Building resilience to compound and cascading disaster risks

- Case Studies from around the world

2021 Ministry of the Environment Japan

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Contents

1. Background

As climate change will lead to more severe and frequent weather-related hazards, the need to deal with compound and cascading disasters has become an emerging issue. The e-learning course "Building resilience to compound and cascading disaster risks" under AP-PLAT capacity development programs objects for the local/national government officers to build capacities to implement specific measures to build resilience against such disasters. As a supplemental material to four video lessons, this booklet compiles examples of compound and cascading disasters from around the world. The learners can gain on-the-ground knowledge from the concrete cases aiming to strengthen the resilience of their country or local community against compound and cascading disasters.

Compound disasters occur when several disasters happen at the same time or in succession. In this case, the hazards could reinforce each other, creating a more complex situation and increasing the impact of the individual hazards. Cascading disasters, on the other hand, occur when one type of hazard triggers another in a sequence. The chain of disasters is usually non-linear and the impact of one disaster may continue beyond the affected area or for a long time.

It is not difficult to imagine that the number of possible combinations of various disasters would be almost infinite when trying to collect examples of compound and cascading disasters based on the above concepts. Therefore, in this report, the selection of examples of compound and cascading disasters were narrowed down to the three categories shown in the following table. The specific disasters that Meteorological, Hydrological, Climatological, Geophysical, Biological and Technological represent are referred to IRDR Peril Classification and Hazard Glossary.

Combinations of disasters making up compound and cascading disaster cases in this report

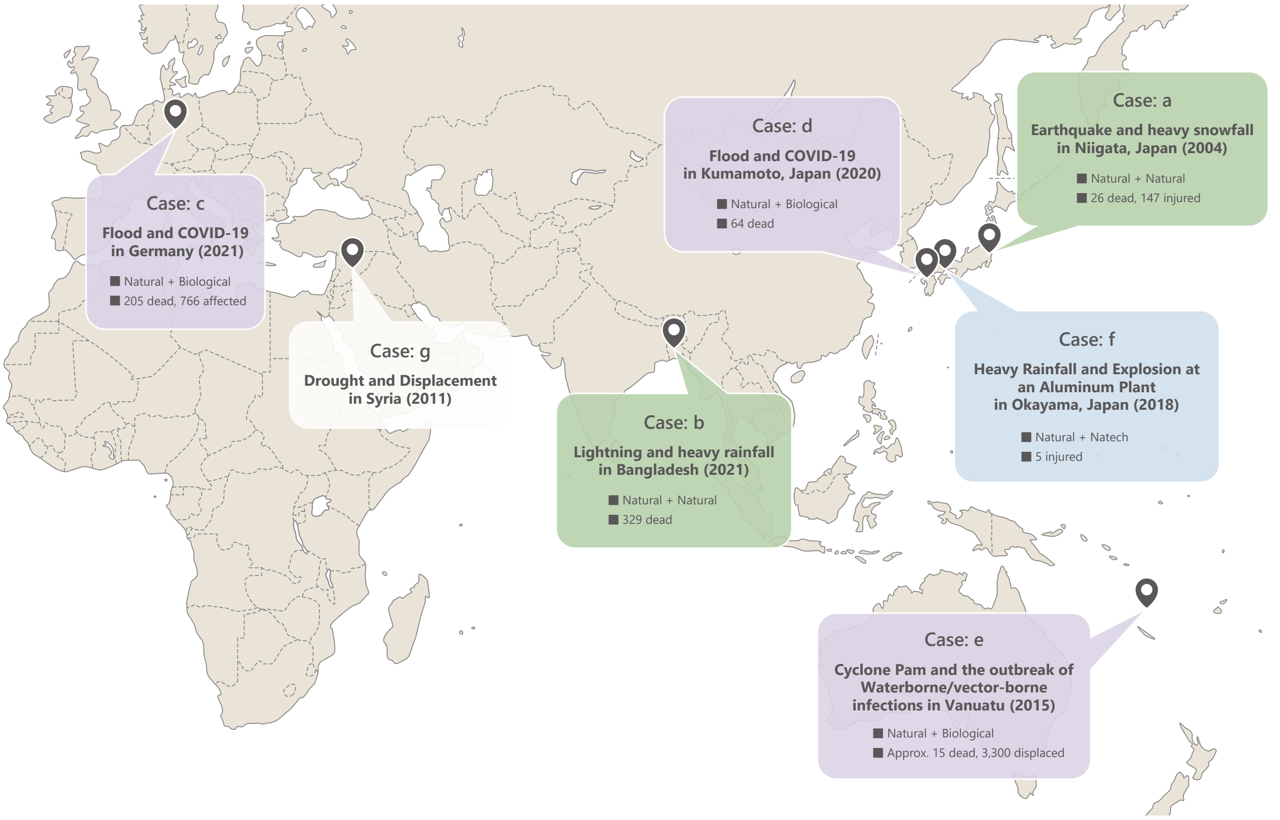
	Disaster 1	**Disaster 2**
Category 1 (Natural + Natural)	Natural disasters with high relevance to climate change: Meteorological Hydrological Climatological	Natural disasters: Meteorological, Hydrological, Climatological, Geophysical
Category 2 (Natural + Biological)		Biological disasters: Biological
Category 3 (Natural + Natech[1])		Natech: Technological

In order to provide a variety of case studies that may be useful to a wider audience, this report has selected seven examples of compound and cascading disasters that have occurred within the last 20 years worldwide, which fall into the above three categories. The list of cases is shown in the following figure.

The Case Studies section provides a brief summary of the details of each case. In order to help the reader apply the lessons from each case to their own work, the causes and circumstances of the disaster, its impact, risk management efforts, and gaps and needs are presented in each case. We hope that this booklet would be instrumental to have a better understanding of compound and cascading disasters on the ground.

1. "Natech" is an abbreviation of "Natural Hazards Triggering Technological Disasters". One of the latest literature define Natech as "accidents triggered by natural hazards that create catastrophic technological calamity" (Galderisi A. et.al, 2008).

List of Cases Studies



	Europe	**Japan**	**Developing Asia**
Category 1 (Natural + Natural)		a. Earthquake and Heavy snowfall in Niigata, Japan (2004)	b. Lightning and Heavy rainfall in Bangladesh
Category 2 (Natural + Biological)	c. Flood and COVID-19 in Germany (2021)	d. Flood and COVID-19 in Kumamoto (2020)	e. Cyclone Pam and water/ vector-borne infections in Vanuatu (2015)
Category 3 (Natural + Natech)		f. Flood and Factory explosion in Okayama, Japan (2018)	

Other
g. Drought and Displacement in Syria (2011)

2. Case Studies

Earthquake × Heavy Snowfall

Niigata, Japan (2004)

Type of compound disaster:
Natural × Natural

Date:
October, 2004

Place:
Niigata, Japan

Death, injured/ causality:
26 dead, 147 injured

No. people affected:
About 100,000 evacuates

Financial damage:
About 27.6 billion USD

1. Impact of compound disaster

The Niigata Chuetsu Earthquake that occurred in October 2004 severely damaged areas that usually experience heavy snowfall, and various infrastructure such as roads, houses, and agricultural facilities were damaged. Snow began to fall in December, while the disaster recovery process was still underway, and nearly twice the normal amount of snow accumulated. In the areas where the disaster recovery process was still incomplete, avalanches, snow melt, and heavy snow caused more damage than usual, including to houses and cars.

Due to the earthquake and landslides caused by heavy rains the previous summer, the slopes of some hillsides collapsed, drastically changing the vegetation and topography, and destroying the physical avalanche prevention measures. While the restoration work was in progress, the avalanche caused even more damage to that area. In addition, snowmelt caused rivers that were blocked by sediment from the landslides to overflow, resulting in flooding and erosion of farmlands and residential areas. Although some equipment to control snow was repaired after the earthquake, the work was incomplete, meaning these measures did not work properly. Roads were covered with snow and traffic was affected, which in turn affected the economy. In addition, houses that collapsed due to the earthquake were not repaired in time. The heavy snowfall then caused secondary damage and even resulted in deaths. Furthermore, actions taken to mitigate damage (e.g., increased shoveling of snow) led to increased damage or unusual new types of damage. This compound disaster case demonstrated that if there is not enough time to deal with the initial disaster, the subsequent disaster may lead to more severe damage.

