POLITECNICO DI MILANO
School of Civil, Environmental and Land Management Engineering
Master of Science in Civil Engineering for Risk Mitigation

POLITECNICO
MILANO 1863

Thesis title :

The role of maps in supporting emergency management analyzed through four test cases

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Academic year 2020/2021

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1. Introduction:

Geospatial data and services can help save lives, forecast and mitigate damage, and save money in disaster management. An effective response always starts with a map. Paper maps, vehicle navigation, local government software, environmental management, national census, and analytical mapping, which aids emergency teams and decision-making teams, are all examples of geospatial data and maps in use. Disasters always have a time interval and a geographic footprint, which we can assess using maps to determine the size of the affected area and its impact on the field. It is possible to understand where the threat is prevailing, where the damage has occurred, and where residential or commercial buildings have been damaged using geospatial tools, allowing the emergency response team to act faster, especially shortly after the event when there is a chance to save more lives and assets. When street signs or house numbers are lost after a disaster, or if the event occurs in remote regions, mapping can contribute to locating assets. [1]

Checking through test cases in four events of flood bathtub effect, snowstorm lake effect, earthquake, avalanche, we want to see which maps have been produced, which map should have been produced and how useful every map could be for the different phases of the emergency. We have also considered the time required to process the maps, the time required to acquire the necessary data to obtain the maps, how the maps are created, and how complex is this production.

Considering how different governments reacted and coping with the disaster, as well as how they produced maps to foster the solution of their problems. We want to find which maps are often considered for a certain event. It is conceivable to term them *important maps* or *essential maps*. In this way in case of the occurrence of a similar event, if it is known which are the most relevant maps, they can be produced with higher priority. Understanding the priority or genuine necessary maps, as well as the time required to collect data for these maps, is critical to a speedier response.

Because the presence of human assets varies by location, maps incorporating human assets may be referred to as optional maps, which we use only when the relevant asset is present. We want to also highlight the maps that can be regarded as *optional maps*.

To produce a map, several layers are needed. Some of these layers or data could be already available such as road networks but it must be verified that the available layer is up to date and covering the whole area of interest. In some cases, the available layer is not complete or not updated so when we introduce a map it is needed first to collect and update the necessary data.

The point is that if data is available, no additional processing of the existing layer is required, and it can be used to produce the maps; otherwise, data collection takes time, and most maps cannot be created from current data, for example in an earthquake mapping for producing a rupture zone estimation map, we need seismic records data in the territory plus one base layer. We will not be able to produce this map if we do not have historical seismic records or if this data is not kept up to date, data that spans months and years.

Maps can be classified based on their contribution to life or asset preservation. Preparedness, during an emergency, and recovery are three phases in which maps can help save lives or assets. The majority of Maps considered in this work contributed to the preparedness phase and some maps can be useful in other emergency management phases as well. Also based on how maps are created, also, in this thesis we want to see how much expertise is required for producing essential and optional maps for these four events (flood bathtub, earthquake, avalanche, snowstorm with lake effect).

2.1 Snowstorm and Lake effect

Buffalo City is the focus of this case study (USA)

Buffalo is noted for its severe snowstorms, which occur regularly. Buffalo, located on Lake Erie's northeast shore, is a popular target for "lake effect" snow. The moisture is picked up by the winds as they traverse the lake, and the snow follows, accompanied by freezing air. We go over the history of snowstorms in this city and New York to see how mapping has changed over time. [2]

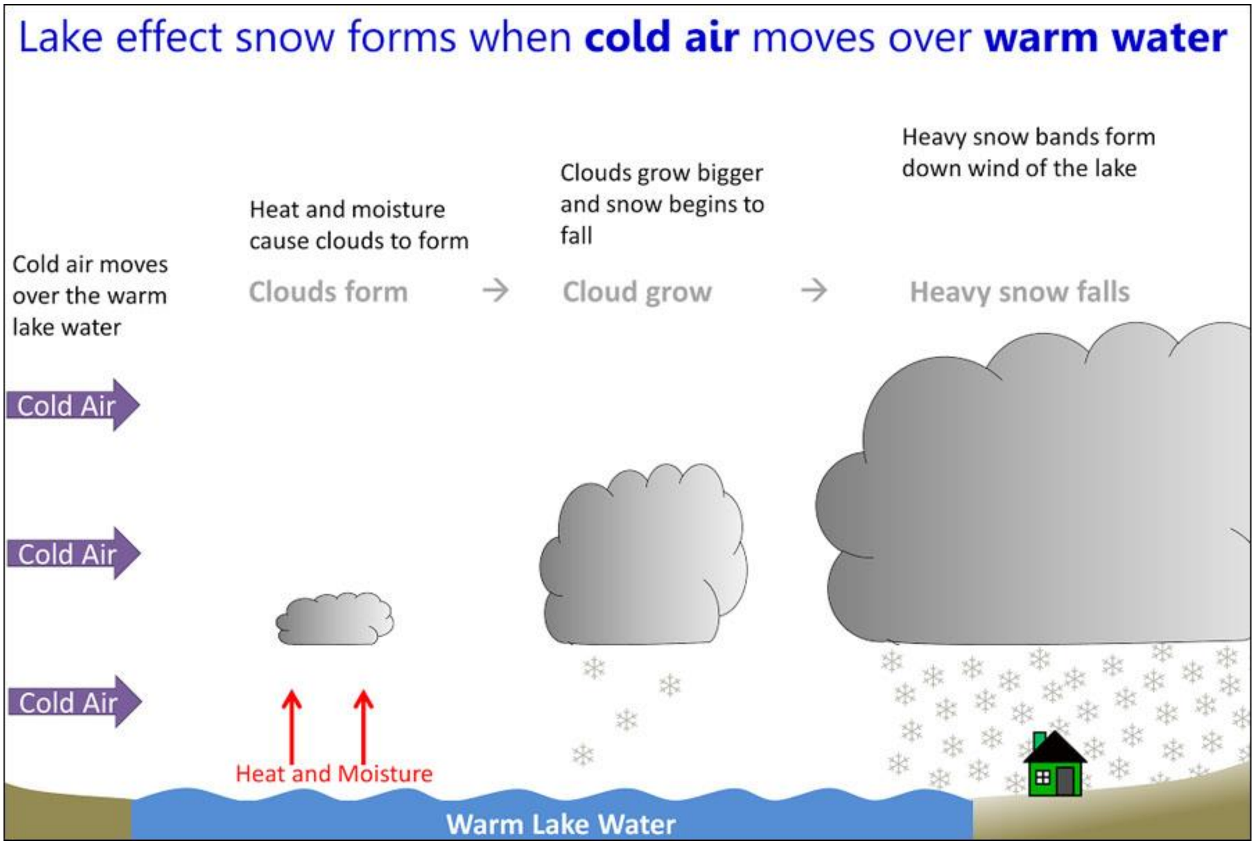

Figure 1 Snowstorm formation

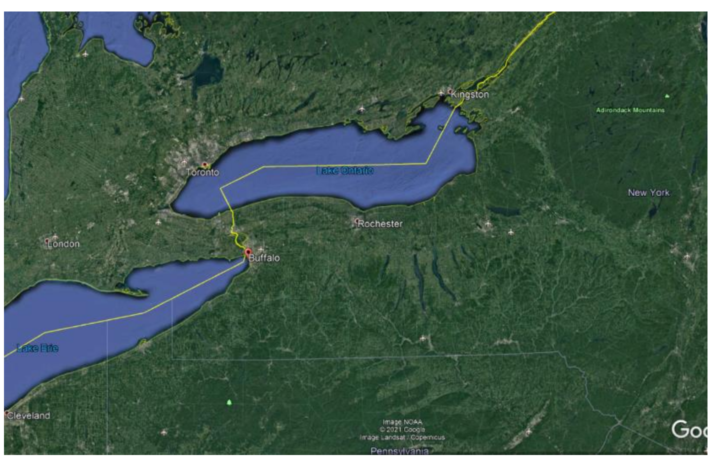

Figure 2 Location of Buffalo city

2.1.1 Buffalo 2001

On Christmas Eve 2001, a classic lake effect (see next section) storm hit Buffalo.

Because the incident occurred over the holidays, no one was outside or at work or school at the time. Roads were closed, roofs were broken, and several structures fell as a result of the 213 cm of snow. Vehicles were left in the roadway, making roads inaccessible. The street and everything on it vanished, and just a few streets had only one lane available.[3]

Figure 3 picture of the event

2.1.2 Climate driver map

In contrast to thunderstorms, which become stronger and more violent as the winding path and velocity shift at higher elevations, a phenomenon known as Wind Shear, Lake effect snow is at its most powerful and devastating when wind shear is at its lowest. Winds blowing in the same direction form the snow in a narrow band that moves a little, and this band can grow to be 150 miles wide if the wind is blowing from the larger side of the lake. The graphic below (figure 4) depicts a 120-mile belt of lake effect snow and moisture originating from the lake. Wind and warm water are climate drivers in this region. [4]

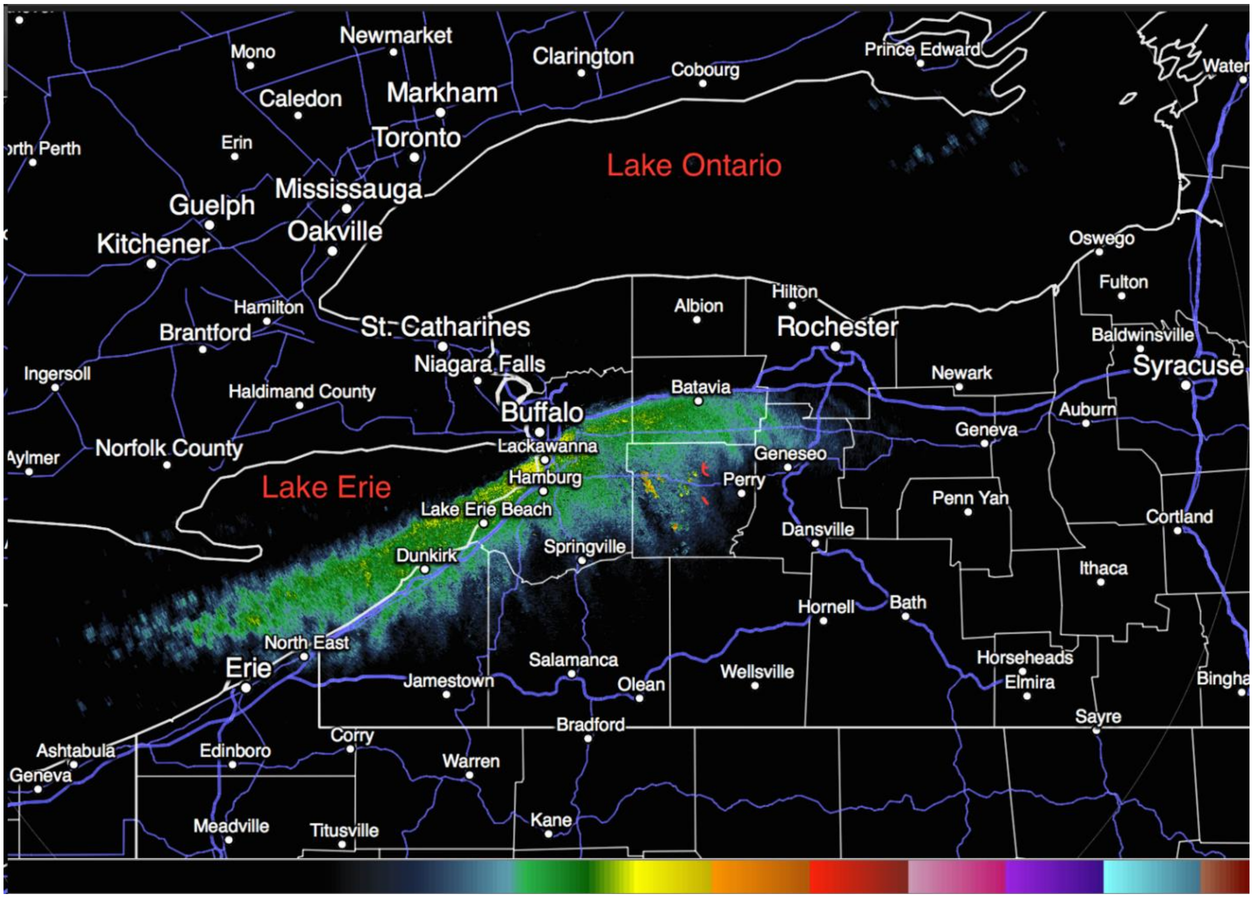

Figure 4 wind influences the moisture

2.1.3 Recovery phase:

The municipality decided to deploy a geographic information system (GIS) for the recovery phase. The County used the GIS to track and communicate the state of street conditions and storm-damaged properties, as well as inventory snow-dumping areas, and keep track of the response effort's map history.

Because of the severity of the snowstorm in 2001, the National Guard, surrounding counties, and even teams from Toronto, Canada, were called in to help. There was a lot of equipment available when combined with the local highway personnel; the challenge was deciding where to deploy it. To coordinate the activities, the county built an Emergency Operations Center (EOC).

2.1.4 Transportation Map Before event (first move from paper-based to GIS)

The New York State Department of Transportation (NYSDOT) established a presence at the EOC. While the NYSDOT normally uses a five-level rating system to assess highway conditions, the decision was made to use only three levels for this emergency. The highways were color-coded. Red indicates that the road is impassable, yellow indicates that one lane is passable, and green indicates that two lanes are open.

The EOC dispatched four-hour shifts of road assessment teams equipped with paper maps and color markers to record road conditions and report back to the EOC.

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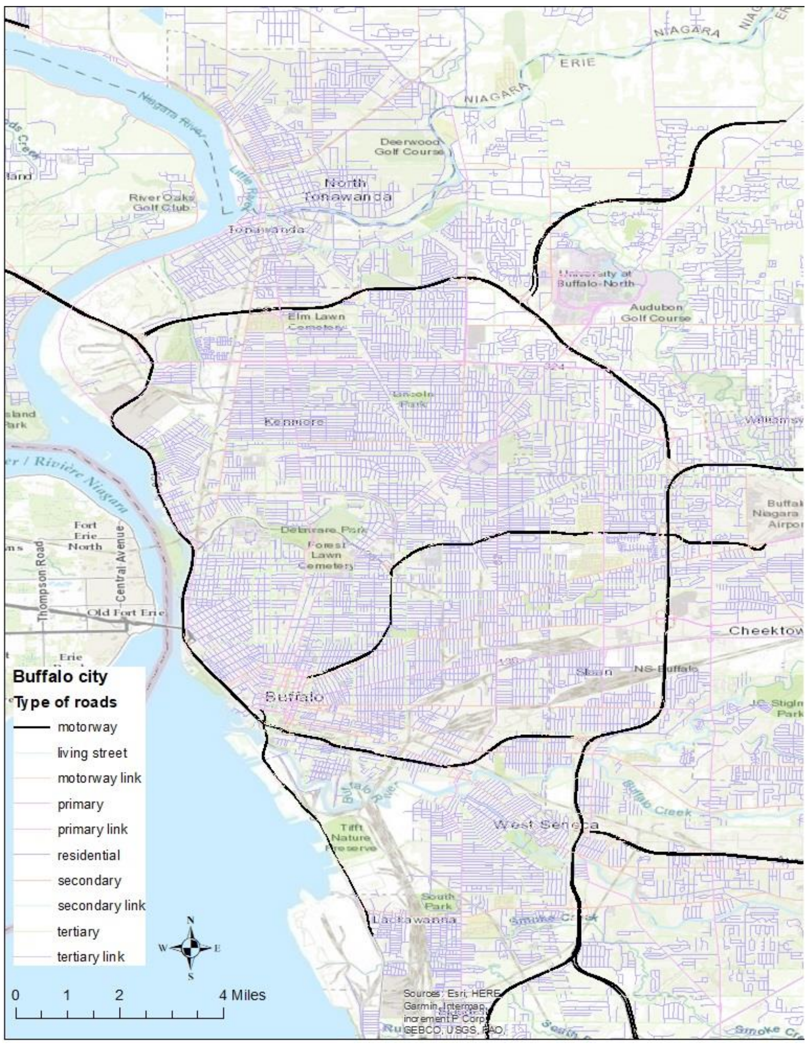

Figure 5 Transportation Map Before the event

2.1.5 Damage Map (Damaged structures and Road conditions map)

The use of this map is extremely important in occurrences that result in physical destruction (earthquake, avalanche, flood, etc.). This map is also known as the After Event Map. This map combines the damaged structure and road condition maps (figure 6), and it is not a good idea to separate these two because debris from damaged structures can also block the road, and in this case, the problem of blockage is not just snow. Having this map and keeping it up to date in real-time can help with a faster recovery phase and lower costs. The cost can be both monetary and human life. Making this type of map is also beneficial for crews who are unfamiliar with the city and its streets.

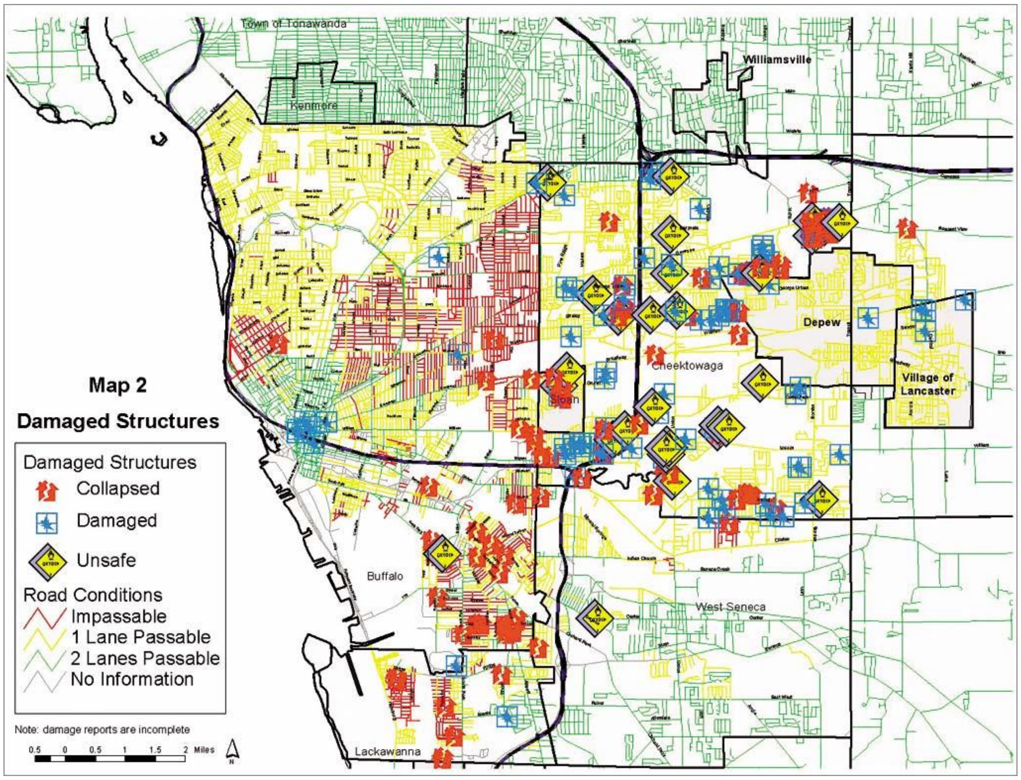

Figure 6 Damage Map

This event ended up with 30$ million costs but New York understood how to better deal with a snowstorm.

2.1.6 Trees Map

A treemap is crucial if the city has an urbanized tree system, as is the case currently because trees can create costs such as blocking a road or harming a property. Before 2001, buffalo did not have such a thorough map, and everything was done on paper. In many areas, the tree's position and species were not even on paper.

Within days after the storm, the city realized it would need to establish a new system to inspect and catalog all damaged trees around the city. The present tree inventory management system was not up to the task of assessing and updating the inventory on such a big scale at the time of the storm.

Since we do not have access to actual data, we made a vegetation coverage map instead of a trees map.[6]

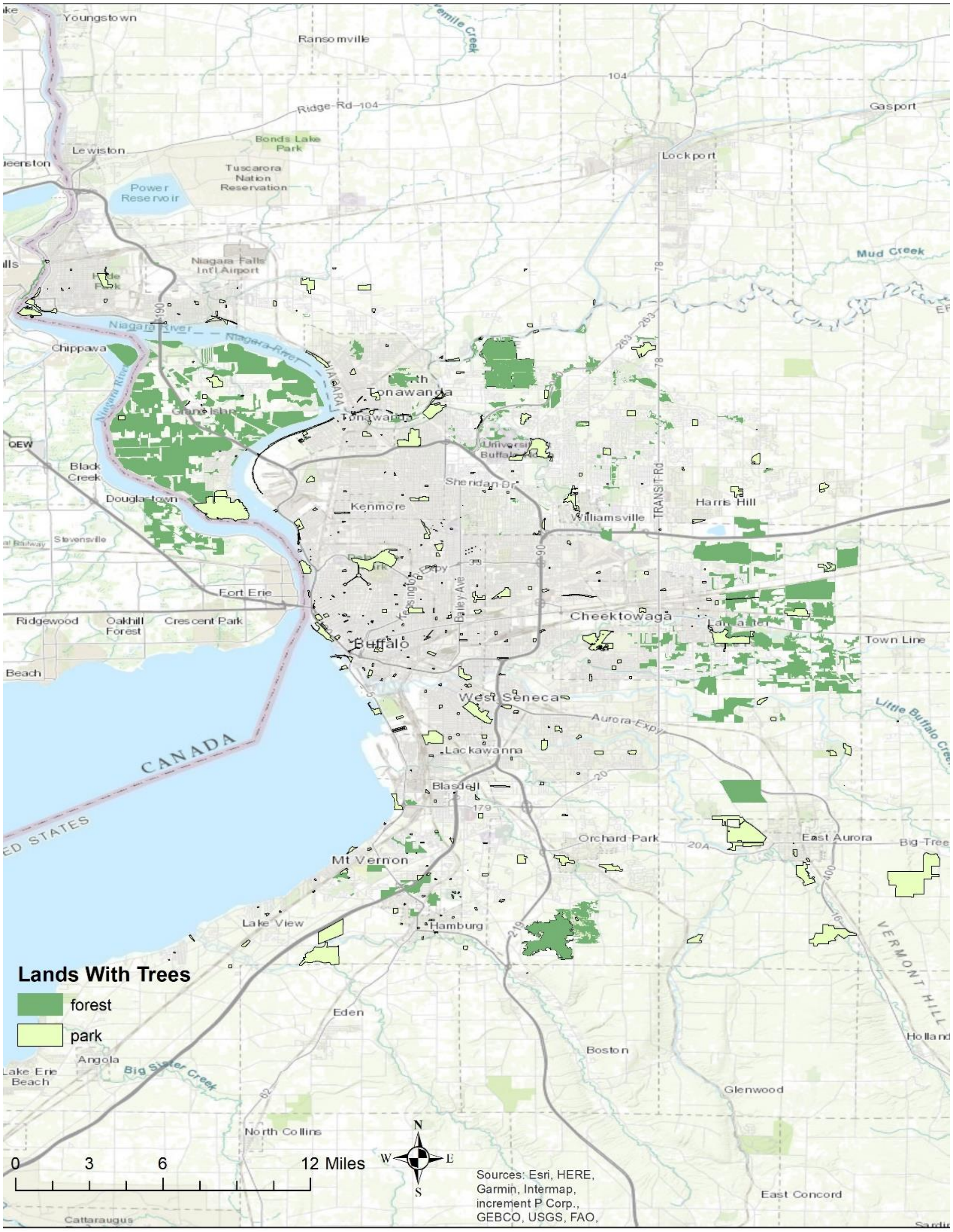

Figure 7 vegetation coverage map

Figure 8 picture of event's impact on one tree

2.1.7 Event's Total Precipitation

The 2006 snowfall was more powerful, resulting in higher costs and new experiences for Buffalo. The event began on October 12, 2006, with lake effect rain in the morning and afternoon on Thursday, and concluded on October 13, 2006, with maximum snowfall or ice accumulation of 150 cm.[7]

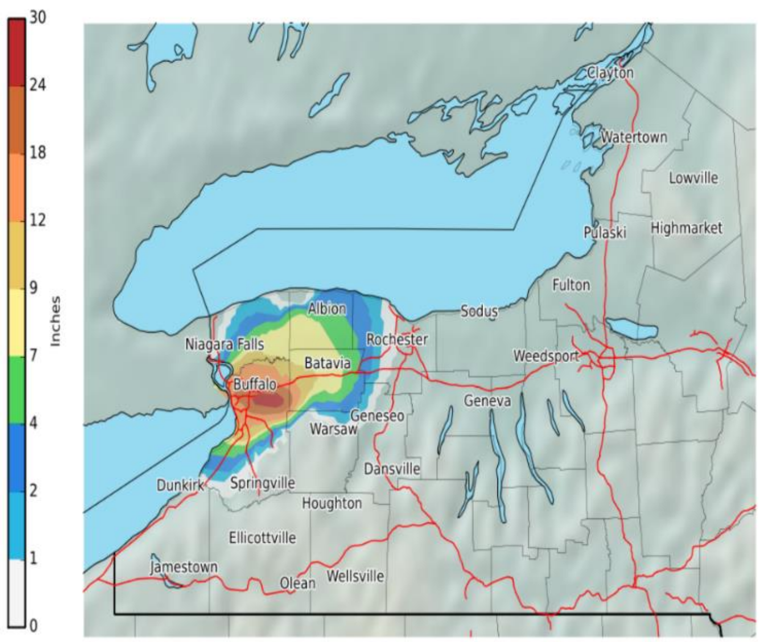

Figure 9 Event's Total Precipitation

Figure 10 event's pictures

The city had a problem with forecasting, the infrastructure, and pre-event planning were so insufficient that they served yet another lesson for municipalities dealing with snowstorms. The city experienced a power outage and a telecommunications problem during the disaster, making emergency services inconvenient and increasing the cost and fatalities.[8]

A 24-inch (61 cm) blizzard on February 13, 2006, knocked off power to 400,000 people. 100,000 houses were without power for a week. Thousands of people were without power for ten days. When the storm hit, hundreds of people were injured, and 15 people died. It was estimated that 90% of the city's trees had been cut down. When all charges are added up for each municipality, including overtime and other storm-related costs, the total amounts to 530 million USD. During storms, debris removal costs more than $150 million. A total of about three million cubic yards of material had to be removed.

2.1.8 Power Outage emergency map

After every outage in a snowstorm, the outage map is critical for emergencies because it allows us to determine which regions have the most people affected by the outage and prioritize them, preventing more fatalities and expenses. As a result, the most crucial factor is population per square meter.[9]

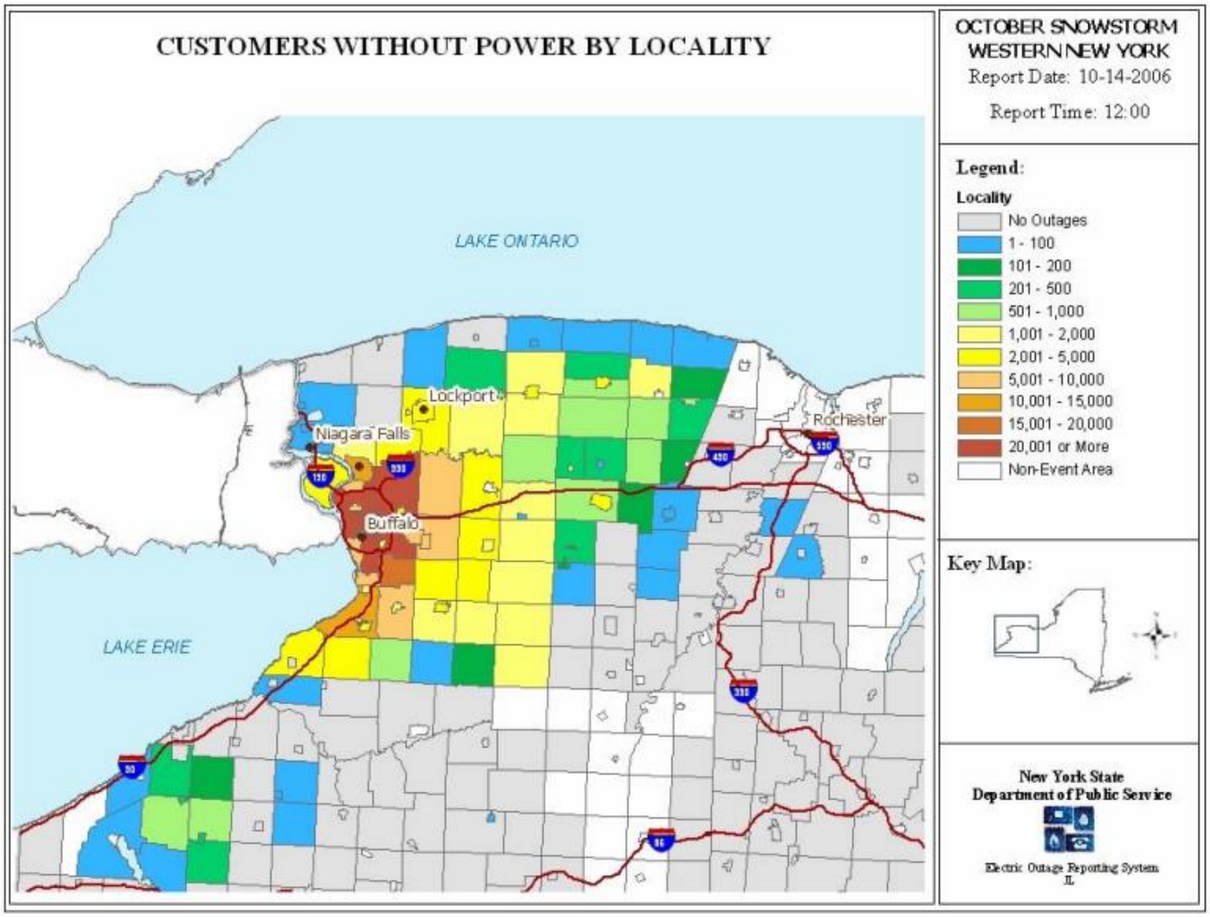

Figure 11 Power outage map

Part 105 of Commission rule 16 NYCRR (National Grid, New York State Electric & Gas Corporation) mandates electric companies to conduct an internal performance evaluation whenever an emergency lasts more than three days.

Buffalo City's outage management system and telecommunication network were modified as a result of this law. In general, the underlying cable, cellular, and wired telephone networks held up well against the storm for telecommunications facilities. Backup power systems permitted customers whose outside plant remained powered and secure to continue receiving service when commercial power was lost.

This was the first time the city had had a power outage of this magnitude during an event, and it prompted the creation of the city's outage system and mapping.

2.1.9 Sensitive places map

It is critical to avoid many dangers in every situation. When one event triggers additional events or when several events occur at the same time, it is referred to as a multi-hazards condition. A snowfall might result in a technical danger called (Natech). What is Natech? [10]

Natural catastrophes such as earthquakes, floods, and storms can cause hazardous chemicals to leak from chemical facilities or oil and gas pipelines. These mishaps are also known as Natech mishaps.

Perhaps certain factories, labs, or military structures will be unaffected by the blizzard. Putting them on a map offers them visibility and attention.

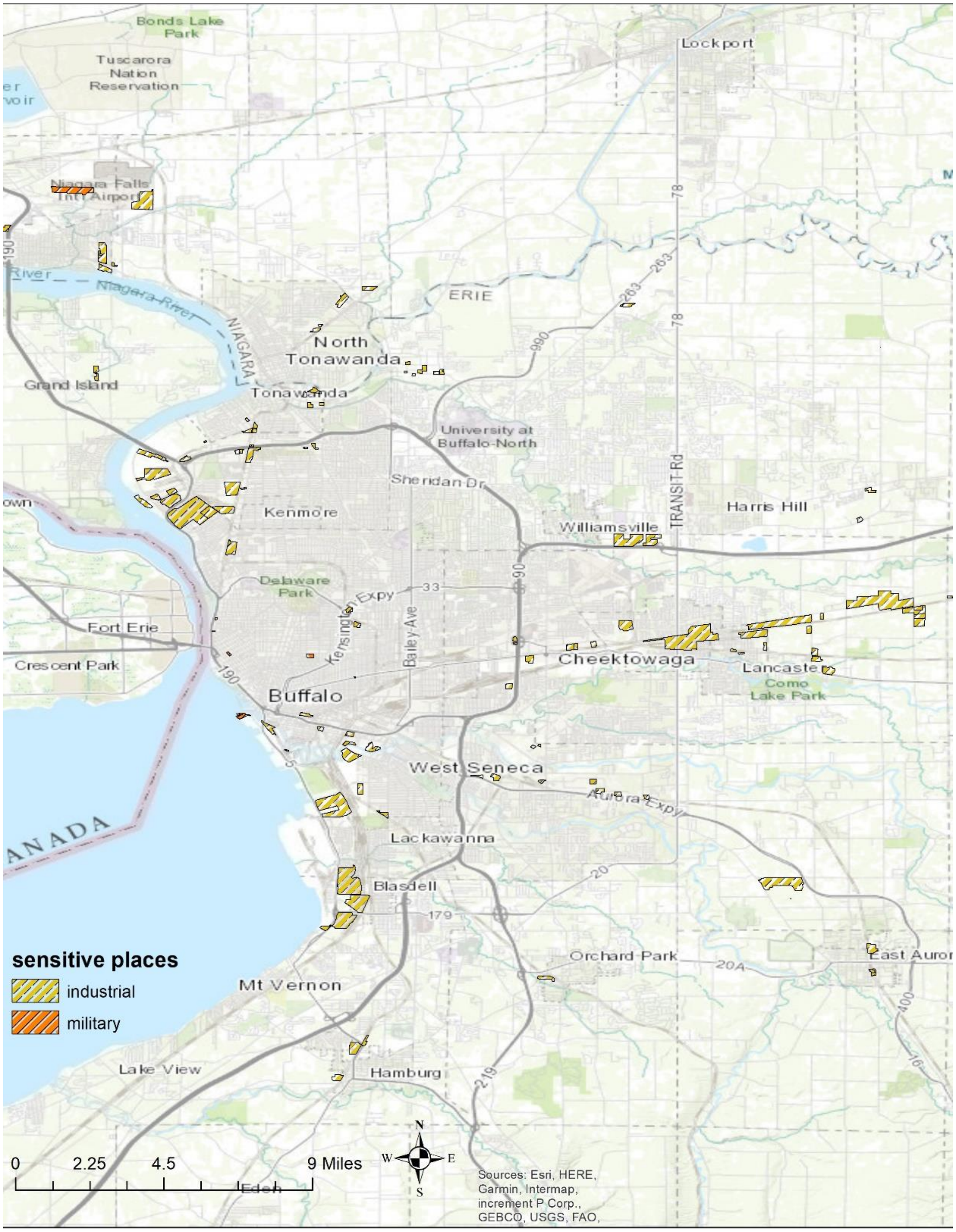

Figure 12 Sensitive places map

2.1.10 Farmlands

Having agricultural locations aids us in having some ideas on how to keep them secure throughout the preparedness phase.

Figure 13 Farmland Map

2.1.11 Before event mapping (state scale)

Having even a basic idea of which sectors are more vulnerable to crises aids in pre-event planning and lower the cost (monetary, life...). Governments and disaster response agencies may use these maps to figure out how to distribute resources to enhance resilience and control venerability.

