogs, 9 cats and an iguana. Over the course of the following days Kim Reynolds, Iowa's governor, issued disaster proclamations for 36 counties as the flooding worsened (Fleig and Webber, 2019). On March 15th the first major casualty occurred whereby a citizen died after being swept away by the oncoming floodwaters. Over the course of the next few days areas within central Iowa began to flood such as the town of Lehigh, where the Des Moines river broke its banks due to ice jams pushing the water over the sandbags along the river bank, resulting in the worst floods the town experienced in 50+ years (Cannon, 2019).

March 17th – 18th: Major Impacts of flooding within Western Iowa

According to the National Weather Service, the Missouri River was recorded at a height of 34.41 feet, making it the third highest level recorded in history. On this same day, two thirds of the town of Hamburg was submerged underwater as a result of the bomb cyclone hit (McMahone & Young, 2019) and the poor condition of the levee which was breached by the water; this caused the town to lose gas and sewage services in the area. The water treatment plant in the town was also shut off before the floodwaters reached the building and residents were asked to keep water use to a minimum and only when necessary (Arterburn, 2019). In the town of Pacific Junction, the Missouri River breached multiple levees, flooding the town in up to 8 feet of water leading to a mandatory evacuation (Baskin, 2019). Furthermore, the local water treatment facility providing 275,000 gallons of water to the residents of Pacific Junction and Glenwood was shut off due to floodwater damage (Peikes, 2019).

On the 18th, a levee is breached by the river in Hamburg. This led to all 1000 residents to make an immediate evacuation in the middle of the night. Following this, Governor Kim Reynolds issues further disaster proclamations for five other counties on top of the previous 36, these counties primarily lie along the west border of Iowa, with some across northern and central Iowa (see fig. 4)

March 19th Onwards

Aid is sent to the town of Glenwood to evacuate disabled citizens from the Glenwood Resources Centre, which is an organization created for those with intellectual disabilities, as water supply to the building was becoming limited.

By March 20th, 81 of 99 counties within Iowa were under hazardous weather outlook, flood advisory or flood warning. Additionally, the US Army had reported that 30 levees along the Missouri River to the south of Council Bluffs were breached. At this point the estimated damage to southwest Iowa was around 1.6 billion dollars according to the governor.

Eastern Iowa

On the east coast of Iowa, by the Mississippi River, the cities of Davenport, Bettendorf, Rock Island and Moline (also known as the quad cities) had a 96 day period whereby the Mississippi river rose above flood stage levels, the river had burst its banks in Burlington and remained above the normal river level for a total of 104 days breaking previous flooding records, (Gerlock, 2019). The towns and cities affected by the flooding of the Mississippi river had an estimated 2 billion dollars total in damage.

Response

On March 23rd, President Donald Trump approved major disaster declaration for the 63 of 99 counties in Iowa. To be more well prepared for future flooding events, the governor Kim Reynolds signed an executive order for the formation of a Flood Recovery Advisor Board. This was tasked with coordinating and planning relief efforts as well as investigating various flood control measures to improve Iowa's flood defences (Fleib & Webber, 2019). Furthermore, on April 20th, after meetings with the US Army Corps of Engineers, they were given a 12 million dollar contract which was to be used to repair the damaged levees in Hamburg in addition to planning permanent repairs to other levees damaged by the floods (AP NEWS, 2019).

Technical Interpretation

Causation

In the earlier months of the year there was a cold spell in the Midwest region of the US with temperatures as low as -15 degrees Celsius and record amounts of snowfall, this left areas around the river covered in thick layers of snow (The NY Times, 2019). Following this, there was a sudden temperature rise, (particularly in Nebraska) as well as heavy rainfall over the course of a few days with as much as 2.27 inches falling according to Omaha's Weather Service (Hassan, 2019), this was declared as the wettest period on record in the US. The incapability of the

snow to absorb the large volumes of rainfall led to the melting of the thick layer of snow in the area, and as a result there was enormous amounts of run off entering the Missouri River and its contributing rivers and streams. The water levels in the river were elevated drastically due to the large amounts of run off and melting ice caused the river to burst its banks and break levee systems put in place, flooding the surrounding areas. Another factor which played a role in the flooding of the river was the previous flooding that took place in the autumn of 2018. The soils around the river saturated in autumn and froze within the soil during the winter. This meant that when the temperatures rose the water melted and no more rainfall or snowmelt could be absorbed into the soil, so they went directly into the river instead.

Due to the river's enormous size it's no surprise that people living nearby have taken the most advantage of it as a natural resource. During the 20th century irrigation and flood control was implemented as well as a hydroelectric power station and 15 dams along the course of the river. Its natural course has also been altered with meanders being cut through for channelization in order to make navigation along the river easier. Human intervention on the river is one of the contributing factors as to why the flooding in the area was so severe. The urbanisation of the areas surrounding the river creates more impermeable surfaces which cause more run-off to enter the river system and lead to a rise in river levels, this allows the river to breach its banks and flow onto the floodplain where towns and cities are located.

History of past events

In 1993 there was a catastrophic flooding event which caused 17 deaths and roughly $3 billion in damages. The flooding damaged 20,000+ homes with many destroyed, causing 10,000 people to be evacuating. During this time, Iowa had 130 days of rainfall and every county within the state had been declared as a federal disaster area. In response to this flooding, levees across the state were improved, especially in Des Moines which was severely affected. The levees were raised around domestic water and sewage treatment plants for extra protection, (Zogg, 2014).

Since 1993, the last notable major flooding event that Iowa experienced was the 2008 floods, this lasted roughly a month, starting on June 8th and ending on July 1st. Although this did not damage as many states as this year's flooding, it was still considered a major flooding event and had severely impacted the state, causing damage estimated at 6 million dollars. People were evacuated as their homes were at risk of being destroyed; considerable damage was also caused to the Amtrak rail services, with a rail bridge in Cedar Rapids being destroyed (Zogg, 2014). Many roads and other public transport services were also unable to operate during the flooding.

Conclusion

Being situated in between the Missouri River and the Mississippi River, the two longest river systems in the United States, Iowa is always going to be vulnerable to flooding from both ends of the state, there is evidence of this from the floods that have occurred in the recent past. As there are many tributaries of both rivers which run through central Iowa, there are a lot of towns and cities/urban areas that have been built upon the floodplain. This puts many people and areas in danger of regular flooding. As flooding will be a major issue for Iowa, the state needs to invest in more permanent flood defences to manage flooding and mitigate the effects, in the long run this will protect them from future floods and increase preparedness therefore reducing the economic and social impacts.

As the floods are still ongoing, the people or Iowa are still experiencing floods and haven't had the chance to recover and rebuild their homes from the wreckages. The total damage has been estimates at $2.9 billion and as the floods are still on going, its likely that this estimate will increase to well over $3bn.

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Amazon Fires 2019

Bethany Everton

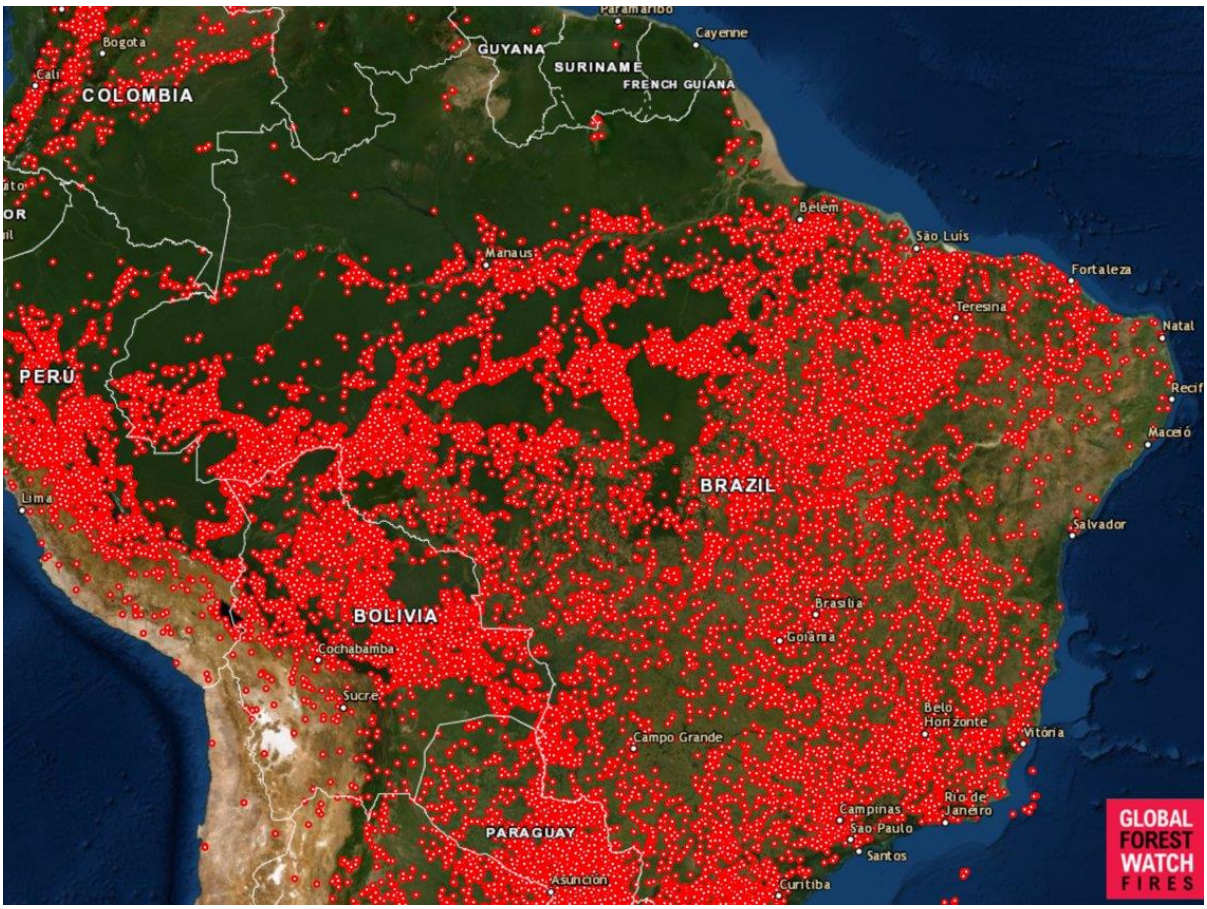


Figure 2 Fires in the Amazon rainforest from 13th-22nd August 2019, with each fire being shown by a red circle. Within this short period, Brazil was issued with 109,000 fire alerts (Global Forest Watch, 2019 & Business Insider, 2019).