2. Risk management efforts for compound disasters

Pre-disaster preparedness

It is important to develop a DRR plan, improve hard and soft measures, and conduct drills of the worst-case scenario, such as an earthquake occurring during heavy snowfall. In many cases this is not currently envisioned. In the case of the Niigata earthquake, researchers surveyed residents about the impact of heavy snow damage on the areas that had just been affected by the earthquake. They then informed the local communities by mapping out the hazards and risks in the region.

Response in disaster

When many houses collapse in an earthquake, temporary housing is required; however, during winter in heavy snowfall areas it may be difficult to live in evacuation shelters until temporary housing is built. In Niigata, construction of temporary housing was completed before the snowfall, but it is necessary to consider in advance where people should evacuate to when an earthquake occurs in the middle of winter.

Post disaster recovery

During recovery in heavy snowfall areas, securing the transportation network is of high importance. Clearing roads is critical for recovery because snow can delay aid and isolate villages. In Niigata, there were problems, such as limited capacity and increased time for snow removal, due to insufficient recovery from the earthquake. Some roads were blocked due to avalanches and landslides.

In addition, a flexible approach is required to provide assistance for compound disasters. In Niigata, financial aid was provided before the government determined the thresholds for compensation because it was clear the situation was different to previous years and could not be explained by snow alone. This was an exceptional measure which allowed the fast provision of aid money to victims.

3. Good elements of risk management

(Early response) Despite the heavy snowfall there were no large-scale disasters in the areas where restoration work and emergency measures were completed before the snow season. So, it is important to respond to disasters and complete recovery work as early as possible to help prevent the occurrence of compound disasters, especially in higher risk regions like those receiving heavy snowfall in winter.

(Local community) This event showed that having a connected and prepared community (fostered in response to past heavy snowfall disasters) is beneficial for dealing with disasters, including compound risks. This is why it is important to establish good communication within local communities on a daily basis. The local community cooperated to perform patrols for hazards and remove snow from roads and roofs. This volunteer work contributed greatly to mitigating the damage caused by snowfall in the affected areas. Furthermore, since each region has its own skilled personnel, it is desirable to use locally available personnel as temporary human resources until government support arrives. Especially in areas with heavy snowfall, support may be delayed because of snow, so it is better to proceed autonomously where local support is available.

(External support) Many academic societies and research institutes carried out prompt and energetic activities (e.g., disaster surveys, recommendations, and technical guidance) immediately after the earthquake, which made it possible to raise awareness and prepare residents for the heavy snowfall that followed.

4. Recommended improvements to disaster risk management

If there are a large number of damaged slopes or facilities, full recovery requires a long-term strategy. It is necessary to consider how to cope with snow damage to the affected areas until restoration is complete. In addition, in areas where many residents have moved into temporary housing, the community itself may become weaker and smaller and it may not be possible to maintain the normal mutual-aid system. Therefore, the impact of the loss or decline of the local community needs to be considered.

Case: b

Lightning × Heavy rainfall

Bangladesh

Type of compound disaster:
Natural × Natural

Period:
2021 (throughout the year)

Place:
Across the country specially in Sunamganj, Gaibandha, Netrokona, Faridpur, Comilla, Manikganj, Kishoreganj, Cox's Bazar, Feni, Tangail, Magura, Khulna, Madaripur, Sirajganj, Rajshahi, Satkhira, Bandarban

No. people affected:
329

Death causality:
329

1. Impact of lightning in pre-monsoon and monsoon season

Nowadays lightning events are recognized as a climate disaster because of a large number of death tolls from this natural phenomenon after floods, tornados, and cyclones (Faruk et al, 2017). Bangladesh is one of the most prone countries to lightning. In total, 2770 deaths were reported due to lightning strikes between 2011 and 2021 (Figure 1). However, due to its nature of localized incidents lightning didn't get the attention of the government agencies until 2015 and no government data is available on causalities is available until 12th and13th May 2016 when 89 people were killed by lightning across the country in two consecutive days (Holle and Islam, 2017). Seasonal distributions between 1998-2014 show that nearly 95% of lightning flashes counted from pre-monsoon to monsoon season (Dewan et al. 2017). Figure 2 shows the seasonal distribution of fatalities and clearly indicated that the pre-monsoon and monsoon seasons accounted for 94% of fatalities from 1990-2016. The long-term seasonal rainfall data (1961-2010) shows that Bangladesh received nearly 90% of annual rainfall during pre-monsoon and monsoon seasons (Ahasan et al. 2011). Due to low-lying plains, most of the areas of the country face flash floods and waterlogging due to heavy rainfall within a short period of time. Waterlogging conditions increase the risk of getting electrocuted due to lightning strikes, particularly the work outside during the lightning event is at high risk. An analysis showed that 40% of the lightning strike death was accounted for by agricultural activities and 8% water-related activities (Holle and Islam, 2017). Spatially the major hotspots of lightning are located in the northeast and western parts of Bangladesh.

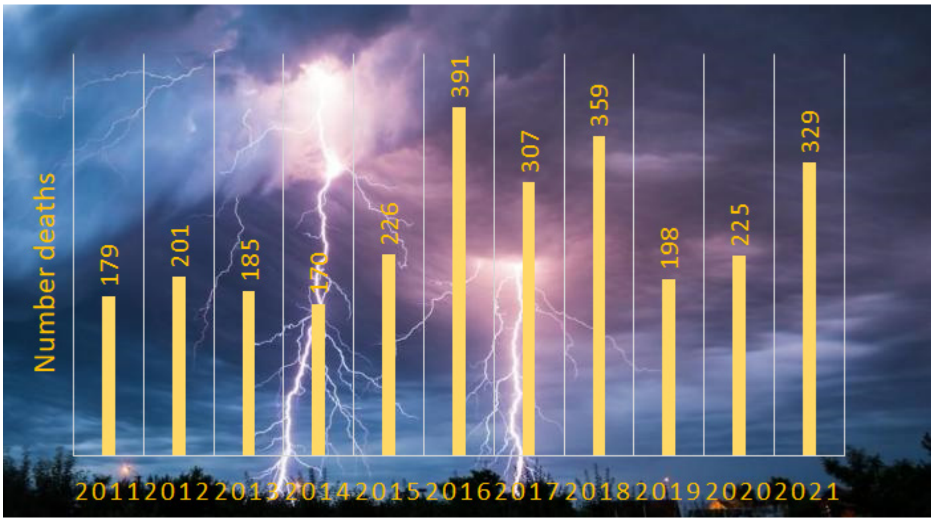


Figure 1: Number of deaths form lightening

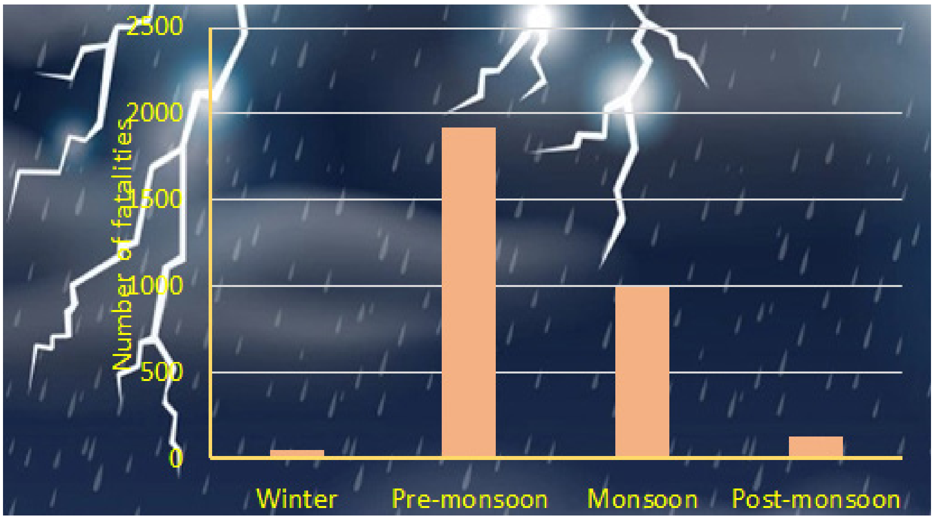


Figure 2: Seasonal distribution of fatalities due to lightening

2. Risk management efforts for lightning disasters:

- In recent years lightning hazards have been raising concerns due to due increasing number of fatalities compared with other natural disasters. Considering the increasing number of fatalities due to lightning strikes the Ministry of Disaster Management and Relief of Bangladesh declared this hazard as a natural disaster on 17 May 2016 (MoDMR 2020). The National for Disaster Management (NPDM)-2021-2025 recognizes lightning as an important and emerging issue that needs special attention in the disaster management areas (MoDMR 2020).