2.1.12 Annual average snowfall

Annual average snowfall is a map showing the State's historical average snowfall totals. The Cooperative Observer Program (COOP) of the National Weather Service gathers daily meteorological data, including snowfall. The yearly average surface from the COOP stations was created using monthly totals from 1960 to 2012. This diagram depicts locations that are likely to be affected by future events and are prone to heavy snowfall.[11]

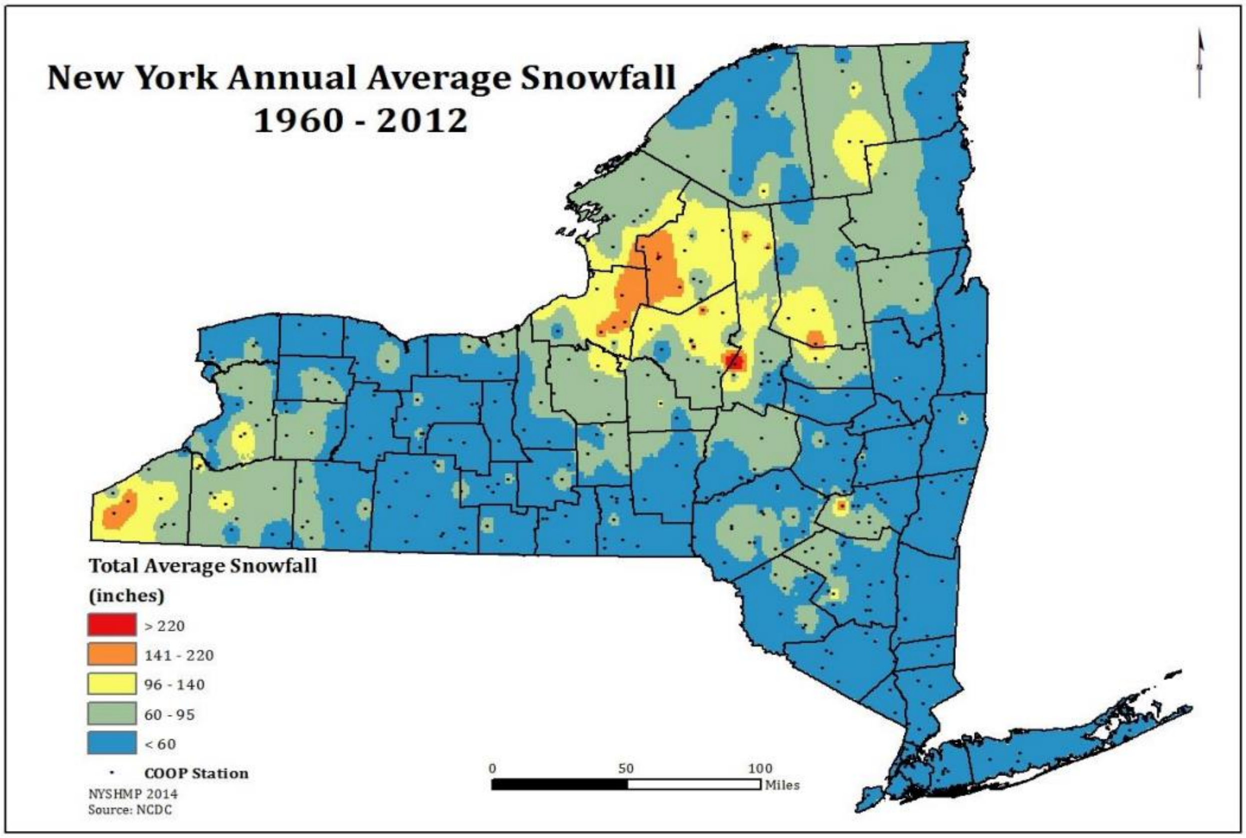

Figure 14 Annual Average Snowfall 1960-2012

2.1.13 Presidential disaster declarations for winter events

Winter events from 1960 to 2012 are listed by county. From 1960 to 2012, Western, Central, and Northern New York had the highest number of Severe Winter Storm occurrences. Chautauqua, Erie, Oswego, Oneida, Lewis, St. Lawrence, Franklin, Clinton, and Essex counties reported between 290 and 370 occurrences on average. Suffolk, Nassau, Bronx, Queens, Kings, Richmond, Rockland, and Westchester Counties had the lowest number of incidents, ranging from 60 to 89.

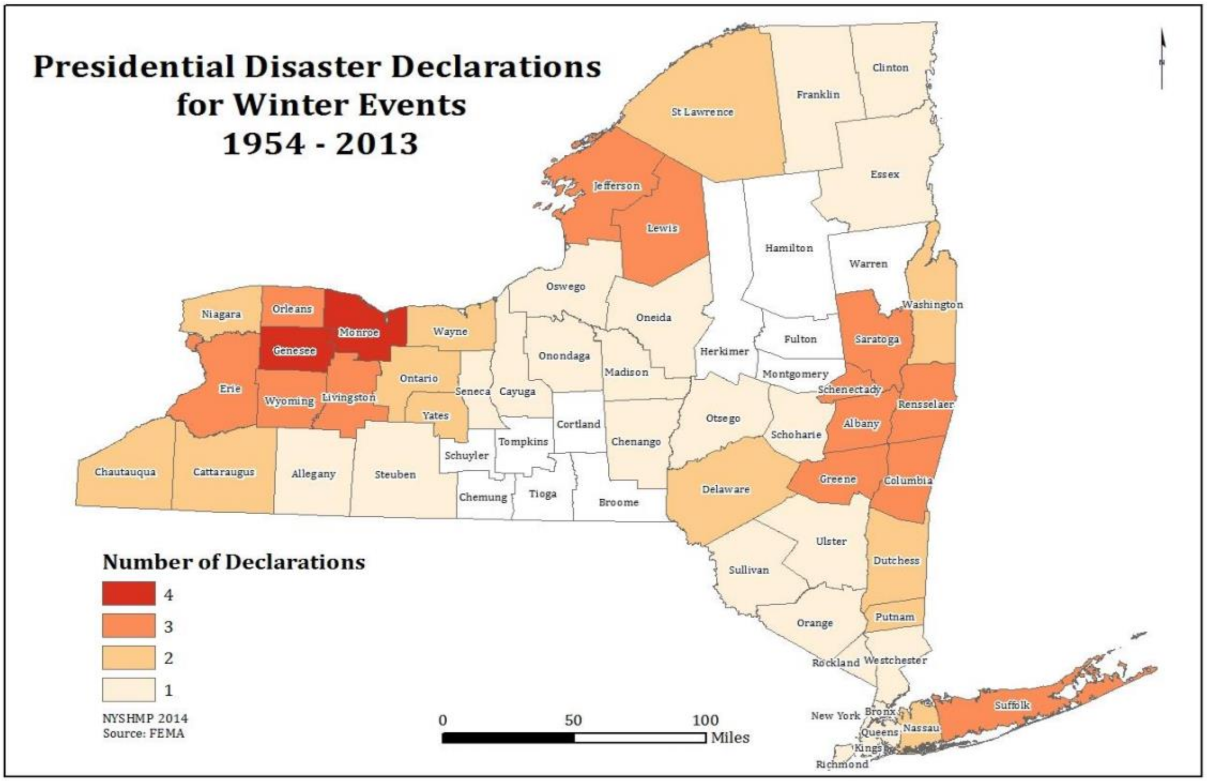

Figure 15 presidential disaster declaration

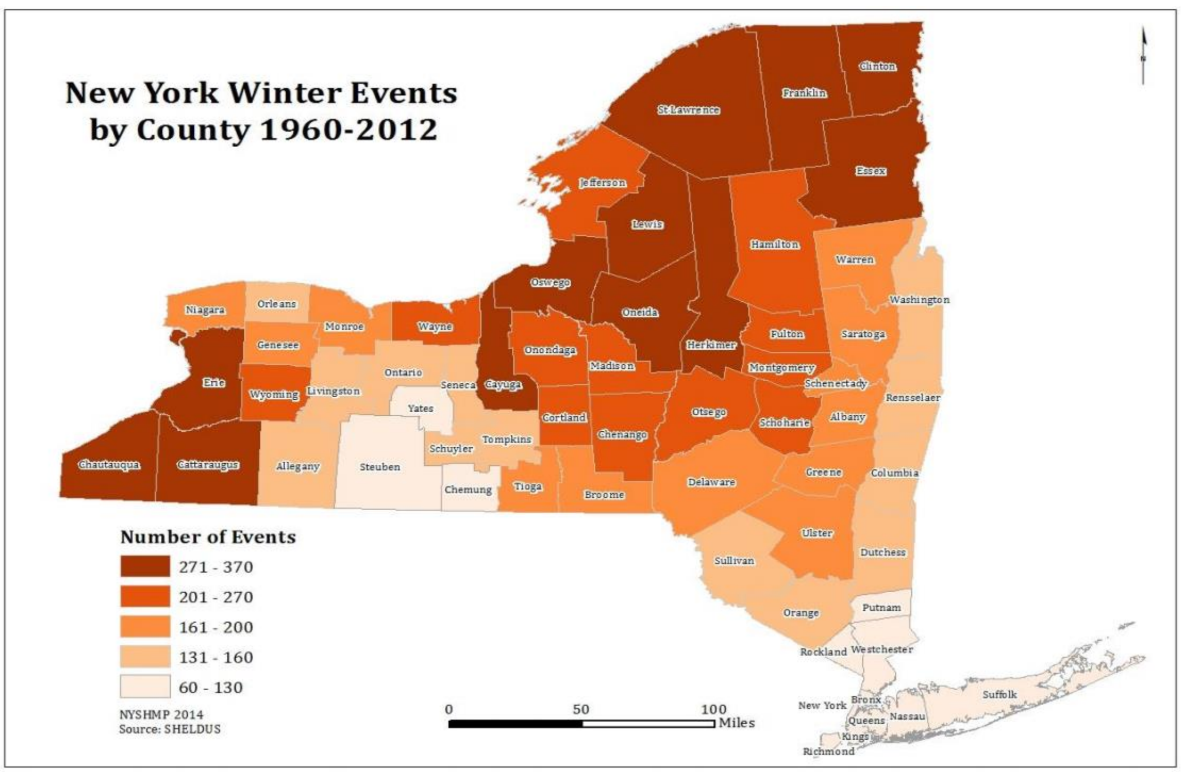

Figure 16 Historical Events

2.1.14 Property historical damage

This map can show where there is a lack of infrastructure and where it needs to be addressed. The total cost of property damage caused by severe winter storm events from 1960-2012. Over the past 52 years, 11,876 severe winter storm events occurred throughout NYS. Counties reporting the highest amount of property damage were Monroe, Erie, Genesee, Herkimer, and Niagara collectively exceed more than $276 million in property damage.

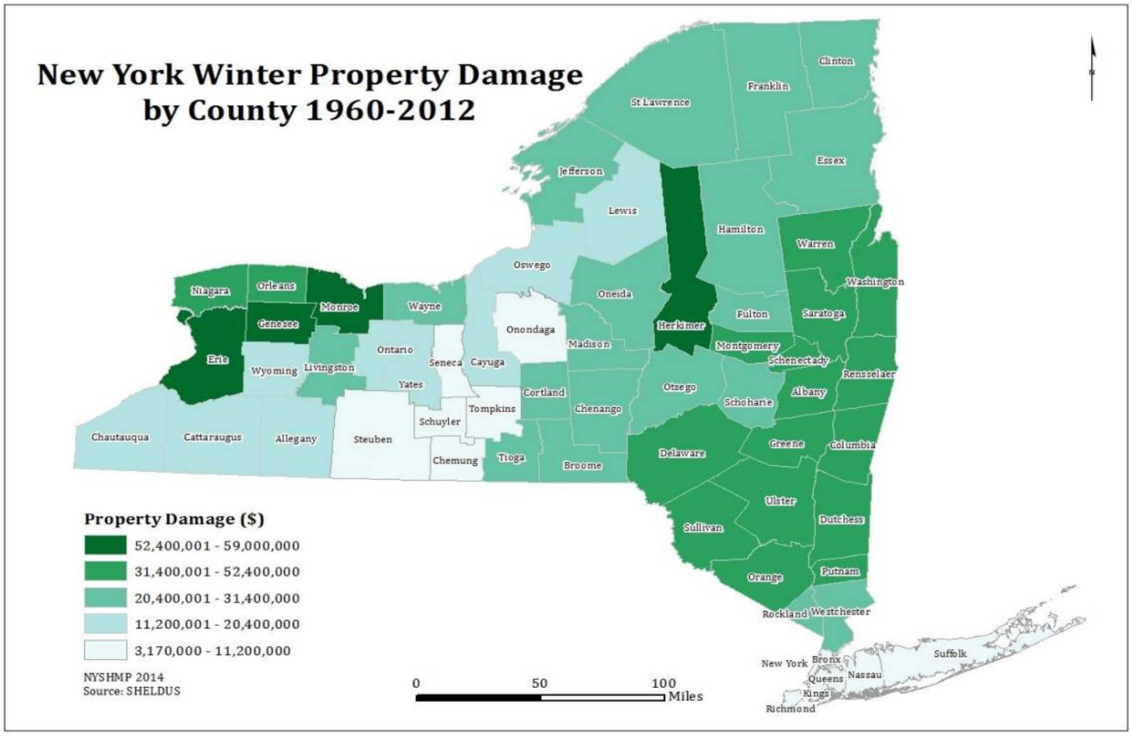

Figure 17 Winter property damage

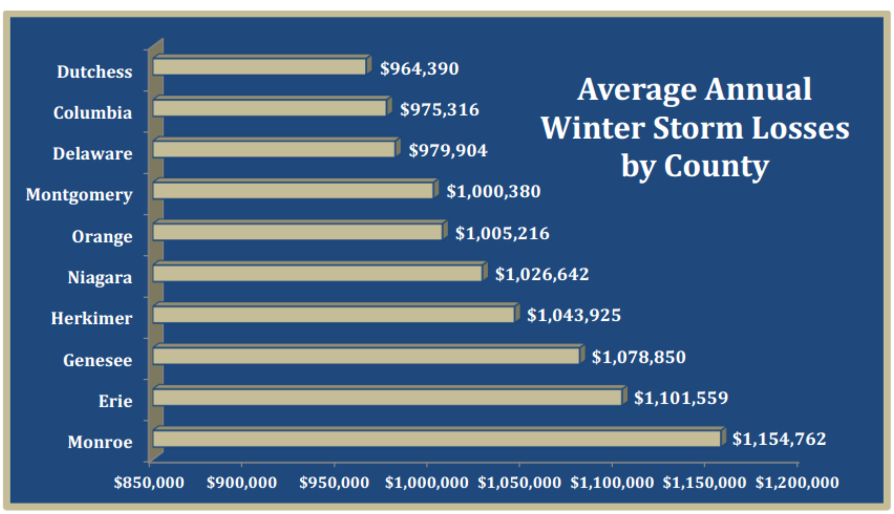

Figure 18 Average annual winter storm losses by country

2.2 Flood with atmospheric blocking and bathtub effect

The Hawkesbury-Nepean Valley (the valley) has a floodplain area of 425 square kilometers. It is mostly located in four rapidly rising Western Sydney local government areas: Penrith City, Hawkesbury City, The Hills Shire, and Blacktown City. It encompasses Penrith, Richmond, Windsor, and some adjacent suburbs.

The valley is prone to sudden and deep floods, which have a long history of causing damage and, in some cases, dredging.

As they reach the sea, most river valleys tend to broaden. In the Hawkesbury-Nepean River, this is not the case. Natural chokepoints are created by narrow sandstone gorges that run between Sackville and Brooklyn.

The five major tributaries flow back up and rise quickly, flooding the floodplain deeply and widely. It's similar to having five taps turned on but just one plug hole to let the water out of a bathtub.[12]

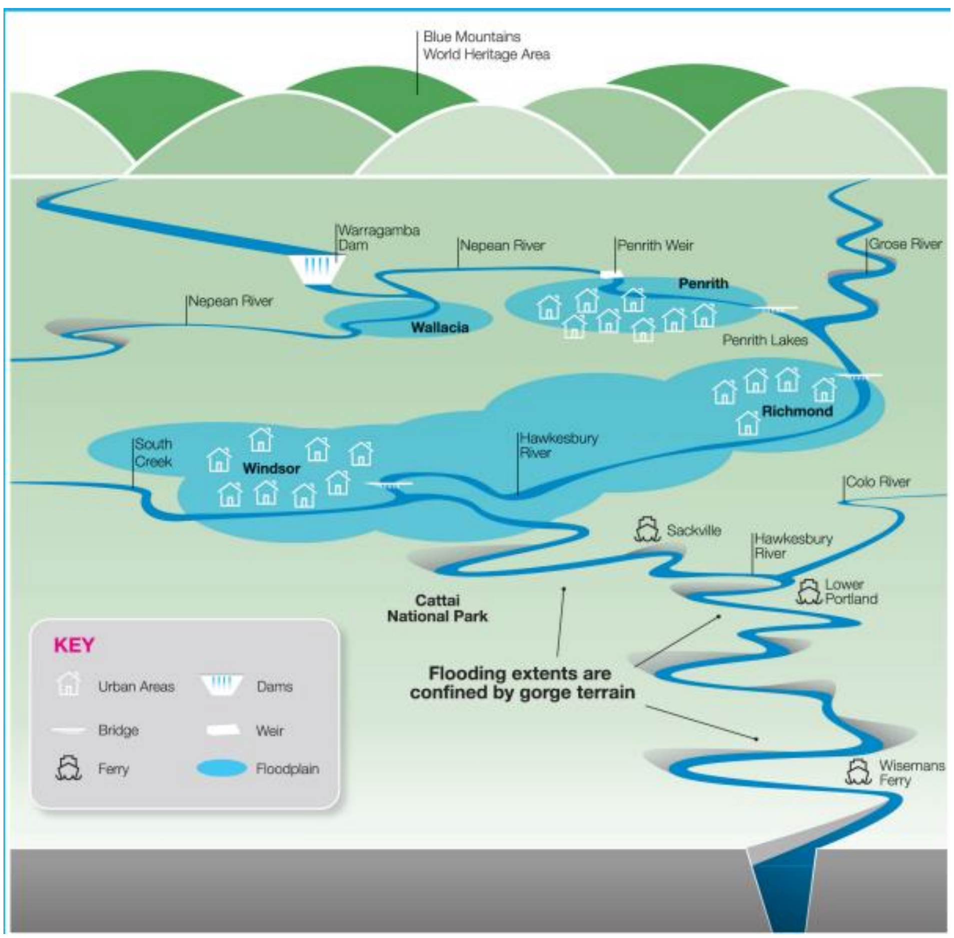

Figure 19 The 'bathtub' effect in the Hawkesbury–Nepean Valley

2.2.1 Sydney 2021 (Eastern Australian flood)

Figure 20 Study Area

New South Wales, the Mid North Coast, the Hunter Valley, and Western Sydney will endure a flood event from March 18 to March 29, 2021. Heavy rains poured in Queensland, Logan City, and the Gold Coast during summer, causing the region's worst flooding in decades. In four days, Sydney, the Hunter, and the Mid-North Coast received between 400 and 600 millimeters of rain, with some areas receiving up to one meter. 18000 people were evacuated, and many individuals perished as a result. Crops and cattle have been lost by farmers. There have been five confirmed deaths. The damage cost of the catastrophe is expected to exceed one billion dollars. [13]

2.2.2 Atmospheric patterns and climate divers Map and Event's Total precipitation map

To get a complete picture of a region, you need to look at its climatic patterns and how different climate drivers affect it.

Atmospheric blocks are usual in some areas like Australia. Atmospheric patterns tend to repeat themselves, after a block has formed, the same cycle repeats itself for several days to weeks. This results in floods, temperatures that are above or below average, and other meteorological extremes. It is feasible to anticipate it with great precision up to many days ahead of time.

Because high pressure covers a vast geographical area and travels slower than low pressure, blocking across broad areas is most prevalent. However, low pressure can also produce atmospheric blocks. [14]

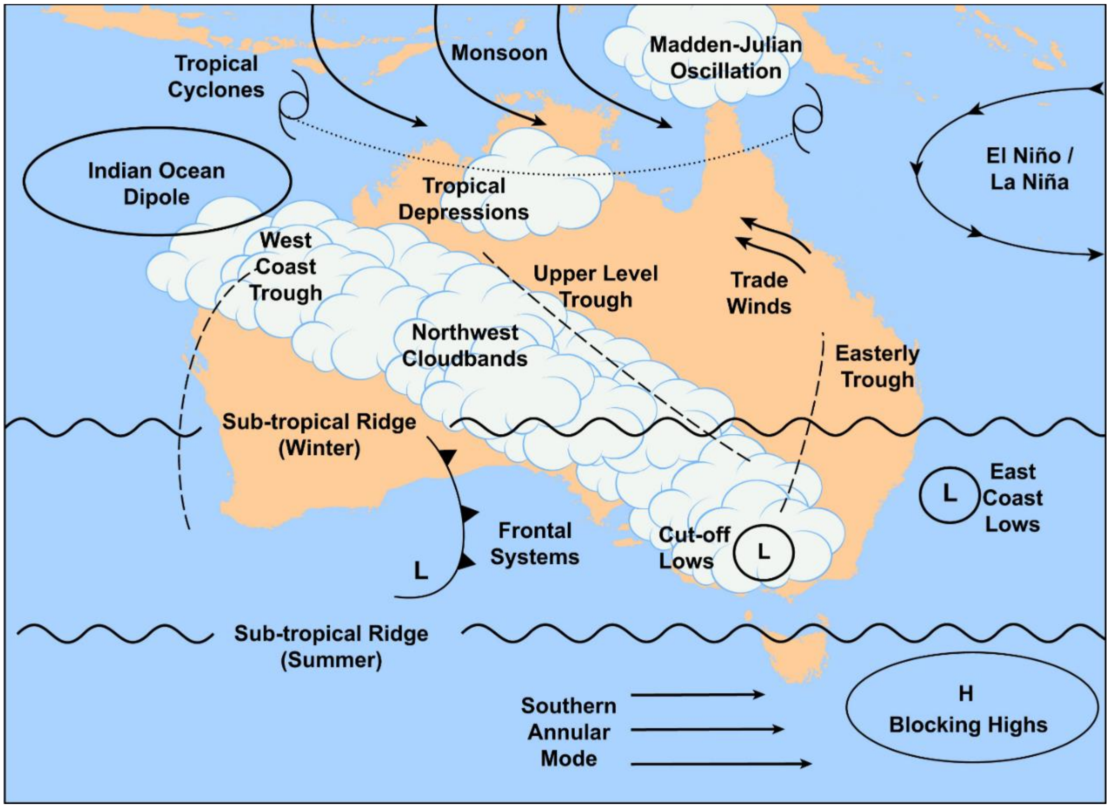

Figure 21 Atmospheric patterns and climate drivers in Australia

The South West Land Division encompasses the southwest of Western Australia as well as the WA Wheatbelt (SWLD). The climate of the SWLD is impacted by several global and local climatic factors, which are listed in the table below:

Climate driver		Influence on rainfall
Sub-tropical ridge	Band of high pressure across the mid-latitudes,which moves north (equatorward) in winter and south (poleward) in summer	November-April can block cold fronts for days or even weeks at a time. Winter - moves north allowing cold moist air to create rain
Indian Ocean Dipole	Difference in sea surface temperature between western and eastern Indian Ocean	May-October either negative (more rain), neutral or positive (less rain)
Southern Annular Mode	North-south movement of the westerly wind belt that circles Antarctica. Drives cold front movement	All year
El Niño/Southern Oscillation (ENSO)	Ocean and atmosphere conditions of the Pacific Ocean	Limited influence, in an El Niño winter/spring rainfall can be lower than average due to a weaker Leeuwin current

Figure 22 global and local climatic factors

Volatile, Dangerous, and Dynamic is how the incident in Australia has been described. Blocking High in the Tasman Sea drove a powerful, low-pressure system into New Southwest, resulting in heavy rain.

The rain totals map for the week ending March 23rd, 2021. [15]

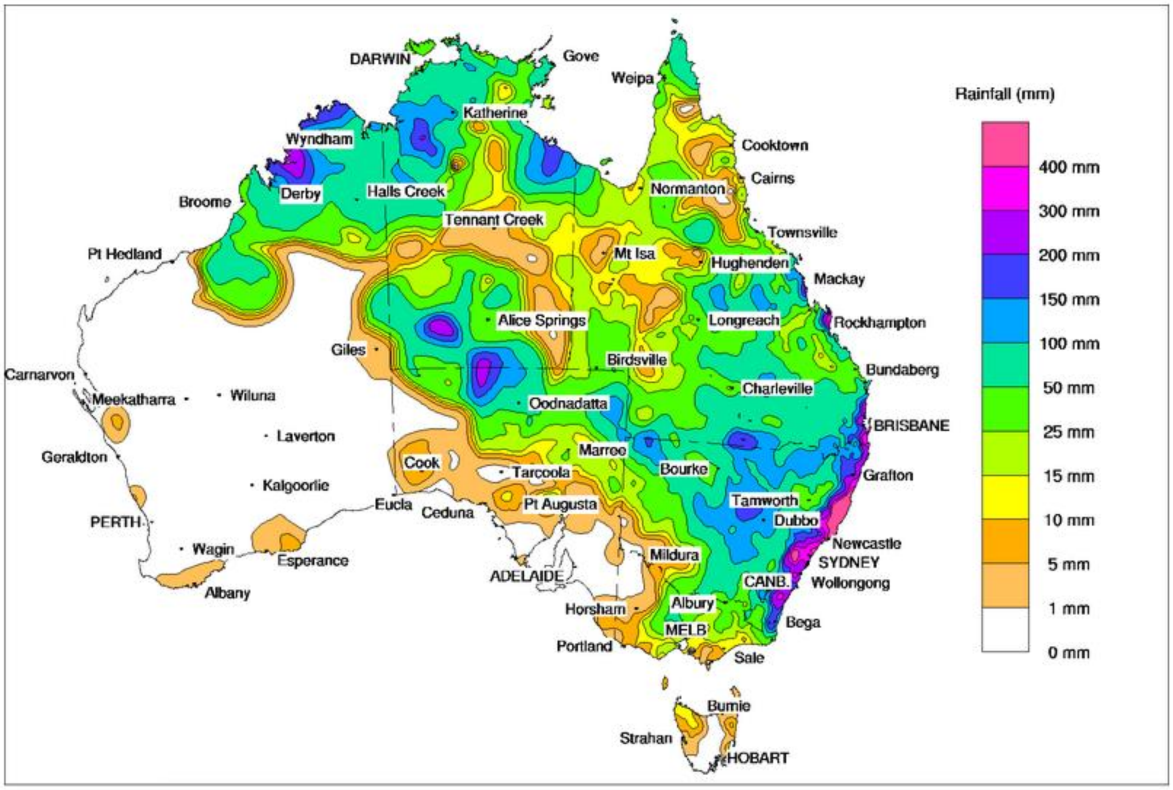

Figure 23 Event's Total precipitation map

Figure 24 pictures of the event

2.2.3 Before Events Map

Before events, a map provides a comprehensive perspective of a region, allowing for a more detailed analysis. Prior mapping can also reveal which regions are more vulnerable to flooding or drought (which is not the case here).

The preparation process is aided by a map created before the event.

2.2.4 Bathtub effect Map

The city of Hawkesbury in the local government area of New South Wales, Australia, has been flooded. Because it has five major rivers that pour water into the valley during a flood, Nepean Valley is so vast and deep. South and Eastern Creeks, Warragamba River, Nepean River, Grose River All of these fluids must eventually reach the sea, but natural choke spots where the river narrows impede the flow through this valley, a phenomenon known as the bathtub effect.

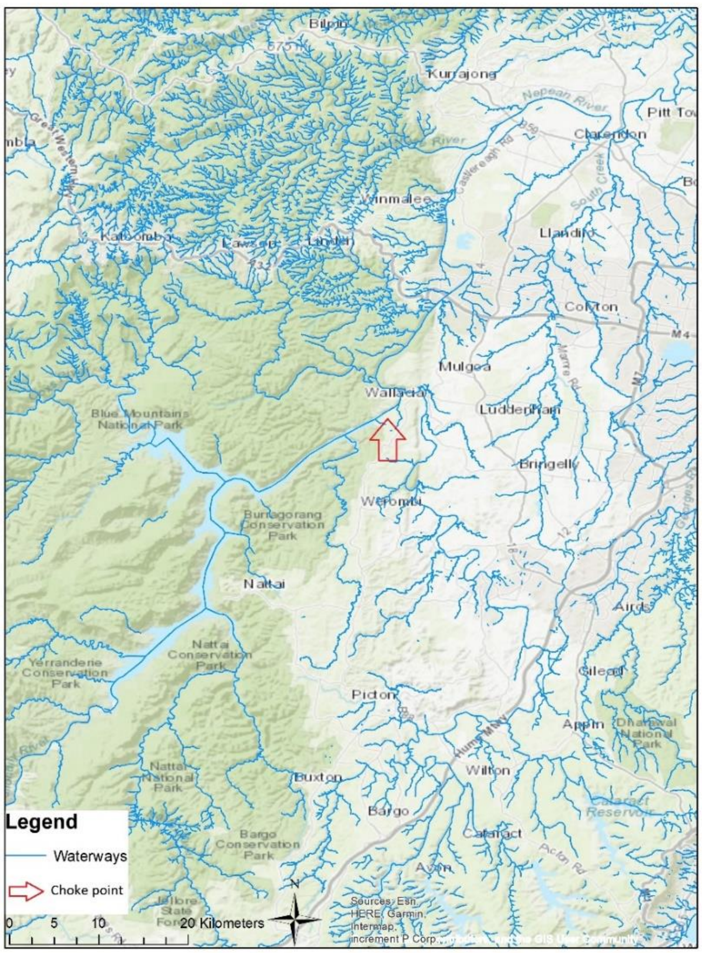

Figure 25 Wallacia chokepoint map

Because there is just one plug hole letting water out, water backs up and begins to fill the floodplain. The worst flood in Walachia reached depths of about 20 meters above typical river levels because water is trapped in this narrow valley. The second chokepoint farther downstream creates the floodplain in Penrith and Emu Plains. Low-lying regions surrounding Emu Plains and Peachtree Creek are first affected since Penrith has naturally high riverbanks that hold the water back. Floods have swept as far east as Woodruff Street in Penrith in the past. The water level was only 12 meters above average. The floodplain in Richmond Winds is generally flat and broad, allowing floodwater to swiftly spread across a large region during the greatest flood on record when the river rose 19 meters above its usual height. Floods are extremely hazardous and catastrophic because of the bathtub effect.

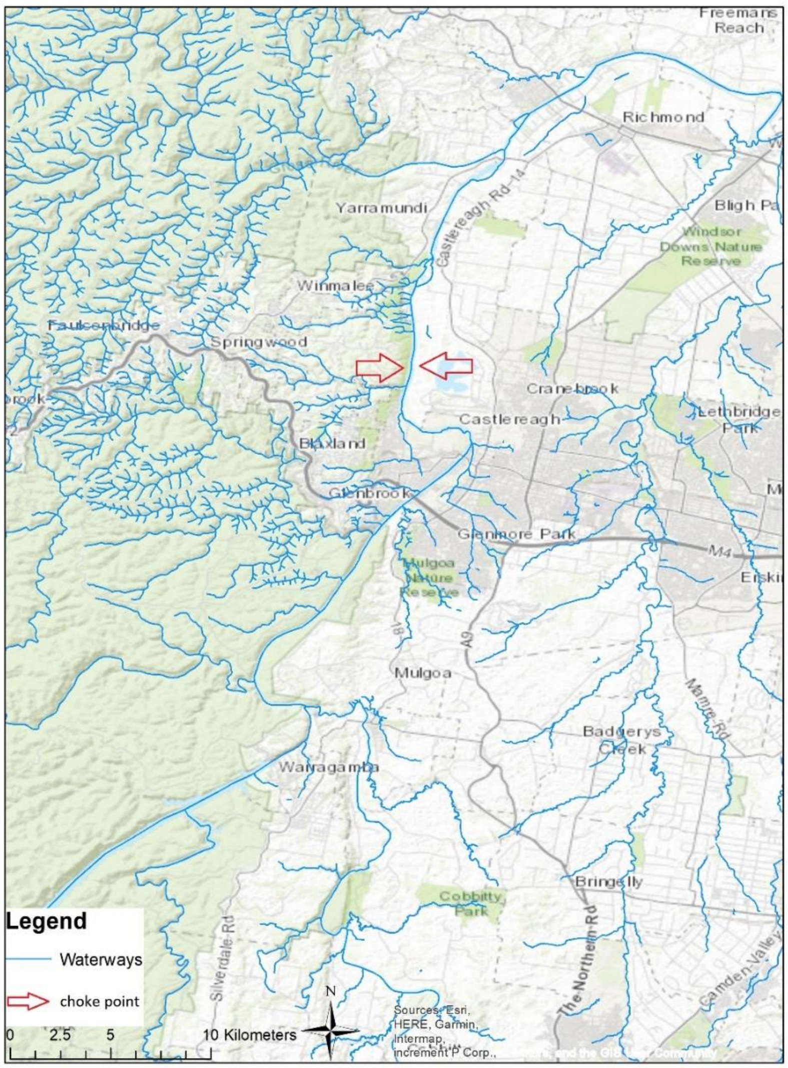

Figure 26 Castle Reagh chokepoint map

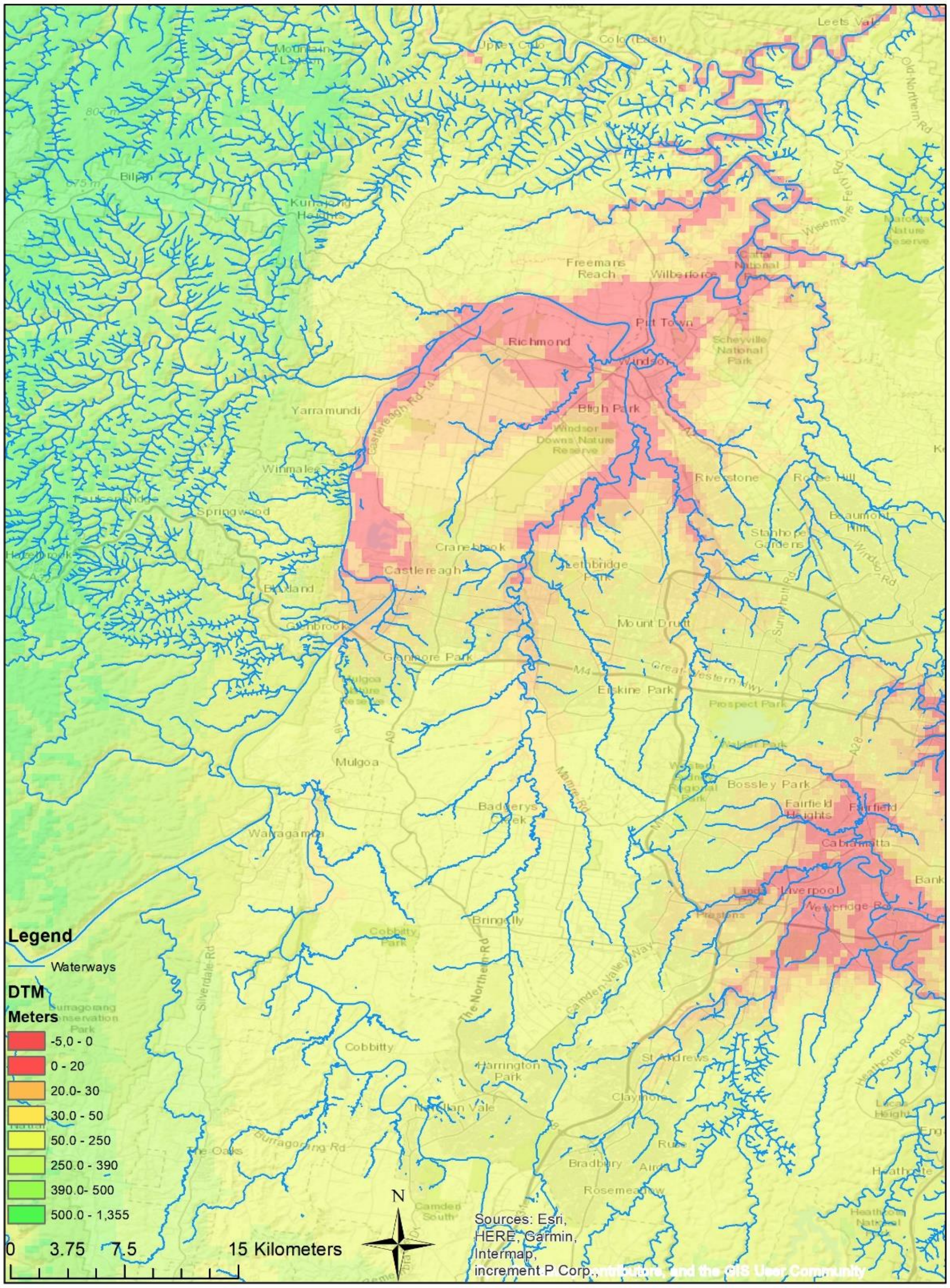

Figure 27 bathtub area map

The red regions indicate locations that are likely to be flooded and require appropriate engineering to reduce vulnerability and exposure, which are two key components of risk assessment. [16]

2.2.5 Main Road Map

It is critical to know which routes are critical and have greater capacity during an emergency.