Background and Causes of the Fires

During 2019, there were over 70,000 fires in the Amazon Rainforest, which is over 80% higher than in previous years. The large increase in fires, especially during August of 2019, were widely thought to have been due to Brazilian President Bolsonaro's new environmental policies. These policies encourage businesses such as the soybean and cattle industry, for which large areas of rainforest are cleared (National Geographic, 2019a & BBC, 2019). Figure 1 shows the location of the Amazon within South America. This section of the study was researched using the Google search term 'Amazon Wildfires 2019' to find grey literature, which came up with 33,500,000 results. News articles were the main and most useful source, very few first-hand accounts were found.

From 1960 to 2010, the human population of the Brazilian Amazon rose by 19 million people, and the forest cover had been reduced to just 80% of its original coverage. It is important that the ecosystem is protected, since it provides 20% of freshwater to the world and stores 100 billion tonnes of carbon in its biomass (Davidson et al, 2012). Fires naturally occur in hot areas like the Amazon, particularly during the dry season, due to events such as lightning. But it is thought that the increased number of fires this year result from human causes, as fire can be used to quickly clear large areas of land for businesses such as the logging and farming industries (BBC, 2019 & Abbott, 2016). For a fire to occur, there must be fuel, heat and oxygen present. Dry wood can absorb less heat than wet wood, meaning drought conditions make forests more vulnerable to fires (Abbott, 2016). During May to September, the Amazon tends to be much drier than the rest of the year, which can allow the fires to spread rapidly (Reuters, 2019). Figure 2 shows the number of individual fires across the Amazon during August 2019, a period when there was a very high number of fires compared to previous trends.

Mechanisms and Impacts of Wildfires

The first stage of a fire is preheating, which allows the chemical structure of the wood to break down during pyrolysis. Then, hydrocarbon vapours are released, which mix with oxygen and become ignited in combustion. In the Amazon, there are different plant heights making up separate canopies, which act like a ladder to allow fires to spread (Abbott, 2016). This means the rainforest is particularly vulnerable when faced with fires, as once a fire breaks out it is able to spread and increase in intensity very easily, which make them difficult to extinguish.

The fires in 2019 reached their height in August, leading to large releases of carbon dioxide into the atmosphere, depleting a major carbon store (BBC, 2019). As well as releasing carbon dioxide, burning for deforestation reduces the number of trees available to absorb further carbon dioxide, which further contributes to climate change (National Geographic, 2019a).

The clouds of smoke from the August fires could be seen from space (National Geographic 2019a), and this has caused pollutants such as PM2.5 to spread into places such as São Paulo, Manaus and Cuiabá. Safe levels of this pollutant are 25µg/m³ and below, yet in Acre (a state in Brazil), levels were found to be more than 600µg/m³. This particulate can lead to serious health problems when inhaled in high concentrations (Mongabay, 2019b). Figure 3 shows a satellite image revealing the extent of the fires and plumes of smoke. It was reported by CNN (2019) that following the increase in wildfires, the number of children in Brazil suffering from breathing problems increased. This is likely as a result of fine particulates being inhaled, with around 5000 children having to be hospitalised in May and June 2019 alone – before the peak number of fires in 2019 were reached. Children are most at risk to these particulates since they do not have a fully developed respiratory system and may have low immunity. They also tend to be outdoors for more time than adults, meaning they could be breathing in more of the harmful pollutants (CNN, 2019).

It isn't just human health that is a concern though, as some species such as amphibians, insects and slow-moving vertebrates in close proximity to the fires are unlikely to be able to survive. Also at risk is the vegetation itself, as even trees which are not fully burned are most likely not able to recover to their former state (Mongabay, 2019b). Previously mentioned increases in fine particulates can have other major effects too, such as causing droplets of water in clouds becoming too small to precipitate. This can reduce local rainfall, as well as causing possible health problems in animals (Davidson et al, 2012). Other impacts include increased soil erosion as well as changes to the flow of water, which could in turn have effects for the fishing and farming industries (Mongabay, 2019b). However, there are some benefits of fires, including increased plant regeneration, nutrient cycling and the decomposition of organic matter (Abbott, 2016).

Action Taken Against the Wildfires

After outrage from the public as well as NGOs, President Bolsonaro banned fires from being started for 60 days, which consequently led to fires from August to September falling by a third (BBC, 2019). Bolsonaro also sent 44,000 troops to attempt to put out the fires, with the help of planes able to release 12,000 litres of water at a time onto the burning forest (The Independent, 2019). Planes are used to decrease the heat of fires in an attempt to put them out, as they cannot burn without heat, oxygen and fuel (Abbott, 2016). To lower future wildfire intensity, fires can be intentionally started to burn off ground litter which could act as an initial fuel. Another option is for firebreaks to be built in the most vulnerable areas, acting as barriers to prevent the spread of fires (Abbott, 2016). But since the Amazon covers an area of around 8 million km2 (Butler, 2019), protecting the whole forest from fires would not be an option.

But although the number of fires has reduced in the Brazilian Amazon, following the introduction of fire bans and stricter monitoring, they are worsening in other areas such as the Cerrado Savannah (shown in Figure 4). In areas like this, land is burning at an even higher rate, and the number of fires increased by 78% from August to September. This is likely because the Cerrado has not been covered by the same bans and levels of monitoring. This suggests that the problems are being moved elsewhere rather than being combatted, and that in order to protect the whole of the Amazon, a co-operative and long-term response will be needed (BBC, 2019).

Technical Assessment

Amazon Fire Trends in 2019

Tropical rainforests usually have a moist layer helping to prevent burning, meaning wildfires are quite rare. One of the main causes of natural wildfires is said to be lightning, but this rarely occurs and would be unlikely to lead to the large individual number of fires seen during 2019 (van Marle et al, 2017). It is widely thought that the high number of fires in 2019 have been due to anthropogenic causes (AAAS, 2019 & National Geographic, 2019a).

NASA's Goddard Space Flight Centre is able to identify fire spots across the planet, defined as areas hotter than their surroundings. It has found that fires in the Amazon during 2019 follow different patterns seen in previous years, when rates of deforestation were lower (AAAS, 2019). From January to September 2019, over 7000 square kilometres of the Amazon had been cleared, which equates to a higher rate of 85% more than deforestation in the same period last year (Mongabay, 2019a).

Conditions in the Amazon make it more susceptible to drought, as happens every year for several months (Reuters, 2019). The rainfall in the Amazon and therefore conditions concerning fire development can be affected by El Niño/Southern Oscillation. More severe droughts can be triggered when El Niño occurs during the dry phase of the cycle (Davidson et al, 2012). But in 2019, burning trends differed from patterns seen over the past decade. It is known that where fires are due to changing climate, large areas of forest are at risk to fires no matter the type of land use. But satellite data showed that in 2019, there were mainly increases in fires only in areas which have been recently deforested, thought to be for agricultural use (AAAS, 2019).

Increases in fires were also recognised to be close to human settlements, which have allowed the development of agriculture and road building (van Marle et al, 2017). In areas close to human populations and road networks, there are often increases in slash and burn deforestation, where small areas of the forest are burned to be used for industries such as cattle ranching. Later, larger areas of forest may be deforested for agriculture on a larger scale, which can lead to permanent removal of areas of rainforest (van Marle et al, 2017). Most anthropogenic deforestation is observed close to road networks, which contribute to forest clearing since they are needed to transport heavy equipment and logs (Davidson et al, 2012).

Future Predictions for the Amazon

It is predicted that water stress levels and temperatures in the Amazon will increase with climate change. Emissions of CO2 and other greenhouse gases are also expected to rise, so it is important that the number of fires and rates of deforestation are reduced, as they can be a major contributor to climate change. Currently, estimations are that humans have led to the conversion of more than 752,000km2 of rainforest into cattle ranching pastures or land for other agricultural activities. This area of land is 15% of the original area of the Brazilian Amazon, or around three times the area of the UK (Aragao et al, 2014).

Even though there have been attempts to reduce the rates of deforestation, the Amazon has high levels of edge formation and fragmentation, where large habitats are turned into smaller areas (Didham, 2001). This in turn can result in negative effects for biodiversity and conservation efforts. Increased fragmentation has been linked to the amplification of fires, as it enables fires to spread into other forests and fragments in close-proximity (Aragao et al, 2014). It has also been found that fragmentation of forests alters habitats, makes regeneration of vegetation more difficult and can cause biomass collapse around edges (Arima et al, 2016).

Conclusion

To conclude, there have been many more fires seen throughout the Amazon in 2019, compared to previous years. Climate change predictions indicate that conditions are likely to get drier during some months of the year for the Amazon. This could mean that fires will become even more widespread in future years. It is important that there are more punishments for carrying out slash and burn deforestation, as these practices enable fires to spread over large areas of forest. The bans this year were moderately successful in Brazil, but there was a subsequent increase in fires for deforestation in the Cerrado Savannah.