- The continuous destruction of tall trees (eg. palm trees) increases the risk of a direct strike of lightning (Iqbal 2021). Hence, the plantation of tall trees including palm has been prioritized as of the mitigation measures for lightning strikes. 3.8 million Palm trees have been planted across the country to minimize the impacts of lightning strikes and casualties (Financial Express 2019).

- The early warning system has been considered as another priority mitigation measure to reduce the number of fatalities from lightning strikes.

On a pilot, scale government has installed 8 early warning centers in the selected areas. Now the government has planned to establish 723 warning centers in lightning-prone districts across the country (Financial Express 2021). The early warning center can send an advisory to the people 40 minutes before the lightning.

- Since agriculture workers are the most vulnerable to lightning strikes, the Ministry of Disaster Management and Relief has launched a project to construct a lightning resilient concrete shelter in rural areas of the 23 most lightning-prone districts (Financial Express 2021). The concrete shelter will be constructed every one-kilometer interval.

3. Good elements of the risk management efforts

Considering a large number of death tolls due to lightning, the Government of Bangladesh responded quickly by declaring this hazard as a natural disaster. This declaration is reflected in the draft National Disaster Management Policy (2021-2025). Afforestation with palm trees has been considered as one of the key measures to reduce lightning fatalities.

The government has also prioritized early warning systems to save people from lightning strikes. Since agriculture workers are the most vulnerable to lightning strikes, the government has planned to construct lightning resilient concrete shelters in the lightning vulnerable districts.

4. Recommended improvements for disaster risk management

- There is no concrete set of measures for lightning management unlike cyclones, floods. Due to a lack of scientific data, there are a lot of misperceptions about lightning. Scientific research can generate useful information that helps to overcome these misconceptions and supports to development of appropriate sets of measures.

- A little effort has been put into raising awareness of people on lightning protection measures including palm tree plantation, installing lightning arrestors in home, how to get early warning advisory, where people should take shelter to protect them from lightning. Therefore a mass public awareness-raising program should be formulated involving communities, agriculture extension department, health department, disaster management department, education institutes, and mass media.

- There is weak coordination among relevant stakeholders towards planned actions for lightning events. A multi-stakeholder platform needs to be established at the local level involving medical doctors, public health professionals, engineers, meteorologists, and political leaders, to identify possible and effective solutions for preventing lightning-related deaths.

- An emergency pre-hospital care system for lightning victims needs to be established at the village or union level. For this, the staff of the primary level healthcare center should get training on emergency and per-hospitalization treatments.

- For making the concrete shelter project effective, the location mapping of the concrete shelter and its management should be co-developed together with communities.

- The establishment of early warning centers is a good measure to reduce the number of causalities due to lightning strikes. However, accessibility to the early warning system needs to be

Case: c

Flood × COVID-19

Germany (2021)

Type of compound disaster:
Natural × Biological

Date:
12-15 July, 2021

Place:
Rhineland-Palatinate, North Rhine-Westphalia, Bavaria (Germany)

No. people affected:
766 (em-dat, 2021), about 200,000 properties remained without power for few days (Zeit online, 2021)

Financial damage (est.):
5.3 billion USD (Insured money)

Death, injured/ causality:
205 (death) (em-dat, 2021)

1. Impact of the compound disaster

Heavy rains swept across western Germany between the 12th and 15th of July 2021. More than 150 liters of rain fell per night, a rare and extreme climatic event that occurs less than once every 100 years. Although floods are the most common natural disaster in Europe, this event has been categorized as the "flood of the century" due to its intensity and occurrence during the COVID-19 pandemic, which caused compound effects. The main cause of this flood was torrential rainfall caused by a slow-moving area of low pressure—named "Bernd". The main river basins that were affected were the Ahr, Volme, Dhünn, Moselle, Inde, Kyll, and Jagst Rivers. The river water level rose in such a swift manner that areas along the riverbank were inundated with up to 12 feet of water within approximately 2-3 hours . The secondary effects of this big disaster were land-, mud-, and rock-slides. The states of Rhineland-Palatinate and North Rhine-Westphalia were particularly hard hit. This event caused both tangible as well as non-tangible losses. Fast moving river water swept away everything in its path. Beautiful landscapes along the riverbank turned into scenes of devastation with vehicles and houses floating like bath toys, bridges breaking, and streets filling with crushed cars, tree stumps, rocks, mud, and debris. As many as 205 people lost their lives and several thousands of people were left without electricity, water, internet, and cellphone connections. Although the European weather agency issued an "Extreme flood" warning for western Germany days before this devastating event, the response from the disaster management and flood warning systems was insufficient. Addressing these issues could help prepare communities and disaster management agencies for similar events in the future.

In addition, ongoing COVID-19 related restrictions and measures for pandemic control posed difficulties for rescue workers and helpers who were tasked with setting up a risk-free environment for the flood victims. During the cleanup and search and rescue efforts, it was almost impossible to obey the COVID-19 related guidelines, viz. wearing masks, social distancing etc. During the rescue operations, affected people were brought into shelter houses or evacuation centers, which increased the risk of transmitting the virus. There was an increased sense of fear that this situation might cause a sharp rise in the rate of COVID-19 infections in western Germany. State agencies struggled to organize and manage mobile COVID-19 vaccination centers for those people seeking shelter in evacuation centers. Institutional management systems came under scrutiny as people became concerned that flood recovery activities would become a super spreader event for COVID-19.

2. Risk management for compound disasters

Pre-disaster preparedness

Several days before the disaster, the European Flood Awareness System (EFAS) predicted a severe flood risk and sent a warning to the German authorities. However, because this warning was only for big rivers like the Rhine, the corresponding authorities and decision makers did not consider tributaries, like the Ahr River, to also be at risk. This is why the flood alert service for Rhineland-Palatinate was slower to predict just how extreme the flooding would be in the Ahr valley, and hence just issued mild warnings. Later, the water level rapidly rose to an alarming level and the local authority gave an evacuation warning. But by that time it was too late for many people. Although there was a disaster management system in place, it was not enough for an event of this magnitude.

Response during the disaster

The German Ministry of Defense declared a state of emergency in the places that were severely damaged by the floods. The Finance Ministry released €300 million in emergency aid, providing up to €3,500 ($4,129) to each affected household to help repair and rebuild houses. Insurance companies also assisted in the recovery and rebuilding of cities. Volunteers, NGOs, and different community workers worked tirelessly to help people with clean-up activities, to search for trapped people, and to distribute necessary items like food, toiletries, school bags, and hand sanitizers/soaps etc. Due to a COVID-19 induced economic slump and higher inflation rates, the price for construction materials increased, resulting in additional financial burden for various institutions during this recovery/reconstruction process.

Post-disaster recovery

The local government kept updating a database containing information about those affected by the disaster, including missing and deceased people. Information was disseminated through different kinds of announcements so that people from other regions were aware of the kind of help needed in the affected regions. Food, masks, and hand sanitizers were distributed to volunteers and self-help groups that helped in the recovery and rescue process. The local government also kept updating local residents with real time information about the few mobile medical facilities that were available to provide COVID-19 vaccinations. They also conducted a risk assessment for flood waters and mud before allowing the rescue workers and helpers to commence cleaning activities.