Figure 28 Main Road Map

2.2.6 Flood Hazard Map (Danger Map) and exposed elements

Precipitation and surface-level are used to create a danger map. Due to precipitation, Sydney can withstand sea floods as well as river overflooding.

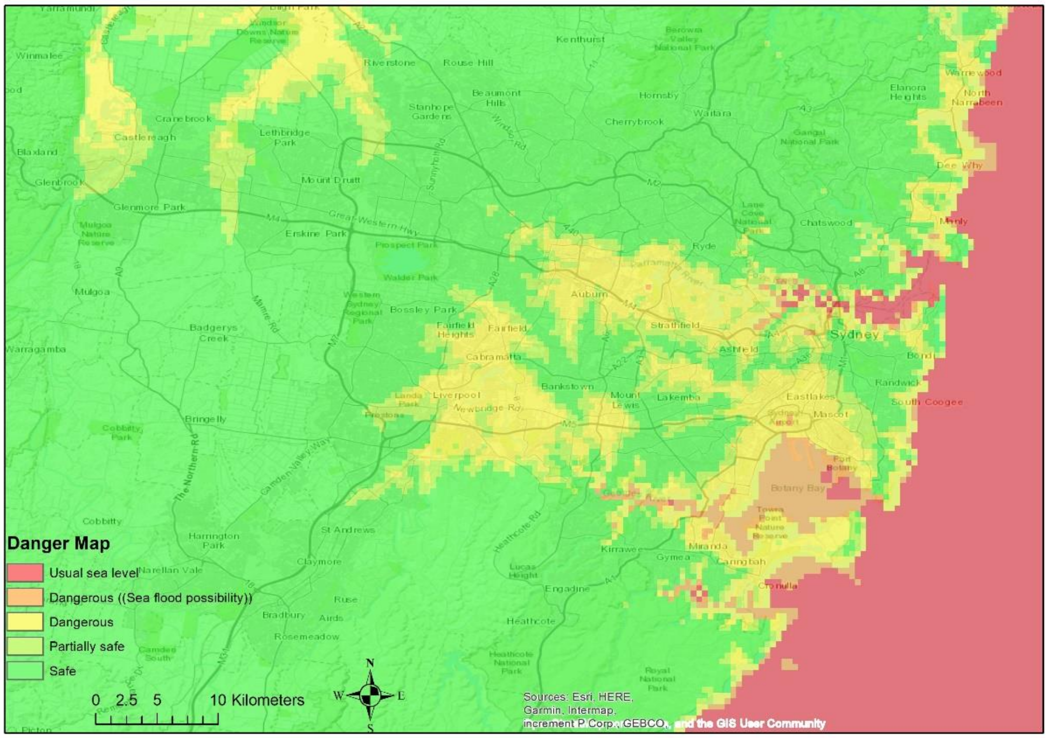

Figure 29 Flood Hazard Map (Danger Map)

Emergency elements and Danger Map; Hospitals, police stations, and fire stations are lifesavers in the emergency phase and even before it. To serve better, they should have stayed clear of risky flooding regions.

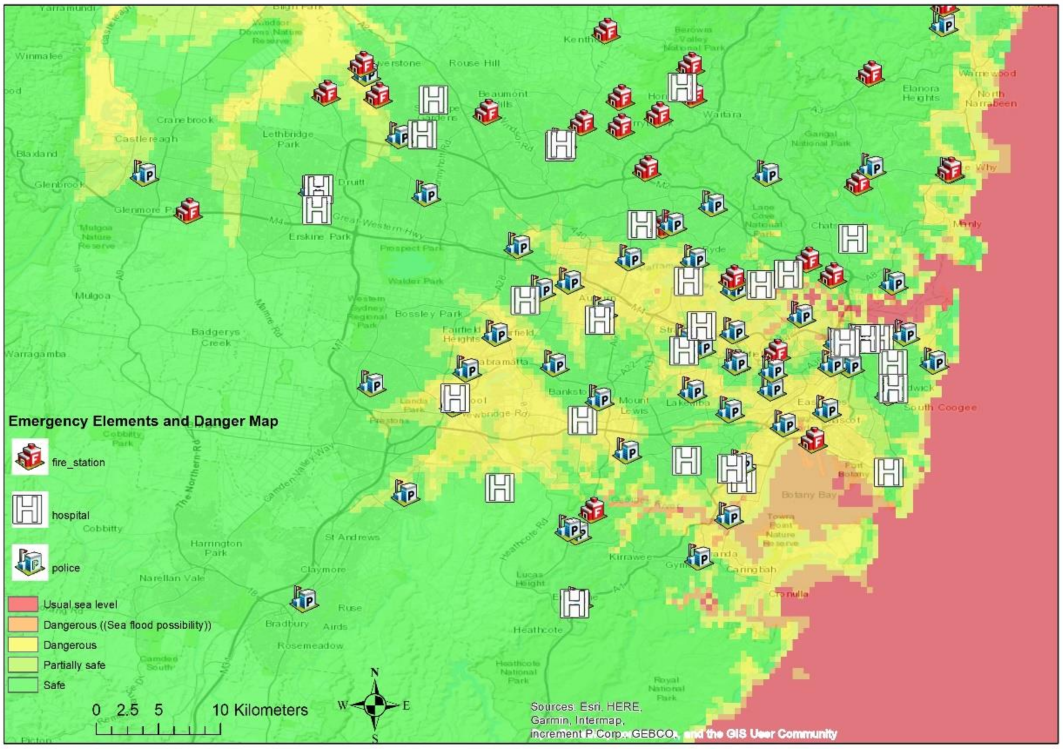

Figure 30 Emergency elements and Danger Map

Farm exposed to flood map; A flood may wipe off the fields. Fortunately, just a few tiny farmlands are at risk of flooding.

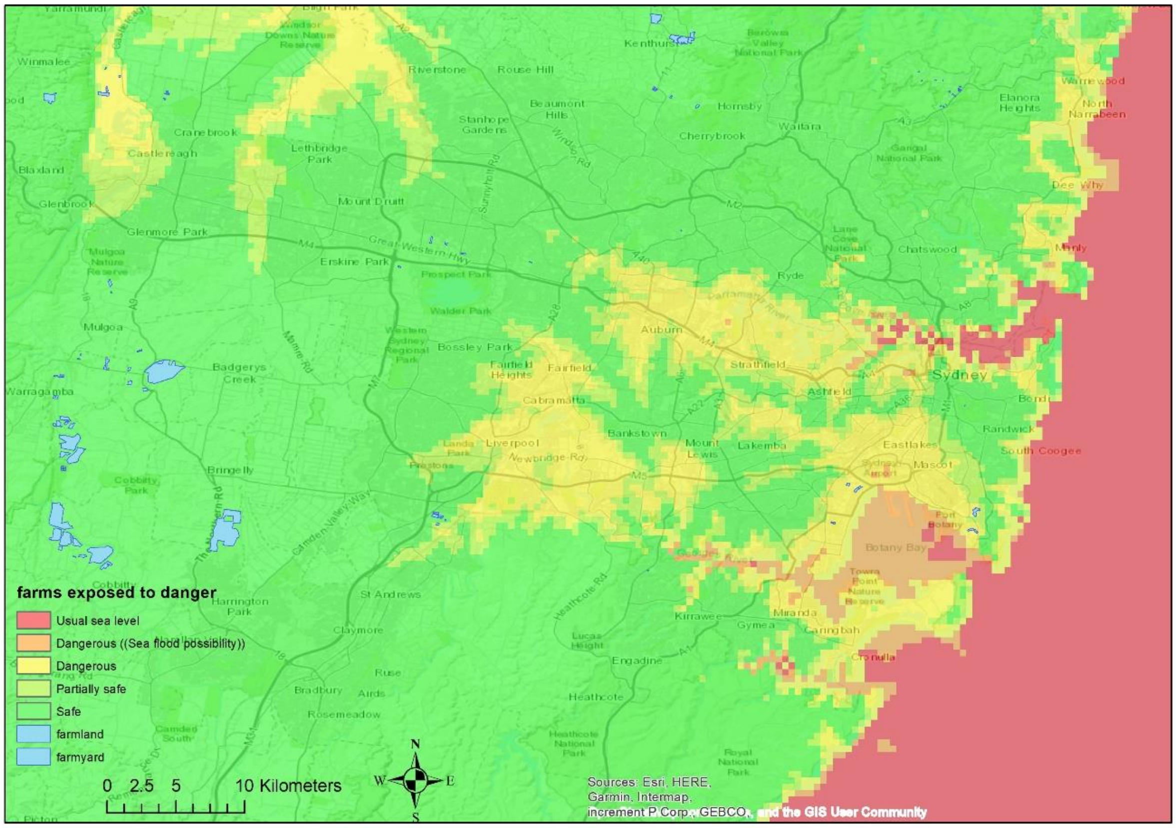

Figure 31 Farm exposed to flood.

Main Roads Exposed to flood map; This map can be created using a combination of a road map and a hazard map.

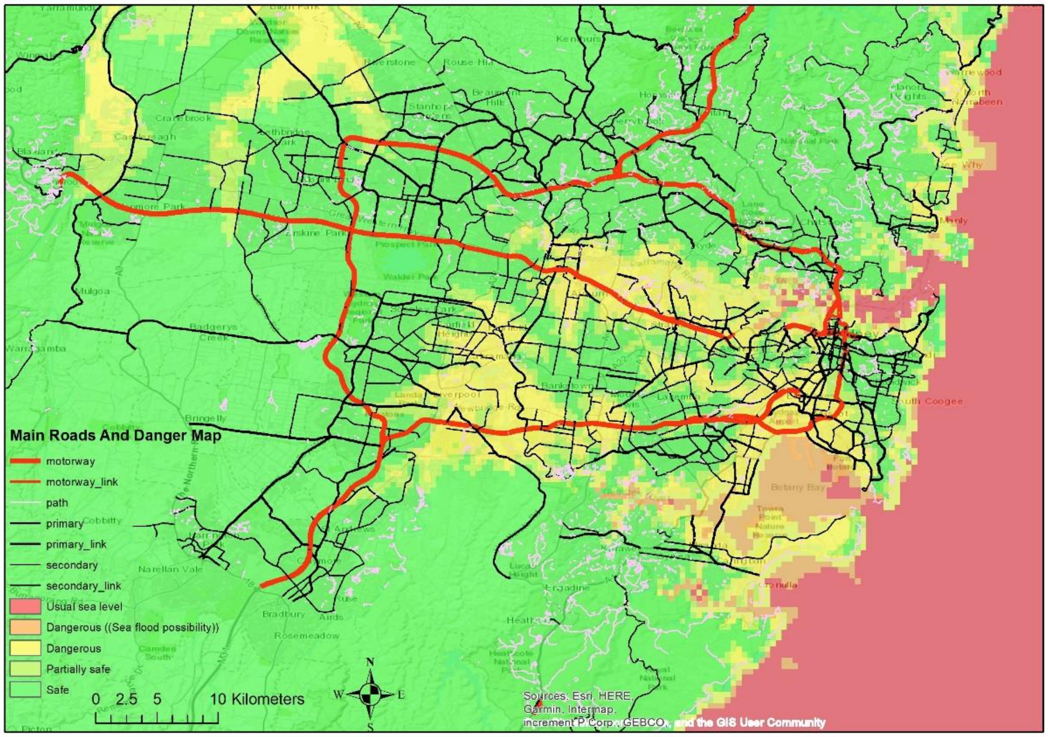

Figure 32 Main Roads Exposed to flood

Houses Exposed to Flood map; There is a lot of housing in flood-prone locations, which increases people's risk of being flooded.

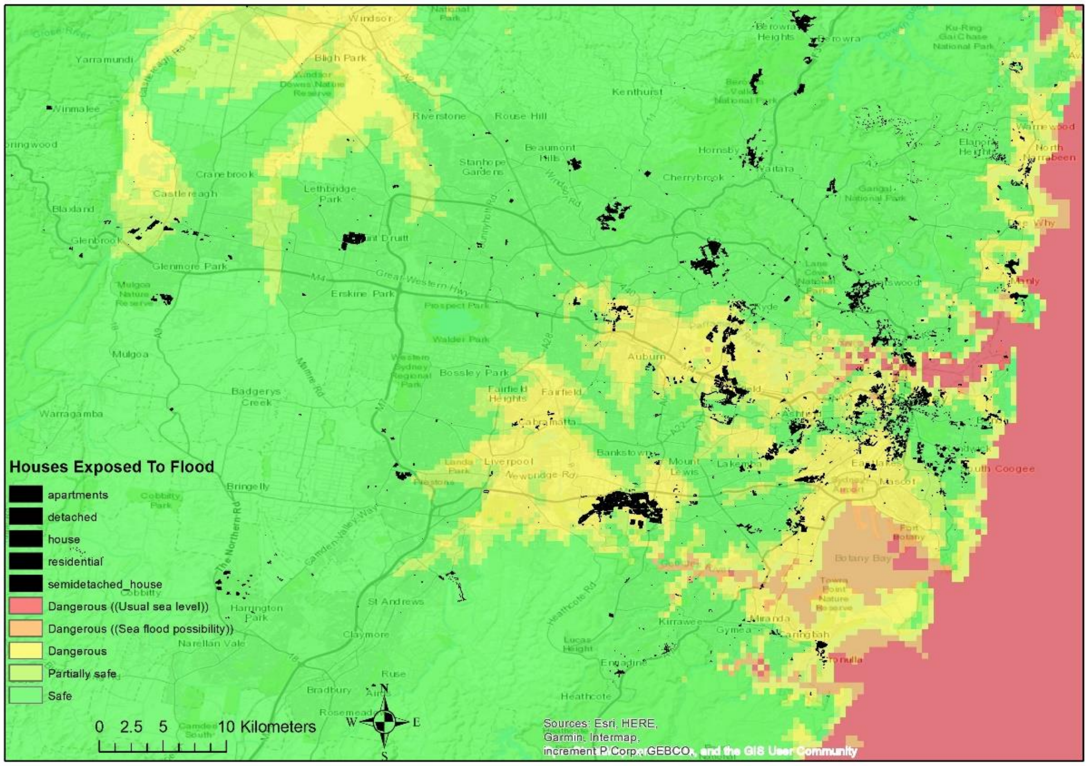

Figure 33 Houses Exposed to Flood

All buildings which are exposed to hazard map; Combination of all buildings layer and hazard map we can produce all building which is exposed to hazard.

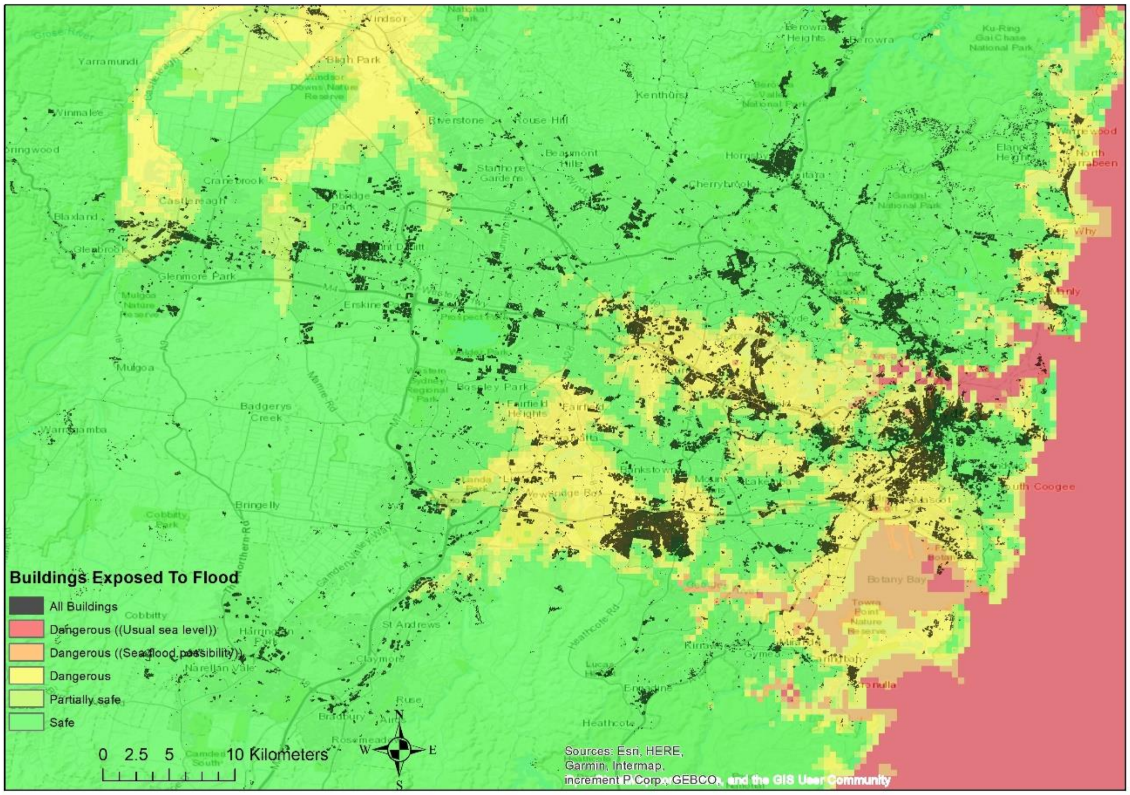

Figure 34 All buildings which are exposed

Dangerous buildings exposed to flood map; buildings such as military, industrial, factories, and manufactories can trigger another event known as NATECH.

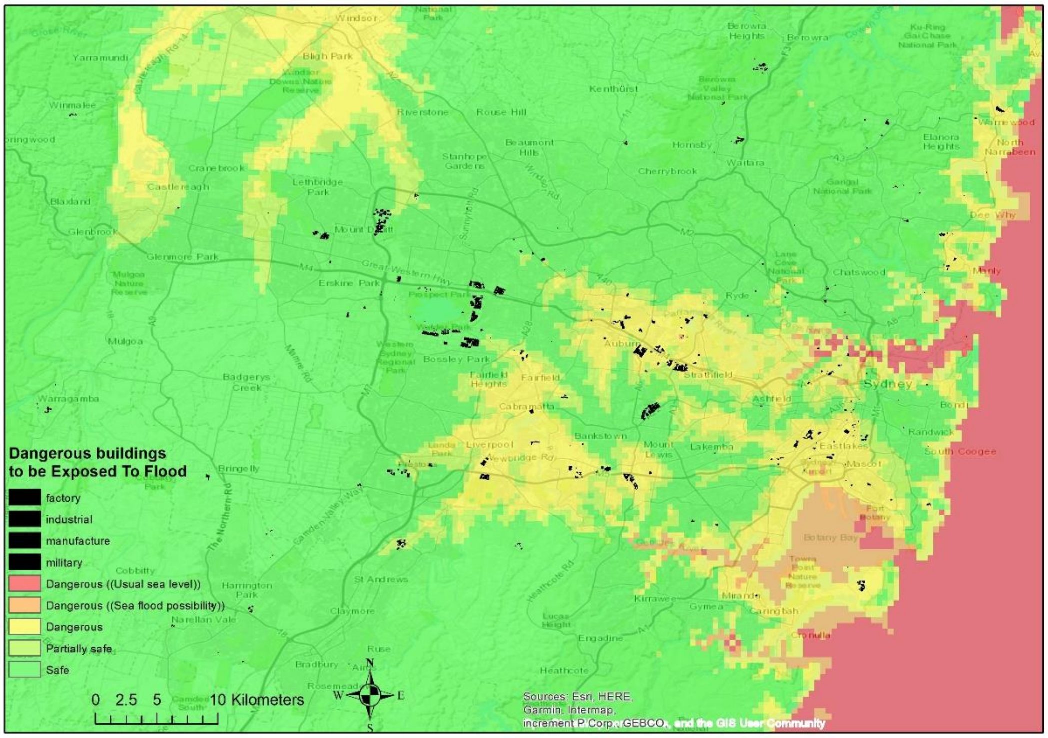

Figure 35 Dangerous buildings to be exposed to flood

2.2.7 Drought Map (CDI)

Drought-hit the New Southwest (NSW) from 2017 to 2020. The vegetative condition was recovering after the March rains, and soil moisture was improving. However, in other regions of NSW, the recovery has been slow and uneven. The Combined Drought indication is plotted on a map from 12 months to 31 March 2021. 96 percent of NSW is in recovery or non-drought, according to the Combined Drought Map (CDI). When we are dealing with drought-stricken areas, this type of flood chart is essential. The major biophysical indicators of drought are CDI and rainfall, soil quality, and agricultural growth. CDI indicates a good recovery, but full recovery takes time and does not happen in a matter of months. March 2021 is seen on a map. [17]

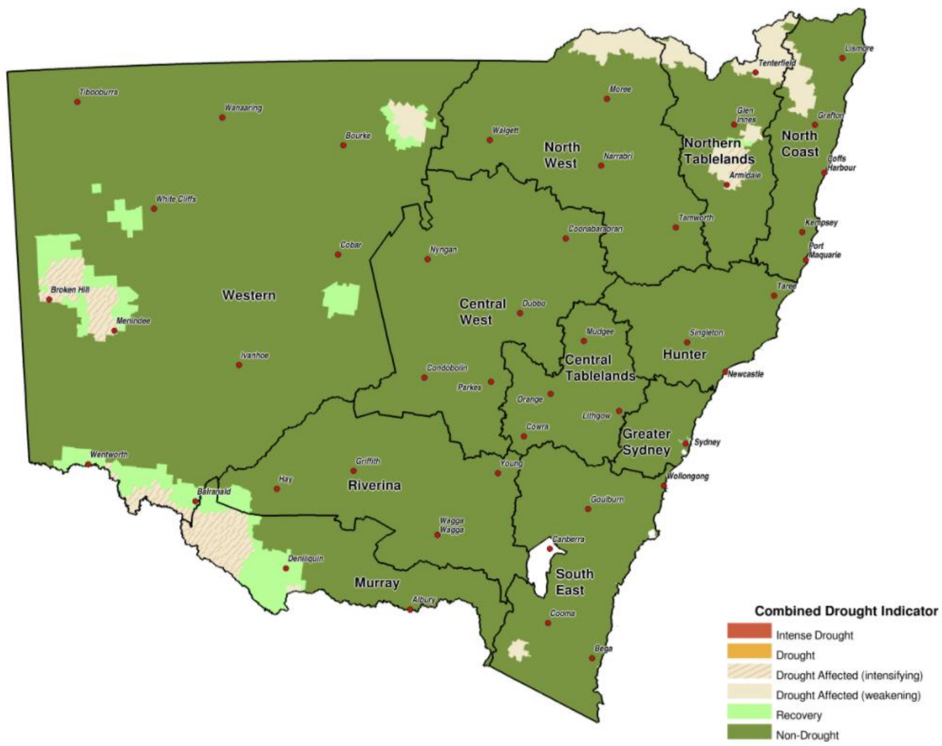

Figure 36 Drought Map (CDI)

CDI depicts the overall picture of each region or the average state of each area.

2.2.8 Rainfall related maps

April showers in practically all places, conditions have been set for early sowing of winter crops in 2021. Because main crop planting does not begin until April and takes several weeks, there is a lot of water retained in the soil.

From March 1 to March 31, 2021, this map depicts total rainfall. This map can be used to identify flood-prone locations. There are dams in some regions, and when the reservoir of the dam reaches a high level, the risk of overflooding from intense occurrences increases.

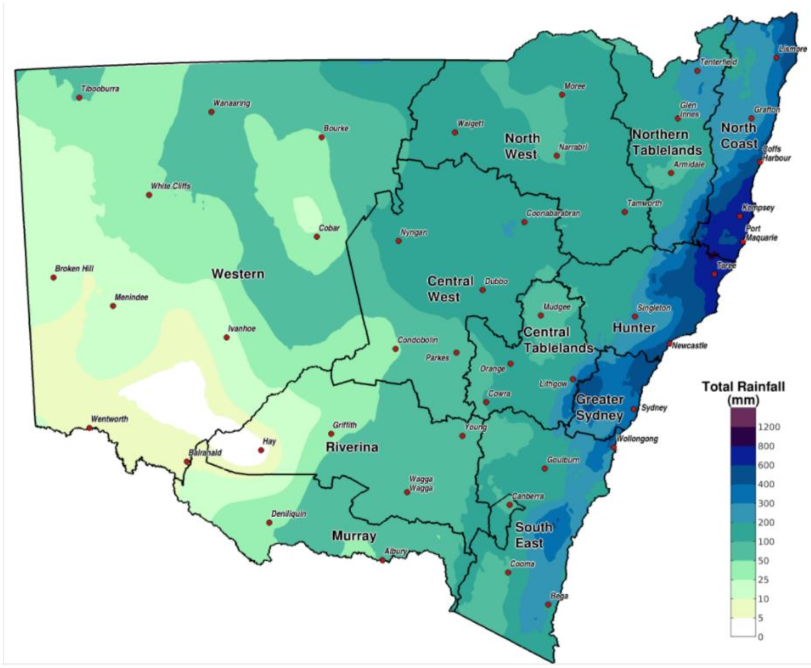

Figure 37 Monthly Rainfall Map

Seasonal Rainfall Map: the probability of dry weather overcoming the autumn-winter season can be shown on this map. For the next three months, the Bureau of Meteorology (BOM) predicts a moderate chance of below-median rainfall in NSW. From January 1, 2021, through March 31, 2021, (figure37)

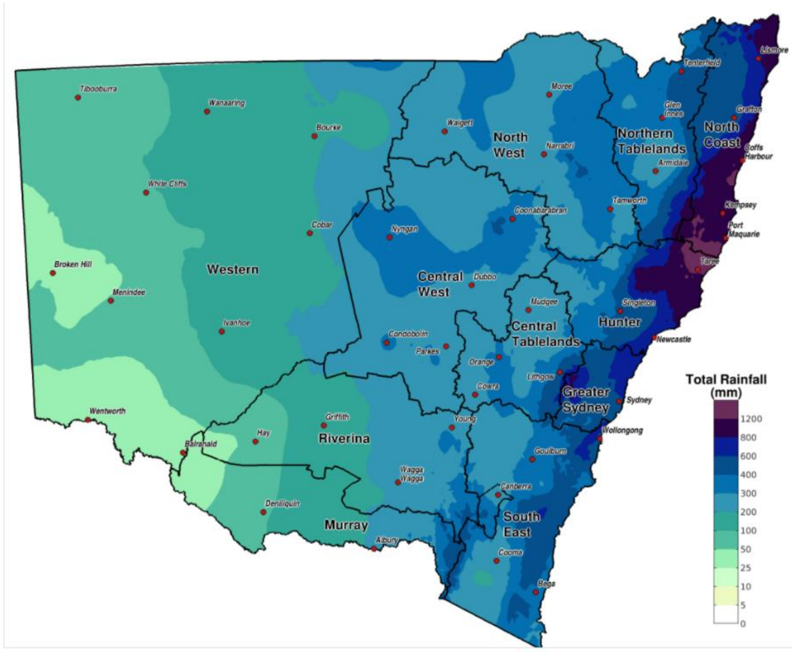

Figure 38 Seasonal Rainfall Map

Rainfall Anomaly Map: Monthly precipitation anomalies in mm/month represent the difference between monthly rainfall and the long-term average rainfall. In comparison to the March average, most regions in the New South West received more than 25 mm. March 2021 map (figure 38). Green regions on the map show that precipitation for the month was above the long-term average, while brown areas indicate that precipitation was below average.

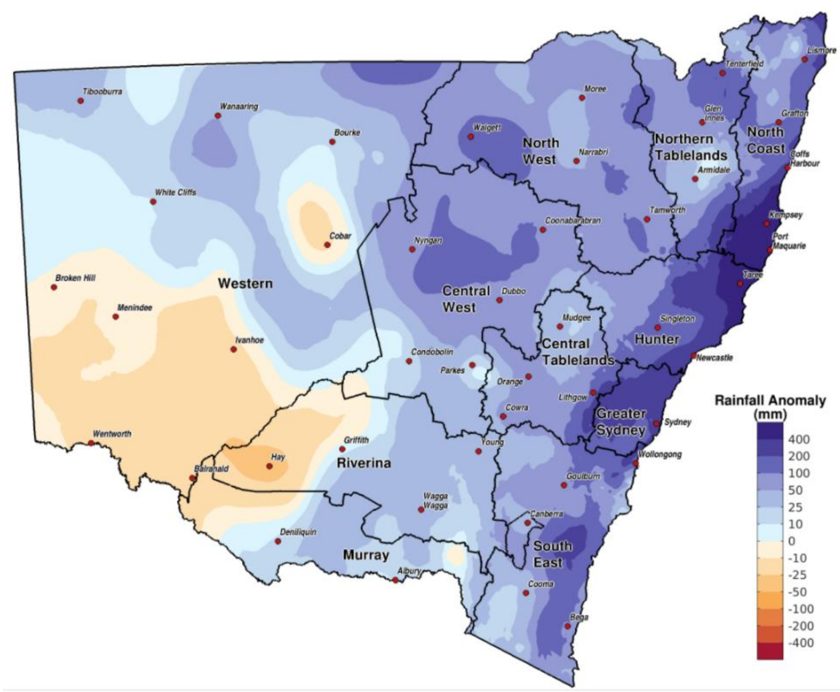

Figure 39 Rainfall Anomaly Map

2.2.9 Temperature Maps

In the new southwest, maximum temperatures were below average in March. A temperature map can illustrate the chance of rain in a specific location, as well as drought and vegetation systems. March 20, 2021 map

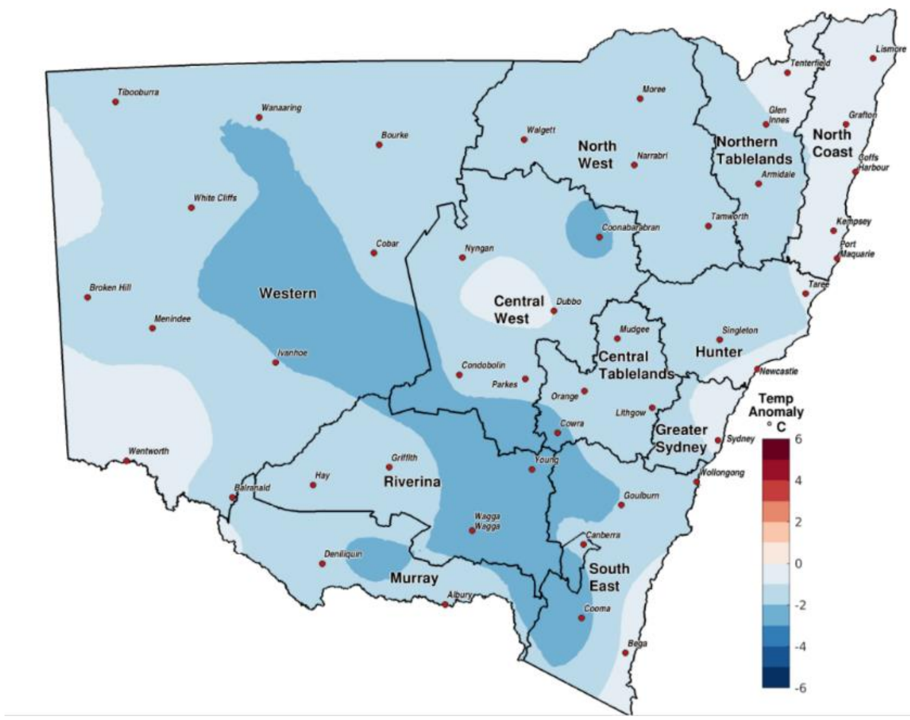

Figure 40 Maximum Temperature Anomaly Map

Mean Maximum Temperature: The average maximum temperature in March. Map from March 1 to March 31, 2021.

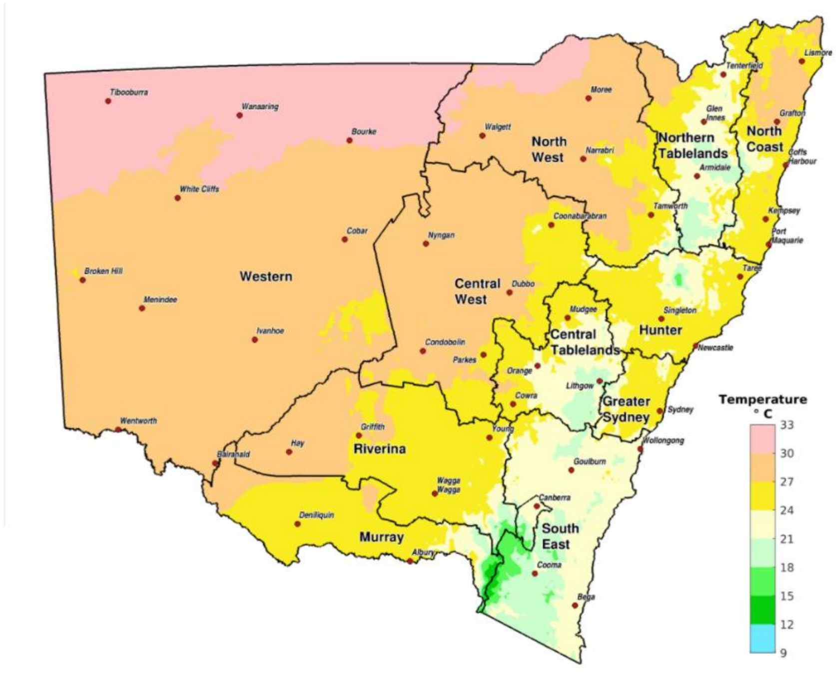

Figure 41Mean Maximum Temperature

Minimum Temperature Anomaly: In practically all states, the minimum temperature anomaly was below average, except the eastern half of the new southwest, which was only 1-2 degrees over average. March 2021 is seen on a map.