A long-term plan will be needed in order to ensure the problem is not transferred to other areas. To prevent large numbers of fires like those seen during 2019 happening again, firebreaks could be installed to try and stop the spread of fires. But since it has been found that most fires are due to human causes, increased education on the environmental effects of fires may be needed to prevent them being started. There are many studies covering the impacts of fires on the Brazilian part of the Amazon, but more studies in the surrounding areas are needed to see how best they could be managed.

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Camp fire (California)

Jake Godfrey

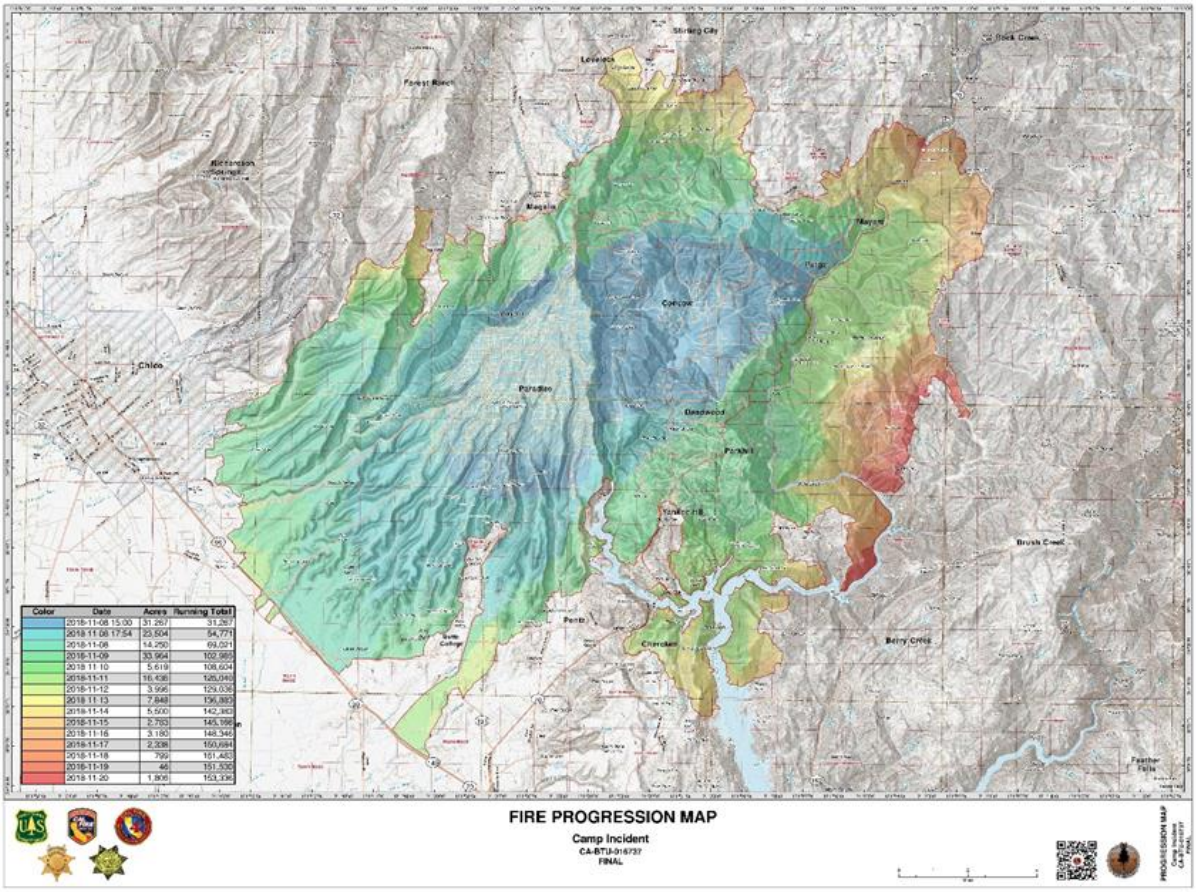


Figure 1 The total burn area of Camp Fire (InciWeb, 2018)

Introduction

Camp Fire was a wildfire event that occurred in Butte County, located just north of the state capital of California Sacramento caused by a faulty electrical transmission. The wildfire event was given the name Camp Fire due to the origin point being identified as Camp Creek Road (Ting, 2018). Camp fire is the deadliest wildfire in Californian history, killing 85 civilians, burning over 153,000 acres of land (Chan & Sterling, 2019) (Hagerty, 2019) and destroying 14,000 residences (Wootson Jr, 2018). This is a massive increase compared to California's second deadliest wildfire which occurred at Griffith Park, LA in October 1933 which killed 29 people and burned 47 acres of land (ABC7News, 2019). Paradise, located just south west of the initial fire (See Figure 1) suffered the most deaths, tallying in at 50, while an estimated 10,000 homes and businesses destroyed by the fire (Lenthang, 2018). Other areas that were directly impacted by the wildfire were Magalia, Centerville, Concow, Pulga, Butte Creek Canyon and Yankee Hills which were all evacuated. The fire started on the morning of November 8th, 2018 Camp Creek Road where it was identified that the cause of the original ignition points were caused by PG&E powerlines (Robertson, 2019) (Sacbee, 2019).

The Event

Contributing factors

There was a mixture of conditions that facilitated the wildfire to become the deadliest wildfire in Californian history. During early October the area received 0.25 inches of rain, before this, the area had gone 7 months without any significant rainfall (CAL FIRE, 2018) with only 0.88 inches of rain since May 1st compared to the expected 7 inches that usually falls during the same time period (Cappucci, 2018). Additionally, between 2012 and 2016 the area was suffering from a long drought, the year 2017 was a normal year and then in 2018 precipitation levels were 50% of their usual level further increasing the dry nature of the area (CAL FIRE, 2018). Throughout October and early November, there had been

northernly winds across northern California which brought poor humidity and hotter than normal temperatures, especially across the thermal belts where Paradise is located (CAL FIRE, 2018). As a result, the conditions were sucking water out of the ground and plants causing the ground and vegetation to become extremely dry which intensifies the burning potential (See Figure 2). In addition to the ground and vegetation being extremely dry there was roughly 1.5x more vegetation present than normal due to heavier rainfall that fell during late spring in 2018 (CAL FIRE, 2018). Due to the very dry environments, strong warm winds and masses amount of fuel with virtually no moisture, Camp Fire was able to become a deadliest wildfire in a short amount of time.

Timeline of events

The day before the faulty PG&E powerline caused the fire, a resident of Paradise who owned the land near the initial fire zone received an email from PG&E indicating that repairs were needed on their property due to hazardous sparks from their powerlines (CBS Sacramento, 2018) and 15 minutes before the fire they receive a error from the site (Johnson, 2019)

On November 8th at 6:33am a fire broke out under the faulty PG&E transmission lines on Camp Creek road (The NewYorkTimes, 2019). Due to the dryness and abundance of fuel and the direction and speed of the wind the fire had spread to Concow in less than 20 minutes. Due to the speed that the fire was travelling at the town did not receive any warning of the fire. By 8AM, the fire had spread to Paradise and it wasn't until the fire had reached the area that the local fire department issued an evacuation notice (Serna, St. John, & Lin II, 2018). The wind speeds can reach 50 MPH due to the high pressure situated over the mountains which pushes the winds down the ridges towards the Pacific Ocean (Simon, 2018) which resulted in the fire spreading very quickly. In the first 12 hours the fire had spread and burned 55,000 acres, covering a distance 15vmiles downwind of Camp Creek Road which equates to the fire spreading at a rate of 76 acres per minutes (CAL FIRE, 2018)

Damage statistics

As previous mentioned, 85 people were killed and 52,000 people were evacuated because of the wildfire (McBride, Guitierrez, & Asimov, 2018).There was a mass displacement of people as 52,000 people were evacuated from there homes in a relatively short period of time ensued a strain on public resources.

The fire had reached and destroyed both Paradise and Concow within the first 6 hours of the event, losing an estimated 95% of the buildings in both communities (ABC7NEWS, 2018). Financially, it was the costliest global disaster of 2018 causing a total of $16.5 billion of damage. It is estimated that $12.5 Billion of damages were insured while $4 Billion worth of damages were uninsured. The $4 Billion of uninsured damages were mainly a high quantity of low valued buildings which tended to be residences being uninsured had a much greater effect on the community compared to the $12.5 Billion being mainly high cost insured commercial structures. Although the damage was about 1/3rd less costly than insured buildings, it will be more vastly lifechanging and felt more throughout the communities as peoples entire residences and possessions were burned to ash (Reyes-Valarde, 2019).

As a result of the fire burning 153,000 acres of land, there was large amounts of particulate matter entering the air causing harmful pollutant levels for humans. There was a 10-day period in which the air quality was not classed as healthy, even entering very unhealthy levels between the 15th and 18th November in San Francisco. Additionally, there was widespread severe air pollution across the San Francisco Bay area and the Central Valley (see Figure 3) (Morrison, Chen, Linou, & Linos, 2018)with 5 schools were closing in Sacramento to protect children from inhaling harmful substances. Not only was the air pollution rife across California, smoke was documented in New York City 3000 miles away casting a haze over the city skyline (Willingham, 2018)

Technical interpretation

When comparing the frequency of wildfires year on year, it is apparent that wildfires are very common as at least 3 million acres of land has burned every year since 1999 (Brusentsev & Vroman, 2017) with the wildfire season running June through to October, being influenced by the Diablo and Santa Ana winds (Accuweather, 2019). The Diablo winds affect Northern California which produces high wind speeds with low humidity that contribute to wildfires by reducing moisture from the environment creating greater burn potential, whilst spreading fire through its high wind speeds (Smith, Hatchett, & Kaplan, 2018).