3. Good elements of risk management

During flood events, animals may seek refuge in flooded houses and become aggressive upon contact with humans. Also, various chemicals can leak into the water and mud, potentially affecting helpers and rescue workers. Therefore, before any rescue or recovery activities were performed, officials quickly performed risk assessments and based on their evaluation teams were provided with appropriate tools and techniques to undertake their activities.

Social media and various news sources played a constructive role. Rather than spreading panic or exaggerating the level of danger they remained informative and vigilant. To help keep people calm, they conveyed the true account of what was happening on the ground and only did what was necessary.

Because of COVID-19 related complications, medical officials from different departments were deployed to the flood affected region. As vaccines were not immediately available, medical personnel helped people to measure their body temperature, provided advice to help prevent transmission of COVID-19, and gave counseling for mental health issues like depression and anxiety.

4. Recommended improvements to risk management

- This flooding event highlighted that there is still a big gap between the scientific information available and its direct application to the decision-making process during natural disasters. Following this event, a panel was established to discuss the involvement of more scientific experts in the decision-making processes to design more robust management system for extreme disasters.

- No real time warning system is available via the mobile network, which meant that most of the residents were caught unprepared and the number of casualties was higher. Government agencies are now under pressure to urgently develop a real time warning system for the mobile phone network.

- Another key aspect for higher death toll was non-preparedness for any climatic extreme event of such magnitude. As of now, most of the infrastructure available could cater a climatic or hydro-meteorological event with a return period of 50 years. Therefore, now decision makers are emphasizing on enhancing the capacity of existing infrastructures with a return period of 100 years.

- Another key factor contributing to the high death toll was a lack of rescue equipment, especially for disabled or elderly people. Twelve people from the same location remained trapped during the flood and could not evacuate in time. This was a bitter lesson for the authorities and they are now developing specialized evacuation equipment for disabled people, such as mechanized wheelchairs which help people to move from upper floors without any assistance.

- Dependency on critical infrastructures like telephones, mobile phone networks, and electricity was underestimated, which hampered recovery work for days to months. The extent of the damage to river gauges, rail lines, roads, and bridges from such high intensity flood water was also underestimated, further hampering rescue and recovery work.

- Due to COVID-19 regulations and protocols, affected people were required to shelter in small separate compartments. This did not allow people to share their emotions or discomfort, which increased their distress. Also, people who were partially- or non-vaccinated feared getting infected in these evacuation centers/shelter houses. There is insufficient infrastructure available to provide mobile medical services such as those needed during the COVID-19 pandemic.

- Since the COVID-19 pandemic is ongoing, the government is forming a taskforce which will prepare detailed guidelines for how to manage compound disasters considering the above-mentioned challenges and gaps.

5. Lessons Learnt

The existing flood forecasting system is largely based on historical data, which may not be effective for predicting future extreme weather conditions. Government agencies and other relevant institutions must think about how new scientific developments, such as artificial intelligence and spatial technologies, could be combined with human perception to implement a robust management plan. Also, most of the infrastructure dedicated to hydrometeorological disasters is designed considering a 50-year flood. However, the July 2021 flood induced damage exceeded existing capacity and imagination. Hence, decision makers must start to plan for the more frequent occurrence of extreme natural disasters in the future. Hence, they are planning to expand these exitsing infrastructures with higher return period of time. However, just expanding the carrying capacity of the existing infrastructure will cost a lot of money and does not guarantee a permanent solution, hence other solutions need to be considered, like nature-based solutions, and better landscape and land-use planning. Also, long-term planning should take a wide, multisectoral, all-hazards approach for emergency preparedness, and the development of local plans which include public health and primary care policies. COVID-19 imposed additional challenges, e.g., wearing masks, frequently washing hands, or maintaining social distances, compounding the effect of this natural disaster. Reflecting on this event, many countries now understand the value of timely vaccination programs to help minimize the challenges imposed by natural + biological compound disasters. Also, designing some additional mobile health care units like mobile vans with vaccination facilities will give a short-term solution to cope up with these extreme events. For the long-term solution, additional measures could be providing more training to the youth/able persons for the disaster preparedness drills, which will help building disaster management taskforce at local level and reduce the dependency on state disaster management team during the time of emergency. A better social coordination system should be developed, so that people should be aware about the most vulnerable groups (kids, disabled persons, old persons etc.), who needs more help during the time of emergency. This will also lessen the dependency on the communication networks (telephone, internet, mobile phones etc.), which often fails during the time of such emergencies. Finally, this event underscores the need for increased investment in disaster management plans.

Case: d

COVID-19 × Heavy Rainfall

Kumamoto, Japan (2020)

Type of compound disaster:
Natural × Biological

Date:
July, 2020

Place:
Kyushu, Japan

No. people affected:
Over 1.3 million people temporarily evacuated

Financial damage (est.):
220 billion yen (in agricultural sector)

Death, injured/ causality:
64 (age of 65+ accounts for 79%)

1. Impact of the compound disaster

The torrential rains that occurred between July 3 and July 31, 2020, caused damage in several parts of Japan, particularly in the southern Kyushu region. Kumamoto Prefecture was the hardest hit by the heavy rainfall, with evacuation orders issued to more than 1.3 million people. The Kuma River system, which flows through Kumamoto, overflowed or collapsed in 13 places, inundating about 1,060 hectares. At a nursing home for the elderly in Kuma village, 14 residents died when the facility was submerged. In this area, the depth of flooding is believed to have reached up to 9 meters. Of the 64 deceased people from Kumamoto Prefecture, 52 drowned, 33 of whom were found indoors. In Hitoyoshi city, a wide area of the city center was flooded, with flood waters reaching greater heights than in past floods. There were also deaths due to landslides. Compared to Typhoon Hagibis in 2019, the damage caused by this heavy rain event in Kumamoto Prefecture had a higher percentage of deaths among people over 65 years old and a higher percentage of deaths indoors.

In the event of a large-scale natural disaster during the COVID-19 pandemic, the priority is to avoid the risk of infection, which leads to insufficient news coverage, lack of support, and reluctance to evacuate. First of all, media reporters couldn't enter the disaster area, making it difficult to report on what was happening there. Secondly, government support staff and disaster volunteers were halted due to the concern that human contact and transportation across prefectural borders would facilitate the spread of COVID-19, leading to significant delays in recovery. Lastly, the capacity of evacuation centers was limited due to concerns about infection. As a result, people may have hesitated to go to evacuation centers and delayed their evacuation or may have been affected in places they thought were safe. In addition, there were many residents who stayed in their cars, which caused concerns about the occurrence of economy-class syndrome.

2. Risk management for compound disasters

Pre-disaster preparedness

In April, 2020 the Cabinet Office has published reference materials on how to deal with COVID-19 in evacuation centers and notified local governments that, as a measure to prevent the spread of the COVID-19 virus, people should open as many evacuation centers as possible to avoid overcrowding, utilize accommodation facilities, and consider dispersing evacuation to relatives' homes.

Response during the disaster

People had their temperature checked when entering evacuation centers and separate spaces and flow lines were designated for people with fevers. To avoid crowding of evacuees, it was recommended to keep 2 meters between people and to set up partitions made of cardboard or other materials to prevent droplet infection. The capacity of evacuation centers was reduced to prevent the risk of infection and in some cases evacuees were encouraged to move to other evacuation centers to maintain social distance.

Post-disaster recovery

The National Institute of Infectious Diseases and other organizations released information that may help prevent the spread of infectious diseases in disaster areas and evacuation centers, including disinfection measures. A risk assessment was published 10 days after the disaster; it outlined the prevention of infectious diseases among volunteers in disaster areas and evacuation centers. The Cabinet Office updated its reference materials on how to deal with COVID-19 infections in evacuation centers in September 2020 and released a collection of case studies on measures to deal with COVID-19 infections in evacuation centers in May 2021.