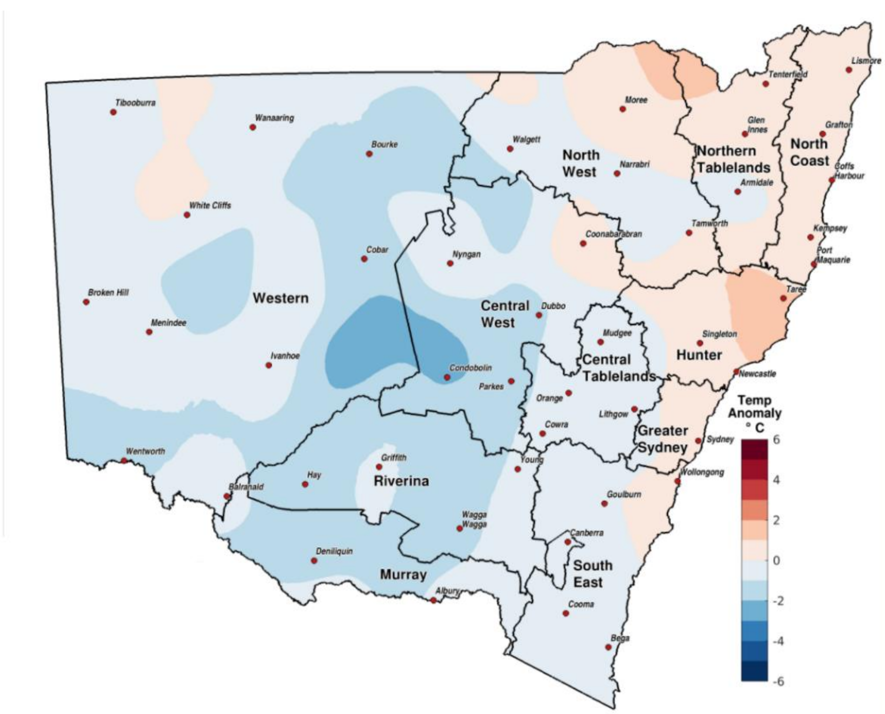

Figure 42 Minimum Temperature Anomaly

Mean Minimum Temperature map: During the month, the average minimum temperature in practically the whole new southwest was above 12 degrees Celsius. March 1 to March 31

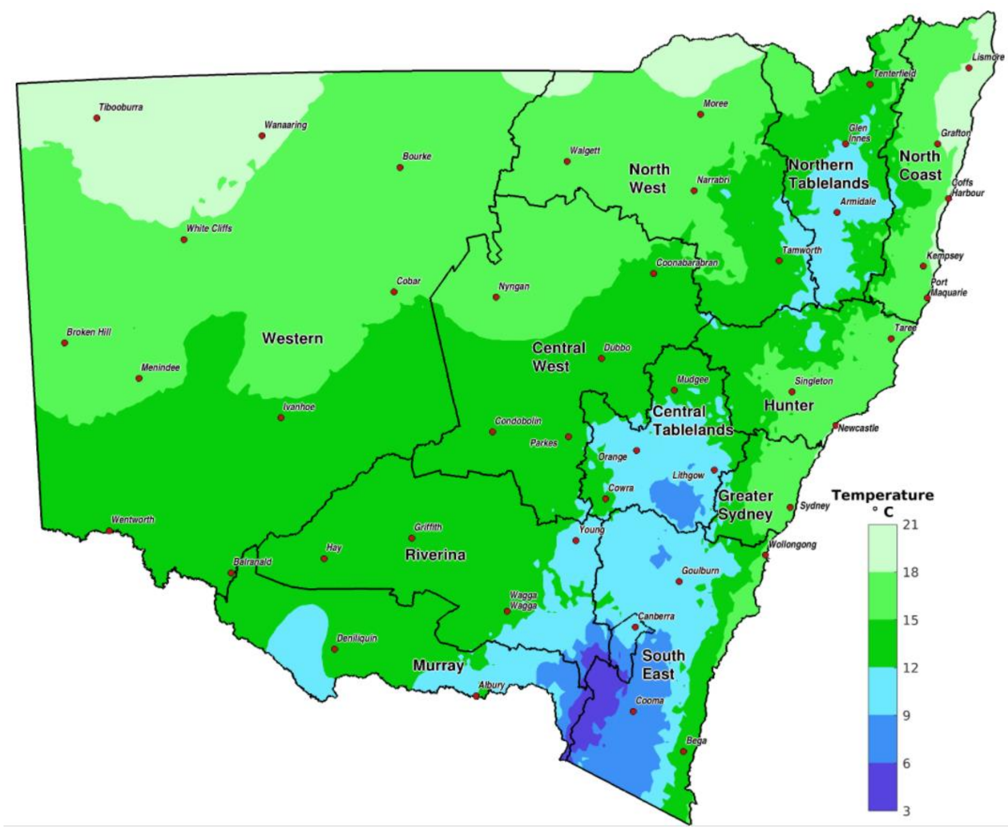

Figure 43 Mean Minimum Temperature

2.2.10 Normalized Difference Vegetation Index (NDVI) Anomaly

The level of greenness in each location is depicted on this map. For the months of January to March 2021, the greenness level in New South West is slightly higher than typical. The NDVI will improve in the following months as a result of the March rains in NSW. Bushfires occurred in some places (Central Tablelands, South East, and Alpine) in 2019-2020, resulting in a poor greenness ratio that is still recovering.

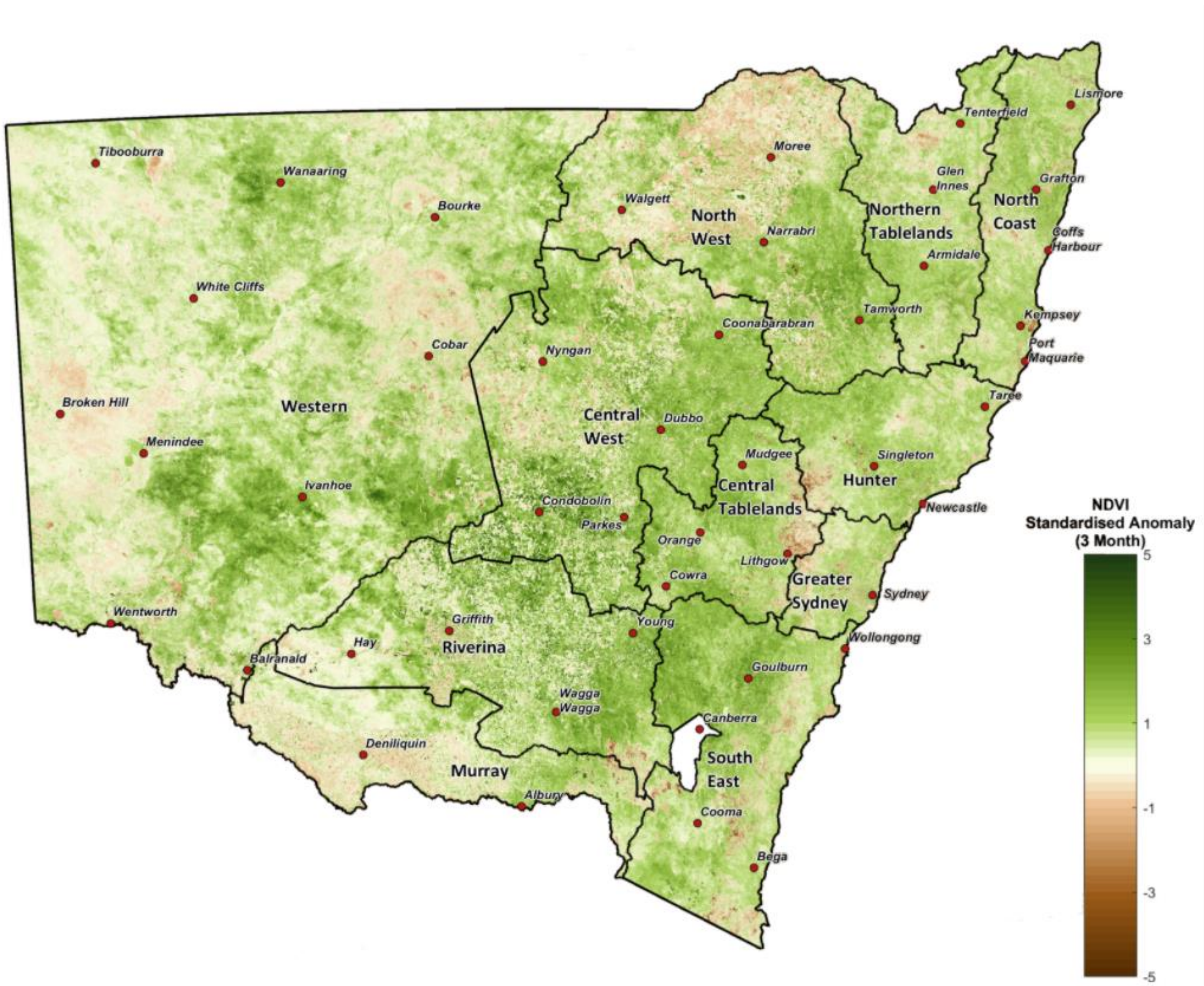

Figure 44 Normalized Difference Vegetation Index (NDVI) Anomaly

2.2.11 Farm Dam Survey

The map illustrates that farm dam levels are greater in the central and eastern parts of New South Wales and that some regions have farm dam levels that are less than 20% of capacity. In the western, southern, and northern parts of New South Wales. Rainfall and precipitation are projected to improve in the next months, as they were in March.

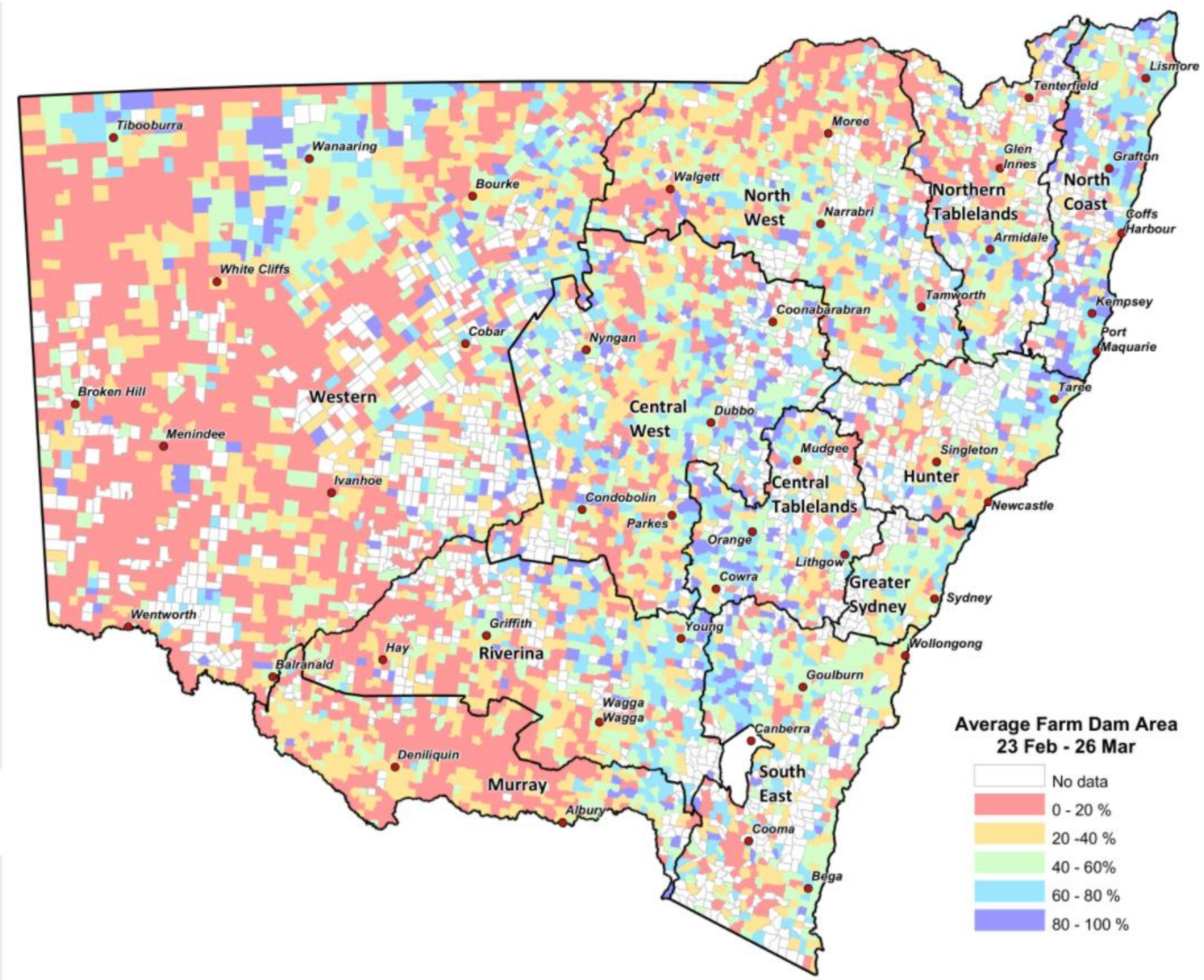

Figure 45 Farm Dam Survey

2.3 Earthquake

Any abrupt shaking of the ground caused by seismic waves passing through the Earth's rocks is referred to as an earthquake. Seismic waves are created when energy held in the Earth's crust is released unexpectedly, generally when masses of rock straining against one another fracture and "slide."

2.3.1 Nepal 2015

The earthquake that struck Nepal on April 25, 2015, occurred at a shallow depth (about 15 kilometers), causing greater damage than a deep earthquake. Around 9000 people were killed, and 22000 were injured. The epicenter was 34000 meters away from LAMJUNG, which is one of Nepal's 77 districts and is part of the GANDAKI province. It takes 15 seconds for the epicenter to form. The magnitude of the earthquake was estimated to be between 7.5 and 8.1 by various sources. BHARATPUR, with a population of 280502 people at the time, was the nearest city to the earthquake.

Because many individuals were working outside during the earthquake, the number of injuries was reduced, but it was still a significant number. In addition, the earthquake created an avalanche on Mount Everest and the Langtang valley, resulting in the deaths of 272 individuals.

2500 people were injured, and 200 people were killed, as a result of aftershocks that occurred every 15-20 minutes with a maximum magnitude of 7.3 (Mw).

The city of BIJUKCHHEN suffered the most damage, which is the subject of part of the analysis in this paper. [18]

2.3.2 Historical seismic record

Earthquakes are caused by tectonic movements, and historical seismic data show that the Himalayas contains an active fault zone and active thrust. Earthquakes occur frequently throughout history, and governments should have learned to develop suitable infrastructures. The map below depicts historical earthquakes and aftershocks in the Himalayas, along with their magnitude and fault locations. [18]

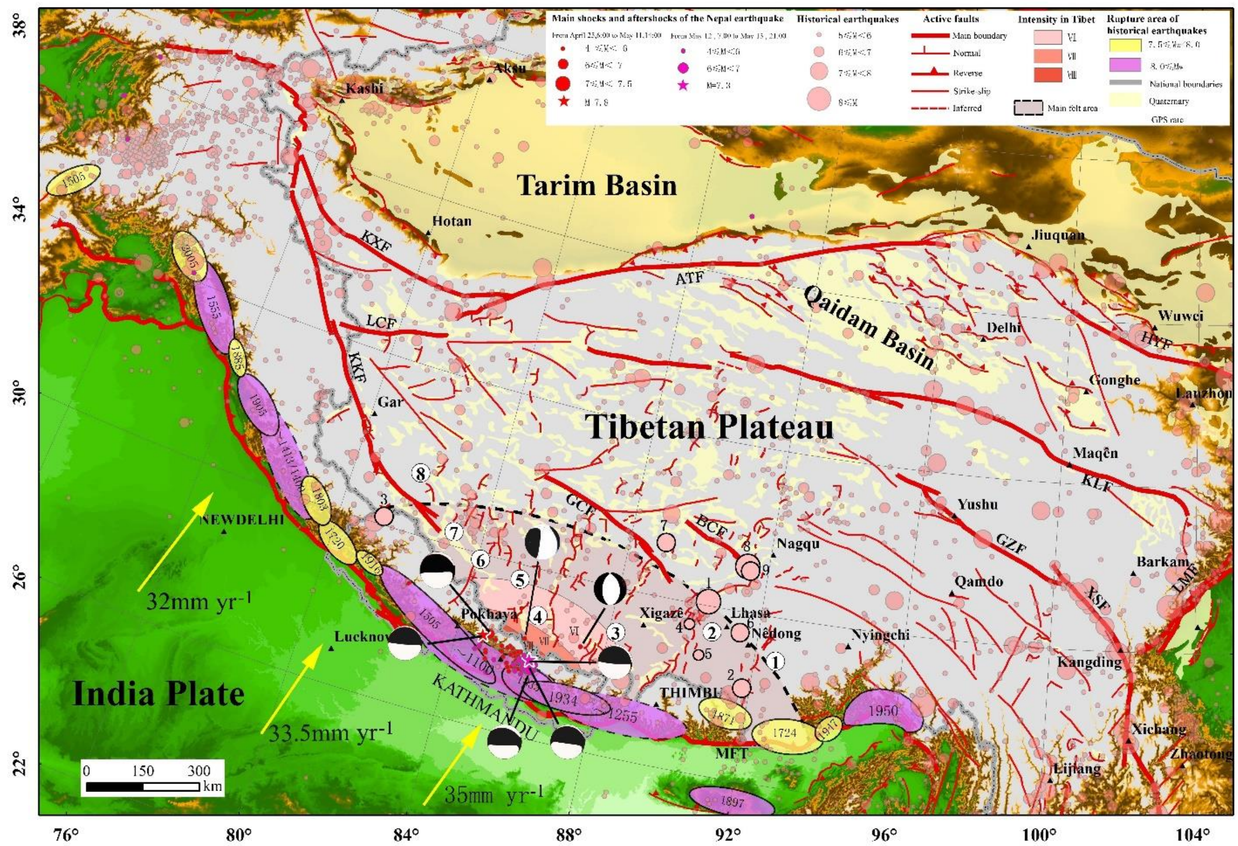

Figure 46 Historical seismic record and intensity map

2.3.3 Event's location impacted Area.

The severity of the earthquake lessens as we go away from the epicenter, and the cost and impact may be less than in local places. It is necessary to use the word "may" because some risky places may exist outside the epicenter and be triggered by the earthquake. Governments and countries in earthquake-prone areas must have some standards for buildings and other infrastructures to reduce the cost, whether monetary or lifesaving.

The impact region map is combined with the affected population to provide a visual representation of what would happen or occurred after or before an earthquake, as well as the potential for fatalities.

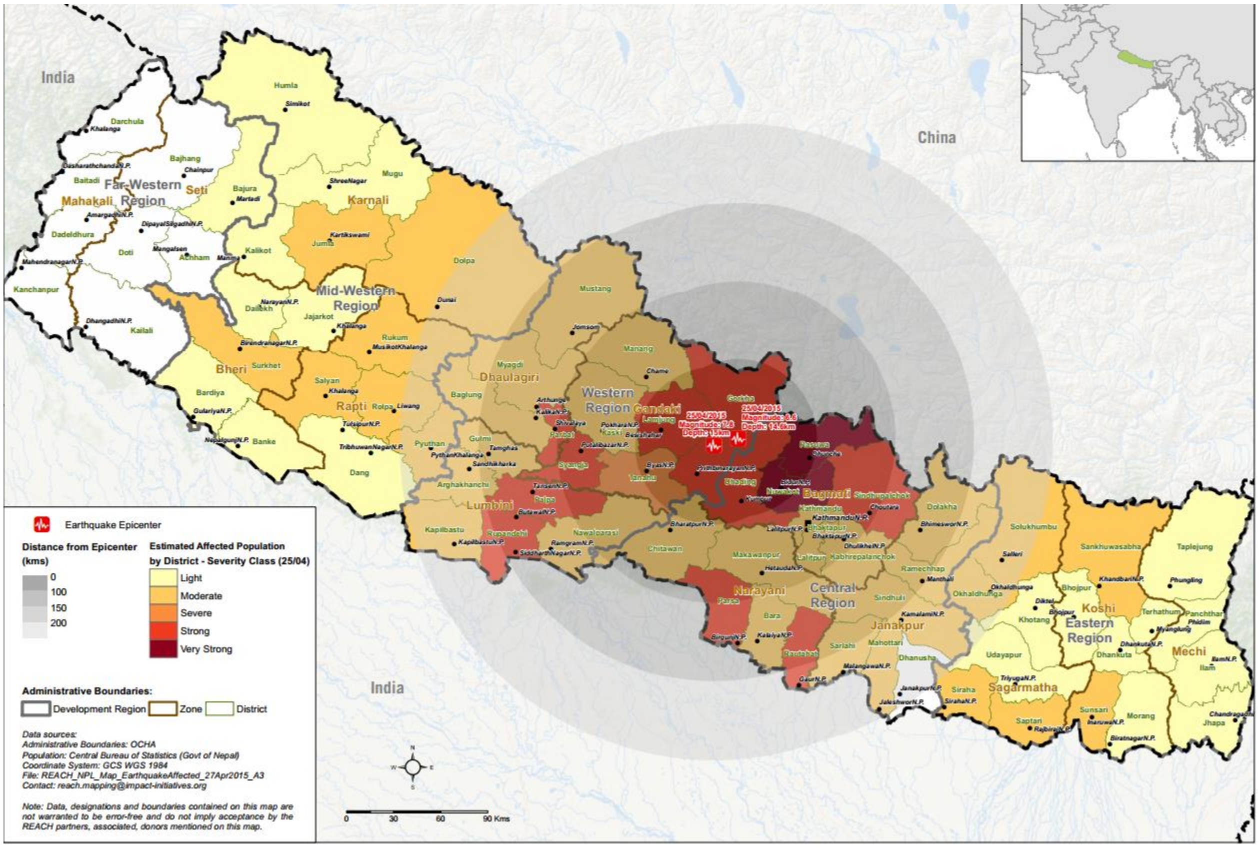

Figure 47 Event's location impacted Area.

2.3.4 Seismic related map

The modified Mercalli intensity MMI depicts the seismic power impact of a seismic event in each area, taking into account the impact on people and infrastructure. The seismic event would cause damage to buildings if it had a severe impact (MMI 6 or higher).[19]

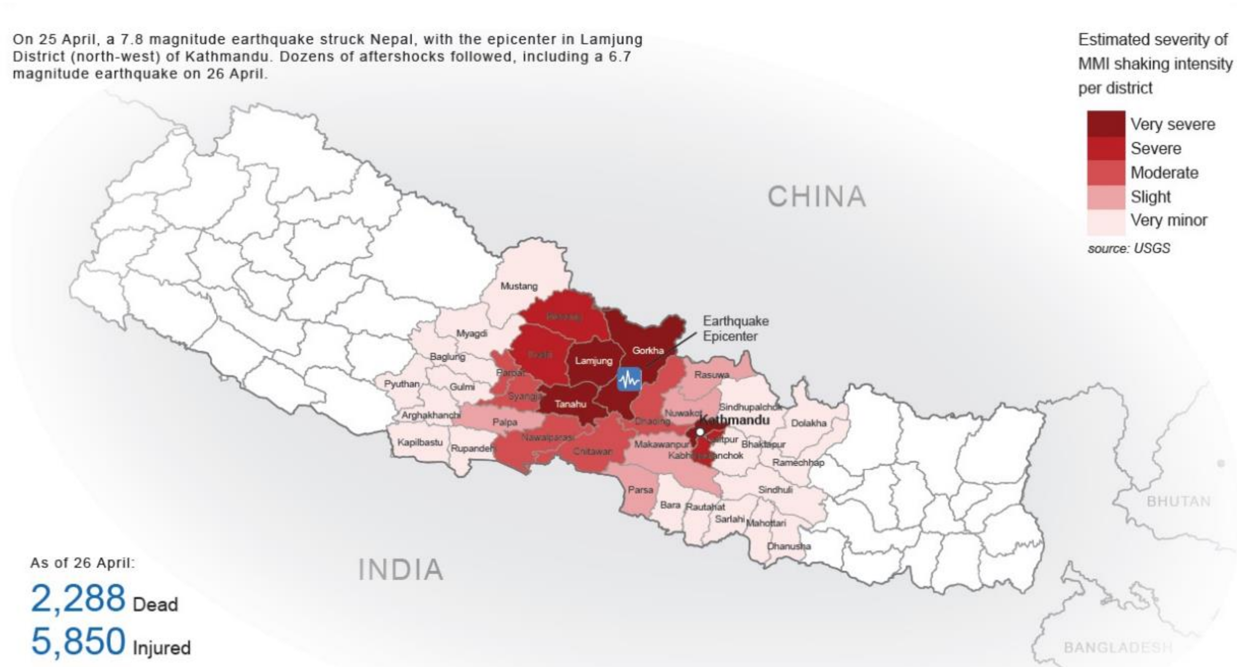

Figure 48 Shaking intensity per distinct map

Aftershocks in 2015: Aftershocks are regarded as a succession of the largest shock because they have fewer shocks than the main shock of an earthquake. It is feasible to estimate the number of aftershocks for the following earthquake based on the pattern. The location of the aftershocks can reveal the likely rupture zone, which is approximately 80 kilometers.

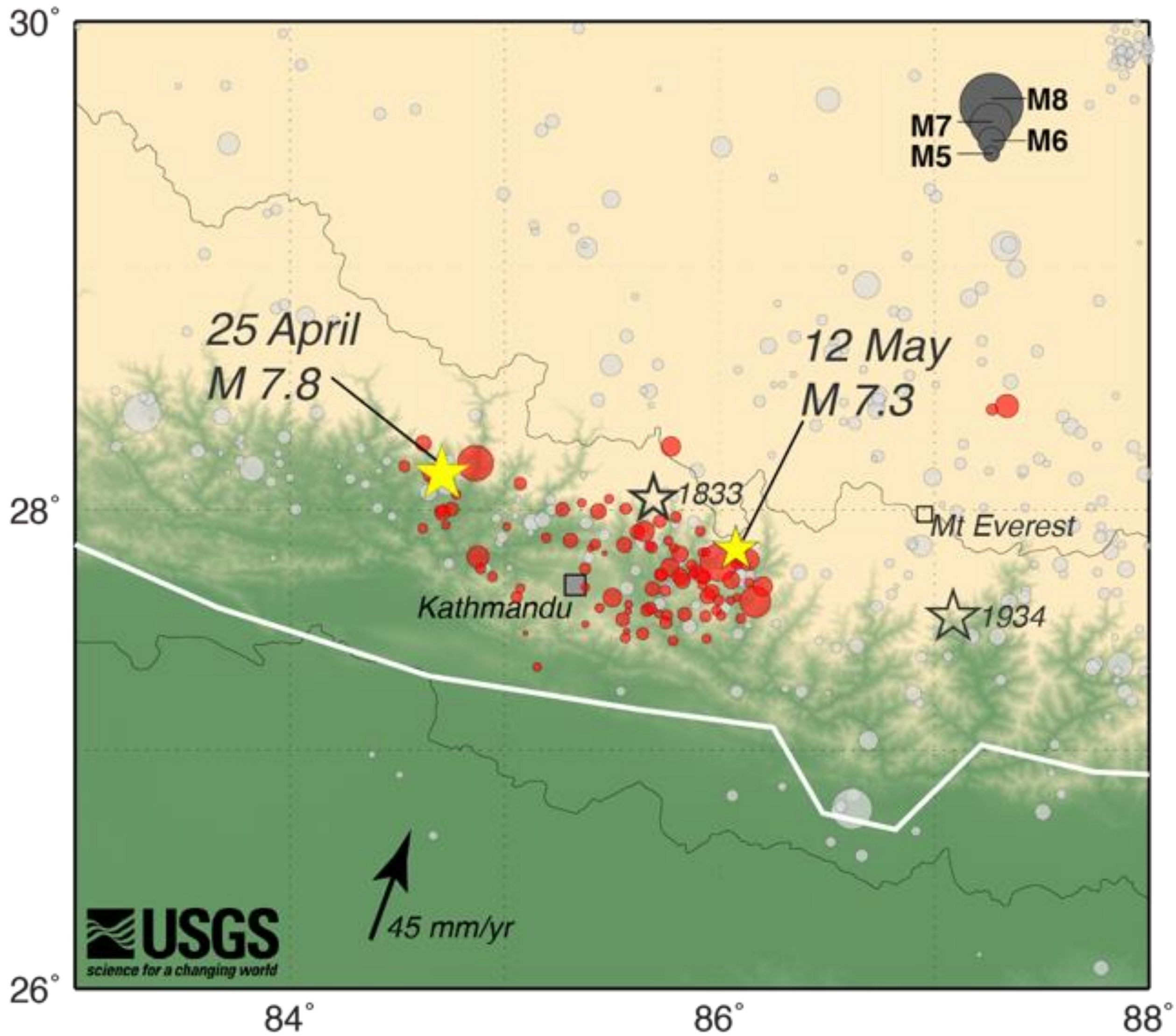

Figure 49 Aftershocks in 2015

Rapture zone estimation map: The likely rapture zone, which is roughly 80 kilometers, may be seen in the aftershock sites.

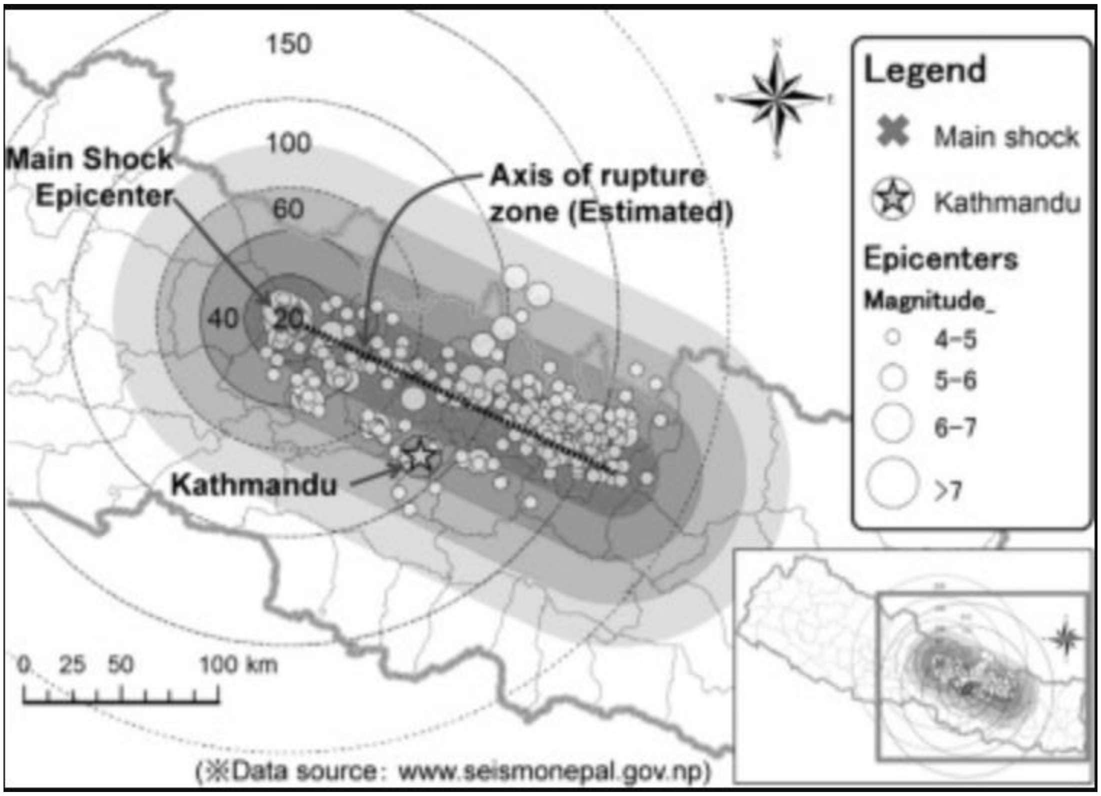

Figure 50 Rapture zone estimation map

The transportation (Roads) map is in figure 50.

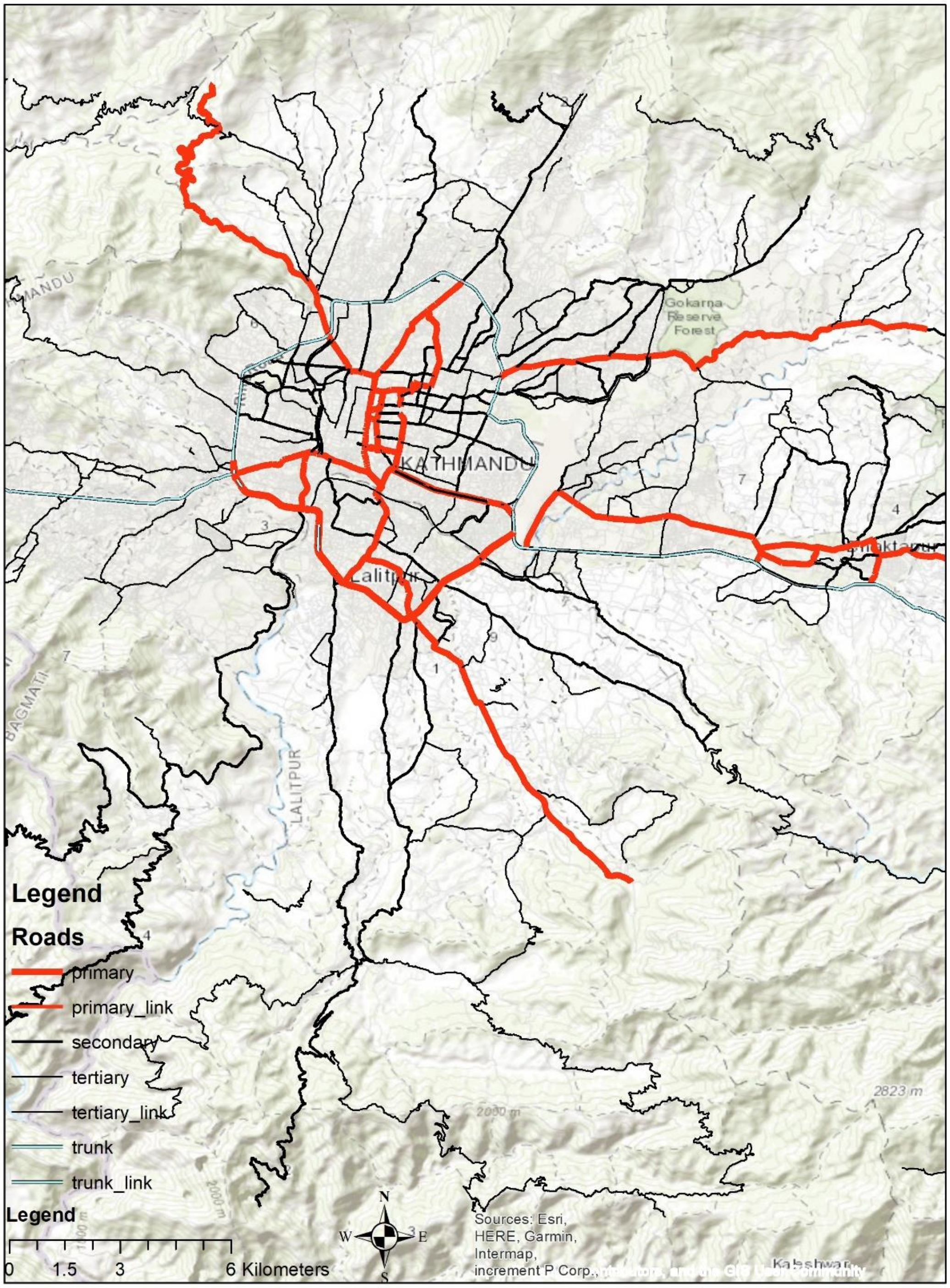

Figure 51 Transportation map

2.3.4 Fatalities

The most important expense is fatality. It is completely intertwined with the afflicted area and infrastructure. The number of fatalities will be reduced by improving infrastructure, particularly early warning systems. Due to the higher severity of the earthquake, the death rate in the epicenter is higher than in other places, as seen on the map. In this occurrence, Katmandu had the highest number of fatalities.