With the rise of California's population, wildfires are increasingly having a larger impact on property loss due to the fact the need for more property is being developed previous burn regions resulting in a greater wildland-urban landscape (Westerling, et al., 2011), suggesting that the property damage inflicted by Campfire could be somewhat but not fully expected in terms of the increasing wildfire trends. Wildfires occur under a set of conditions that include droughts, high temperatures and oxygen rich fast winds (Palliser, 2012). Heat, oxygen and fuel are components of the fire triangle and all must be present for fire to occur. When all components are present combined with enough heat entering the fuel, the three stages of combustion begin to occur. The first stage is preheating in which the fuel absorbs heat through convection and radiation, and the fuel temperature begins to rise reducing the moisture content as it is

evaporated. The second stage is pyrolysis where once the fuel reaches a certain temperature it undergoes thermal degradation subsequently releasing volatile components into the air which leads into the final stage that is combustion in which the hydrocarbons start to oxidize resulting in the ignition of a fire (Lackner, 2011).

Temperature, moisture, fuel type and topography all affect the stages of the fire triangle and the intensity of the wildfires. Historical data shows that wildfire frequencies and climate change are closely linked (Clark, 1988) and as one increases, so does the other. The fuel type in the area is a mixture of grass, bush and forest vegetation as shown is figure 4, this type of vegetation was in abundance due to the heavy rainfall that fell in late spring 2018 (CAL FIRE, 2018). The mass abundance of fine fuels such as grasses and shrubland can ignite easily due to a lack of moisture while the pine trees in the area hold a lot fuel potential which increases the intensity of the fire. It has been found that as elevation increases, the amount of non-native trees which tend to be fire resistant species decreases which lowers the wildfire frequency however it increases the severity of wildfires when they do happen (Lambert, D'antonio, & Dudly, 2010) which may have been a contributing factor to Camp Fire. The strong winds that pushed the wildfire to spread quickly are likely to have caused new non-local fires through spotting. Wildfires create strong convection columns that pull firebrand upwards and out into the surrounding environment which causes further dispersed fire making it difficult for firefighters to react to the evolving fire, reducing the effort to suppress them (Martin & Hillen, 2016). Rugged topography can produce fire channelling that causes extensive flame zones. It is usually directed downwind and is enhanced by steep terrain (Sharples, McRae, & Wilkes, 2012) which is what the case was like at Camp fire, further adding to its destructive power.

Conclusion

Due to the climate of the area, the mass amount of fuel, the terrain of the land and the fact that wildfires burn lots of land each year means that the residents of California will be always be vulnerable, with some being more than others. The region on paradise and surrounding areas had recently been awarded a sum of $5 million in the effort against fire prevention by reducing the amount of fuel and for educational projects which inform the local community on how to prepare for wildfires (Paradise Post, 2018). Although the money will have a direct impact on fuel reduction and education, it fails to address the problem that many of the deaths that occurred were elderly and/or disabled people (The Sacramento Bee, 2019) that were unable to escape and the $5 million awarded does provide the extra assistance that these people need. Furthermore, the early warning system is conducted through an opt in service that sends alerts through mobile phones that generally older people do not use, again limiting the old age residents but also the entire population who never signed up.

Wildfire fires can be a result of natural forces such as lightening, but increasing more wildfires are a result of humans and specifically transmission lines like the cause of Camp fire is becoming a regular hazard. 800,000 people are intermittently without power as PG&E are turning off the power to prevent wildfires stemming for transmissions lines (PG&E, 2019) as 5 wildfire events, most notably of the year the Kincade fire has or is believed to be from transmissions lines. The potential risk the transmission lines cause can however provide an sustainable, minimal hazard alternative as many owners of the Tesla Powerwall 2 indicated that their household are able to use power generated by solar panels that is stored by the Powerwall 2 while the grid electric has been turned off (TESLARATI, 2019). If such strategies were implemented in hazard prone areas not only would a renewable local energy source be able to sustain the local population, it would reduce the future potential risk of any wildfires.

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River Flooding in Honduras, Costa Rica, Nicaragua, El Salvador and Guatemala

Leila Ahmed



Figure 1: Locations in different countries that experienced heavy rainfall. (Flood list News,2018).; A - Managua (Nicaragua); B - Granada Nicaragua); C - Chinandega (Nicaragua); D - Puntarenas (Costa Rica); E - Guanacaste (Costa Rica); F - Tegucigalpa (Honduras); G - Valle department (Honduras); H - Olancho (Honduras); I - Morazán (El Salvador); J - La Unión (El Salvador); K - Santa Rosa (Guatemala); L - Escuintla (Guatemala); M - Pinar del Río (Cuba)

Account of the Event

The Caribbean Sea, which lies between two continental landmasses and is part of the greater Central American Sea is well known to have a tropical climate coupled with strong trade winds that come from the coast of Africa, creating storms and hurricanes from time to time (Curley, 2019). The vastness of the area also means that the climatic conditions vary in regards to their severity but since the deadliest hurricane reported in the Caribbean, Hurricane Flora, which caused more than 7000 deaths in 1963, the area is well acknowledged for its storms. On the 2nd of October 2018 the National Meteorological Institute (IMN) in Costa Rica reported that there was a low-pressure system that had been noted to have activated an inter-tropical convergence Zone over Costa-Rica and the waters of the pacific (IFRC, 2018) bringing with it a significant amount of rainfall.

The system came through the South Western parts of the Caribbean Sea, most likely pushed on by the steady and strong winds experienced in the Southern Caribbean (Curley, 2019). By the 4th October 2018, IMN detected two other pressure systems in the South Western parts of the Caribbean (Costa Rica and Nicaragua) which released between 50 and 150 mm of rainfall in most parts of that region. Reports of the heavy rainfall that had been noted by the 2nd, made headlines in the region.

According to ACT Alliance (2018) the low pressure system that had been attributed to the heavy rainfall in the South Western part of the Caribbean Sea also concurred with the tropical storm Michael which was heading towards the US gulf coast resulting to large area of surface low pressure that is referred to as a Central American Gyre. The system was characterized by a counter-clockwise flow of air that brought a moist flow of pacific air into areas of Costa Rica, El Salvador, and Nicaragua, resulting to the more than 48-hour rainfall amounts that were in excess of 10 inches and experienced from Thursday 4th October through to Monday 7th October and resulting to dangerous flash floods and mudslides in the region (ACT Alliance, 2018).

Blaskovic (2018) notes that the red alert was raised for heavy rains in Honduras and Costa Rica while a yellow alert was put into effect in Nicaragua and in 31 municipalities of El Salvador. The heavy rainfall expected in the weekend that followed was experienced in 6 different countries in the region and left a route of destruction that affected people, vegetation and animals altogether. Although the month of October is usually one of the wettest in the South West region of the Caribbean Sea (Curley,

2019), most of the places that experienced the downfall reported more than normal rains during the short period the storm passed through the Southern Western parts of the Caribbean Sea. The heavy downpour of rain that resulted to a high concentration of floods and mudslides was reported in more than 10 locations in the region (Floodlist News, 2018).

The rains had different effects in the different locations. Blaskovic (2018) reports that 4 people died as a result of the floods and mudslides caused by the heavy downpour in Nicaragua, 4 in Honduras and one person in Costa Rica. In addition, ECHO (2018) reported that 2 people were also killed in Honduras as a result of the heavy rainfall and more than 100000 people were affected with thousands being evacuated to shelters so that they would get out of low-lying areas on the river banks and valleys. By the 8th October, the number of people that had died as a result of the heavy rains were 13 in total (6 in Honduras, 4 in Nicaragua, 2 in El Salvador and 1 in Costa Rica) (ACT Alliance, 2018).

According to ECHO (2018), even by the 8th October 2018, alerts were still being put in effect especially in areas in Honduras and Costa Rica that had places put on red alert while a yellow alert was put into effect in most areas in Nicaragua, El Salvador and Guatemala. According to a communiqué from the Government of El Salvador on the 6th October noted that the ongoing heavy rains had so far caused damage in regard to fallen trees, collapsed walls, obstructed streets, landslides, over flown rivers and flooded houses. Flood list News (2018) indicates the precipitation recorded during this few days was as much as 270 mm in areas such as Puerto Barrios in Guatemala and 232 mm in El Salvador. ACT Alliance (2018) also reported between 300 and 400 mm of rainfall in the areas that had been put under a red alert. According to the IFRC (2018) by the 5th of October precipitation had reached highs of 400 mm of accumulated rainfall in Piquero in Costa Rica while other high altitude areas drained the flood waters into low lying areas such as the Abangares River.

The number of people affected by the heavy rainfall increases as the low-pressure system continued to flow in the region. ECHO (2018) reports on the 11th October that the number of people that had died as a result of the heavy rainfall being experienced in the region was 18 people (8 in Honduras, 5 in Nicaragua, 4 in El Salvador and 1 in Costa Rica). The effects of the heavy rainfall caused by the passage of tropical storm Michael were to be felt as far as Cuba and the Dominican Republic and the region experienced between 50 and 250 mm of rainfall between the 6th and 7th of Cotober (Floodlist News, 2018).

Technical Interpretation of Event

The factors that influence the rainfall cycle are therefore important to assess and understand in order to be able to set up an effective disaster preparedness plan. According to Moron, Gouirand and Taylor (2015) the cycle of rainfall in the Caribbean is related to a number of factors including the longitudinal shift and intensity of the North Atlantic subtropical high (NASH), the intensity of the Caribbean low level jet (CLLJ), the latitudinal shift of the planetary-scale ITCZ which stretches over Northern South America and the Pan-American isthmus in boreal summer, as well as local sea surface temperatures (SSTs), which are usually warmer 110 than 270C from May to December. This is also in addition to the African Easterly Waves and the tropical storm activity starting around May with a peak activity in autumn. Based on this information, public and private institutions could be able to make better disaster management plans for the Caribbean region.