3. Good elements of risk management

When a case of fever or other suspected infection occurs in an evacuation center, the municipality running the center will first isolate the person in a private room. The prefectural public health center will be contacted, and the prefecture will handle all subsequent cases. Since mid-March in 2020, the prefecture has independently established a system whereby people who may have come into contact with infected people can undergo PCR testing, regardless of whether or not they have symptoms. The prefectural Institute of Public Health and Environmental Sciences has been conducting a maximum of 340 tests a day, and when an infected person is found in an evacuation center, it takes only a few days to complete the test, including those who have come into contact with the infected person, so that the spread of the infection can be monitored. Currently, the test can be done with saliva submitted by the patient. This is faster than when a public health nurse found out about the infection, which required a doctor to collect a specimen, and can be used even if the same thing happens in a relatively large evacuation center.

In the evacuation shelter, beds made of cardboard were neatly lined up, and partitions were made for each household to secure a private space. Public health nurses took the evacuees' temperatures and interviewed them about their health conditions, and carefully checked their physical condition at the entrance. In Hitoyoshi city, maximum of about 830 disaster victims stayed in the shelter, and they had impression that the shelter was more comfortable than they expected. In addition, the government also made early progress in providing supplies such as disinfectants and masks, and this was successful and did not lead to any clusters. Only two cases in Hitoyoshi City have identified as "disaster-related deaths" (deaths due to physical problems caused by stress from the disaster).

4. Recommended improvements for disaster risk management

1) Lack of manuals or guidelines for evacuation center management in case of COVID-19 clusters

There are no guidelines for how to manage cluster outbreaks in evacuation centers. Although prefectural officials are aware that this is necessary, they have not been able to handle the situation due to the spread of infection. In the case of an infected person, he or she is to be quarantined and housed in an accommodation facility with which the prefecture has an agreement. However, there are no clear regulations about whether or not evacuation centers should be closed when a cluster of infections occurs within them, or about where uninfected evacuees should be housed when the evacuation centers are closed. Evacuees cannot be made to stay at home because their homes have been swept away. If a similar disaster were to occur in a more populated urban area, COVID-19 preventive measures would be even more difficult. In a survey of nine cities in eight prefectures in Kyushu and Yamaguchi, many cities included infectious disease epidemics in their local Disaster Risk Reduction plans, manuals, and guidelines. However, only a minority thought that the current plans were sufficient. (Sankei Shimbun's survey, released on July 7).

2) Information divide between evacuees in shelters and those at home

In Kumamoto, a noticeable number of people chose to evacuate at home rather than to shelters due to concerns about COVID-19. As home evacuees were scattered throughout the prefecture, it was difficult to confirm their safety, raising concerns that relief supplies and information may not have reached them. Disparities in home evacuation have already been identified as an issue in past disasters, such as the Great East Japan Earthquake in 2011. In 2013, the Cabinet Office formulated guidelines to support home-bound evacuees, calling on local governments to ensure that local government officials visit evacuees door-to-door, and to pay attention to those who need assistance. However, in Kumamoto this did not work out as intended. Support for homebound evacuees under a pandemic requires ingenuity to reach them in a way that requires as little human contact as possible. For example, an online system that allows people to actively obtain information on support while at home could be established.

3) Lack of human interactions

During the COVID-19 pandemic, it is difficult to create a place for evacuees to gather to relieve their sense of isolation and share their worries, so their mental anguish tends to accumulate. Some elderly people complain of stress and lack of exercise due to the lack of space for socializing in evacuation centers. Taking these concerns into account, it would be worthwhile to consider setting up a contact point where people can talk about their problems, or face-to-face counseling with thorough infection prevention.

4) Difficulties in providing social services for widespread evacuees.

Evacuation centers are better able to monitor the health of evacuees and provide medical services. But, evacuation centers can be dispersed, making it difficult to provide medical services. It is difficult to provide medical services to evacuees in the immediate aftermath of a disaster because a large number of people are needed to go door-to-door to check on the condition of evacuees at home. It is effective to timely ascertain the status of medical services in the affected area and to provide support from neighboring local governments, as well as to establish a system of cooperation in advance to make these possible.

5. Lessons Learnt

The torrential rain disaster that caused extensive damage throughout Japan in 2020 occurred at a time when COVID-19 vaccines had not yet been developed. Although Kumamoto experienced mass evacuation on an unexpected scale, the region also succeeded in limiting the spread of COVID-19. This was due to a rapid inspection system in evacuation centers, thorough quarantine, and minimizing human interactions. The impact of COVID-19 has completely changed how people evacuate in response to a disaster. Affected areas faced many challenges, such as caring for people who refrained from evacuating to public facilities and stayed in their homes for fear of being infected, the ongoing mental strain caused by the loss of human interactions in evacuation centers, and the shortage of volunteers and other manpower for post-disaster reconstruction. Even though vaccines are becoming more widely available, these challenges are likely to occur in other parts of the world whenever a large-scale disaster occurs. The ideal solution is to reduce the number of evacuees per shelter by subdividing the shelters into smaller groups, but this would be expensive to manage. Therefore, it is worthwhile to consider other methods, such as using online systems to communicate with evacuees at home and provide psychological care for evacuees.

Case: e

Cyclone Pam × water/vector-borne infections

Vanuatu (2015)

Type of compound disaster:
Natural × Biological

Date:
March, 2015

Place:
Vanuatu

No. people affected:
3,300 people were displaced/188,000 people

Financial damage (est.):
$692 million

Deaths, causalities:
11–16 people died

1. Impact of the compound disaster

Cyclone Pam, a category 5 storm, was among the most powerful tropical cyclones in recorded history. Cyclone Pam struck Vanuatu on the 13th of March 2015 and affected about 188,000 people—more than half of the national population—across all six provinces. The storm sustained a maximum wind speed of 165 miles per hour and produced 1-metre storm surges, which particularly affected the southernmost provinces of Tafea and Shefa, where 50–90% of shelters were destroyed. Owing to an early warning and effective evacuation, the death toll was considerably low (only 11). Nonetheless, the storm destroyed a large extent of agricultural land, food stocks, and water sources, leaving communities hungry and vulnerable for a long period, even years.

Over 95% of crops in affected areas were destroyed, and winds and water damaged more than 70% of health facilities and 50% of schools. Total damage in Vanuatu reached VT63.2 billion (US$600 million). The destruction of critical infrastructure, particularly the fragile health infrastructure of the island nation, made many of the disaster victims further vulnerable to the post-disaster health impacts. For example, after Cyclone Pam dirty water has affected almost everybody in Vanuatu. Before the cyclone, Vanuatu was in the midst of a measles outbreak, but the mitigation efforts were vastly discontinued owing to the destruction caused by the cyclone.

2. Risk management for compound disasters

Despite the scale of Cyclone Pam, one important aspect of this disaster is the considerably low number of deaths compared to similar storms. For example, Category 5 Super Typhoon Haiyan killed more than 6,300 people in the Philippines. The effective preparation of the government and community made this possible.

Pre-disaster preparedness

As Cyclone Pam approached, Vanuatu's National Warning Centre played a crucial role in disseminating hazard information. The Centre, based in the capital Port Vila, disseminated information about the storm through radio, social media, and SMS messages. The Centre began issuing warnings, using color-coded information to depict the intensity of the threat. Thirty-eight different types of SMS warnings were sent to Vanuatu's 160,000 mobile phone users. At the same time, many local communities had their own emergency preparation plans owing to their previous experience of earthquakes, volcanic eruptions, large storms, and the threat of a tsunami. In addition, evacuation centers, such as churches and public buildings, were pre-identified and residents were asked to stockpile food and water for the emergency, which, to a certain extent, minimized the risks.

Response during the disaster

The government, various NGOs, the UN, and international aid agencies responded to the disaster. In the evacuation shelter, water, sanitation, and hygiene kits were provided to families. It was estimated that 110,000 people were in urgent need of water, sanitation, and hygiene (WASH) assistance. UNICEF provided some 2,800 water containers to Tanna, as well as purification tablets and soap. Emergency food aid for an estimated 19,000 households were also prepared. According to WHO, eight Foreign Medical Teams were engaged to provide immediate medical relief. An Asian Development Bank project also provided medical kits, food, drinking water, and personal hygiene kits.