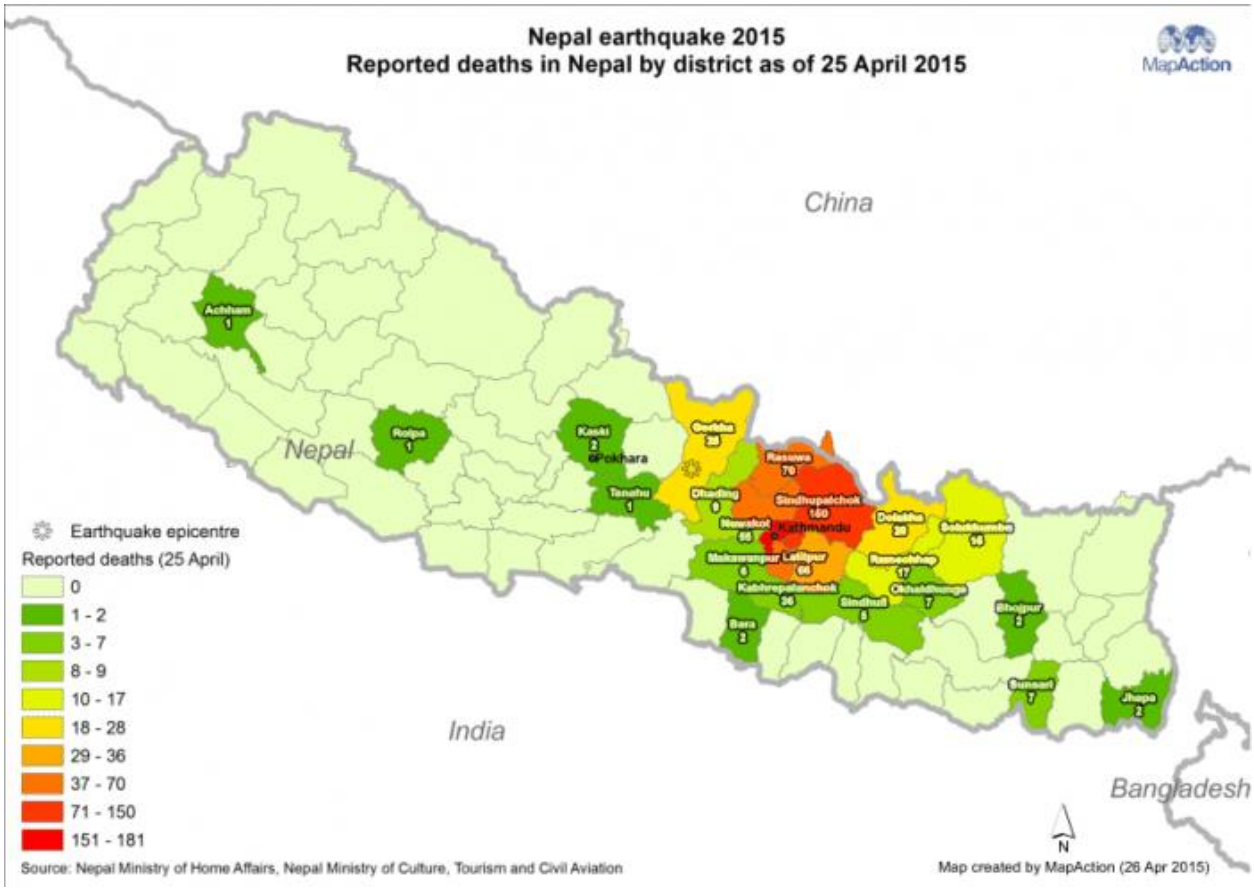

Figure 52 Fatalities per distinct map

2.3.5 Soil maps

Soil Investigation map: Nepal has geo-information data for a variety of purposes. There are 700 boreholes in the Kathmandu valley for geotechnical or soil studies. For better exploration, boreholes are arranged in two lines in two different directions. [20]

Figure 53 borehole maps

Soil Liquefaction map: Because the soil in the Kathmandu valley is saturated with sand and clay layers, and there are some groundwater tables in multiple regions, the risk of liquefaction is significant.

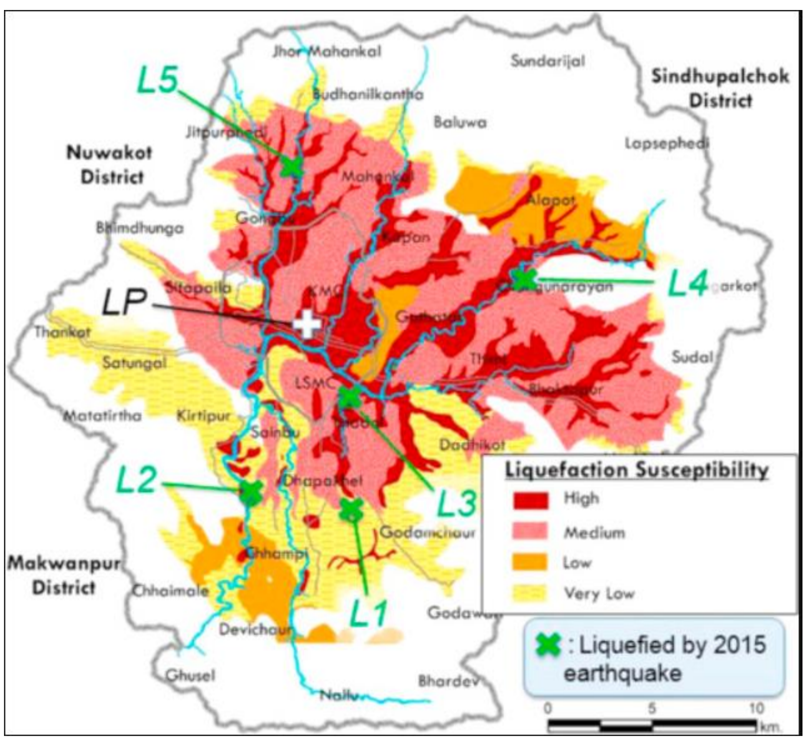

Figure 54 Soil Liquefaction

Damage assessment (Structures): The structural damage assessment map depicts the structures that were damaged during the 2015 earthquake and are divided into three levels. (Figure 54)

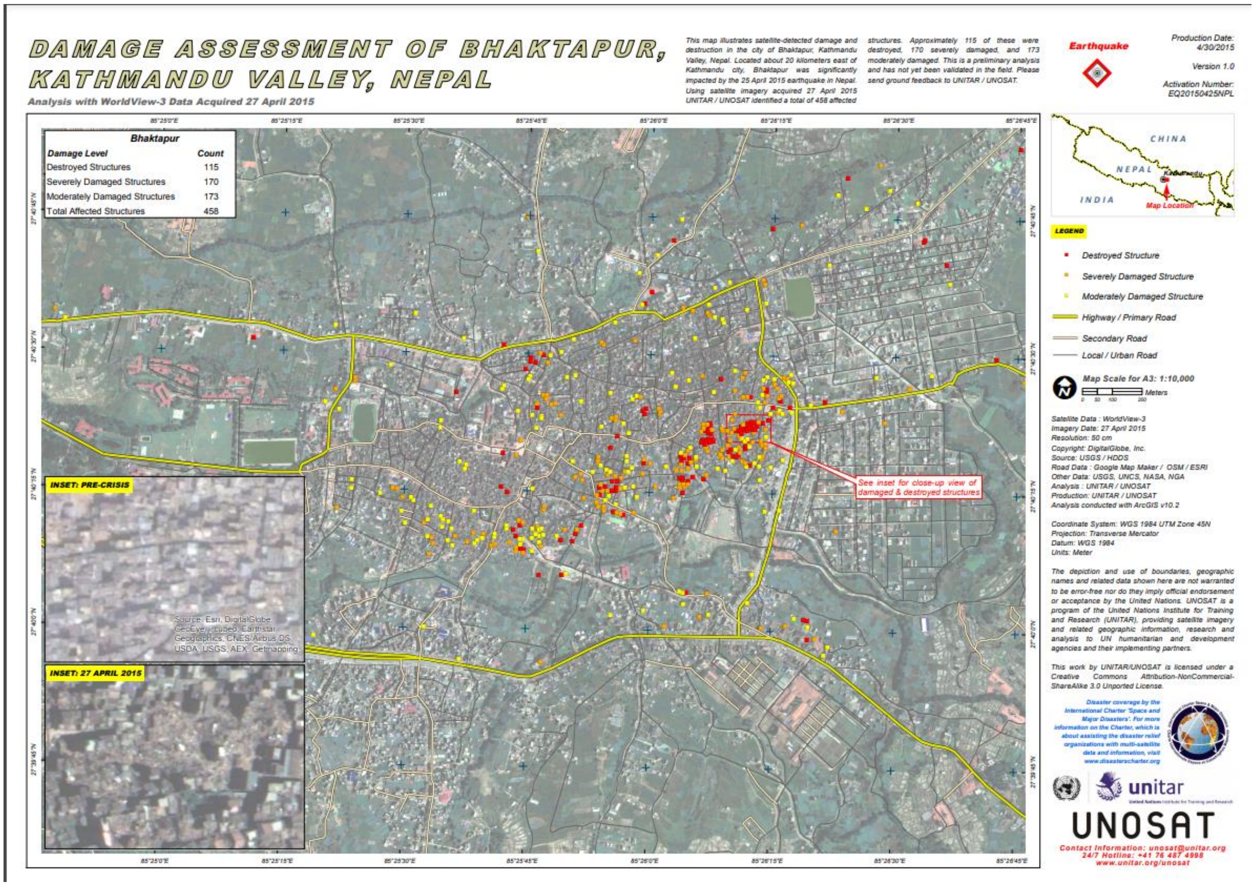

Figure 55 Damage assessment (Structures)

2.4 Avalanche

A mass of snow slides swiftly down an inclined slope, such as a hillside or a building's roof, causing an avalanche. Natural causes (such as precipitation, drifting snow, and abrupt temperature fluctuations) or human action can cause avalanches. Avalanches are sometimes known as snowslides.

2.4.1 Bahcesaray 2020

Two avalanches occurred in the left portion of Turkey's Van province in February 2020. One occurred on February 4th, and the other on February 5th. The second occurred while the rescue crew was on the scene, and some individuals perished as a result. There were 41 deaths and 90 injuries in these two incidents.

The first avalanche occurred in the Bahcesaray region's mountain trail. During the rescue phase, Turkey's disaster and emergency management presidency, National Medical Rescue Team, and Gendarmerie Search and Rescue Battalion Command were involved.[21]

Figure 56 Event's Location Map

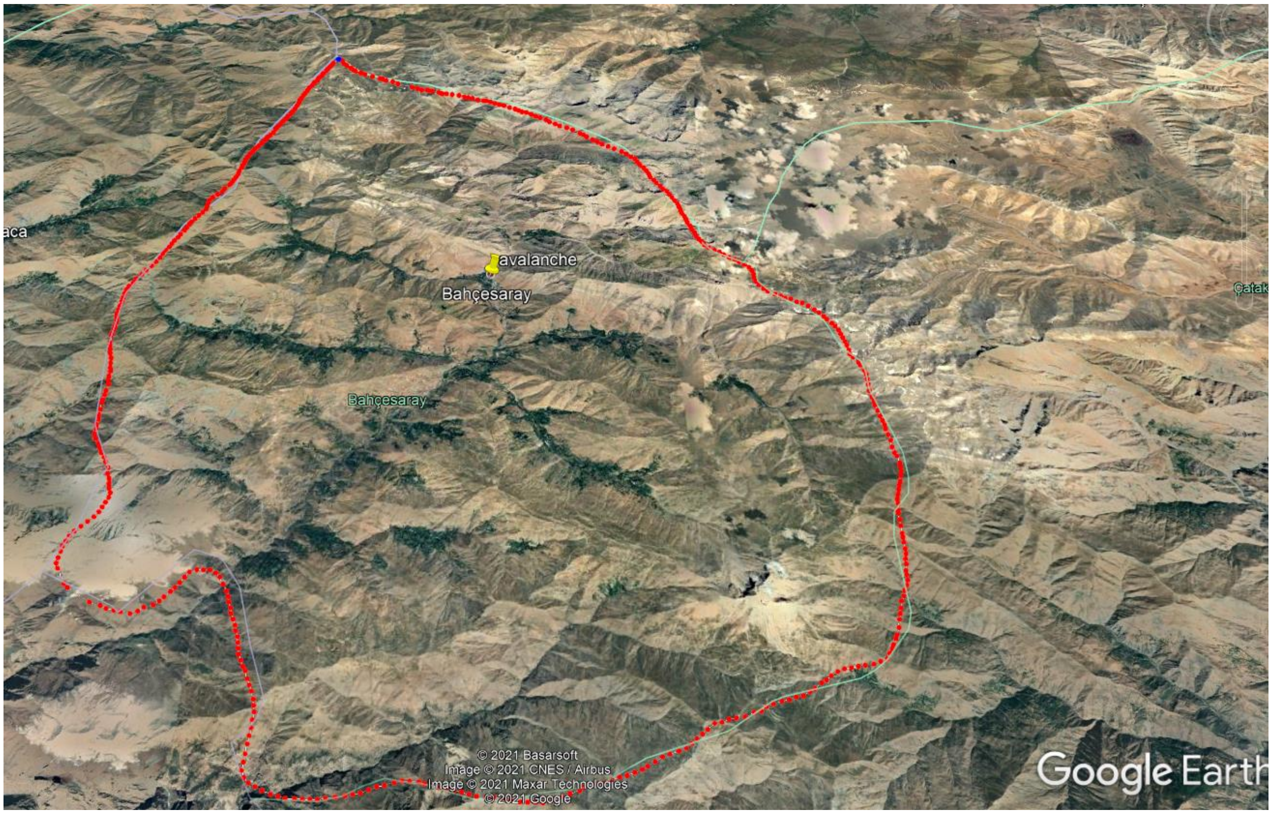

Figure 57 Event's Location Map

Figure 58 pictures of the event

The first stage in analyzing a high-quality avalanche, which is dependent on the form of the field, is to find a high-resolution Digital Elevation Model (DTM).

Avalanche hazard is determined by a variety of elements such as snowfall amount, field slope, wind direction in different seasons, vegetation coverage, and so on.

These factors have varying degrees of importance in the event's occurrence. The important factors are considered in this paper.

Because there is no vegetation in this location, the hazard assessment is based on morphologic danger and wind direction.

DAV's table can be used to determine morphologic hazards.

SLOPE AND AVALANCHE PROBABILITY (DAV, 1994)

Slope	Avalanche probability
Below 10°	Practically no avalanches are triggered
10° - 28°	Avalanches are scarce
28° - 45°	Major danger zone for avalanche triggering
Above 45°	High avalanche frequency, however low snow accumulation due to steepness

Figure 59 slope and avalanche probability

Slope: between 28 and 45 degrees (55 degrees) (depending on literature sources). The most dangerous slopes are those with slopes lower than 28°, where snow sliding is unlikely, and slopes higher than 45° 55°, where snow amassing is unlikely (55° is used to minimize possible underestimate of hazard).

Slope variation: greater than 10 degrees Six Break lines (zones where the snow mantel can be broken) is found in convex zones with a slope change of at least 10°.

DTM map is in figure 59. [22]

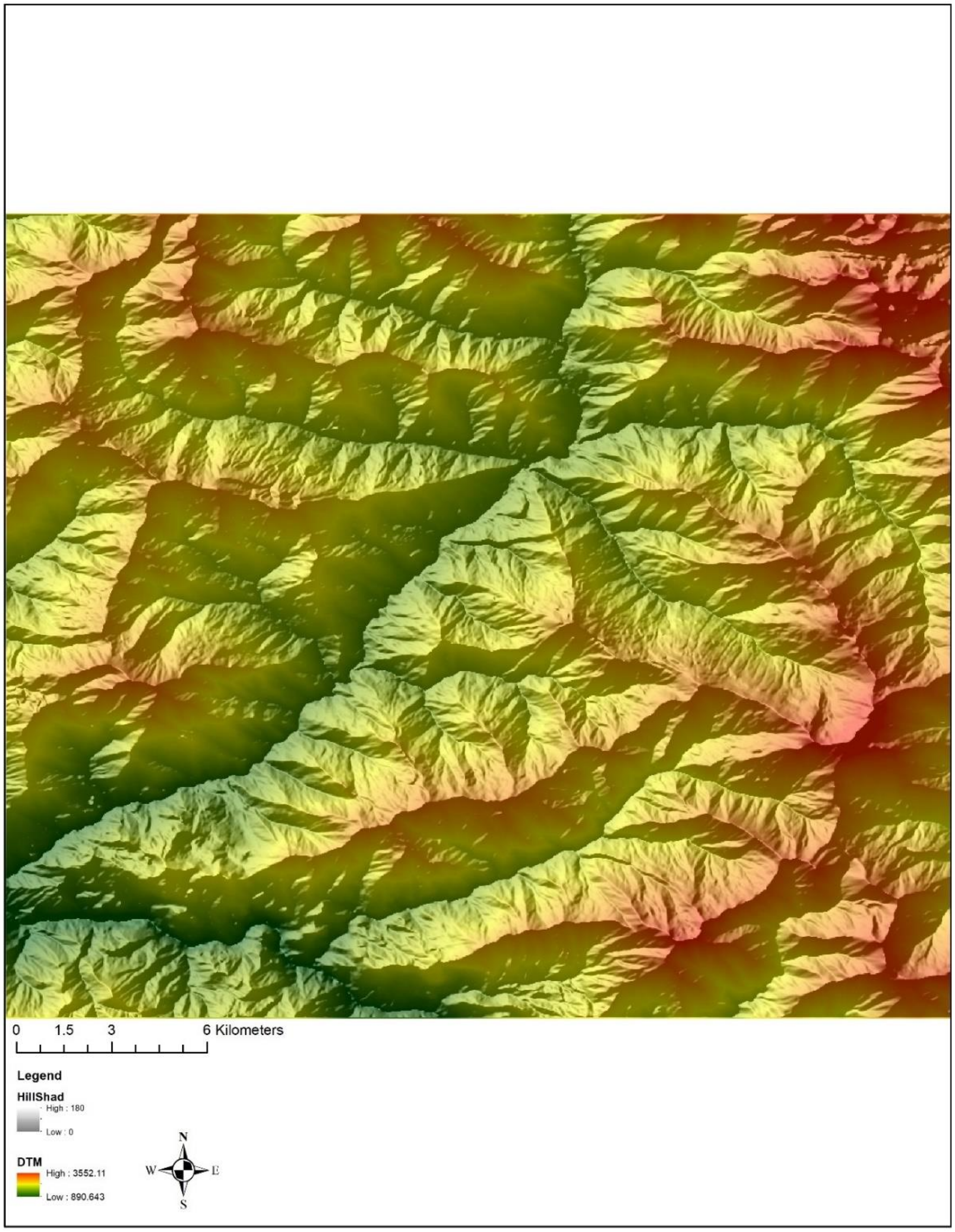

Figure 60 DTM map

2.4.2 Snow map of the province (VAN)

The normalized difference snow index (NDSI) is a pixel-by-pixel indication of the presence of snow. In the case of short waves such as infrared, snow exhibits a large (VIS) reflection and a tiny (IR) reflection. When there are clouds present, this feature aids in the detection of snow more precisely and with fewer mistakes.

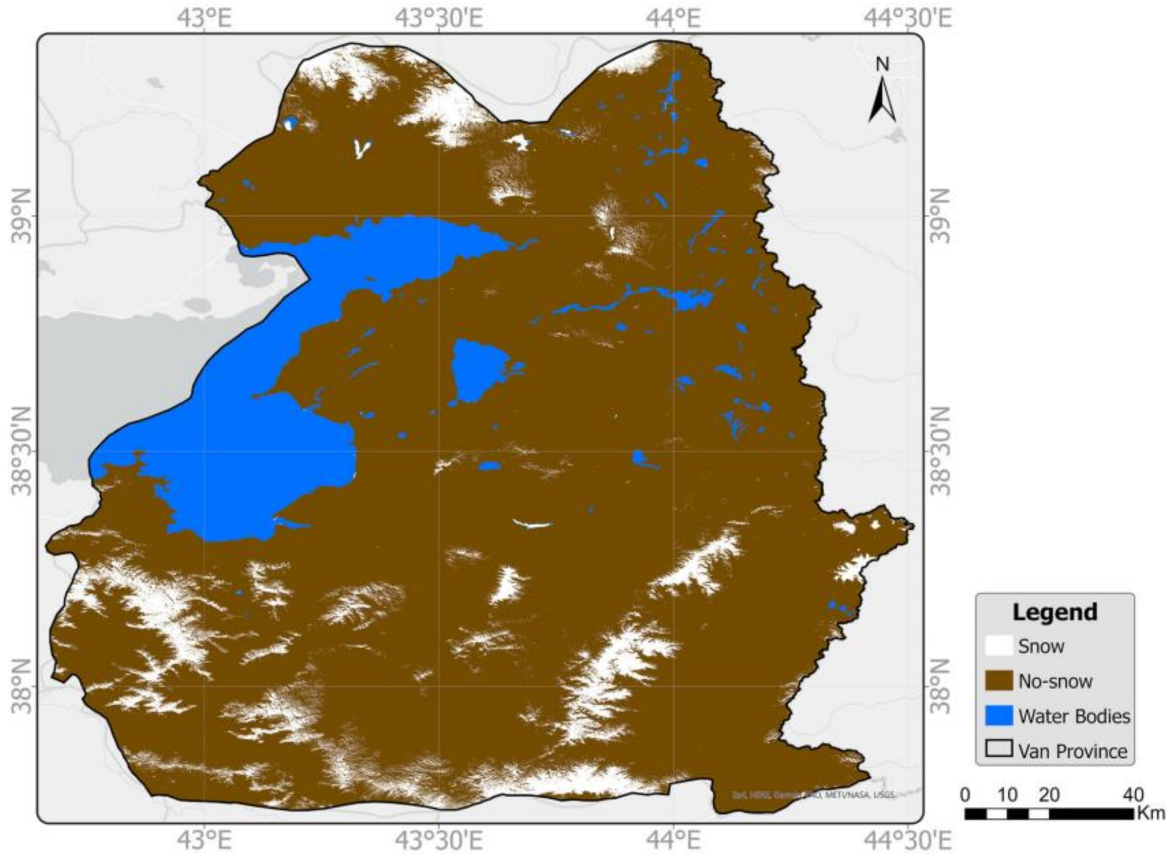

Figure 61 Snow map of the province

2.4.3 Slope maps

When paired with additional data such as geology, vegetation, and hydrography, slope maps can be quite valuable. Slope maps are used to construct landslide danger maps.

In assessing avalanche dangers, the slope is the most essential component. The terrain slope map is built by starting with the DTM. It is especially important to identify regions with a slope between 28° and 55° for this hazard study.

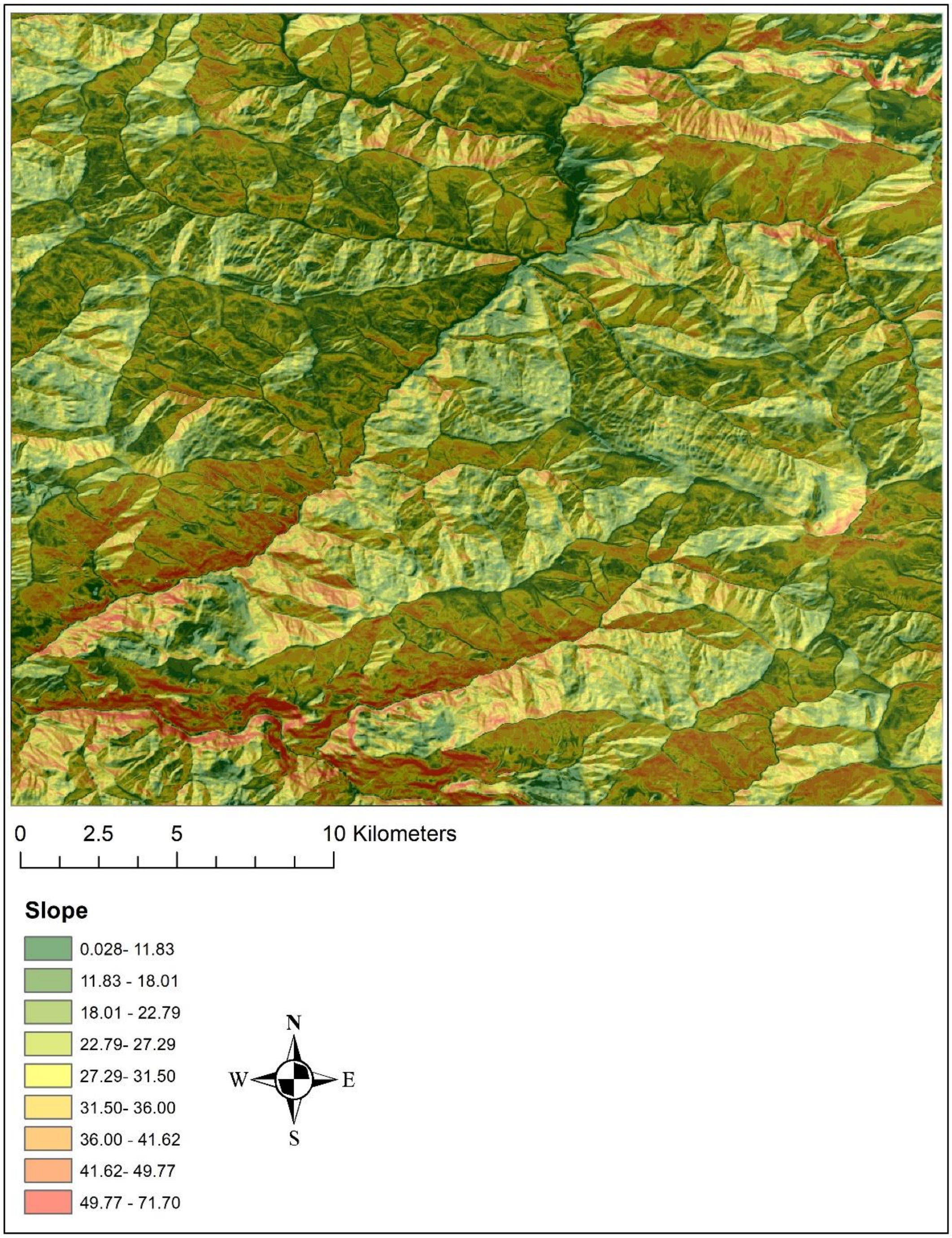

Figure 62 Slope map

The slope 28-55 degrees map is in figure 62.

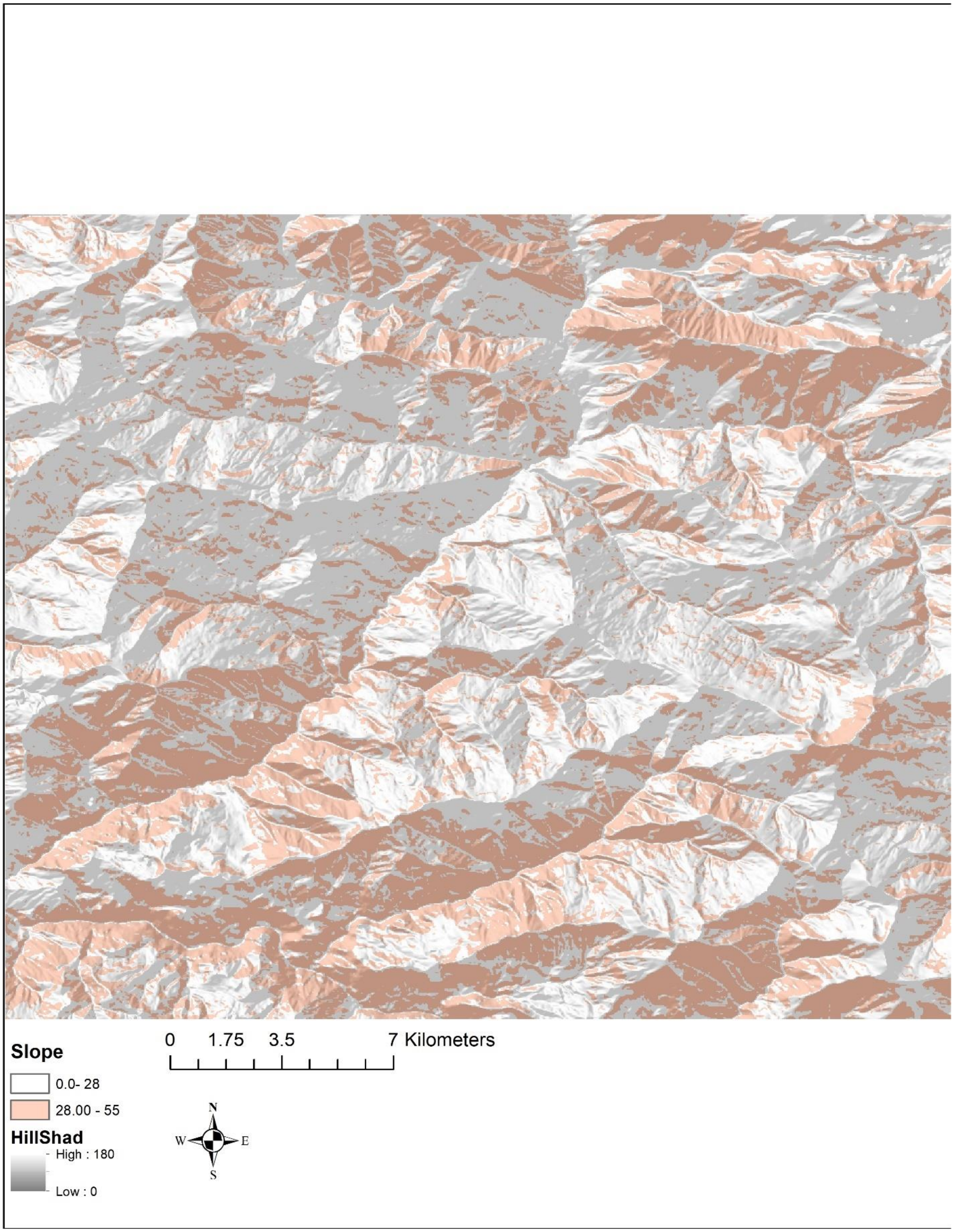

Figure 63 Slope 28-55 degrees

Slope variation map: The slope variation is another essential aspect in identifying break lines in this avalanche danger study. Slope variations can be used to determine this. Different slope variations are determined as the threshold of having brake lines in various types of publications. Break lines are usually defined as areas with a slope change of more than 10°.

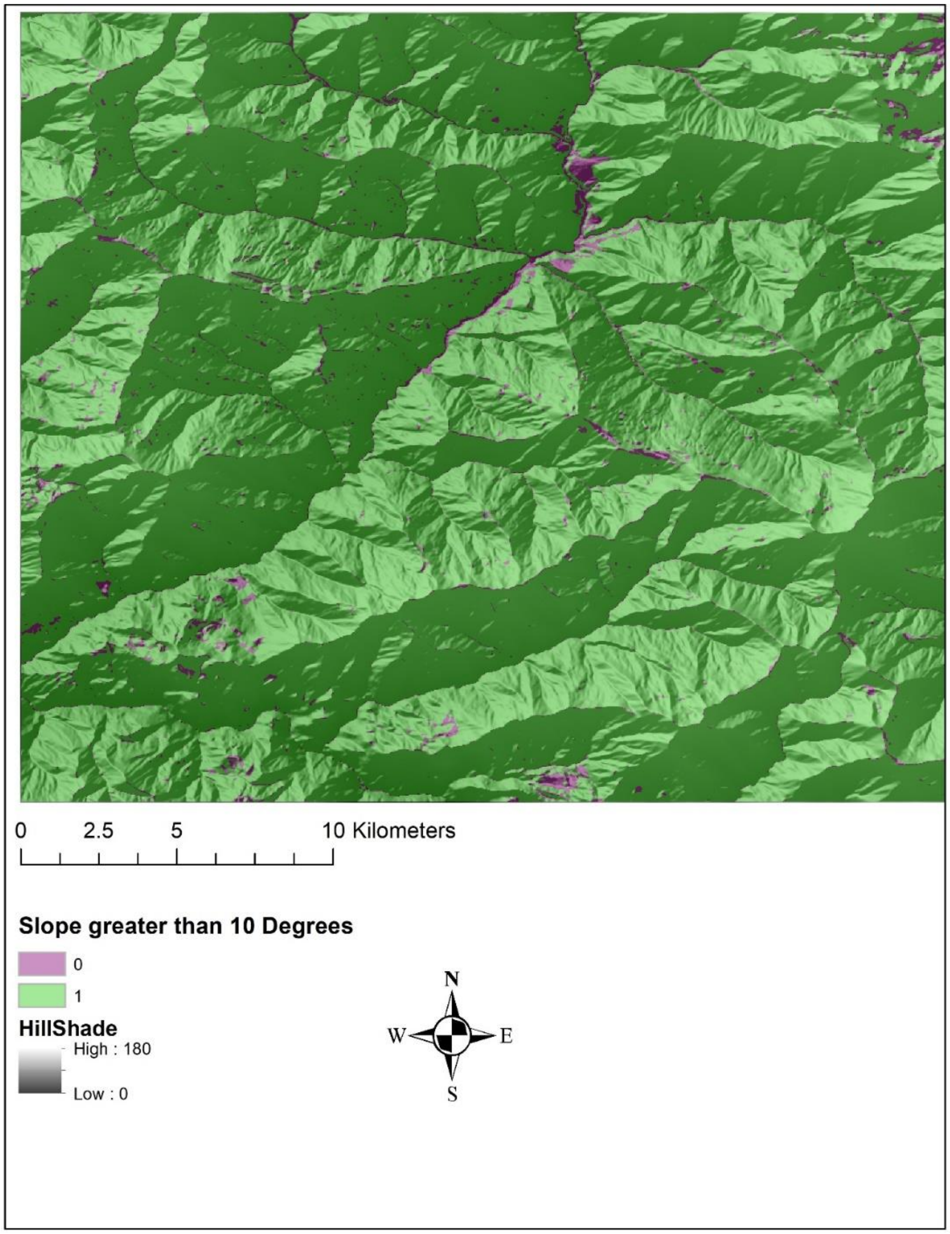

Figure 64 Slope variation

2.4.4 Land use

Avalanches are unaffected by the sparse vegetation coverage in the Bahcesaray region. On the map, you can see the residential areas and military bases. In the north of the region, there is only one large farmland. [23]

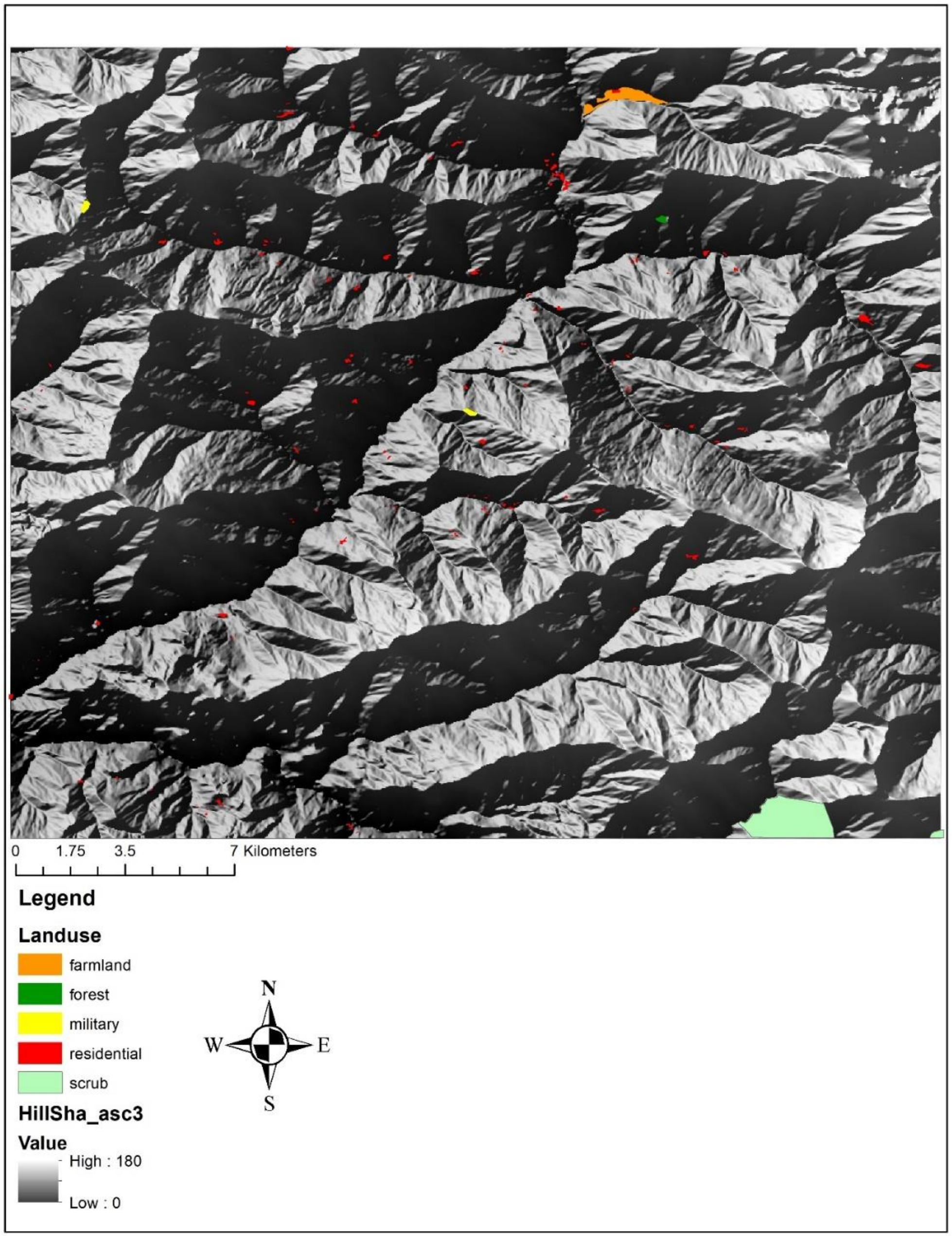

Figure 65 Land use, the gray areas, and white areas are just for a better perspective which is created by Hillshade tool in arc gis

2.4.5 Morphologic Hazard Map

A morphologic hazard map would be created using a mix of slope variation and slope between 28 and 55 degrees. In comparison to the center, the map shows that there is increased avalanche potential in the northeast and southwest.