The weather patterns in the Caribbean are changing just as noted in other parts of the world. Stair and Pottinger (2005) note that in the last decade or so, the Caribbean region has experienced several significant life costing events that are due to the changing climate including the eruption of the Soufriere Hills volcano, Montserrat, in 1995, and the passage of Hurricane Ivan through Grenada, Jamaica and the Cayman Islands in September 2004 and floods in Guyana in 2005. In as much as the tropical storm Michael may not be equated to some of this past events, it also calls for better preparedness and mitigation strategies so as to reduce the adverse effects on lives, livelihoods and the effects on the environment. Such plans are based on the occurrence of past events, learning from the responses in those events and on forecasts for similar events in the future.

There have been recent growing concerns all over the world in regards to environmental challenges and problems associated to disasters, especially due to the fatalities and economic losses caused by both natural and man-made hazards (Zare and Afrouz, 2012). According to Nojavan, Selehi and Omidvar (2018) the process of planning for disasters and especially on pre-disaster preparedness has been acknowledged as noted to be essential in eliminating some or all severe damage. In as much as a disaster preparedness plan may not manage to anticipate and set procedures for all the human, operational as well as regulatory issues that may arise with the disaster, a disaster preparedness plan enables an institution or community affected by a disaster to continue essential functions and reduce the impacts associated to the disasters.

Small island communities such as those in the Caribbean Sea, are at an increased vulnerability to the risks of climate change including the risk of loss of livelihoods and assets. Macpherson and Akpinar-Elci (2013) note that most areas in the Caribbean Sea are already experiencing increased salinity in their drinking water, rising sea levels, decreases in the land that can be used for habitation and reduced food security as a result of reduced agricultural areas and

disrupted fisheries. Efforts to improve the well-being of the communities in the Carribbean are likely to have an impact when focused on increasing the building of assets by the communities and developing coping mechanisms that will assist in restoring themselves after such natural calamities in the future.

Taylor, Clarke, Centella, Bezanilla, Stephenson, Jones, Campbell, Vichot and Charlery (2018) in an assessment of what could be the future Caribbean climate note that as the world continues to experience increasing temperatures, significant serious implications will be experienced especially in regions that are surrounded by Sea water. The tropical storms such as Micheal which hit the South West area in October 2018 are expected to increase by 20%-30% as the trade winds also increase in speed by 2%-11% (Taylor, et al. 2018). This primarily means that there will be an increase in the number of disasters in the particular region as global climatic changes continue to take effect. Essential components for emergency preparedness for such conditions include early warning systems, readily available equipment for excavating and moving sand, establishing emergency centers as well as documentation of emergency preparedness plans that highlight the responsible individuals and agencies.

Conclusion

Weather patterns have become increasingly unpredictable over the past years. There are also indications that future weather patterns may be more erratic and result in greater damage. It is therefore necessary that governments and private institutions focus their attentions on mitigation and response strategies that will save lives and reduce the damage caused by some of this natural disasters. It may not be totally effective since some natural disasters such as the Tsunami and hurricanes are more difficult to predict and mitigate against. It is however, necessary that the right information is provided to people, adequate mitigation measures are created and response mechanisms put in place.

The publication, in 1987, of the report "Our Common Future", from the World Commission on Environment and Development, alerted the governmental authorities about the need to adopt public policies with the objective of reaching a state of sustainable development, "which satisfies the needs of the present without hurting the possibility of future generations from satisfying their needs." The recommendations found within this report were fundamental in founding the Conference on the Environment and Development in 1992 in Rio de Janeiro, Brazil. Agenda 21 of the conference reinforced, in chapter 36, "Promoting education, public awareness and training", indicating the importance of the role of education in reaching a model of development which takes the pressures on the environment into consideration, as education, increasing public consciousness and training are considered transversal themes among all the areas of the programs of Agenda 21.

By identifying successful and unique pathways to sustainable development in less-favored areas, and providing this information to policymakers, It would work to improve the environment in parts of the world that emit the most of the greenhouse gases while at the same time educating those in countries that receive the majority of the consequences to be prepared for such hazards.

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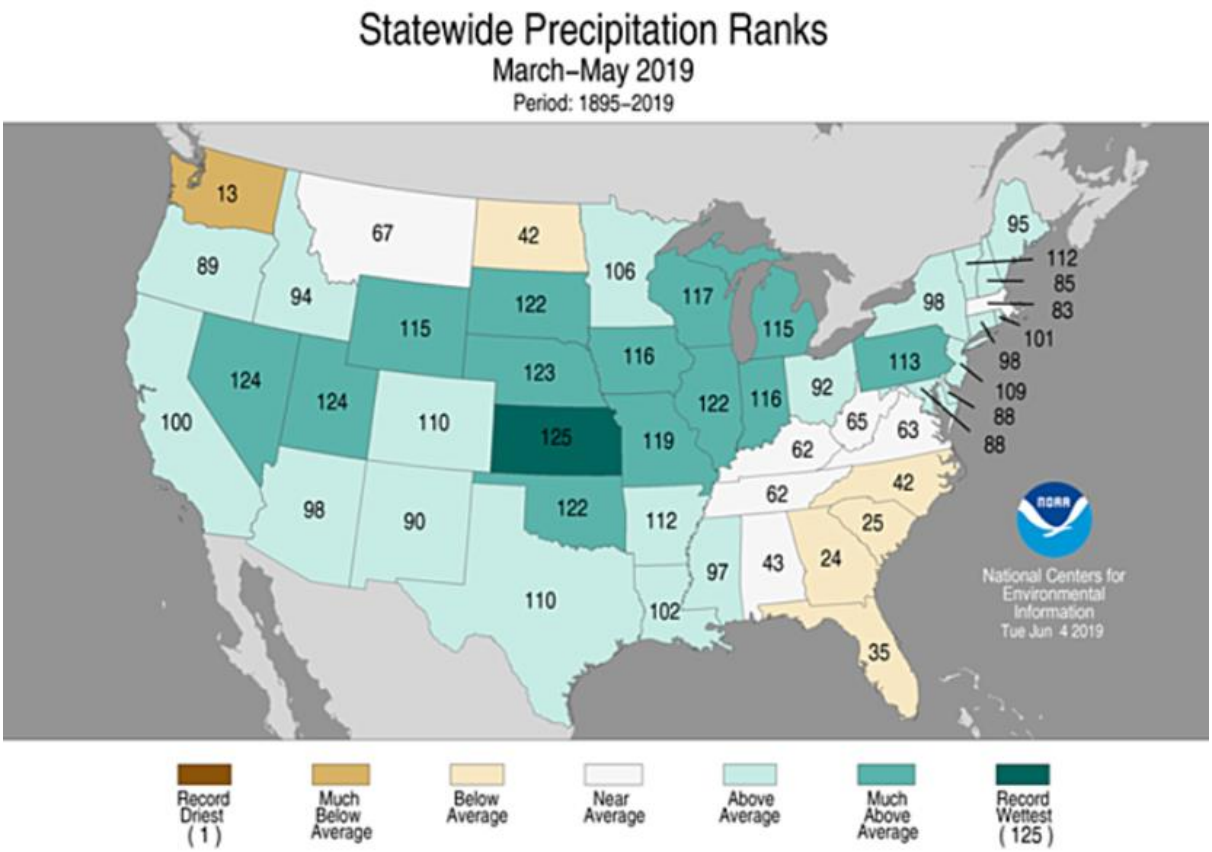
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The Great Flood of the US Mid-West 2019

Jonathan Williams



Account of The Event

Introduction

The Mississippi sits in one of the world's largest river basins. This river basin collects water from around 41% of the mainland United states. Over 2018 and 2019 above-average precipitation and very cold winter temperatures combined with high levels of snow melt in parts of the Midwest produced the longest running flood event in the Mississippi's recorded history. there was flooding across eleven states along the Mississippi river. (USA Today, 2019). This flood was the longest lasting since the 1927 great flood. Figure 1 above is a map of the United States that highlights the Mississippi river basin and separates it into its different named quadrants.

Background information - Location.

The area has a long history of flooding going back to the great Mississippi flood of 1927. At this time, over 100,000 people were forced to leave their homes and millions of acres of land were submerged. The Mississippi rose over 55 feet above its flood stage and the river was 8o miles wide in Arkansas. This led to the building of the early flood defences and levees to try to prevent a reoccurrence of this event. (Burt. C, 2004, Extreme Weather). However, further significant flooding was repeated as recently as 1993 and 2011. These events indicate that the Mississippi river is prone to flooding. However, the factor that makes the 2019 floods so unusual and severe was that the river was flooded at some point for a record 226 days rather than the number of lives lost which was lower than previous flood incidents.

Timeline of the 2019 Great Flood.

The first 6 months of 2019 were among the ten wettest January to June periods on record in most of the Mississippi Valley, Plains and the Ohio Valley according to the NOAA. (National Oceanic and Atmospheric Administration). This is shown in the NOAA diagram shown below which indicates that many of the surrounding states were experiencing one of the wettest periods in the last 125 years. For example, Nebraska was ranked as 125 for that period indicating it was experiencing the wettest March – May on record. Figure 2 Map to show 2019 rainfall compared to last 125 years of precipitation records

In February 2019 the records for snowfall were broken with areas in Nebraska getting 27 inches of snow. This area also had its snowiest winter, December through February had 47.5 inches of snow. During these months there were also multiple heavy rain events and record snow one after another that

didn't allow the main Mississippi river to recover and let river levels lower. These floods affected around 14 million people across the 400 counties. (New York Times, 2019). Much of the lower Ohio and lower Mississippi river took on more than 2 feet of rain with few areas along the Mississippi taking on more than 40 inches of rain during this time. (USA Today, 2019). Because of this continual and heavy rain, the Mississippi eventually broke its banks causing widespread flooding to the area. Since February 2019 over 550,000 acres of land in the rural Yazoo in the lower Mississippi delta has been flooded. Around half of this land is farmland. This land is often flooded but however, this year the flood waters has lasted much longer that is usually seen in this area. (Guardian, 2019). This has had an impact on an area where the primary job source and lifeblood of the economy is agriculture. The flooding started in early March after months of heavy rain and earlier than usual snow melt. Record flooding at 42 locations, mainly in the Missouri Valley from south eastern South Dakota into Nebraska and Western Iowa. (NOAA, 2019). In March 2019 the upper Mississippi river basin experienced a winter storm, Winter storm Ulmer. This storm was a "bomb cyclone" and hit areas in Colorado and North Dakota with intense blizzard conditions and high winds. When Winter Storm Ulmer was named on the 11th of March 2019 it was expected to reach an aerial criterion of 400k sq./km. (Weather.com). On the 13th of March Casper and Wyoming had its second-snowiest March day on record with 13.6 inches of snow falling. (Weather.com). This Snowfall and very cold temperatures created the groundwork for the long-lasting flooding that followed in upcoming months.