Post-disaster recovery

The Government of Vanuatu, USAID and several other organizations conducted a Post-Disaster Needs Assessment across key sectors, including water, telecommunication, livelihood, health, and food security. International banks, NGOs, countries, and aid agencies came forward with financial and technical assistance that was used for recovery and reconstruction. For example, the Government of Vanuatu, with ILO's technical assistance launched Employment Services Vanuatu, a program that supported people who lost their jobs due to the cyclone. Given more than 80% of the local communities are engaged in agriculture and suffered major disruption of livelihood, the FAO also came forward and worked with Vanuatu Food Security and Agriculture Cluster to restore agricultural production and rebuild people's livelihoods, as well as to increase the country's resilience to extreme weather events. WHO, USAID, and other international agencies helped to restore crucial health infrastructure and re-established some of the discontinued disease surveillance systems (e.g., Leptospirosis, dengue, and malaria). Supported by WHO, the government's health department proposed the establishment of the disease Early Warning and Response Network, vaccination programs (i.e. measles), clinical case management, vector control (malaria mosquito net distribution, dengue rapid diagnostic tests), and risk communication (WASH assistance etc.).

3. Good elements of risk management

One of the most impressive things that surprised the global community was the low death toll. Multitudes of factors were responsible for this achievement, including an effective early warning, self-reliance and traditional knowledge, previous disaster experiences, training, and evacuation shelters. The existing National Emergency Operations Centre provided an important focal point for the meeting of all concerned agencies. In addition, the Government Information and Communications Office provided excellent communication through local telecommunications providers, utilizing SMS, satellite phones, and many other modes of communication. Local customs and traditional knowledge also played a pivotal role in safeguarding communities. For example, 'cyclone houses' and food preservation techniques (manioc, coconut jam) helped communities to quickly recover from the cyclone. An Evacuation Centre Exit Strategy was also developed, and the Vanuatu Humanitarian Team provided support through strong established networks of local partners. Moreover, communities with previous exposure and training were most resilient. Lastly, good collaboration with the international community helped to ensure an effective response and recovery strategy, which included assistance from multiple aid and humanitarian agencies.

4. Recommended improvements to risk management

Improving and increasing coverage of all modes of communication

Although communication through SMS messages and broadcasting worked well, inclusive communication among national-provincial-community levels needs improving, particularly for communities located in remote locations. In addition, the warning messages need to be clearer for local people. For example, just stating 'category 5 cyclone' may not be informative enough, the underlying risks of a category 5 cyclone need to be articulated in simple language.

Strengthen the disaster legislation and include community-based organizations

Both informal and formal community organizations played a critical and decisive role in the evacuation and in the aftermath of the disaster. Community Disaster Committees should be further strengthened with financial and technical resources. There is a need to revise the existing disaster legislation, especially the Standard Operating Procedures. There is also a need to further strengthen the linkages among the responding agencies as well as with the international aid agencies.

Strengthen schools, evacuation shelters, and other critical infrastructure

While many schools have been rehabilitated and newly constructed, their design should be further improved to be resilient to future climate-induced disasters. In addition, the 'build back better' principle should be proactively promoted, particularly to diversify cyclone shelters and strengthen hospitals and other critical infrastructure.

5. Lessons Learnt

Cyclone Pam was a Category 5 storm that made landfall over some of the most populated islands of Vanuatu, yet there was a very limited loss of lives. This is a great lesson that despite the high exposure and the fact that the cyclone damaged critical resources, the culture of preparedness, early warning, and effective risk communication paid off immensely and protected precious human lives. In addition, local and traditional knowledge helped the communities to effectively prepare for the disaster. Quick mobilization of resources, particularly related to water and basic hygiene, helped communities in dire need of basic resources. Moreover, houses constructed with traditional and local materials fared better than houses built with cement sheeting and iron roofing. The use of traditional materials was likely also instrumental in minimizing injuries. Another important factor that contributed to effective resilience was the involvement of civil society and international NGOs, as well as effective mediation by the government of Vanuatu.

Heavy Rainfall × Explosion at an Aluminum Plant

Okayama, Japan (2018)

Type of compound disaster:
Natural × Technological

Date:
July, 2018

Place:
Western Japan
(Factory explosion occurred in Okayama)

No. people affected:
More than 2.3 million people temporarily evacuated

Financial damage (est.):
220 billion yen (for insurance, in Okayama)

Death, injured/ causality:
263 fatalities; 5 injured due to the explosion)

Photo credit @Mieko Kumasaki

1. Impact of the compound disaste

From June 28 to July 8, 2018, a wide area of western Japan was hit by torrential rains. The rainfall caused river overflow, inland water flooding, landslides, and mudslides. The death toll was estimated to be 263, with 8 people missing and 484 injured. According to the Japan Meteorological Agency, the cause of the torrential rains was a rainy season front and a large amount of water vapor flowing into the area. Various lifelines were severely damaged and evacuation orders and advisories were issued to over 2 million people. The torrential rain also caused subsequent disasters, including landslides. In this article, however, we will focus on the explosion of an aluminum factory caused by the rainfall and flooding. This is known as a Natech case, where a technical accident is caused by a natural disaster. The risk of Natech events has attracted a high degree of attention in recent years.

The explosion at the aluminum plant occurred at around 11:30 p.m. on July 6 in Soja City, Okayama Prefecture. The cold floodwater coming inside the factory and into contact with the hot molten aluminum in a chamber, which caused a severe explosion. The plant, which recycles aluminum, was in operation 24 hours a day. The explosion was followed by a fire, which spread to four houses in the vicinity. In addition, the blast broke the windows of a house, and at least five people were injured and sent to hospital. Fortunately, no one was killed, and no one was in the factory at the time of the accident. After the accident, there was a risk of a secondary explosion. Therefore, the residents of the surrounding area were ordered to evacuate. Hundreds of nearby residents were moved to evacuation facilities.

2. Risk management for compound disasters

Pre-disaster preparedness

Detailed laws and regulations have been prepared for safety and risk management related to chemical plant factories. It requires large plants to conduct risk assessment and establish guidelines for safety management. When natural hazards hit the factory, the on-site supervisor is the only person who can decide whether to invoke a response as stipulated in the safety management guidelines. Therefore, it is necessary for site supervisors to have a good understanding of Natech risks.

Response during the disaster

It was only after workers reported that rivers were swollen due to heavy rains that the manager of Soja plant decided to shut down its aluminum processing operations. It is because the factory manager was not sufficiently aware about the risk of flooding and how swiftly it would hit the factory. Eventually, the plant staff had to evacuate while hot aluminum was left in the plant. But at least the factory workers were able to evacuate before the explosion occurred, so there were no casualties. Nearby residents were evacuated due to the risk of second explosion. Fortunately, the second explosion didn't actually happen.

Post-disaster recovery

The damage at the factory was covered by insurance. However, once an accident has occurred, the major issue is to restore trust with the local residents.

3. Good elements of risk management

First, it is worth mentioning that no one was killed in the explosion. This is because the factory managers did not misjudge the evacuation of the factory workers. It is commendable that the factory managers recognized the vulnerability of aluminum plants to flooding, and at least decided to shut down the factory after the reporting of flooding. If this had been delayed, it could have caused even greater damage and harm to the employees.

The aluminum plant in Soja City, Okayama Prefecture, was not the only plant affected by this torrential rain event, and the responses of neighboring factories also provide an opportunity to learn about good practices in disaster management. A plant located in Kure City, Hiroshima Prefecture was able to avoid an explosion because the factory management was more aware of the risks of flooding and instructed the factory to suspend operations at an early stage. The factory manager communicated with local authority about the possible risk of flooding and it helped this decision-making. This is a good example of how a Natech incident was avoided because of a good understanding of Natech risks by the factory manager and the factory's close cooperation with the local government.