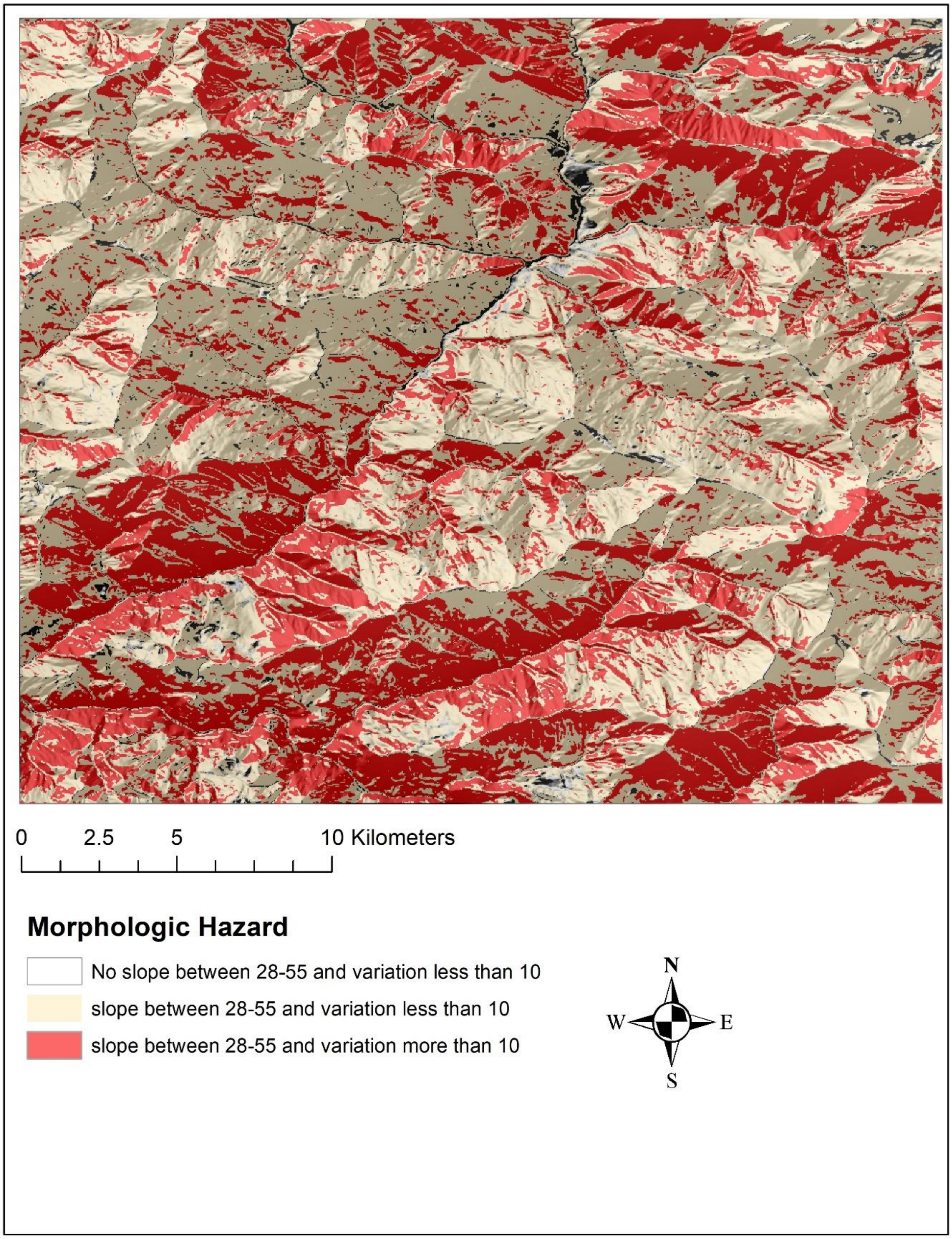

Figure 66 Morphologic Hazard Map

2.4.6 Morphologic hazard Map and Land use

We can observe that there are a lot of residential areas vulnerable to morphologic hazards using the combination of morphologic hazard maps and land use.

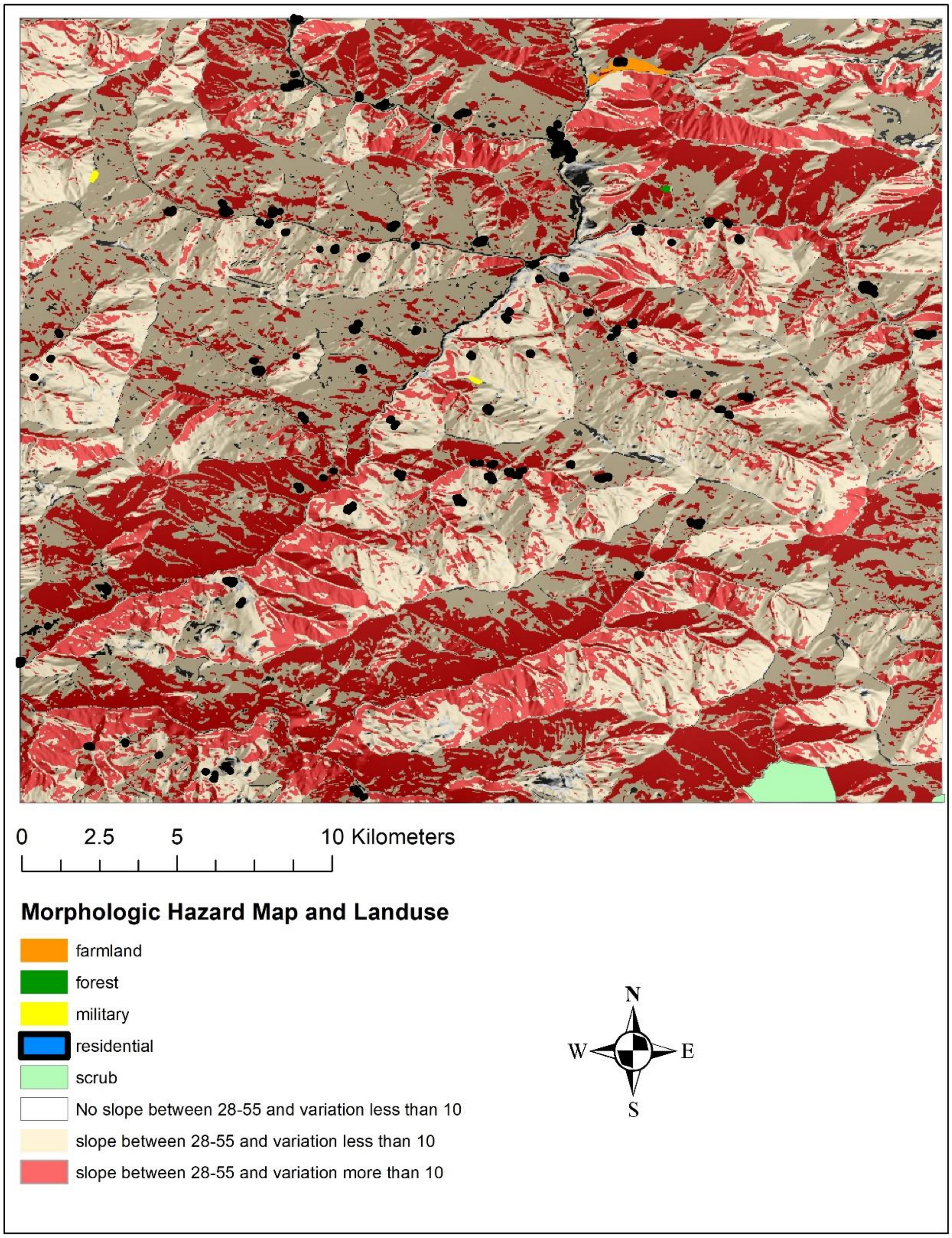

Figure 67 Morphologic hazard Map and Land use

2.4.7 Aspect maps

The cardinal directions of the slope are graphically displayed on aspect maps using DTM.

The aspect aids in determining the quantity of sunlight impacting the terrain's surface, as well as taking into account seasonal and wind-related factors.

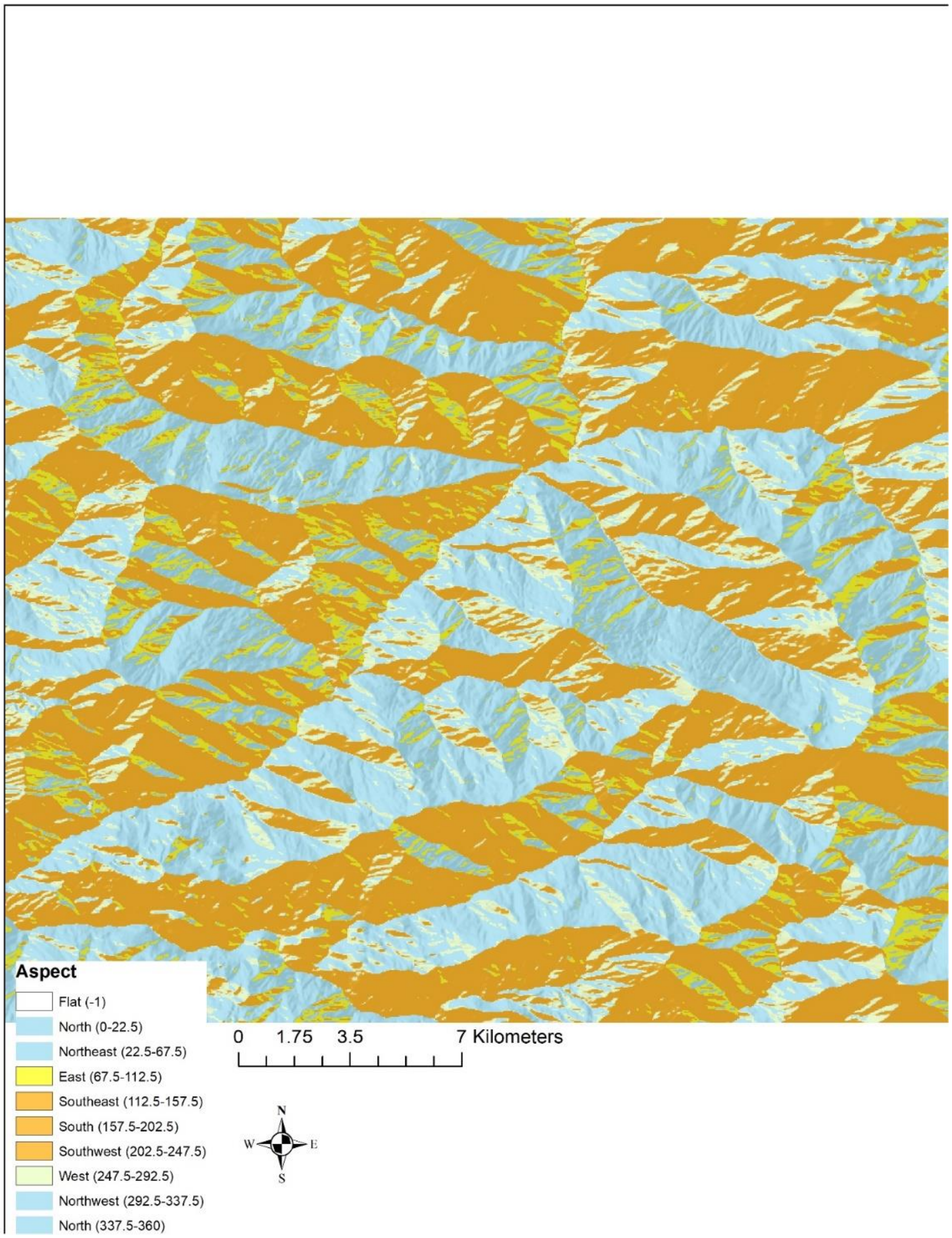

Figure 68 Aspect

2.4.8 Winter Wind direction (aggravating circumstances):

Northeast Aspect: a difficult situation in the winter. As a result, this aspect is considered an exacerbating element in the winter hazard map (less important than principal factors like slope).

Because the wind direction in the winter at the south of VAN lake is northeast to southwest, it is conceivable to use this wind direction as a morphologic hazard factor.

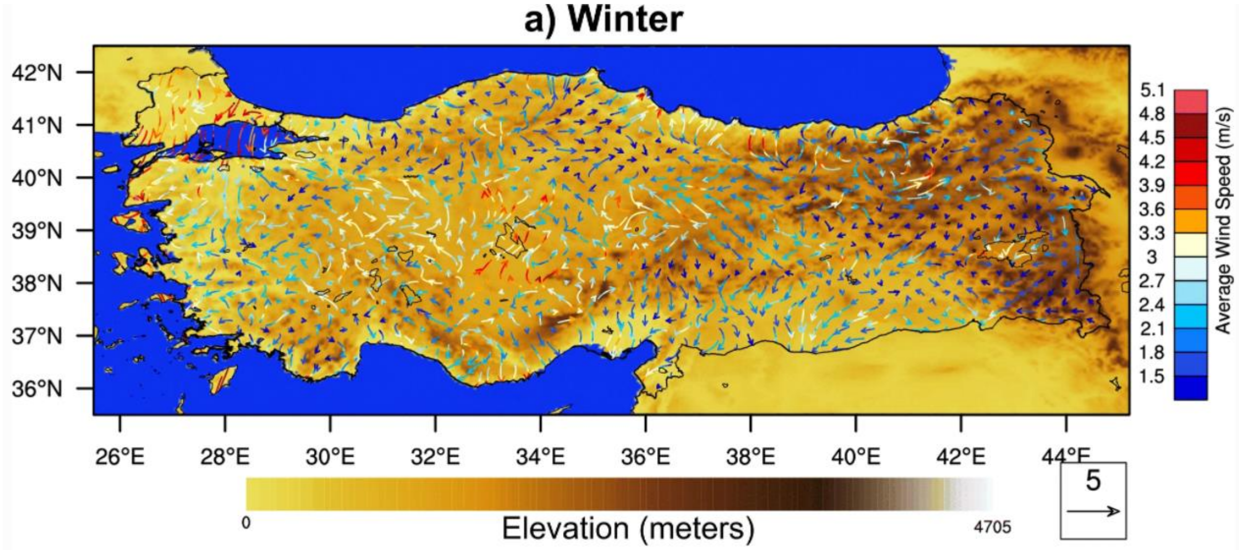

Figure 69 Winter Wind direction

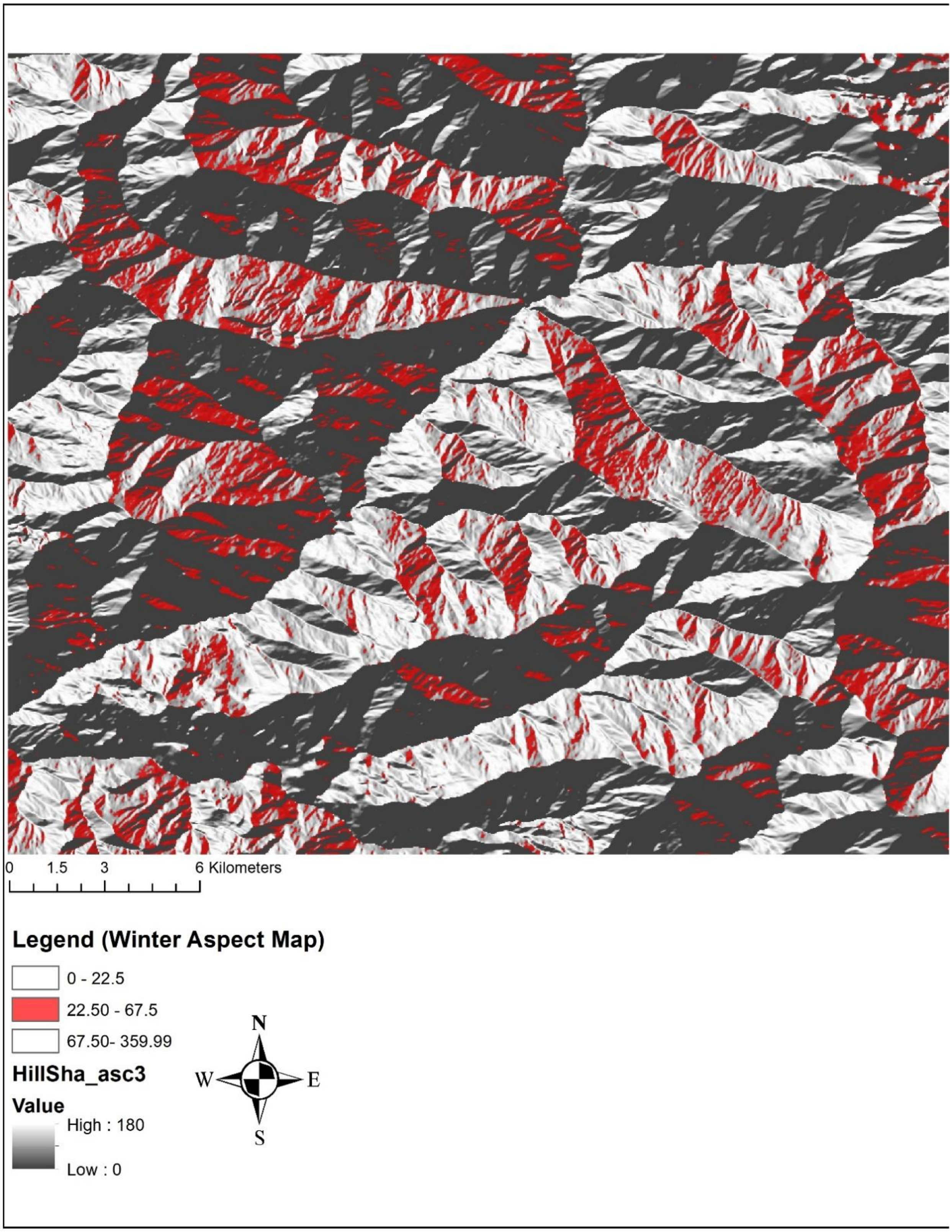

Figure 70 Winter aspect Map

2.4.9 Avalanche hazard Map and exposed elements

This map would be created by combining the key features of an avalanche. When we combine an avalanche hazard map with a residential map, we can see that while the majority of residential areas are not in danger, some areas are likely to have an avalanche.

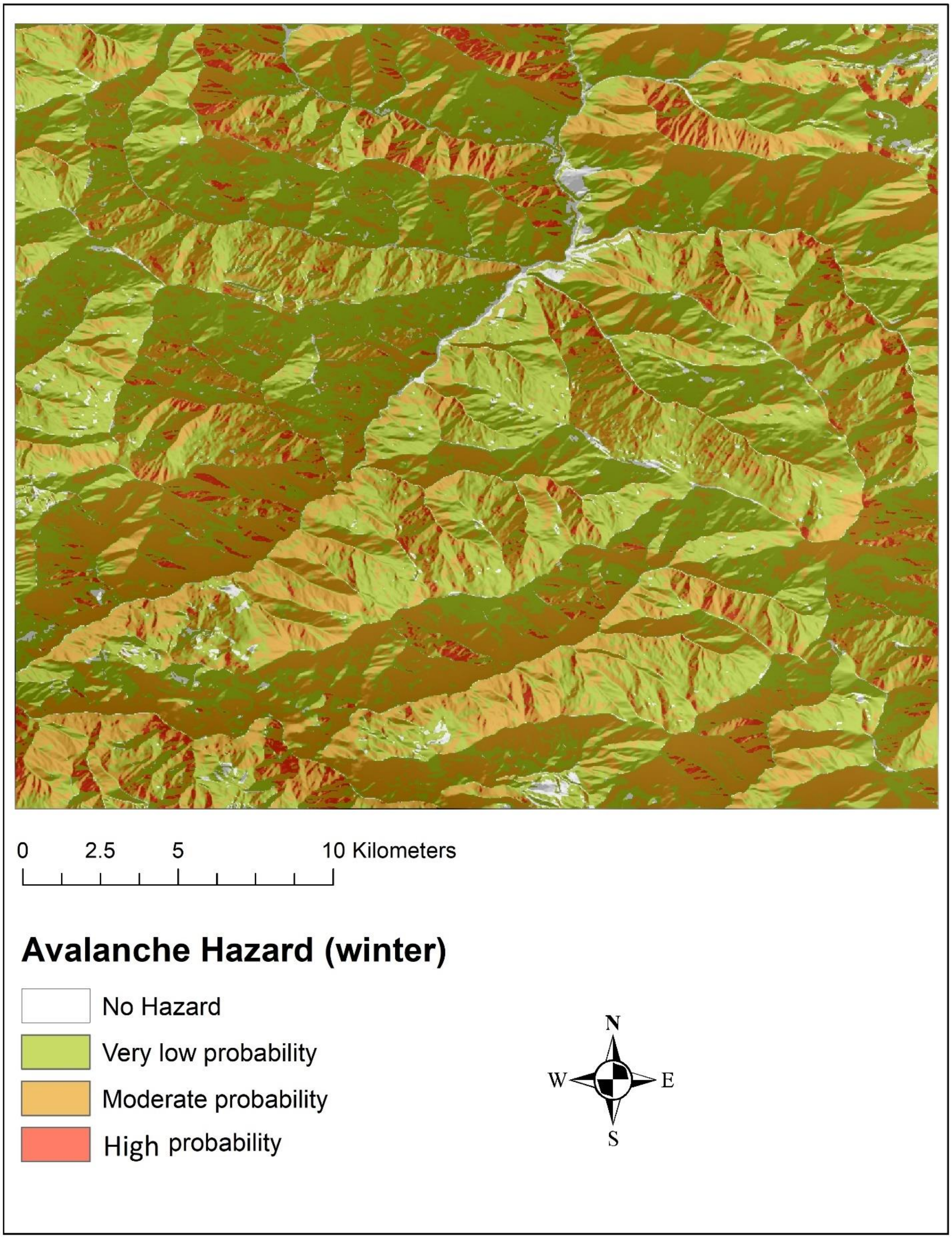

Figure 71 Avalanche hazard Map

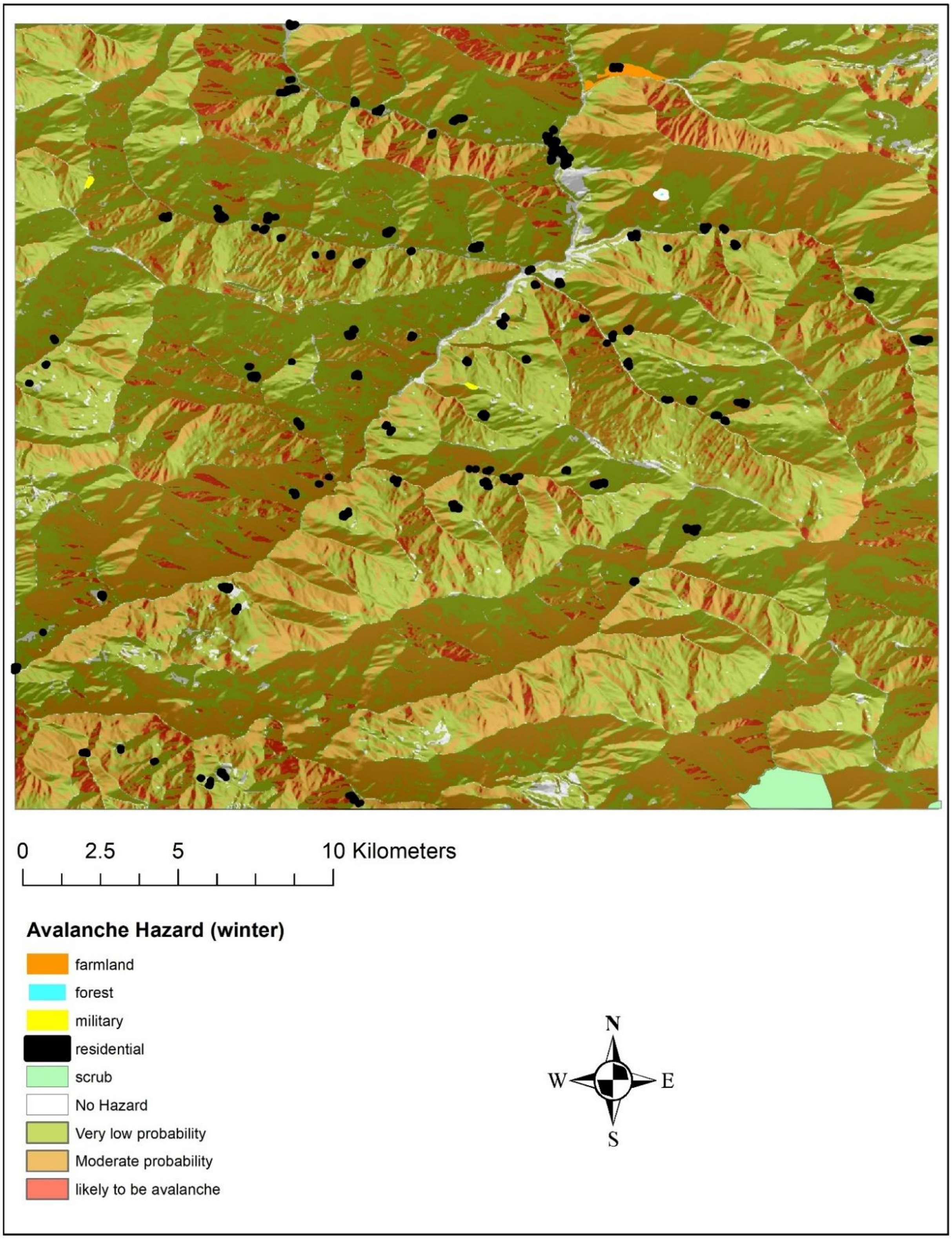

Figure 72 Houses Exposed to Danger (Residential)

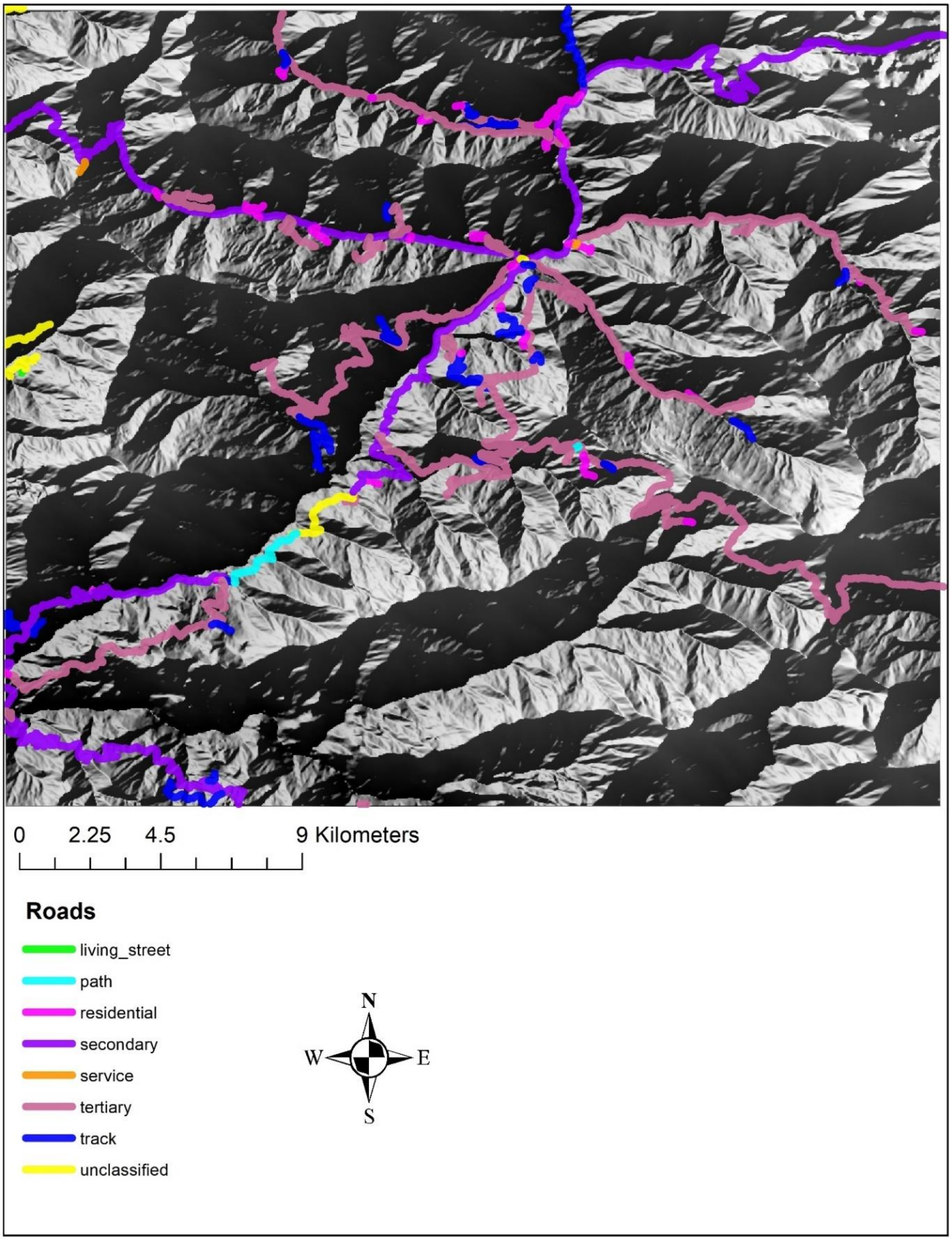

Figure 73 Roads Map

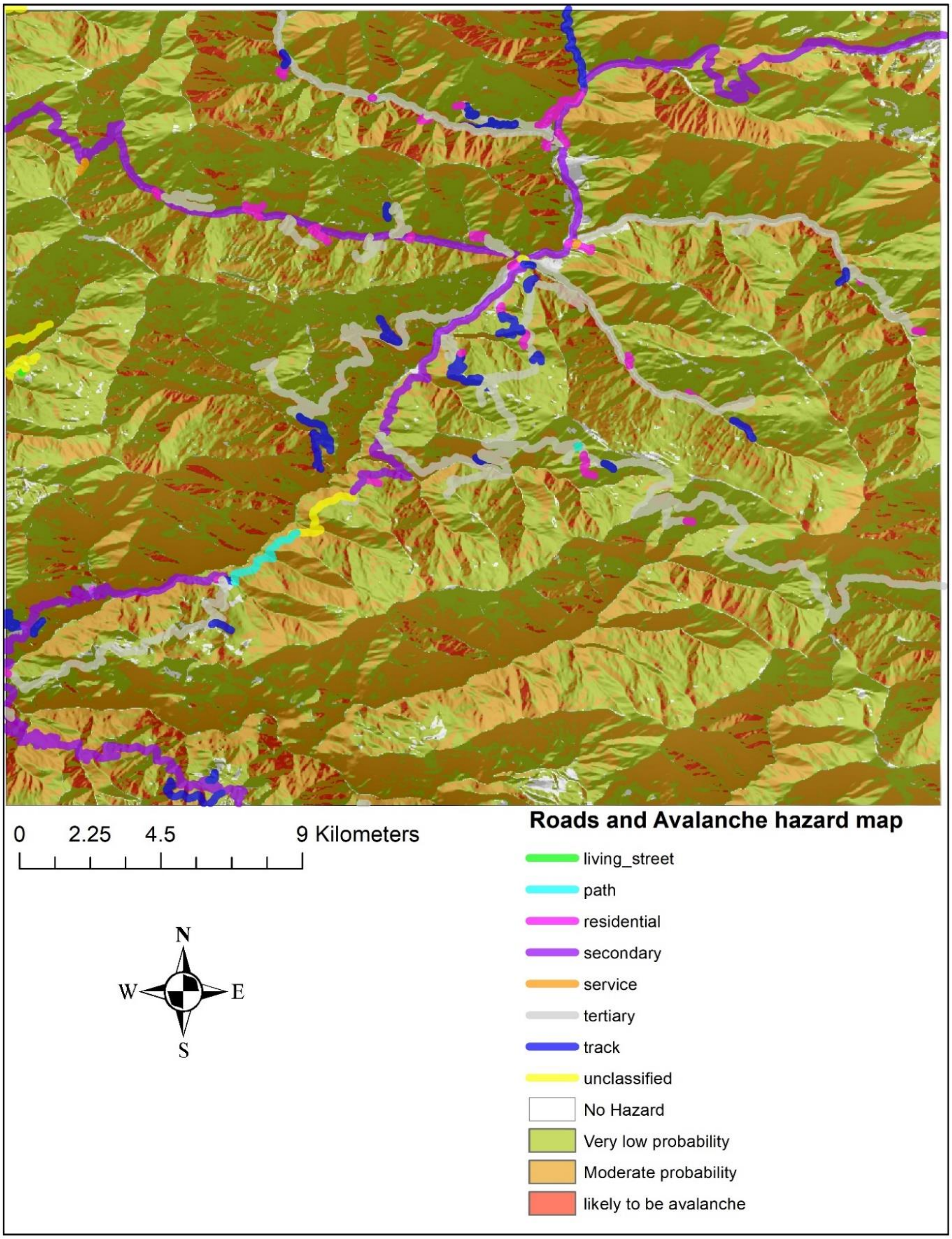

Figure 74 Transportation (Roads) Exposed to Danger

2.4.10 Van province avalanche AHP method

All the maps needed for evaluating the avalanche in the entire VAN province, such as slope, aspect, elevation, land cover, and curvature, can be found here. [24]

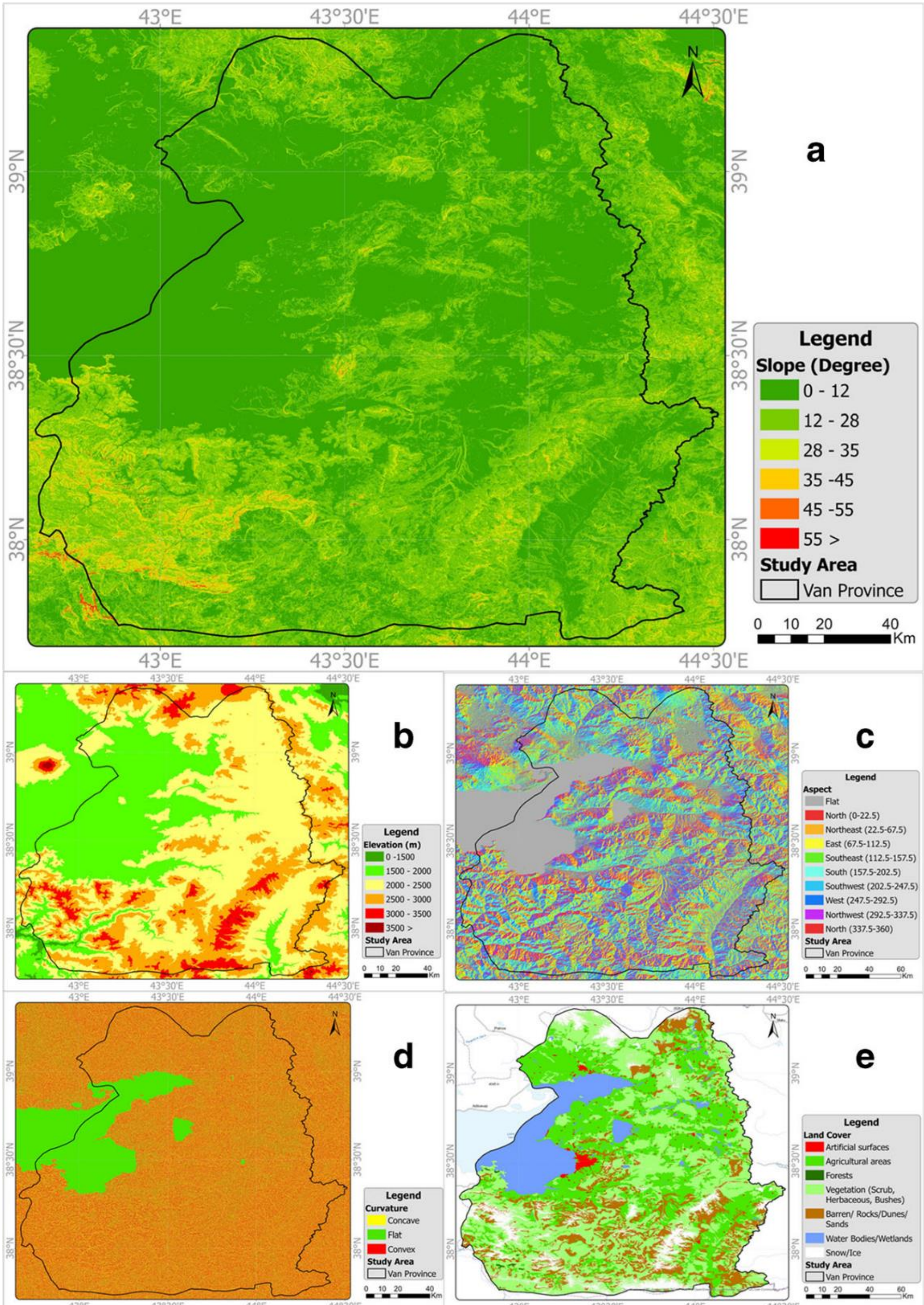

Figure 75 Van province avalanche AHP method

2.4.11 Hazard map of the province

The hazard map is created by combining all of the maps. The technique for creating an Avalanche Risk Map is outlined in the table below.