On the 24th of March flooding in Nebraska caused 74 emergencies, 1/3 of the state. Below is a map showing the locations of flooding in the Mississippi river basin between January 15th to June 30th shown by the blue circles. This map also shows counties with Federal assistance. These are shown by the grey highlighted areas In Iowa, the flooding in March 2019 left damages of nearly $1.6 billion. This was damages to buildings and roads in town and cities in the state. Nebraska was heavily hit by these floods with multiple rivers flooding at the same time due to the high rain and snowfall. In an interview on the PBS News hour show Governor. Pete Ricketts said that the flood caused damages to the local agriculture $400 million in cow/calf losses, $440 million in crop losses and large amounts of damage to the states infrastructure with:, 2000 homes damaged or destroyed, 340 businesses damaged or destroyed, 16 bridges affected worth $439 million and around 200 miles of highways and roads left unusable. Lots of people were left without water, food or power in the days following these floods in March 2019 in the Nebraska and Iowa areas.

Technical Interpretation.

Causes of the flooding

In December 2018, multiple heavy rain events caused the start of this flood along the Mississippi river at multiple locations. Factors that also influenced and help cause this flood was large levels of snowfall and a very cold winter, the cold weather lead to frozen soils. Frozen soils have important implications for hydrology, the frozen soils limit the infiltration of water. This is the movement of water from the soil into underlying rock layers below into ground water. Without infiltration of water the soils will become saturated. Saturated soils lead to greater levels of surface runoff which will mean rainwater will enter the river systems at a faster rate. Frost depth is closely linked to air temperature. An index that measures how often and by how much air temperature remains below freezing through the winter serves as a proxy measurement for frost depth. On March 14th, 2019, there was a "bomb cyclone" that affected the northwest of Colorado around the great lakes in the northern section of the Mississippi river basin. A "bomb cyclone" forms where there is a rapid drop in pressure which in turn will cause a rapid intensification of a winter storm. This winter storm brought in high levels of precipitation in the upper Mississippi river basin. (The Weather Channel, 2019). This Winter storm also caused "Ice Jams" in some places in Niobrara, Nebraska the slabs of ice were up to 2 feet thick and stacked at least 10m high. (The Weather Channel. (2019). These ice slabs caused blockages in the river systems and also helped to raise the water levels in the river. In some places the water rose from around 1 foot to over 5 feet in 20 minutes. (The Weather Channel. (2019). The ice slabs blocked roadways and bridges. There was indications that the floods were subsiding in the spring but warnings were issued by the NOAA National Weather Service on March 7th when they pointed out that further flooding was likely for the rest of the spring and summer due to possibility of ice jam flooding caused by large amounts of ice on the rivers and the large amounts of snow likely to melt in the coming weeks. This means that areas under threat should have been prepared for some of the problems that were to follow. Figure 3/4 below shows the flood warnings put out by the NOAA.

Potential global causes of the flooding.

As the planet warms due to human-caused climate change, heavy downpours are increasing in the Midwest, according to the National Climate Assessment. From the early 1990s to the mid-2010s, very heavy precipitation events in the Midwest increased by 37%, the assessment said. (USA Today, 2019). Across the U.S 2019 was extraordinary rainy, there was nearly 8 inches more rain than normal from July to June 2019. As the climate warms this will only increase because, a warmer atmosphere can hold a greater volume of water leading in more frequent and

heavier downpours. (Time.com, 2019) This has been checked on the original report produced by GlobalChange.gov called Extreme-Weather. Heavy downpours are increasing across the US. This has been seen especially in the last 30 years. Recently the heaviest rainfall events have become more frequent and much more significant. Also, the volume of rain falling during these events is getting greater. This change has been greatest in the Northeast, Midwest and upper great plains of the united states. In these areas there has been 30% more rain above the 1901-1960 average in the last 30 years. ("National Climate Assessment", 2019).

Mitigation strategies.

By May 2019, the U.S army corps of engineers had been trying to defend against the flooding in Louisiana for 200 days. Louisiana was flooded by more than 8 million gallons of water flowing through the burst banks of the Mississippi. The Army Corps officials were deciding whether to open a spillway that would divert the flood waters away from the main city and into the Gulf of Mexico. This could have had damaging impacts on the Gulfs ecosystem. (Time.com, 2019). Man made flood control schemes can also makes predicting flood events more difficult. The Mississippi is one of the most built on rivers in the world, and last year the up to three-quarters of the flooding ion the Mississippi was caused by human engineering like, levees that can raise the height of the river. (Time.com, 2019)

Conclusion

This flooding event is one of many flooding events around the world that is above the normal expected level for the time and year. This trend will continue in this fashion as the world's climate changes. As the effects of global climate change take more prominence, we will see more and more instances of this type of event and at or above the extent seen at the Mississippi in the last year. One of the main ways to tackle this potential threat would be to reduce the global carbon emissions and put less of a reliance on fossil fuels and fossil fuelled transport. When these weather incidents are first identified, there should be more detailed plans ready to enact to mitigate the effects with clearly identified areas of land flooded to prevent further problems downstream. Landowners need to be fully briefed at the earliest possible point and compensation agreed if it leads to greater savings further into the event. This would lead to less financial pressure in the time after the event.

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Hurricane Humberto

Sarah Claydon

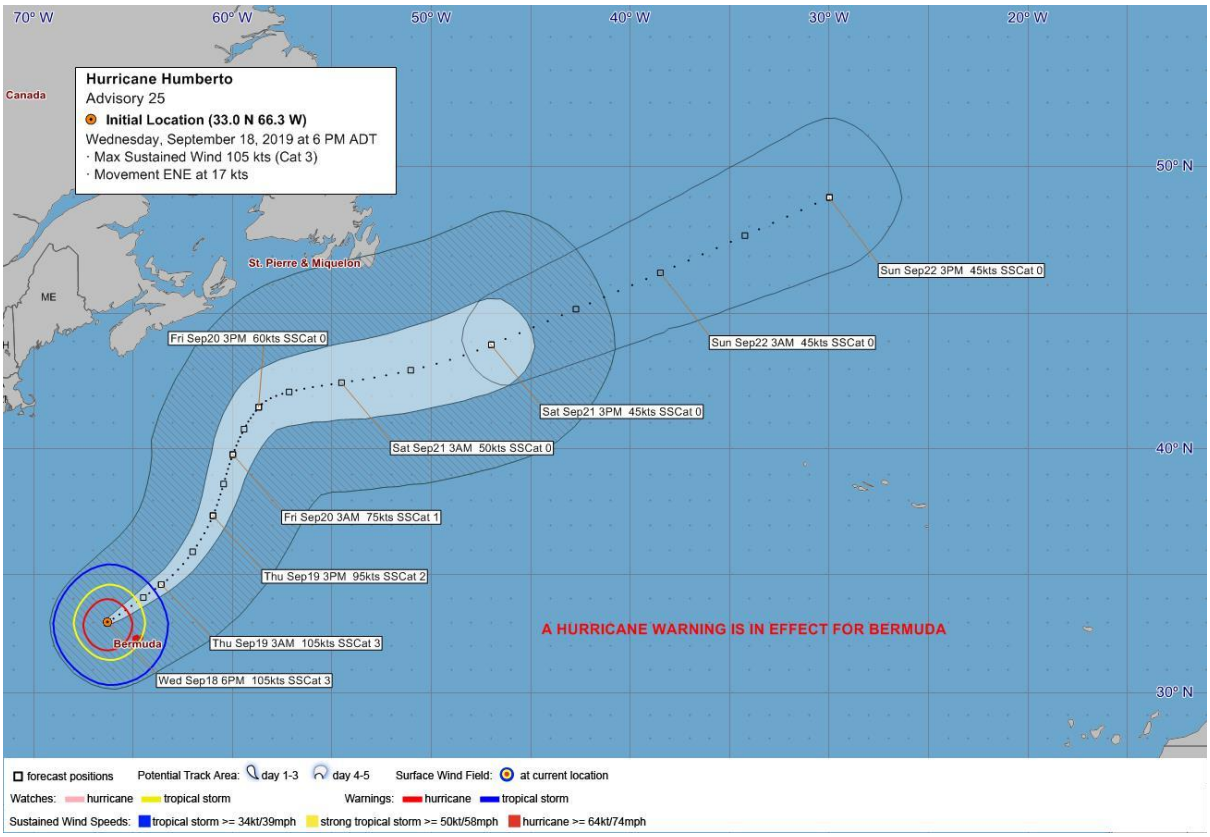


Figure 1- map showing the path of Hurricane Humberto (NHC, 2019)

Introduction

On September 13, 2019, a cyclone formed from a disturbance over the Atlantic Ocean. As the storm strengthened, it was designated as Tropical Storm Humberto. By September 16, the storm had reached hurricane strength, eventually reaching its peak as a Category 3 hurricane on September 18. It eventually dissipated on September 24, as it gradually weakened, moving eastwards to join a different extratropical storm over the British Isles.

In the aftermath of the storm, it was found that one person was dead and one missing. The countries affected by Humberto included Bermuda, which hadn't had a hurricane make landfall since 2016, the Bahamas, and South-eastern USA. The total financial damage of the hurricane is still unknown.