4. Recommended improvements to risk management

1) Improved approach for risk assessment

According to the legal regulations for factory safety management in Japan, business operators conduct risk assessments on a voluntary basis. One of the reasons for this is that it is difficult to set uniform risk assessment standards due to the diversity of disaster risks for various factories and plants. Compound disaster risks are expected to become more complex and systemic. As such, it is necessary to reconsider the meaning of, and approach to, risk assessment, including who should conduct risk assessments. For example, it may be necessary to strengthen the safety management regulation in response to deepening risk, or to provide a more detailed risk criteria for companies and wider public so that the quality of risk assessment is improved.

2) Factory managers' awareness of Natech risks

Factories typically develop guidelines to prepare for accidents. However, it is up to the factory management to decide whether to take preventative measures based on the guidelines. Therefore, it is important for factory managers to be aware of the risk of accidents and to prepare for the worst-case scenario.

3) Informing residents of Natech risks

As mentioned above, in the post-accident process, it is necessary to gain the understanding of the local residents in order to rebuild the plant and continue its operation. However, it is very difficult to inform local residents of the risk of a Natech disaster. Inevitably, the factory management tends to explain to local residents that the factory is safe. As such, it is important to have a multi-stakeholder process in cooperation with local government and fire departments, so that factories can properly inform residents about the risks of factories.

5. Lessons Learnt

This Soja case has many implications for countries in the Asia-Pacific region and beyond. It shows what kind of weather hazards need to be considered when setting up factories and other technical facilities often included in development plans. Also, in the current case there was a difference in the response between Soja City in Okayama Prefecture and Kure City in Hiroshima Prefecture. This shows that proper guidelines, as well as their implementation, are key elements of disaster risk management. Moreover, given the deepening of risks, the risk assessment stipulated in law may need to be amended so that the proper knowledge and decision-making of the factory manager should not be the last resort.

The importance of countermeasures against weather-related disasters and the consideration of Natech risks need to be integrated into development policy. Specifically, there is a need to establish procedures and processes that take into account the risk of Natech events when constructing factories. Chemical knowledge is also essential to determine what types of weather and other hazards pose a high risk to factories. International support, including capacity development, needs to take these various aspects into account and facilitate comprehensive risk management in developing countries.

At the policy level, safety standards and labor management for factories need to be set at the national and local levels. In addition, consideration needs to be given to how to build relationships between factories, local governments, and local residents. In particular, factories in developing countries are sometimes managed by a foreign company. In these cases, it is even more essential for the factory to have good communication channels with the local government and local residents in order to respond to unforeseen circumstances, as well as to set up guidelines in advance.

Drought × Displacement

Syria (2011)

1. Background

The Syrian refugee crisis has been ongoing for ten years and remains one of the world's greatest challenges. According to The Office of the United Nations High Commissioner for Refugees (UNHCR), more than 6.6 million Syrians have been forced to flee outside the country and 6.7 million people remain internally displaced. Some scholars have attempted to link this humanitarian crisis with global climate change. However, it remains difficult to prove causality as there are multiple factors affecting the socio-economic and political crisis in Syria. We should acknowledge this complication but also see the value of considering the link between environmental changes and displacement.

The Middle East and North Africa (MENA) is a region that has experienced water-related conflicts since ancient times. In the case of Syria, a series of severe droughts have triggered social unrest and even human migration. During the late 2000s, Syria and the Fertile Crescent experienced the worst drought on record, causing greater water and agricultural insecurity, crop failures, and livestock mortality. Migrants placed additional stress on the cities which, combined with existing political tension, resulted in conflict that generated a massive, displaced population.

2. Chain of influences

The association between climate change and displacement is likely to be complex. Many previous studies have tried to untangle this complexity, but there is no universal consensus and the reasons behind the association are locally specific and context sensitive. Syria is the representative case that illustrates climate variability, such as drought, does not directly induce forced displacement, but generates a chain of influence.

On top of that, this case demonstrates that a local climate change issue could result in a transboundary crisis. The initial trigger of the crisis in Syria was water scarcity due to the occurrence of serious droughts, but this was amplified by unsustainable natural resource policies. Human-induced water shortage due to, for example, subsidies to water-intensive farming activities encouraged inefficient irrigation systems. Water shortage, combined with rapidly increasing population, caused land desertification, which pushed the agriculture-dependent population to migrate elsewhere. According to the report published by International Federation of Red Cross and Red Crescent Societies in 2009, over 800,000 Syrians had lost livelihood because of water shortages, which led to an influx of internal migration from rural to urban areas. This led to socio-economic unrest, particularly in urban areas that were also receiving Iraqi refugees. Poor immigrants suffered from limited employment opportunities as well as insufficient access to water resources in cities.

Discontent with the government erupted across the MENA region in the wake of Arab Spring and resulted in the Syrian uprising that began in 2011. As a consequence, many Syrians were forced to immigrate to neighboring countries (Turkey, Lebanon, and Jordan hosted the largest population) and some countries in the European Union. According to another UNHCR report, an estimated 11.7 million Syrians were displaced by the end of 2015. The majority of them faced hardships, such as limited permission to work, lack of access to health care, and language barriers. There were also numerous challenges for host countries, including humanitarian assistance and social protection.

3. Implications

The first thing to note is that climate change does not immediately cause conflicts or refugees. Tracing the history of the situation in Syria shows that it started with non-climatic issues, such as the poor management of water resources and a growing population in urban areas. This case also shows that these potential problems may be compounded by political, social, and economic instability, resulting in serious consequences of displacement. Currently, international law does not allow for the definition of 'climate change refugees'. In fact, it is extremely difficult to attribute refugee problems to climate change. While some previous studies have shown a causal association between climate change and migration in the case of MENA (see Abel et al.), this does not mean that Syrian refugees can be called climate change refugees. What is needed is to recognize that environmental changes, including climate change, can displace people and force them to relocate, and to break the chain of influence at an early stage. Recently, 'climate-induced displacement' has received growing attention from the international community, and further discussion and actions are needed to collectively resolve this issue.

3. References

1. Background

Integrated Research on Disaster Risk. Peril Classification and Hazard Glossary (IRDR DATA Publication No. 1). Beijing (2014) available at https://www.irdrinternational.org/uploads/files/2020/08/2h6G5J59fs7nFgoj2zt7hNAQgLCgL55evtT8jBNi/IRDR_DATA-Project-Report-No.-1.pdf

Galderisi A., Ceudech A., Pistcci M. A method for na-tech risk assessment as supporting tool for land use planning mitigation strategies. Nat. Hazards. 2008;46:221–241. doi: 10.1007/s11069-008-9224-8.

2. Case Studies

a. Earthquake and heavy snowfall – Niigata (2004)

Masaaki Niwayama. (2005). Lessons from Niigata Chuetsu Earthquake in Japan -Experience of a small medical association in hilly and mountainous areas-. JMAJ 48(7):334-340. available at https://www.med.or.jp/english/pdf/2005_07/334_340.pdf

Compound disaster by the Mid Niigata Prefecture Earthquake and the heavy snow (2005) available at https://www.sc.niigata-u.ac.jp/geology/saigai/164.pdf

Experience of the cascading disaster of earthquake and heavy snow. (2005) available at http://coastal.nagaokaut.ac.jp/~jisin/report/2-15.pdf

Reflecting on Multi-Disasters Caused by Interaction of Heavy Snowfall with Seismic Activities in the Heisei Era. (September, 2019) available at https://www.jstage.jst.go.jp/article/jcsir/2019/0/2019_56/_pdf

Recovery and reconstruction after the heavy snow. (October, 2005)available at https://www.pref.niigata.lg.jp/uploaded/attachment/78559.pdf

Research on the prediction of the damage from and local DRR of the compound disaster of earthquake and heavy snow. (2008) available at https://kaken.nii.ac.jp/ja/grant/KAKENHI-PROJECT-18310127/

b. Lightning and Heavy rainfall in Bangladesh

Ahasan, M., Chowdhary, M. A., and Quadir, D. (2011). Variability and Trends of Summer Monsoon Rainfall over Bangladesh. Journal of Hydrology and Meteorology, 7(1), 1–17. https://doi.org/10.3126/jhm.v7i1.5612