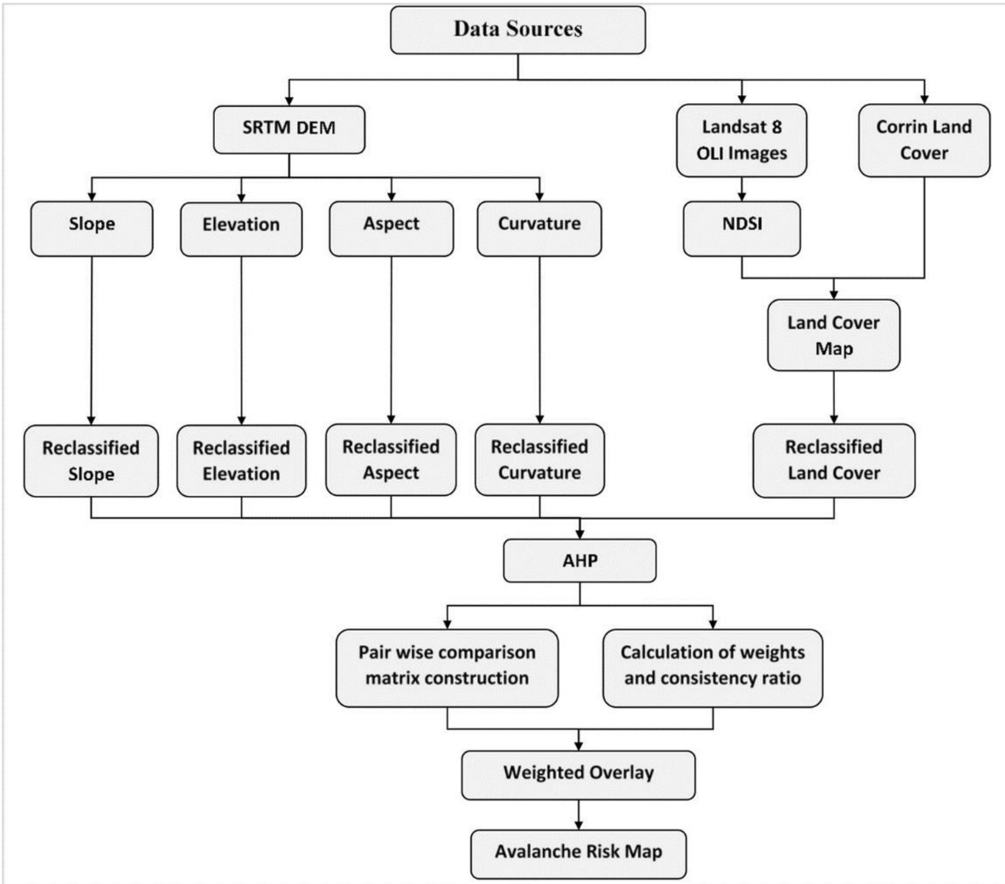

Figure 76 AHP Method

2.4.12 AHP Method

Each avalanche element weights the AHP approach, which is vital to consider throughout the analysis.

Normalized pairwise comparison matrix and derived weights of each parameter using the AHP method

Criteria/criteria	Slope	Elevation	Aspect	Curvature	Land cover	Weights
Slope	0.552	0.660	0.432	0.391	0.375	**0.48**
Elevation	0.184	0.220	0.432	0.326	0.292	**0.29**
Aspect	0.110	0.044	0.086	0.196	0.167	**0.12**
Curvature	0.092	0.044	0.029	0.065	0.125	**0.07**
Land cover	0.061	0.031	0.022	0.022	0.042	**0.04**

Figure 77 table of weights AHP Method

2.4.13 Avalanche Hazard (Risk) map

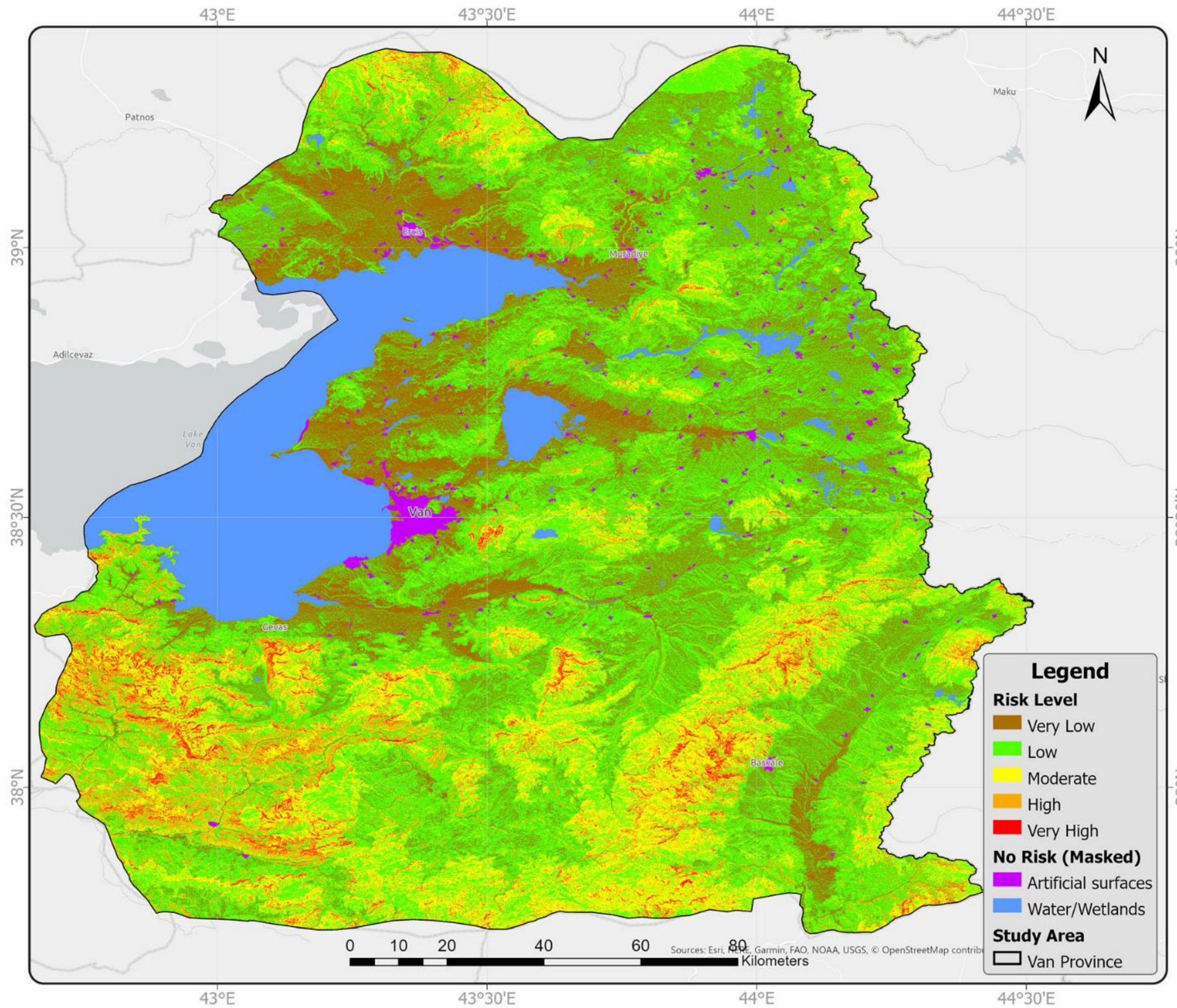

Figure 78 Avalanche Hazard (Risk) map

The percentage of very high-risk locations is 2%, and high-risk areas are 5%, which is a large number for an avalanche occurrence, according to the Risk Map.

Distribution of avalanche risk map based on risk level

Avalanche risk	Area (km^2)	Percentage %
Very low	7297.50	29
Low	11504.68	46
Moderate	4475.72	18
High	1280.94	5
Very high	367.77	2

Figure 79 Avalanche Hazard (Risk) map

2.4.14 Historical avalanches and hazard map (province)

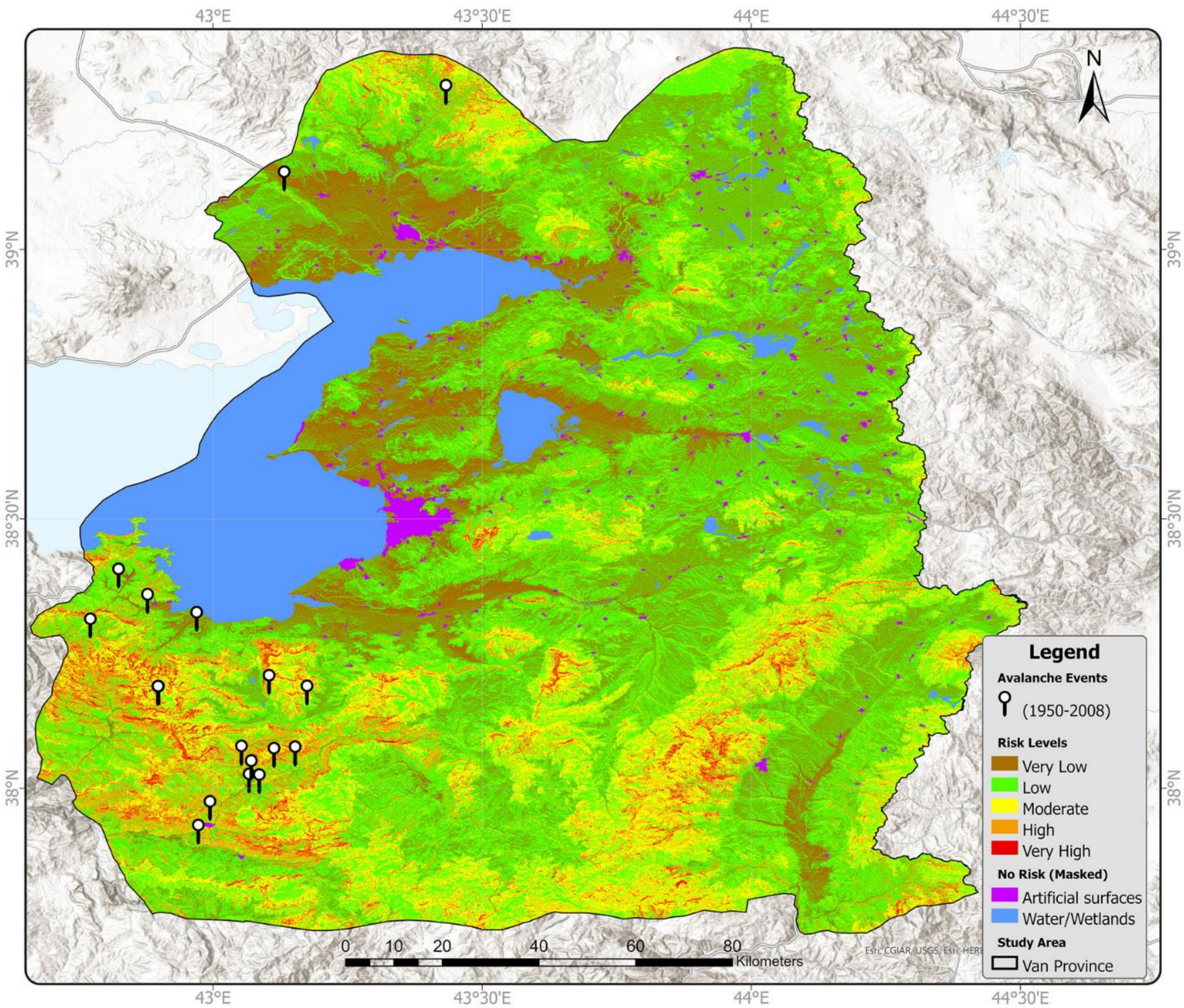

Figure 80 Historical avalanches and hazard map (province)

2.4.15 Historical avalanches (south of province)

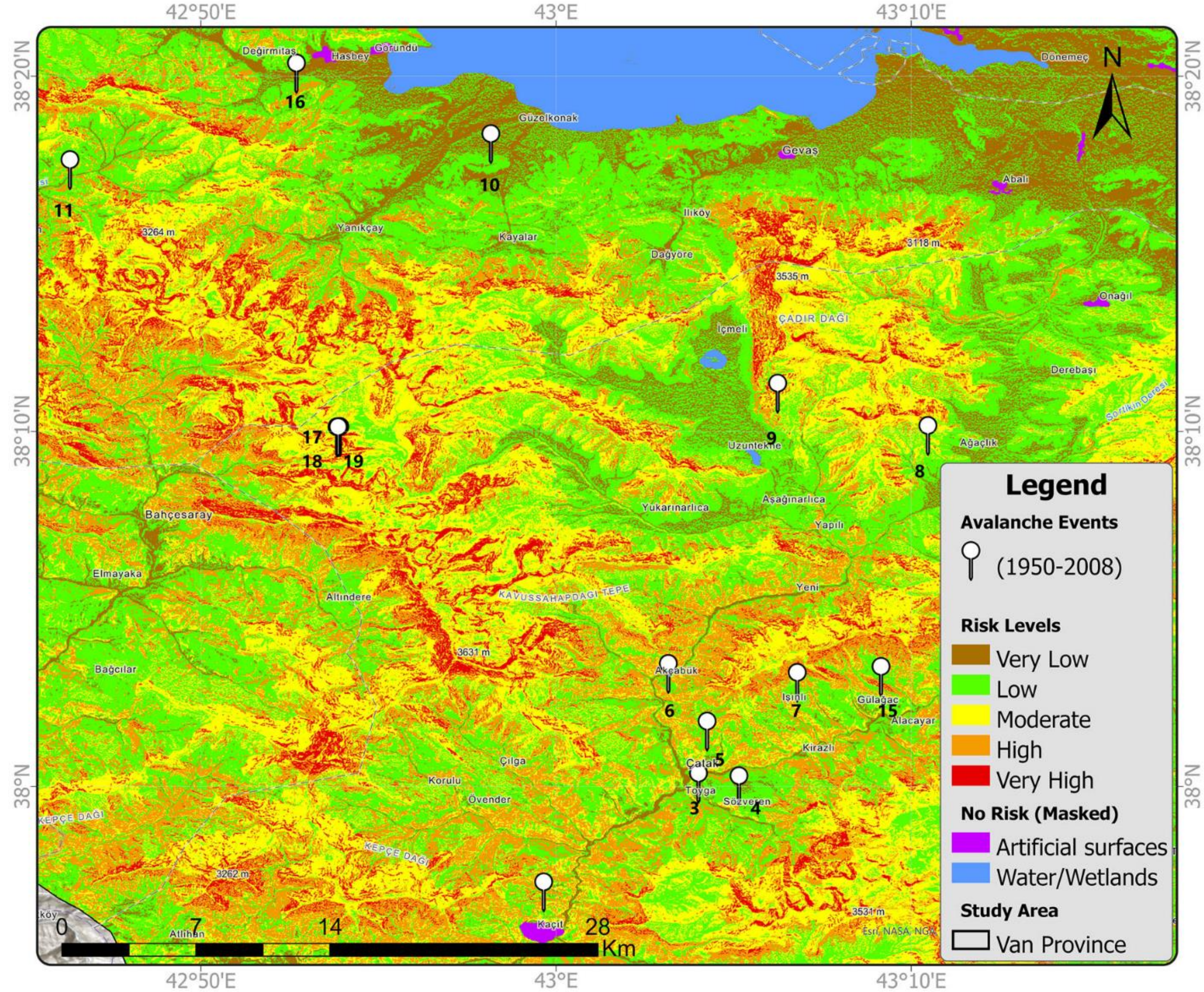

Figure 81 Historical avalanches (south of province)

2.5 Essential and Optional maps

By going over all these case studies, we were able to determine which maps are the most relevant and commonly used for analyzing the events. Other maps are categorized as optional maps since they are tied to human assets and can be created whenever that asset is present. Essential maps are listed in the picture below. There are two sorts of maps within other maps in flood critical maps that are related to temperature and rainfall data that we separate them with green color.

The snowstorm and lake effect event requires five essential maps, the flood needs fourteen, the earthquake requires nine, and the avalanche requires nine.

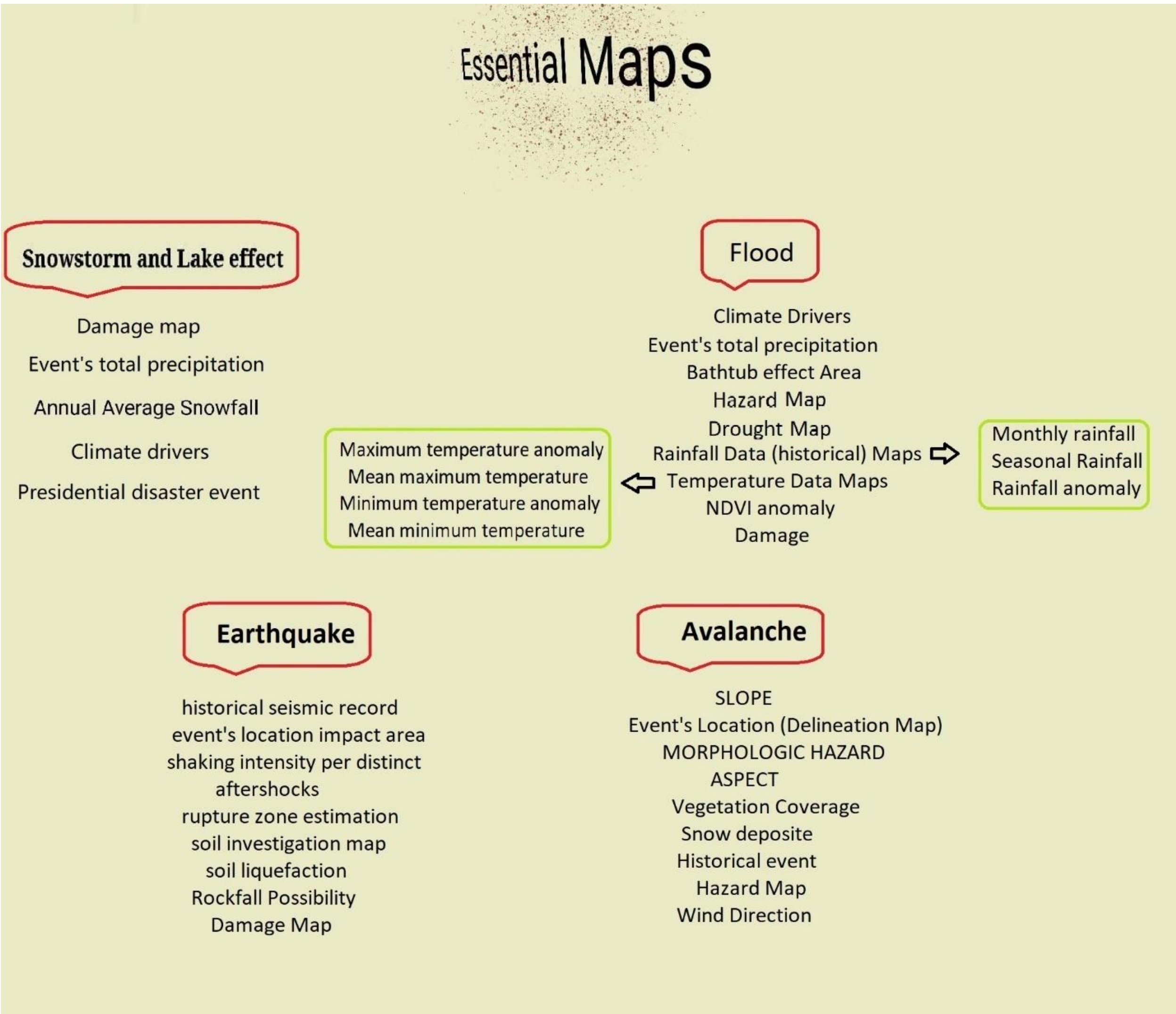

Figure 82 Essential maps for four events

3. Conclusion tables

You can see essential maps and optional maps in the following six tables below, which are indicated by red and green colors in the table. We also noted which maps were created by a reference source with (A) symbol and which were created by me for this thesis with (M) symbol, because in some cases, such as during a snowstorm, maps were of poor quality, or we were unable to access maps. Some of the maps in the table are labeled ‘'this map was not in our case" with the (N) symbol, because they are optional and would be created wherever the specific human assets exist like sensitive building maps.

We also divided all maps into two categories: those that existed before the event and those that were created after the event using old data. For maps that had previously existed, we used the (Ex) symbol, and for maps that were created from old data, we used the (O) symbol.

3.1 Map's best time of production

Events	Maps	Best Time of Map Production								
		Before event -Preparedness					After Event			
		Less than a week	1Week- 1Month	1Month-1Year	More than a Year	Not needed (Not Possible)	Less than 1 Day	1, 3 Days	3-30 Days	Long Term (Months)
Snowstorm and Lake effect	Trasnportation (M)(O)			1						1
	DAMAGE (A)(Ex)					1		1		
	VEGETATION COVERAGE (trees) (M)(O)			1						1
	Event's Total Precopitation (A)(Ex)					1		1		
	Outage (A)(Ex)					1	1			
	Sesitive Buildings (Natech triggers) (M)(O)			1						1
	Annual Average snowfall (A)(Ex)			1						1
	Climate drivers (A)(Ex)	1						1		
	Presidential Disaster Events (A)(Ex)			1						1
	Farmlands (M)(O)			1						1
	Property Damage Historical (A)(Ex)			1						1
	PERCENTAGE %	9	0	64	0	27	9	27	0	64
Flood (bathtub)	Atmospheric patterns and climate drivers (A)(Ex)	1						1		
	Event's Total Precopitation (A)(Ex)					1		1		
	bathtub effect Area (M)(O)				1					1
	Transportation (A)(Ex)			1						1
	Hazard Map(Danger or hazard) (M)(O)			1						1
	Emergency elements exposed to danger (M)(O)			1						1
	Farms exposed to danger (M)(O)				1					1
	Transportations Exposed to danger (M)(O)				1					1
	Houses Exposed to danger (M)(O)			1						1
	all type of building exposed to danger (M)(O)			1						1
	sensitive buildings exposed to danger (M)(O)			1						1
	Drouth map (A)(Ex)			1						1
	monthly rainfall (A)(Ex)				1					1
	seasonal rainfall (A)(Ex)				1					1
	rainfall anomaly (A)(Ex)				1					1
	maximum temperature anomaly (A)(Ex)				1					1
	mean maximum temperature (A)(Ex)				1					1
	minimum temperature anomaly (A)(Ex)				1					1
	mean minimum temperature (A)(Ex)				1					1
	NDVI anomaly (A)(Ex)				1					1
	farm dam survey map (A)(Ex)				1					1
	Damage Map (N)					1		1		
	PERCENTAGE %	5	0	32	55	9	0	14	0	86
Earthquake	historical seismic record (A)(Ex)			1						1
	the event's location impact area (A)(Ex)					1	1			
	shaking intensity per distinct (A)(Ex)					1	1			
	aftershocks (A)(Ex)					1	1			
	rupture zone estimation (A)(Ex)			1					1	
	fatalities (A)(Ex)					1		1		
	soil investigation map (A)(Ex)			1						1
	soil liquefaction (A)(Ex)			1						1
	Rockfall Possibility (N)			1						1
	Damage Map (A)(Ex)					1		1		
	Transportations (M)(O)			1						1
	PERCENTAGE %	0	0	55	0	45	27	18	9	45
Avalanche	SLOPE (A)(M)(Ex)				1					1
	Event's Location (Delineation Map) (A)(N)					1	1			
	LAND USE (M)(O)			1						1
	MORPHOLOGIC HAZARD (M)(O)				1					1
	ASPECT (A)(M)(O)				1					1
	Vegetation Coverage (A) (M) (O)			1						1
	Snow deposite (A) (Ex)		1						1	
	Transportations Exposed to danger (M)(O)			1						1
	Historical event (A)(Ex)				1					1
	Hazard Map (A)(M) (Ex)			1						1
	Wind Direction (A)(M) (O)			1						1
	Farm exposed to danger (M)(O)			1						1
	Emergency elements exposed to danger (M)(O)			1						1
	Houses Exposed to danger (M)(O)			1						1
	Transportations (M)(O)			1						1
	Damage Map (N)					1	1			
	PERCENTAGE %	0	6	56	25	13	13	0	6	81
This Map was Not in our case	(N)									
Maps Produced by me	(M)									
Maps from refrence authors	(A)									
Maps Existed before event	(Ex)									
Maps created from old data	(O)									
Essential Maps										
Optional Maps										

Figure 83 table of map's best time of production

It is feasible to classify maps according to when they are required and when the optimal time to produce them is. Some maps are crucial and useful immediately following an event, yet they are nearly useless days later. Departments like municipalities need to remember the best map-making practices.

Based on when different emergency offices in different countries (USA, Turkey, Nepal, Australia) made the maps for events, the best time of production has been noted for four events in this table. Less than a week, one week-one month, one month-one year, more than a year are considered for before events, and less than a day, one-three days, one-thirty days, more than a month were considered for after events.

In the following graphs which were created from the table, we will discuss the results for these four events.

3.1.1 Earthquake maps the best time of production.

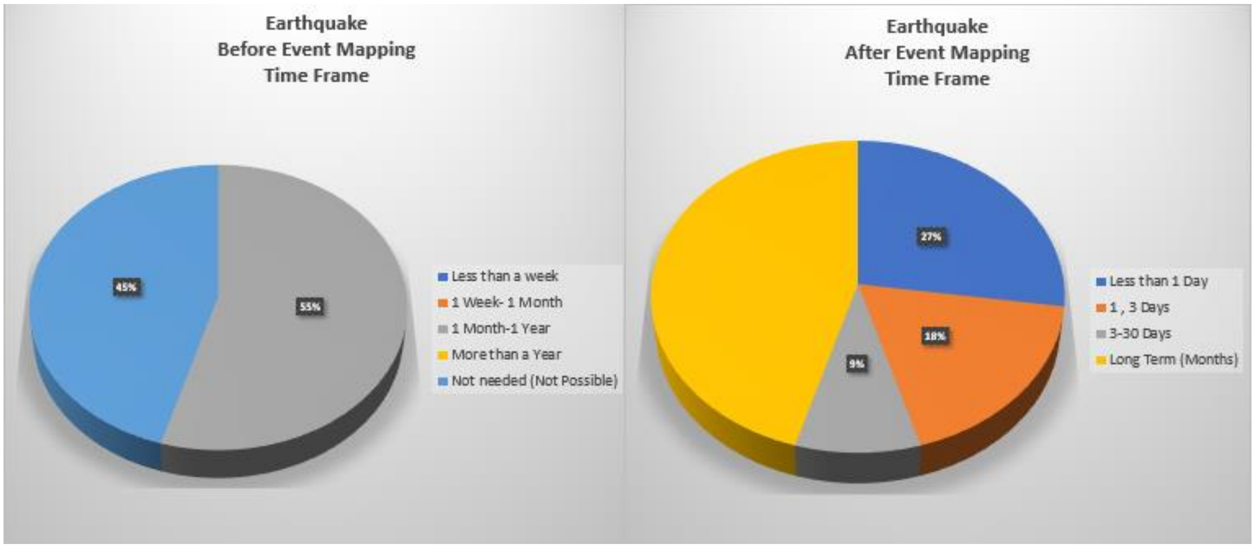

Figure 84 Graph of earthquake map's best time of production

Before the event, Nepal's emergency office made these maps for the preparedness phase, the historical seismic record map, soil investigation map, soil liquefaction map, rockfall map, and transportation map, which refer to a one-month-one-year period before an earthquake event. These maps account for about 55% of the most popular before-event earthquake maps. The remaining 45 percent of maps are unrelated to the pre-event period.

After the earthquake, Nepal's emergency office made the event's location impact area map, shaking intensity per distinct map, aftershocks map, following the occurrence, and these maps account for 27% of earthquakes after the event map.

If there are any fatalities, a fatalities map must be generated within 1-3 days of the event. A rupture zone estimating map should be developed 3-30 days after the occurrence since this map allows us to estimate where the next probable earthquake or aftershock would occur like in Nepal's earthquake.

The rest of the maps in the after-event phase are marked as long-term because these are the maps that are useful for preparedness and they were produced in the preparedness phase but we have to update them for future events like the historical seismic record map, soil investigation map, soil liquefaction map, rockfall map, and transportation map.

3.1.2 Avalanche Maps time of production

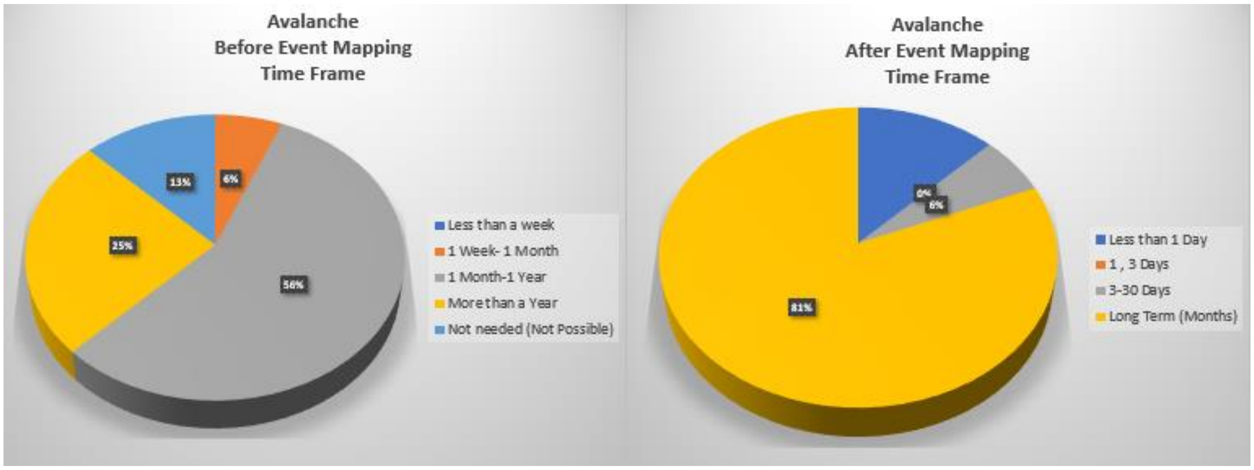

Figure 85 Graph of Avalanche Maps time of production

Avalanche maps are frequently based on the shape of the terrain, which in the majority of the cases, can change over hundreds of years, such as the slope of the terrain and the DTM map. The only map that has to be updated every week-month is the snow deposit map for dangerous regions, whereas the rest of the avalanche maps best practice is every month to a year like vegetation coverage map, Hazard Map, etc.

In the Van province case, the event location map was created following the event, and a snow deposit update was created weeks later. As a result, we consider the updates of the snow deposits map into 3-30 days after the event.

There is usually no Damage Map in an avalanche because the event's intensity is so high that it wipes out everything at the location. Snow has blanketed the entire area in the aftermath of the disaster, making it difficult, but not impossible, to pinpoint the exact location. The use of a delineation map in avalanche studies is common, yet this map is rarely useful. As a result, we rely on the event's Location Map instead.

3.1.3 Snowstorm and flood maps time of production

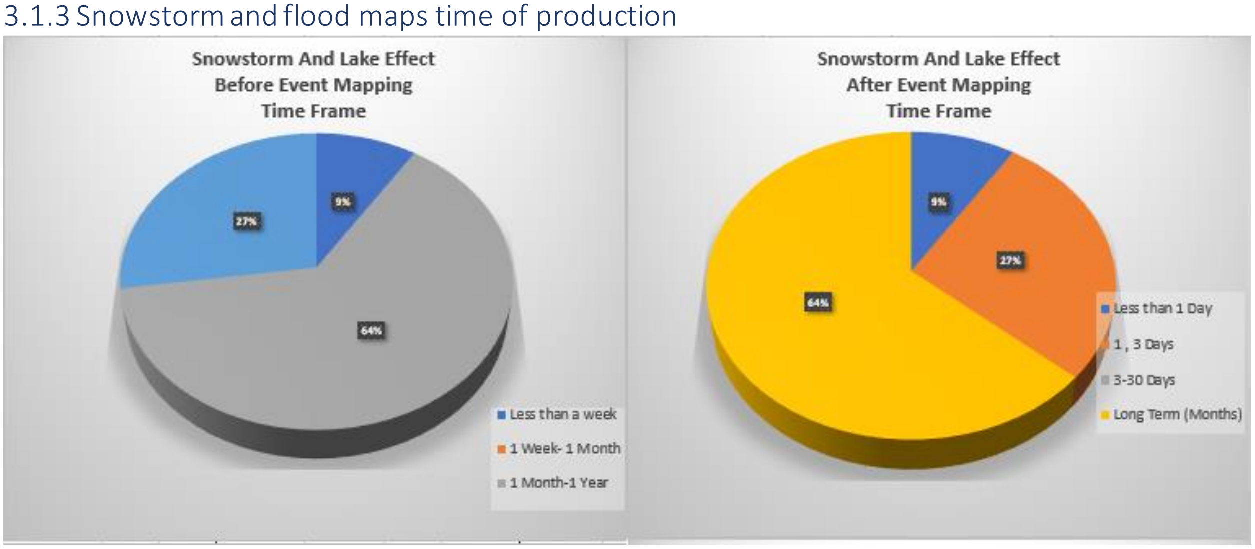

Figure 86 graph of Snowstorm maps time of production

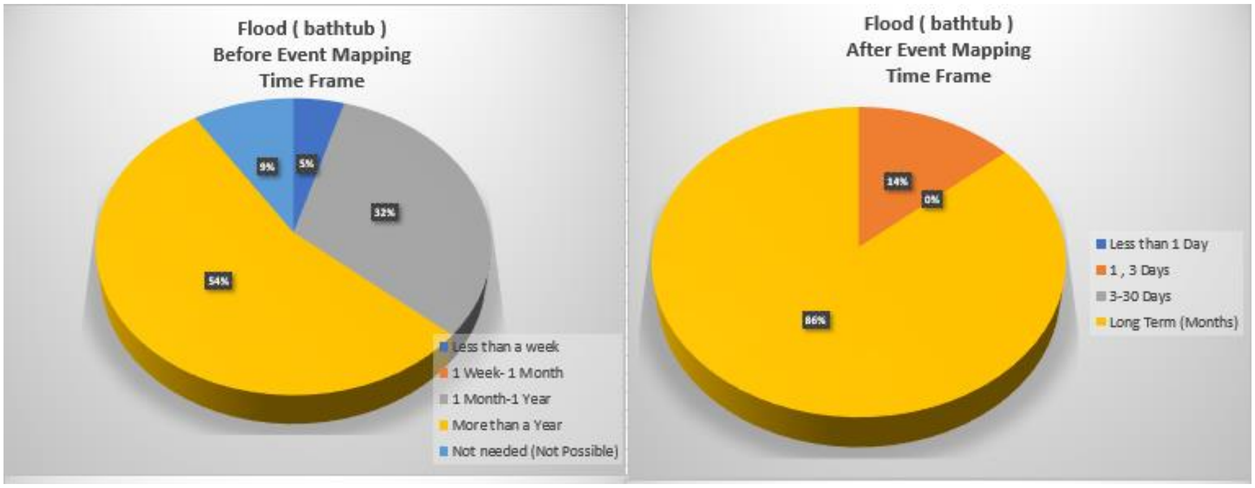

Figure 87 graph of flood maps time of production

The climatic drivers must be constantly monitored in the area that is prone to both of these disasters. Following the incidence, climate drivers should have been tracked, and the map should have been updated every 1-3 days after the event.