Authoritative Account

The National Hurricane Centre (NHC) began monitoring a disturbance over the Atlantic on September 8. The disturbance moved through the Southern Bahamas, where surface pressure began to fall, allowing the convective processes necessary for the disturbance to become a tropical depression. 6 hours later, the cyclone had intensified to become Tropical Storm Humberto. As the eye of the storm grew to 40 miles in diameter, it was reclassified as a Category 3 hurricane, reaching sustained wind speeds of 125mph (National Hurricane Centre, 2019).

On September 18, Humberto made landfall in Bermuda. It was the first hurricane to do so since 2016 (Wikipedia, 2019). Despite this, the Bermudan public had preparedness plans in place for their homes and businesses. The NHC warned of expected hurricane conditions over Bermuda on September 17, allowing the government to issue a warning to residents on September 16. Citizens were instructed to prepare themselves whilst conditions were still dry; the government advised them to check they had appropriate hurricane supplies, such as first aid kits, torches, and radios. They were also reminded to check their stocks of prescription medication and non-perishable foods. As well as supplies, the government also urged the public to check the hurricane plans for their houses and businesses, making sure that windows, doors, and shutters were boarded up safely, and any outdoor possessions such as outdoor furniture and plant pots were brought inside. Finally, citizens were asked to check on family members and

neighbours, particularly vulnerable or elderly people. The government also announced that they were to broadcast updates from the Bermuda Weather Service and the Bermuda Electricity and Light Company once every hour, as well as general updates from the government once an hour (Government of Bermuda, 2019). Authorities instructed that all schools, government offices, and transports must close, and by 4pm all services ceased operating by 4pm on September 17. 120 members of the Royal Bermuda Regiment were called up as in preparation for storm recovery efforts and to assist the public (CBS News, 2019).

All buildings in Bermuda are required by law to be built out of limestone or concrete blocks and solidly enough to withstand windspeeds of 100mph, meaning damage to buildings is minimised (NU Property & Casualty, 2003). Two buildings, both of which are schools are designated as approved emergency shelters (The FMG Hurricane Centre, 2019). Bermuda's largest school, the Cedarbridge Academy, was open for the night as the Hurricane passed on September 18, with cots set up for citizens taking shelter there (ABC News, 2019). There were reports of roofs being torn from buildings, but most infrastructural damage was caused by debris, particularly that of falling trees and other vegetation (Reuters, 2019); the costal nature of Bermuda means that the flora and fauna of the island aren't very well protected against flooding and storm surges (Bermuda.com, 2015). Videos emerged of yachts and sea containers being swept away by strong waves, and a stranded boater was rescued from the harbour (NPR.org, 2019). The Bermuda Fire and Rescue Services reported that gas leaks, structural fires, and minor medical issues made up the 17 incidents that they attended in relation to the hurricane (CNN, 2019). Roads, schools, and businesses remained closed the next day so that debris could be cleaned up and any urgent repairs could be made (Weather Underground, 2019).

Bermuda's power is often knocked out by gale force winds, and Hurricane Humberto caused power-outages to 80% of the island – up to 30,000 people (CNN, 2019). Water supply is affected by electricity outages, as water is drawn using electronic pumps, and there is no central underground water supply (Bermuda.com, 2015). In the past, power outages from storms have lasted up to several weeks, but in the case of Humberto, power had begun to the following day, and continued to return to most of the island within the week (NPR, 2019).

The NHC also warned of swells affecting the north-western coast of the Bahamas, and south-eastern coast of the United States, and issued advice on what to do in the case of being caught in a riptide (National Hurricane Centre, 2019). The Bahamas had been hit by Hurricane Dorian just 2 weeks earlier, which had caused a huge amount of damage and left 50 dead (AP News, 2019). Strong winds, rain, and flooding hindered ongoing rescue and clean-up efforts, and prevented delivery of essential supplies such as clean water and fuel to Bahamian cities (BBC, 2019). Some heavy winds and waves hit the coast, but it is likely that the areas were already heavily damaged from Dorian and were not currently inhabited. The East Coast of the US was hit by large swells, with one man dying in North Carolina due to drowning after being caught in a rip current. A man was also reported missing in St Augustine, Florida, but there are no reports of what happened after this (Wikipedia, 2019). Bermudan officials reported that there had been no fatalities on the island.

At 11pm on September 19, the NHC issued a discussion stating the storm had been declassified to a post-tropical cyclone. They stated that the cyclone would continue to weaken gradually until it merged with another extratropical on September 21, and warned of residents in Bermuda, the Bahamas and the east-coast of the US to stay aware of life-threatening surf and rip current conditions during this time (National Hurricane Centre, 2019). By September 20, most services in Bermuda were running as usual. The Bermuda Tourism Authority issued an update on Twitter stating that all airports and hotels were open, that the weather was pleasant, that power had returned, and that transport services and business would begin running the following day (@BTAInsights, 2019); advising tourists that it was safe to continue with their travel plans as usual would minimise the amount of income lost, as the tourism sector is a large contributor to the economy in Bermuda (Government of Bermuda, 2018). Alternative arrangements were offered to travellers whose plans had been disrupted at no extra cost (Travelandleisure.com, 2019).

Technical Interpretation

Cyclones are centres of low atmospheric pressure with rotating winds. They may form over warm ocean water between 5° to 20° latitude to become a tropical cyclone with a warm central core. Tropical depressions, tropical storms and hurricanes are all types of tropical cyclones, which produced high winds, heavy rain, storm surges, and tornadoes. Extratropical storms on the other hand form at 30° to 70° over land or temperate water, and unlike tropical cyclones are associated with fronts with a cool central core (Keller & DeVeccio, 2014).

Hurricanes are classified into five categories based on their highest 1-minute average windspeed, with Category 3-5 hurricanes being considered as major. For a tropical cyclone to be considered a hurricane, it must have been sustaining a wind speed of up to 74mph somewhere in the storm. The formation of Hurricane Humberto was completely typical, and it started as most hurricanes do - as a tropical

disturbance over very warm water. Tropical disturbances contain low-pressure troughs, in which air is partially rotating due to the Coriolis effect. Easterly waves in the Atlantic ocean move westward with trade winds, causing convergence of air with low pressure, causing the air to rise and clouds to form. Increased wind speed can cause winds to spiral around the tropical disturbance, creating a low-pressure centre to form a tropical depression, which is upgraded to a tropical storm if wind speed reaches 39mph. Many environmental conditions must then be met for the storm to become a hurricane, such as warm water with a sea surface temperature of at least 26° and good depth. The atmosphere must also be cool enough to cause moist air to convect, causing condensation. Lastly, hurricanes will not develop in strong wind conditions; there must be little vertical wind shear (Keller & DeVeccio, 2014).

Since the beginning of the Atlantic hurricane database in 1851, there have been 235 recorded tropical storms or hurricanes that occurred within a 400km radius of Bermuda (Black & Dickey, 2008; National Hurricane Centre, 2019). According to a report by the Bermuda Weather Service, a hurricane-level storm will affect the islands once every 7 years on average (Guishard, Dodgson & Johnston, 2016). Of these storms, only 9 have made landfall (National Hurricane Centre, 2019). The strongest recorded hurricane to affect Bermuda was a Category 4 Hurricane in 1939. A 2008 study compared 3 hurricanes and found several similarities in their formation and dynamic responses, with the variables in responses being caused by the unique nature of the storms' size and intensity.

Hurricane Humberto was the strongest hurricane to have moved so far northing in the Atlantic since Hurricane Ophelia in 2011, which was also a Category 3 Hurricane. Ophelia passed by Bermuda but did not make landfall. The occurrence of stronger hurricanes further north could be caused by climate change; there is currently a large amount of research being done on the effects of rising global temperatures on tropical cyclone formation (Black & Dickey, 2008). It is expected that the frequency of tropical cyclone will increase as climate change provides more favourable conditions for their formation; increased temperatures causing sea surface temperatures to rise, changing atmospheric circulation patters, and rising sea level creating deeper costal waters (Michener et al., 1997; Gualdi, Scoccimarro & Navarra, 2008). Research suggests that as well as the frequency of tropical cyclones increasing by 6–34% by 2100, the intensity will also increase by about 2-11% (Walsh et al., 2015).

Conclusion

Overall, the damage caused by Hurricane Humberto was minimal, having made landfall in only one country. The preparedness plan put into place by the Bermudan government, as well as building laws that they had set, meant that private properties such as business and homes only endured minimal damage. Citizens followed instructions carefully and so came to little harm.

Modern monitoring systems, along with past research, provide valuable information to enable the prediction of how future tropical storms in the region will behave, and since research has shown there are so many similarities, it will provide advanced knowledge on how Bermuda can prepare for a storm to hit. However, changes in frequency and intensity of storms could make this information less accurate and reliable. Bermuda is typically prepared for the level of tropical storm that it must deal with, but if a stronger hurricane did make landfall it would likely be disastrous for the island. The whole of Bermuda is considered to be costal, with no area of land being further than 1.5m away from the ocean, making it very vulnerable to storm surges and high waves. Island nations such as Bermuda can struggle to regain power after a strong hurricane. Clean water, fuel, and food can also be difficult to obtain during the aftermath of a storm on an island. A good example of an island nation facing these issues after a Hurricane came just weeks before Hurricane Humberto hit Bermuda; Hurricane Dorian devastated The Bahamas in early September. Power and services were out for weeks following the storm, infrastructure is still not full repaired to date, and the official death toll reached 70, with 282 people still missing as of November 28.

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"We had to Set the Railroad on Fire" – the January-February 2019 North American Cold Snap

Benjamin Clark



Figure 1 - Train Tracks Alight in Chicago (Metrail - 2019)

Authoritative Account

Where was Affected?