Dewan, A., Ongee, E.T., Rahman, M.M. et al. (2018). Spatial and temporal analysis of a 17-year lightning climatology over Bangladesh with LIS data. Theor Appl Climatol 134, 347–362. https://doi.org/10.1007/s00704-017-2278-3

Farukh, M., Ahmed, S., Islam, M., and Baten, M. (2018). Spatial Vulnerability Assessment of Extreme Lightning Events in Bangladesh Using GIS. Journal of Environmental Science and Natural Resources, 10(2), 11–18. https://doi.org/10.3329/jesnr.v10i2.39008

Financial Express. (2019). 3.8m palm trees planted to minimise impacts of lightning strikes. Available at: https://thefinancialexpress.com.bd/national/38m-palm-trees-planted-to-minimise-impacts-of-lightning-strikes-1577199903

Financial Express. (2021). Govt plans to build lightning resistant shelters in 23 districts. Available at: https://thefinancialexpress.com.bd/national/govt-plans-to-build-lightning-resistant-shelters-in-23-districts-1637588426

Holle, R. L., and Islam, A. K. M. S. (2017). Lightning fatalities in Bangladesh in May 2016, paper presented at the 8th Conference on the Meteorological Applications of Lightning Data, Seattle, Amer. Meteor. Soc., 4 pp.

Iqbal, Mohammad. (2021) Lightning in Bangladesh: A Visible Threat Causing Considerable Damages to Human & Social Life & the Economy. Available at: https://ssrn.com/abstract=3907683 or http://dx.doi.org/10.2139/ssrn.3907683

MoDMR. (2020). National Plan for Disaster Management (2021-2025). Available at: https://modmr.portal.gov.bd/sites/default/files/files/modmr.portal.gov.bd/page/a7c2b9e1_6c9d_4ecf_bb53_ec74653e6d05/NPDM2021-25%20DraftVer5_23032020.pdf

c. Flood and COVID-19 – Germany (2021)

Climate Change News (2021) Fatal floods expose gaps in Germany's disaster preparedness. (20 July 2021). https://www.climatechangenews.com/2021/07/20/fatal-floods-german-authorities-face-criticism-lack-preparation/

Dewan, A. (2021) CNN. Germany's deadly floods were up to 9 times more likely because of climate change, study estimates. (24 August 2021). https://edition.cnn.com/2021/08/23/europe/germany-floods-belgium-climate-change-intl/index.html

DW News (2021) German flood rescue could spread coronavirus, officials say. News and in-depth reporting from Berlin and beyond. https://www.dw.com/en/german-flood-rescue-could-spread-coronavirus-officials-say/a-58581294

European Centre for Disease Prevention and Control (ECDC). Extreme rainfall and catastrophic floods in western Europe – 29 July 2021. ECDC: Stockholm; 2021

EM-Dat (2021) https://public.emdat.be/data . Data accessed on 30 November 2021.

Fekete, A. and Sandholz, S. (2021) Here Comes the Flood, but Not Failure? Lessons to Learn after the Heavy Rain and Pluvial Floods in Germany 2021. Water, 13, 3016.

Kühne, O., Koegst, L., Zimmer, M.-L., Schäffauer, G. (2021) "… Inconceivable, Unrealistic and Inhumane". Internet Communication on the Flood Disaster in West Germany of July 2021 between Conspiracy Theories and Moralization—A Neopragmatic Explorative Study. Sustainability, 13, 11427.

WHO (2021) Public health advice for flooding in Western Europe. 20 July 2021. https://www.euro.who.int/en/home/copyright-notice

Zeit Online (2021) Mehrere Tote und etwa 70 Vermisste bei Unwettern". Die Zeit (in German). 16 July 2021. https://www.zeit.de/gesellschaft/zeitgeschehen/2021-07/haeuser-nach-unwetter-in-der-eifel-eingestuerzt-zahlreiche-vermisste?utm_referrer=https%3A%2F%2Fen.wikipedia.org%2F

The lesson from German floods: prepare for unimaginable.
https://www.climatechangenews.com/2021/08/20/lesson-german-floods-prepare-unimaginable/
Published on 20 July 2021.

AIR worldwide. Pandemic reconstruction costs Germany flood. (21 October 2021)
https://www.air-worldwide.com/blog/posts/2021/10/pandemic-impacted-reconstruction-germany-flood/

d. COVID-19 + Heavy Rainfall – Kumamoto, Japan (2020)

Cabinet Office, Government of Japan. Case studies of measures against COVID-19 in evacuation centers. (May 2020) available at
http://www.bousai.go.jp/taisaku/hinanjo/pdf/coronajirei.pdf

Cabinet Office. Guidelines for training in the establishment and operation of evacuation centers in consideration of countermeasures against COVID-19 (2nd edition). (September 2020) available at
http://www.bousai.go.jp/pdf/korona_0908.pdf

Hitoyoshi Public Health Center, Kumamoto Prefecture. Record of verification of the response to the July 2020 torrential rain disaster. (March 2021) available at
https://www.pref.kumamoto.jp/uploaded/life/90333_127164_misc.pdf

National Research Institute of Land and Infrastructure. Survey Report on the Heavy Rainfall in July 2020. (August 18th, 2020) available at
http://www.jice.or.jp/cms/kokudo/pdf/reports/disaster/15/2020_gouu_01.pdf

e. Cyclone Pam and water/vector-borne infections in Vanuatu (2015)

Handmer, J., & Iveson, H. (2017). Cyclone Pam in Vanuatu: Learning from the low death toll. The Australian Journal of Emergency Management, 32(2), 60-65.

Post-Pam: Lessons learned for development cooperation in Vanuatu and the Pacific
https://www.adaptationcommunity.net/wp-content/uploads/2017/05/PostPam-Study.pdf

https://www.usaid.gov/humanitarian-assistance/tropical-cyclone-pam

Tropical Cyclone Pam – Vanuatu
https://www.who.int/hac/crises/vut/vanuatu_donor_alert_25march2015.pdf

f. Heavy Rainfall and Explosion at an Aluminum Plant – Okayama, Japan (2018)

Kumasaki, M., & King, M. (2020). Three cases in Japan occurred by natural hazards and lessons for Natech disaster management. International Journal of Disaster Risk Reduction, 51, 101855.
https://doi.org/10.1016/J.IJDRR.2020.101855

Cabinet Office, Government of Japan. (2019) Disaster Prevention White Paper 2019, available at:
http://www.bousai.go.jp/kaigirep/hakusho/r1.html

g. Drought and Displacement – Syria (2011)

Abel, G. J., Brottrager, M., Cuaresma, J. C., & Muttarak, R. (2019). Climate, conflict and forced migration. Global Environmental Change, 54, 239-249.

Bilgic, A., & Pace, M. (2017). The European Union and refugees. A struggle over the fate of Europe. Global Affairs, 3(1), 89-97.

Femia, F., & Werrell, C. (2012). Syria: Climate change, drought and social unrest. The Center for Climate and Security, 29, 2-5.

International Federation of Red Cross and Red Crescent Societies (IFRC) (2009). DREF Operation Syria: Drought. Available at https://www.ifrc.org/docs/appeals/09/MDRSY001do.pdf (accessed on 8 December)

Kelley, C. P., Mohtadi, S., Cane, M. A., Seager, R., & Kushnir, Y. (2015). Climate change in the Fertile Crescent and implications of the recent Syrian drought. Proceedings of the National Academy of Sciences, 112(11), 3241-3246.

Selby, J., Dahi, O. S., Fröhlich, C., & Hulme, M. (2017). Climate change and the Syrian civil war revisited. Political Geography, 60, 232-244

The Office of the United Nations High Commissioner for Refugees (UNHCR) (2016) Global Trends: Forced Displacement in 2015. Available at https://reliefweb.int/report/world/unhcr-global-trends-forced-displacement-2015 (accessed on 8 December)

Ministry of the Environment