Across January and February of 2019, a weakened jet stream allowed a part of the polar vortex to move into place over midwestern united states and parts of Canada. Thursday, January 24th, 2019, temperatures around Midwest states and eastern Canada began to fall to what would become record lows. As cold air escaped the counter clockwise spin of the polar vortex it shifted south over parts of Canada including, Alberta, Manitoba, NW Territories, Nunavut, Quebec, Ontario, Saskatchewan and Quebec. In the United States, Illinois, Indiana, Michigan, Kentucky, New York, Minnesota and the Dakotas were all significantly affected. Throughout the 'big freeze' -31F was experienced in North Dakota and -20F in Chicago. These temperatures are already low enough to cause frostbite but combined with high winds up to -60F was recorded in some states. Frostbite will set in on unexposed skin within 5 minutes at these temperatures, which posed a severe threat to life and resulted in multiple fatalities. This event would become known as the '2019 North American Cold Wave'.

Chicago and its Railroad

Chicago felt the full effects during the cold wave, many locals chose to stay indoors and avoid any outside contact. The city was abandoned for nearly 3 days during the chill. According to one man the BBC interviewed, he reported that his eyes had frozen shut as they began watering when walking outside on foot in the wind.

On January 31st temperatures in Chicago had reached a low of -51F, at this temperature the infrastructure within the city was being stretched to its absolute limits. Train tracks are physically moved at intersecting tracks to allow trains to travel across the network however as such low temperature's tracks are not malleable enough to make successful contact; To elevate this issue, tracks are heated by 'Switch Heaters', this can be seen in figure 1. (Often gas-powered flames or electrically heated preventing the build-up of ice and snow). MetraRail, responsible for the Chicago rail tracks state that this is one of many techniques used across the city in order to ensure successful operating of freight and passenger rail.

In the 1970s, manual methods of dousing tracks in gasoline were used however controlled and specific heating methods are used now to ensure safety and precision. The naked flames pose no risk when freight and tanked diesel fuel is transported as this requires pressure as well as heat to ignite. (Global Railway Review, 2019)

Fatalities

22 fatalities had been recorded as a result of the early 2019 cold wave according to BBC reports. Deaths

linked to the cold weather include; A 82-year-old Illinois man who passed away after suffering from hypothermia whilst outside his home. 2 individuals from the state of Michigan found dead in their neighbourhoods after becoming astray whilst not wearing adequate protective clothing. A man from Wisconsin was found frozen to death in his garage. A member from the local medical examiner's office determined that it was likely he collapsed after shovelling snow, and died in the low temperatures a result.

Daily Life

Extreme cold weather effects daily life, even of those whom are used to cold winters. The United States Postal Service, who's inscription of 'Neither snow nor rain nor heat nor gloom of night stays these couriers from the swift completion of their appointed rounds', in New York City, announced a temporary pause of deliveries in parts of 10 states. Colleges, high schools and elementary schools across parts of the effected states announced closures amongst fear of staff and students being in danger whilst traveling. Live-stock and crops were also affected, extra measures by farmers were implemented to prevent fatalities which could lose farmers income and effect the supply of food. Cold weather can cause cows to birth calves prematurely, the few who survive the early birth would not survive such weather conditions.

Warming Shelters

Chicago saw the opening of 6 warming shelters, 2 of which were open 24 hours-a-day. A warming shelter is used by vulnerable people, mostly homeless, in order to survive the frigid conditions that impacted the city. The government and non-profit organisations help to run the shelters along with donations from the public. Money and items such as blankets and clothing were donated. According to the Guardian newspaper, one Chicagoan explained how without this shelter he didn't think he would be able to tell his story, as the temperatures in the city at the moment are just 'too cold to survive in'.

Cold Wavs of the Past

Past events that were similar to the Cold wave of 2019 include the 2017-18 cold wave. Similar to that of 2019, part of the polar vortex had shifted south causing the extreme weather, the 17/18 cold wave also combined with severe blizzards further impacting the effected areas. The most notable cold wave was the 1936 North American Cold Wave. It is the most severe winter ever recorded for this region. One area of North Dakota went for 41 days without going about 0F (-18C), lakes and river completely froze over. During February of 1936 many areas in the mid-west had recorded their coldest ever temperatures which are still unbroken to this day. Following this cold wave, the summer of 1936 was one of the most severe on record with a death toll of over 5,000 and recorded temperatures that were not broken until 2012.

The Economy

It has been estimated that the arctic weather felt in the US has cost the economy an estimated $5 billion. This can have a profound effect on the economy and job security for some. Residents whom work on hourly wage who can't get to work paired with higher energy bills from the cold weather may find it difficult to make ends meet. Citizens in Minnesota were asked by Xcel Energy, a natural gas company to turn thermostats down in order to help manage the demand on energy. (BBC, 2019).

Technical Interpretation

What Is The Polar Vortex

Contrary to the well-known Heatwave, a cold wave phenomena is a shift in the polar vortex known also as a polar cyclone or circumpolar vortex which is defined by a 'large area of persistent low pressure generally located above each of Earth's polar regions and containing a mass of extremely cold air' (J. P. Rafferty, 2019). A polar vortex can be particularly deadly due to its quick moving properties and horrific windchill.

Splitting Of the Vortex

The polar vortex forms every winter on Earth and dissipates in the spring. A split in the polar vortex can cause a cold wave on varying scales determined by a number of factors. This splitting is what caused the cold wave of 2019, and previous cold waves in the past. The polar vortex forms because there is a cut off in any light from the north pole making it inhospitably cold. The polar vortex is usually situated 6 miles (10km) above the North Pole where it experiences regular movements but is relatively stable. A cold wave begins when the polar vortex splits into 2, separating itself from one another, as seen in figure 2. Once the split occurs, the jet stream carries one of the vortices along its path which has a movement southward. As the vortex is carried along this path, it begins to develop into a storm and impacts the areas in which the jet stream moves over, this causes the areas effected to experience very low temperatures. A 'cold wave'.

After a split in the vortex there is no immediate consequence however the effects of the split usually develop into a storm within 1-2 months, this allows some time for preparation. The polar vortex is affected by waves of air which can result in a change in the movement of the vortex. Air flow is affected by earth's surface, and the changes in it. For example, mountain ranges and a change in ground elevation amongst others. The change in these air flows causes waves (Rossby Waves) which in turn, result in impacts on the shape of the polar vortex and its positioning in the stratosphere. When a powerful Rossby Wave impacts the polar vortex, it can cause a breakage and displacement. A highly powerful

Rossby Wave can even result in the complete reversal in the spin of the polar vortex; however, this is rare. Rossby waves help to enable a cold wave phenonium when they impact the movement of a polar vortex to the degree where it splits into 2 individual vortices.

Man's Effect on the Polar Vortex

The human effect on the polar vortex is still being research extensively, however there is evidence, with current scientific knowledge, that increasing carbon dioxide levels in the atmosphere enables cooling in parts of the stratosphere. This increases the difference in temperature over polar regions compared to the equator leading to a stronger polar vortex. Some research has given evidence that the waves are becoming more irregular accompanied with a higher momentum meaning that the frequency in the splitting of the polar vortex has increased, correlating with recent historical data.

Cold Weather and Infrastructure

Cold weather can test infrastructures limits, especially when the infrastructure in questioning is not designed to be placed in such conditions. Cold weather can crack train rails, break water pipes, damage gas pipes and electrical lines. These types of infrastructure are also normally under increased strain during these events when the demand for heating is higher. Power outages are common during cold weather. The increased strain on the system combined with downed lines and conditions making it slow or impossible to repair means some residents can go for extended periods of time with no electrical power. Fuel lines freezing and the inability to properly deice planes can ground planes. This has a knock-on effect on not only travellers but anything transported by air. Cold conditions can crack steel rail tracks, and in some cases sheer them.

Poorly insulated water pipes can stop the free flowing of water to homes and businesses which means they have to be shut and, again, have a knock-on effect. A significant long-term effect of cold weather is freeze-thawing on roads. The infiltration of water into the road and the expansion of water upon freezing inside the roads causes it to breakup with potholes forming. Freeze-thaw effects regions the most where temperatures are above freezing points during the day and are below this point at night. (Such as the UK and other coastal regions).

Conclusion

A split in the polar vortex at the start of 2019 resulted in a cold wave that affected much of the Midwestern United States and parts of Canada. Extremely low temperatures resulted in the immediate need for intervention to prevent further damage to railroads and other infrastructure. Public health warnings were echoed, and residents advised to stay indoors during the most intense periods of cold. As a result of this cold wave 22 people were directly killed. Although the response from the government did include homeless shelters it is difficult to respond to such an extreme event of cold. No immediate aid can be given other than ensuring the most vulnerable parts of the community are cared for.

This area of North America is used to cold weather just not at the extremes that were seen. The opening of warming shelters helped the vulnerable to survive the cold along with generous donations from the public. In order to prevent future power outages and effects on utilities infrastructure needs to be upgraded to work in such conditions if they are seen to become a regular occurrence. The best course of action is to give advice to the public and provide up to date detailing on weather forecasts and warnings. Being prepared in a cold weather event is paramount to the survival along with having the correct clothing and heating for the current conditions outside.

Although the 2019 cold wave was particularly harsh for the people of North America, it won't be the last. Increasing effects of climate change, the continual formation of the polar vortex each winter, and the increasing sporadic movement of Rossby Waves means the people in this region must prepare for the worst every winter.

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The contributions included here represent most of the assignments submitted by students in the Class of 2020, studying the final-year 'Natural Hazards' module as part of their BSc Geography or BSc Environmental Science qualification at Sheffield Hallam University. For a range of reasons not all students enrolled on the module are represented here, however the module team would like to acknowledge the important contributions of all students involved in the seminars and workshops which formed part of the peer review process.

The 19-20 academic year was one which no-one, I think, will forget and all those graduating from this class can be proud of the determination and resolve they showed to complete their studies in such exceptional circumstances.