Damage maps and event total precipitation maps must be made in 1-3 days after these two occurrences, although power or other outages normally occur after the snowstorm, therefore outage maps must be created as soon as possible after the event.

54% of flood maps should have been in use years before the event and in the preparedness phase because they are related to temperature and rainfall data and vegetation coverage.

Last but not least, all four events demand more maps during the preparation phase than during the other phases (during the emergency, recovery).

3.2 Map’s life and assets saving

Events	Maps					assets-saving related							
		Life Saving				Man-Made				natural			
		Preparedness	During Emergency	Recovery	Not Related	Preparedness	During Emergency	Recovery	Not Related	Preparedness	During Emergency	Recovery	Not Related
Snowstorm and Lake effect	Trasnportation (M)(O)	1				1		1					1
	DAMAGE (A)(Ex)		1	1			1	1				1	
	VEGETATION COVERAGE (trees) (M)(O)				1				1	1		1	
	Event's Total Precopitation (A)(Ex)				1				1				1
	Outage (A)(Ex)		1	1			1	1					1
	Sesitive Buildings (Natech triggers) (M)(O)	1				1							1
	Annual Average snowfall (A)(Ex)	1				1				1			
	Climate drivers (A)(Ex)	1	1				1						1
	Presidential Disaster Events (A)(Ex)	1				1							1
	Farmlands (M)(O)				1	1							1
	Property Damage Historical (A)(Ex)	1		1		1		1					1
	PERCENTAGE %	6	3	3	3	6	3	4	2	2	0	2	8
Flood (bathtub)	Atmospheric patterns and climate drivers (A)(Ex	1	1				1						1
	Event's Total Precopitation (A)(Ex)				1				1				1
	bathtub effect Area (M)(O)	1				1				1			1
	Transportation (A)(Ex)	1				1		1					1
	Hazard Map(Danger or hazard) (M)(O)	1	1			1	1			1			
	Emergency elements exposed to danger (M)(O	1				1							1
	Farms exposed to danger (M)(O)				1	1							1
	Transportations Exposed to danger (M)(O)	1				1							1
	Houses Exposed to danger (M)(O)	1				1							1
	all type of building exposed to danger (M)(O)	1				1							1
	sensitive buildings exposed to danger (M)(O)	1				1							1
	Drouth map (A)(Ex)	1				1				1			
	monthly rainfall (A)(Ex)	1				1				1			
	seasonal rainfall (A)(Ex)	1				1				1			
	rainfall anomaly (A)(Ex)	1				1				1			
	maximum temperature anomaly (A)(Ex)	1				1				1			
	mean maximum temperature (A)(Ex)	1				1				1			
	minimum temperature anomaly (A)(Ex)	1				1				1			
	mean minimum temperature (A)(Ex)	1				1				1			
	NDVI anomaly (A)(Ex)	1				1				1			
	farm dam survey map (A)(Ex)				1	1							1
	Damage Map (N)		1	1			1	1				1	
	PERCENTAGE %	18	3	1	3	19	3	2	1	11	0	1	10
Earthquake	historical seismic record (A)(Ex)	1				1				1			
	the event's location impact area (A)(Ex)		1	1			1					1	
	shaking intensity per distinct (A)(Ex)		1	1			1					1	
	aftershocks (A)(Ex)		1	1			1					1	
	rupture zone estimation (A)(Ex)	1						1		1			
	fatalities (A)(Ex)				1				1				1
	soil investigation map (A)(Ex)	1				1				1			
	soil liquefaction (A)(Ex)	1				1				1			
	Rockfall Possibility (N)	1				1				1			
	Damage Map (A)(Ex)		1	1			1	1				1	
	Transportations (M)(O)	1				1							1
	PERCENTAGE %	6	4	4	1	5	4	2	1	5	0	4	2
Avalanche	SLOPE (A)(M)(Ex)				1				1				1
	Event's Location (Delineation Map) (A)(N)		1					1				1	
	LAND USE (M)(O)	1				1		1		1			
	MORPHOLOGIC HAZARD (M)(O)				1	1				1			
	ASPECT (A)(M)(O)				1				1				1
	Vegetation Coverage (A) (M) (O)	1							1	1		1	
	Snow deposite (A) (Ex)	1				1				1			
	Transportations Exposed to danger (M)(O)	1				1							1
	Historical event (A)(Ex)	1	1			1				1			
	Hazard Map (A)(M) (Ex)				1	1				1			
	Wind Direction (A)(M) (O)				1				1				1
	Farm exposed to danger (M)(O)				1	1				1			1
	Emergency elements exposed to danger (M)(O	1				1							1
	Houses Exposed to danger (M)(O)	1				1							1
	Transportations (M)(O)	1				1							1
	Damage Map (N)		1				1	1				1	
	Number of Maps	8	3	0	6	10	1	3	4	7	0	3	8
This Map was Not in our case	(N)												
Maps Produced by me	(M)												
Maps from refrence authors	(A)												
Maps Existed before event	(Ex)												
Maps created from old data	(O)												
Essential Maps													
Optional Maps													

Figure 88 table of Map’s life and assets saving.

Some maps serve as a foundation or necessity for other maps, while others are used directly to keep people and things safe.

Manmade assets and natural assets are the two types of assets we can categorize. Preparedness, during the emergency, and recovery are the three phases considered for lifesaving or asset saving.

The phase of preparation for maps that provide sight and serve as a foundation for life-saving decisions like drouth map and temperature map in flood.

During the emergency phase, maps are used to navigate the situation like damage maps and climate drivers maps.

Throughout the recovery period, the maps that are highlighted improve, and these enhancements may save future lives or assets.

Because the damage map shows the availability of transportation and roads, the transportation map is considered as a map needed for the preparedness in the table.

The damage map is useful both during the emergency and during the recovery phase since it reveals where the vulnerability was and where future improvements may be made.

When we look at these four occurrences in the emergency phase, we see that there are no maps in the natural assets saving subcategory, although natural assets saving maps are mostly used in the preparation and recovery phases.

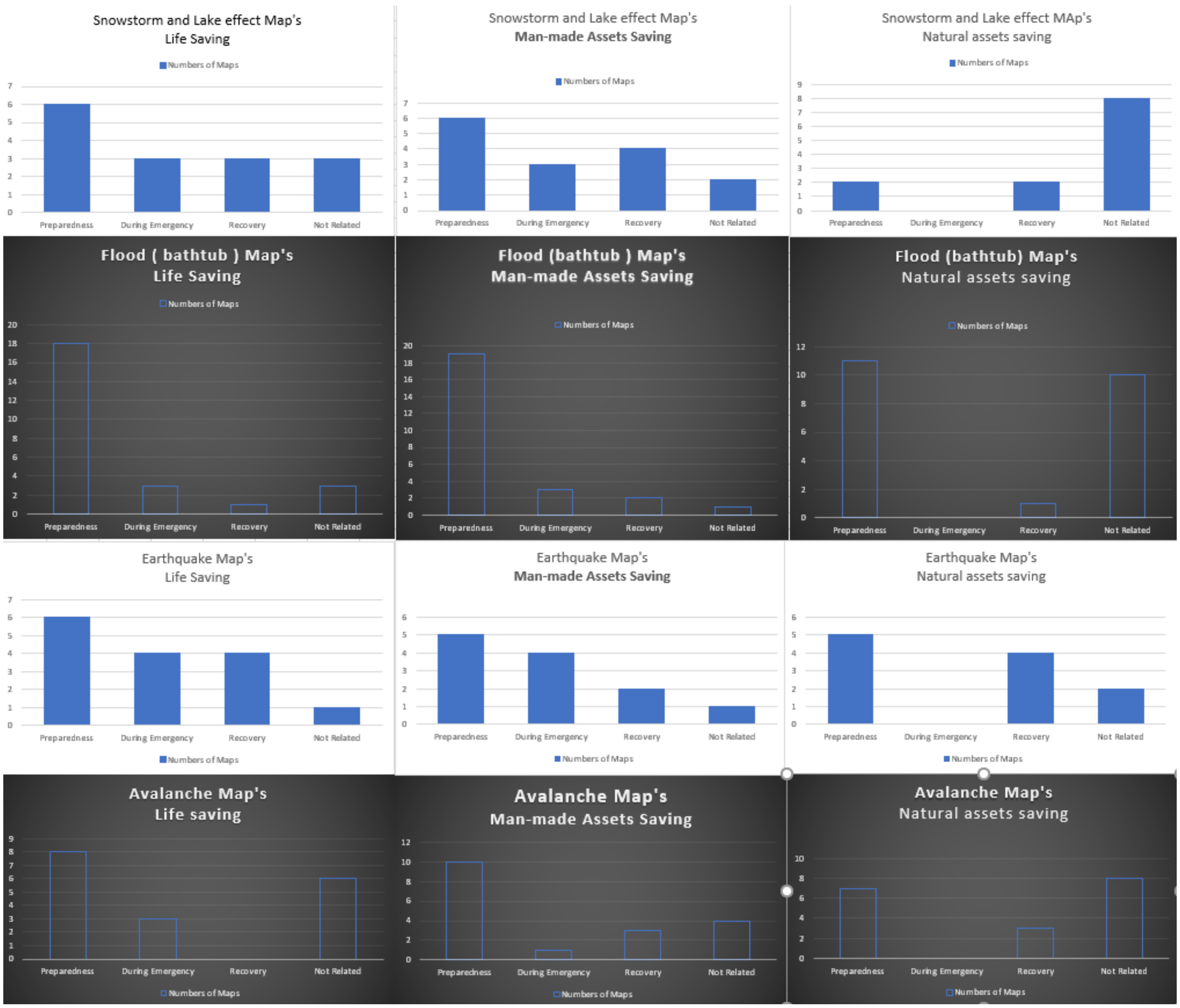

Figure 89 Graph of Map's life and assets saving phases.

After analyzing these four incidents, it's clear that flood and avalanche maps are usually in the planning stages, and it's critical for communities that are vulnerable to these two types of disasters to be prepared before it's too late.

By examining the stages, it is clear that the majority of the maps are used in the preparation phase for assets saving, and mapping has a significant impact on being prepared for events.

3.3 Maps Production Requirement

Events	Maps	Map production what is needed to produce the Map geospatial information	2< multiple layers	Complex Processing	Private Information
Snowstorm and Lake effect	Trasnportation (M)(O)	1	1		
	DAMAGE (A)(Ex)	1	1	1	1
	VEGETATION COVERAGE (trees) (M)(O)	1			
	Event's Total Precopitation (A)(Ex)	1			
	Outage (A)(Ex)	1	1	1	1
	Sesitive Buildings (Natech triggers) (M)(O)	1			
	Annual Average snowfall (A)(Ex)	1			
	Climate drivers (A)(Ex)	1	1	1	
	Presidential Disaster Events (A)(Ex)	1			
	Farmlands (M)(O)	1			
	Property Damage Historical (A)(Ex)	1			
	Number of Maps	11	4	3	2
Flood (bathtub)	Atmospheric patterns and climate drivers (A)(Ex	1	1	1	
	Event's Total Precopitation (A)(Ex)	1			
	bathtub effect Area (M)(O)	1	1	1	
	Transportation (A)(Ex)	1			
	Hazard Map(Danger or hazard) (M)(O)	1	1	1	
	Emergency elements exposed to danger (M)(O)	1			
	Farms exposed to danger (M)(O)	1			
	Transportations Exposed to danger (M)(O)	1			
	Houses Exposed to danger (M)(O)	1			
	all type of building exposed to danger (M)(O)	1			
	sensitive buildings exposed to danger (M)(O)	1			
	Drouth map (A)(Ex)	1	1		
	monthly rainfall (A)(Ex)	1			
	seasonal rainfall (A)(Ex)	1			
	rainfall anomaly (A)(Ex)	1			
	maximum temperature anomaly (A)(Ex)	1			
	mean maximum temperature (A)(Ex)	1			
	minimum temperature anomaly (A)(Ex)	1			
	mean minimum temperature (A)(Ex)	1			
	NDVI anomaly (A)(Ex)	1			
	farm dam survey map (A)(Ex)	1	1		
	Damage Map (N)	1	1		
	Number of Maps	22	6	3	0
Earthquake	historical seismic record (A)(Ex)	1			
	the event's location impact area (A)(Ex)	1	1		
	shaking intensity per distinct (A)(Ex)	1			
	aftershocks (A)(Ex)	1			
	rupture zone estimation (A)(Ex)	1	1		
	fatalities (A)(Ex)	1			
	soil investigation map (A)(Ex)	1	1		
	soil liquefaction (A)(Ex)	1	1		
	Rockfall Possibility (N)	1	1	1	
	Damage Map (A)(Ex)	1	1	1	
	Transportations (M)(O)	1			
	Number of Maps	11	6	2	0
Avalanche	SLOPE (A)(M)(Ex)	1			
	Event's Location (Delineation Map) (A)(N)	1			
	LAND USE (M)(O)	1			
	MORPHOLOGIC HAZARD (M)(O)	1	1	1	
	ASPECT (A)(M)(O)	1			
	Vegetation Coverage (A) (M) (O)	1			
	Snow deposite (A) (Ex)	1			
	Transportations Exposed to danger (M)(O)	1			
	Historical event (A)(Ex)	1			
	Hazard Map (A)(M) (Ex)	1	1	1	
	Wind Direction (A)(M) (O)	1			
	Farm exposed to danger (M)(O)	1			
	Emergency elements exposed to danger (M)(O)	1			
	Houses Exposed to danger (M)(O)	1			
	Transportations (M)(O)	1			
	Damage Map (N)	1			
	Number of Maps	16	2	2	0
This Map was Not in our case	(N)				
Maps Produced by me	(M)				
Maps from refrence authors	(A)				
Maps Existed before event	(Ex)				
Maps created from old data	(O)				
Essential Maps					
Optional Maps					

Figure 90 table of Maps Production Requirement

Sometimes, simply overlaying two layers is enough to make a map, such as a transportation map, but other times, the processing is required, which is not as simple as overlaying and requires engineering knowledge or sophisticated GIS software tools. For example, to understand flood extent, it is necessary to process synthetic-aperture radar (SAR) imagery.

The production of some maps necessitates the use of private information. Which means the data is not available to the general public. The data could be available for purchase in exchange for money, but they are sometimes categorized as government or municipality security information and cannot be purchased. Like a power outage map in snowfall and lake effect, which requires the production of private information about a city's infrastructure. We also grouped maps based on how they were created.

The chart shows that the majority of the maps for these four events only required multiple layers. Just a few maps need complex processing and private information.

3.4 Map’s Layers

Events	Maps	Map's Layers			
		Layers			
Snowstorm and Lake effect	Trasnportation (M)(O)	Base Map	Tranportation		
	DAMAGE (A)(Ex)	Base Map	Damaged Infrastructures	Damaged Structures	Natural Assets Damaged
	VEGETATION COVERAGE (trees) (M)(O)	Base Map	Vegetation		
	Event's Total Precopitation (A)(Ex)	Base Map	Water accumulation Data		
	Outage (A)(Ex)	Base Map	System or infrastructure Map		
	Sesitive Buildings (Natech triggers) (M)(O)	Base Map	Buildings		
	Annual Average snowfall (A)(Ex)	Base Map	snowfall		
	Climate drivers (A)(Ex)	Base Map	Satelight imagery	Historical Movements	
	Presidential Disaster Events (A)(Ex)	Base Map	Historical events location	Damages	
	Farmlands (M)(O)	Base Map	Land use		
Flood (bathtub)	Atmospheric patterns and climate drivers (A)(Ex)	Base Map	Satelight imagery	Historical Movements	
	Event's Total Precopitation (A)(Ex)	Base Map	Water accumulation Data		
	bathtub effect Area (M)(O)	Base Map	DTM	Water Bodies	
	Transportation (A)(Ex)	Base Map	Tranportation		
	Hazard Map(Danger or hazard) (M)(O)	Base Map	DTM	Water Bodies	Flood plane
	Emergency elements exposed to danger (M)(O)	Base Map	Hazard Map (Danger)	Emergency Elements	
	Farms exposed to danger (M)(O)	Base Map	Hazard Map (Danger)	Land use	
	Transportations Exposed to danger (M)(O)	Base Map	Hazard Map (Danger)	Transportation	
	Houses Exposed to danger (M)(O)	Base Map	Hazard Map (Danger)	Buildings	
	all type of building exposed to danger (M)(O)	Base Map	Hazard Map (Danger)	Buildings	
	sensitive buildings exposed to danger (M)(O)	Base Map	Hazard Map (Danger)	Buildings	
	Drouth map (A)(Ex)	Base Map	Vegetation	Water Bodies	Soil
	monthly rainfall (A)(Ex)	Base Map	Water accumulation Data		
	seasonal rainfall (A)(Ex)	Base Map	Water accumulation Data		
	rainfall anomaly (A)(Ex)	Base Map	Water accumulation Data		
	maximum temperature anomaly (A)(Ex)	Base Map	Temprature		
	mean maximum temperature (A)(Ex)	Base Map	Temprature		
	minimum temperature anomaly (A)(Ex)	Base Map	Temprature		
	mean minimum temperature (A)(Ex)	Base Map	Temprature		
	NDVI anomaly (A)(Ex)	Base Map	Vegetation		
	Damage Map (N)	Base Map	Damaged Structure Locations	Damaged Infrastructures	Natural Assets Damaged
Earthquake	historical seismic record (A)(Ex)	Base Map	Seismic Records		
	the event's location impact area (A)(Ex)	Base Map	Seismic Records		
	shaking intensity per distinct (A)(Ex)	Base Map	Seismic Records		
	aftershocks (A)(Ex)	Base Map	Seismic Records		
	rupture zone estimation (A)(Ex)	Base Map	Seismic Records		
	fatalities (A)(Ex)	Base Map	Fatalities		
	soil investigation map (A)(Ex)	Base Map	boreholes location	Soil	
	soil liquefaction (A)(Ex)	Base Map	boreholes location	Soil	nderground Water Bodies
	Damage Map (A)(Ex)	Base Map	Damaged Infrastructures	Damaged Structure	Natural Assets Damaged
	Transportations (M)(O)	Base Map	Tranportation		
Avalanche	SLOPE (A)(M)(Ex)	Base Map	DTM		
	Event's Location (Delineation Map) (A)(N)	Base Map	Location of event		
	LAND USE (M)(O)	Base Map	Land use		
	MORPHOLOGIC HAZARD (M)(O)	Base Map	Slope		
	ASPECT (A)(M)(O)	Base Map	DTM		
	Vegetation Coverage (A) (M) (O)	Base Map	Vegetation		
	Snow deposite (A) (Ex)	Base Map	Satelight imagery		
	Transportations Exposed to danger (M)(O)	Base Map	Avalanche Risk Map	Transportation	
	Hazard Map (A)(M) (Ex)	Base Map	Morphologic Hazard	Wind Direction	Vegetation Coverage
	Wind Direction (A)(M) (O)	Base Map	Wind Direction data		
	Farm exposed to danger (M)(O)	Base Map	Land use		
	Emergency elements exposed to danger (M)(O)	Base Map	Buildings		
	Houses Exposed to danger (M)(O)	Base Map	Buildings		
	Transportations (M)(O)	Base Map	Tranportation		
	Damage Map (N)	Base Map	Damaged Infrastructures	Damaged Structure	Natural Assets Damaged
This Map was Not in our case	(N)				
Maps Produced by me	(M)				
Maps from refrence authors	(A)				
Maps Existed before event	(Ex)				
Maps created from old data	(O)				
Essential Maps					
Optional Maps					

Figure 91 table of Map’s Layers

We realize that we can utilize the same data on different maps after gathering data for the maps. To put it another way, some layers on several maps are the same. We employ seismic records data in five keymaps in earthquake mapping, for example, the event's location impact area map, shaking intensity per distinct map, aftershocks map, rupture zone estimating map, and historical seismic record map.

In addition, flood mapping relies heavily on water accumulation and temperature data.

3.5 Map's Period covered

The timeframe represented by the maps varies on different maps. Some maps refer to weeks and months, while others display data and information for the precise period of map creation. A transportation map, for example, shows us what is happening right now at the precise time of map production, whereas a property damage historical map covers years of data, and the covered time by the map does not always include the current time. We clarified the time range represented by the maps for four occurrences in this project.

Events	Maps	Time span covered by the map				
		Exact Time of Production	Less Than 7 Days	Week-Month	Months-Year	Years
Snowstorm and Lake effect	Trasnportation (M)(O)	1				
	DAMAGE (A)(Ex)	1				
	VEGETATION COVERAGE (trees) (M)(O)	1				
	Event's Total Precopitation (A)(Ex)		1			
	Outage (A)(Ex)	1				
	Sesitive Buildings (Natech triggers) (M)(O)	1				
	Annual Average snowfall (A)(Ex)					1
	Climate drivers (A)(Ex)		1			
	Presidential Disaster Events (A)(Ex)					1
	Farmlands (M)(O)	1				
	Property Damage Historical (A)(Ex)					1
	PERCENTAGE %	55	18	0	0	27
Flood (bathtub)	Atmospheric patterns and climate drivers (A)(Ex)		1			
	Event's Total Precopitation (A)(Ex)		1			
	bathtub effect Area (M)(O)	1				
	Transportation (A)(Ex)	1				
	Hazard Map(Danger or hazard) (M)(O)	1				
	Emergency elements exposed to danger (M)(O)	1				
	Farms exposed to danger (M)(O)	1				
	Transportations Exposed to danger (M)(O)	1				
	Houses Exposed to danger (M)(O)	1				
	all type of building exposed to danger (M)(O)	1				
	sensitive buildings exposed to danger (M)(O)	1				
	Drouth map (A)(Ex)					1
	monthly rainfall (A)(Ex)			1		
	seasonal rainfall (A)(Ex)				1	
	rainfall anomaly (A)(Ex)					1
	maximum temperature anomaly (A)(Ex)					1
	mean maximum temperature (A)(Ex)			1		
	minimum temperature anomaly (A)(Ex)					1
	mean minimum temperature (A)(Ex)			1		
	NDVI anomaly (A)(Ex)				1	
	farm dam survey map (A)(Ex)				1	
	Damage Map (N)	1				
	PERCENTAGE %	45	9	14	14	18
Earthquake	historical seismic record (A)(Ex)					1
	the event's location impact area (A)(Ex)	1				
	shaking intensity per distinct (A)(Ex)	1				
	aftershocks (A)(Ex)		1			
	rupture zone estimation (A)(Ex)		1			
	fatalities (A)(Ex)	1				
	soil investigation map (A)(Ex)	1				
	soil liquefaction (A)(Ex)	1				
	Rockfall Possibility (N)	1				
	Damage Map (A)(Ex)	1				
	Transportations (M)(O)	1				
	PERCENTAGE %	73	18	0	0	9
Avalanche	SLOPE (A)(M)(Ex)	1				
	Event's Location (Delineation Map) (A)(N)					
	LAND USE (M)(O)	1				
	MORPHOLOGIC HAZARD (M)(O)	1				
	ASPECT (A)(M)(O)	1				
	Vegetation Coverage (A) (M) (O)	1				
	Snow deposite (A) (Ex)	1				
	Transportations Exposed to danger (M)(O)	1				
	Historical event (A)(Ex)					1
	Hazard Map (A)(M) (Ex)	1				
	Wind Direction (A)(M) (O)				1	
	Farm exposed to danger (M)(O)	1				
	Emergency elements exposed to danger (M)(O)	1				
	Houses Exposed to danger (M)(O)	1				
	Transportations (M)(O)	1				
	Damage Map (N)	1				
	PERCENTAGE %	81	0	0	6	6
This Map was Not in our case	(N)					
Maps Produced by me	(M)					
Maps from refrence authors	(A)					
Maps Existed before event	(Ex)					
Maps created from old data	(O)					
Essential Maps						
Optional Maps						

Figure 92 table of Map's Period covered

We divide both optional and essential maps period covered in these four events into 5 categories, exact time of production, less than seven days, a week a month, months-a year, years.

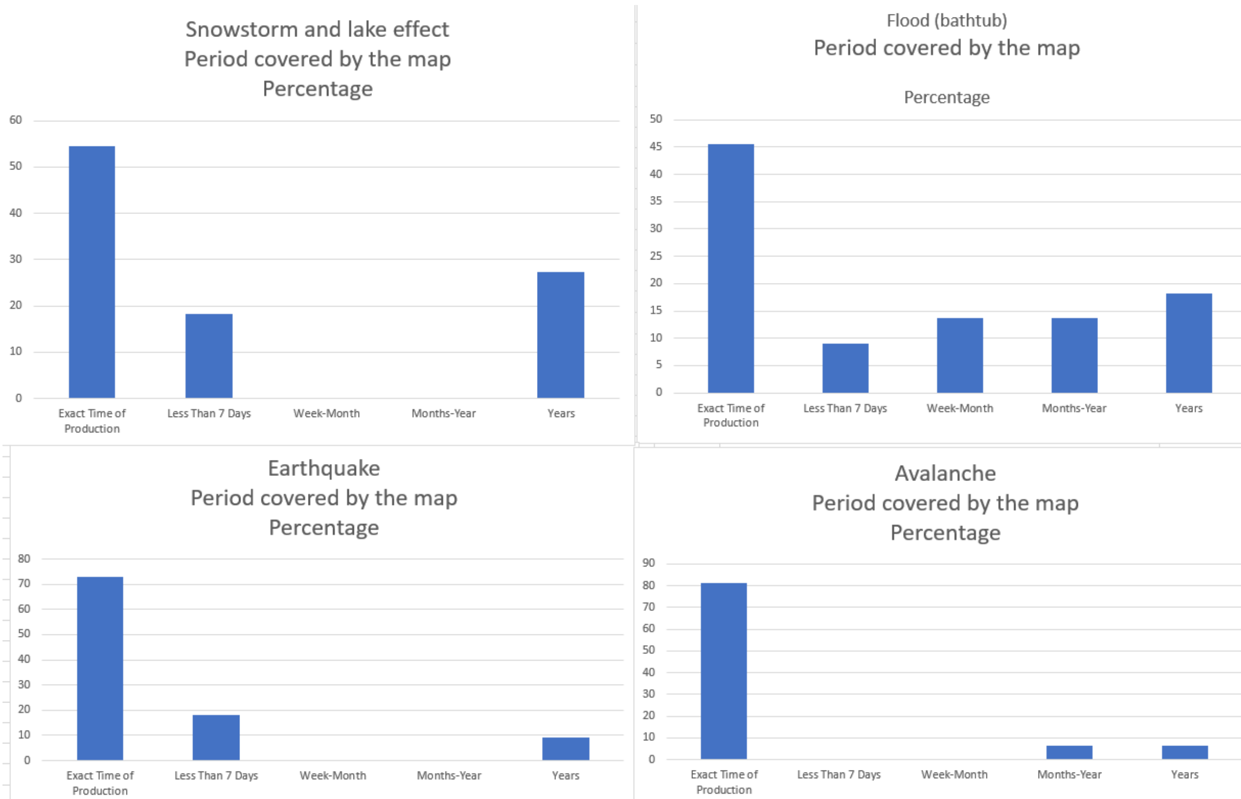

Figure 93 graph of the period covered by the maps

Avalanche and earthquake maps normally pertain to the present, whereas snowfall and flood maps have more variability.

3.6 Map's level of expertise required.

It is feasible to determine the level of competence required to make all maps of an event based on how maps are created (simple classification, overlay, processing, engineering knowledge) in these four occurrences (avalanche, flood bathtub, snowfall, earthquake). We categorize levels of expertise into three groups (beginner, intermediate, expert). We learned in this project that beginners may create a large number of maps, and in some circumstances, such as a flood, they can create more than half of the maps. Knowing what degree of knowledge is required for map development makes it easier to recruit individuals who are qualified for the job and streamlines the process.

Events	Maps	Map's Level Of Experties Requirement		
		Begginer	intermediate	Expert
Snowstorm and Lake effect	Trasnportation (M)(O)	1		
	DAMAGE (A)(Ex)			1
	VEGETATION COVERAGE (trees) (M)(O)	1		
	Event's Total Precopitation (A)(Ex)		1	
	Outage (A)(Ex)			1
	Sesitive Buildings (Natech triggers) (M)(O)	1		
	Annual Average snowfall (A)(Ex)	1		
	Climate drivers (A)(Ex)			1
	Presidential Disaster Events (A)(Ex)	1		
	Farmlands (M)(O)	1		
	Property Damage Historical (A)(Ex)	1		
	PERCENTAGE %	64	9	27
Flood (bathtub)	Atmospheric patterns and climate drivers (A)(Ex)			1
	Event's Total Precopitation (A)(Ex)		1	
	bathtub effect Area (M)(O)			1
	Transportation (A)(Ex)	1		
	Hazard Map(Danger or hazard) (M)(O)			1
	Emergency elements exposed to danger (M)(O)	1		
	Farms exposed to danger (M)(O)	1		
	Transportations Exposed to danger (M)(O)	1		
	Houses Exposed to danger (M)(O)	1		
	all type of building exposed to danger (M)(O)	1		
	sensitive buildings exposed to danger (M)(O)	1		
	Drouth map (A)(Ex)		1	
	monthly rainfall (A)(Ex)	1		
	seasonal rainfall (A)(Ex)	1		
	rainfall anomaly (A)(Ex)	1		
	maximum temperature anomaly (A)(Ex)	1		
	mean maximum temperature (A)(Ex)	1		
	minimum temperature anomaly (A)(Ex)	1		
	mean minimum temperature (A)(Ex)	1		
	NDVI anomaly (A)(Ex)		1	
	farm dam survey map (A)(Ex)		1	
	Damage Map (N)	1		
	PERCENTAGE %	68	18	14
Earthquake	historical seismic record (A)(Ex)	1		
	the event's location impact area (A)(Ex)		1	
	shaking intensity per distinct (A)(Ex)	1		
	aftershocks (A)(Ex)	1		
	rupture zone estimation (A)(Ex)			1
	fatalities (A)(Ex)	1		
	soil investigation map (A)(Ex)			1
	soil liquefaction (A)(Ex)			1
	Rockfall Possibility (N)			1
	Damage Map (A)(Ex)		1	
	Transportations (M)(O)	1		
	PERCENTAGE %	45	18	36
Avalanche	SLOPE (A)(M)(Ex)	1		
	Event's Location (Delineation Map) (A)(N)	1		
	LAND USE (M)(O)	1		
	MORPHOLOGIC HAZARD (M)(O)		1	
	ASPECT (A)(M)(O)	1		
	Vegetation Coverage (A) (M) (O)	1		
	Snow deposite (A) (Ex)	1		
	Transportations Exposed to danger (M)(O)			1
	Historical event (A)(Ex)	1		
	Hazard Map (A)(M) (Ex)			1
	Wind Direction (A)(M) (O)		1	
	Farm exposed to danger (M)(O)			1
	Emergency elements exposed to danger (M)(O)			1
	Houses Exposed to danger (M)(O)			1
	Transportations (M)(O)	1		
	Damage Map (N)	1		
	PERCENTAGE %	82	18	45
This Map was Not in our case	(N)			
Maps Produced by me	(M)			
Maps from refrence authors	(A)			
Maps Existed before event	(Ex)			
Maps created from old data	(O)			
Essential Maps				
Optional Maps				

Figure 94 table of Map's level of expertise required.

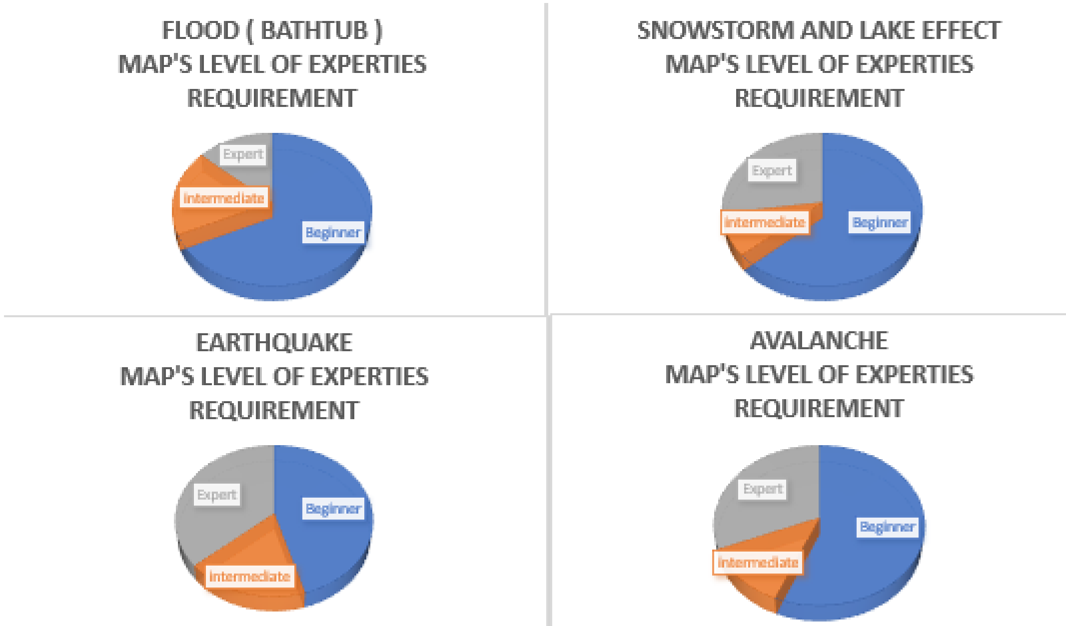

Figure 95 Graph of Map's level of expertise required.

If we compare these four events, earthquake mapping is the most difficult. However, this is a very approximate estimate, and the ''level of expertise required'' mostly depends on the event's location and individual characteristics of the event.

4. Conclusion

We were able to establish which maps are the most relevant and widely utilized for evaluating four events (flood bathtub, earthquake, avalanche, snowstorm with lake effect) and we named them *Essential maps*. We understood that the ''snowstorm and lake effect'' event requires five essential maps, the flood needs fourteen, the earthquake requires nine as well as the avalanche (Chapter 2.5). Other maps are classified as optional since they depend on the type of human assets which exist in the area of interest.

We were able to categorize the maps based on when they were needed because while some maps are extremely important and valuable immediately following an event, they are practically worthless days later, and the ideal period of production has been determined based on when different emergency offices in different countries (USA, Turkey, Nepal, Australia) have produced them. We understood that during the preparation phase of each of the four events, more maps are required than during the other phases (during the emergency, recovery). This again shows the importance of being prepared for an event. (Chapter 3.1)

The maps of the four events have been categorized depending on which of the three phases, Preparedness, during the emergency, and recovery, were useful. Also, manmade assets and natural assets have been categorized. The maps that have been categorized as useful during the recovery period, were meant to improve the existing situation, and these improvements (such as Property damaged historical maps) could save future lives or assets. Some maps can serve as a foundation or necessity for other maps, while others are used directly to keep people and things safe. In the emergency phase, maps are used to support the decision-making during the situation, like damage maps and climate drivers maps. We observed that there are no maps that could be categorized in the natural assets saving subcategory for the emergency phase, indeed, natural assets saving maps are mostly employed in the preparation and recovery phases. (Chapter 3.2)

We determined what types of data are required for the production of essential and optional maps. A few maps, such as the outage map in a snowstorm, require the usage of private information. The data may be available for purchase in return for money, but some data are not purchasable and are categorized as governmental private data. Regarding map production, only a few maps necessitate extensive processing and private data. For example, to map the flood extent SAR imagery is necessary as well as the processing is done by an expert operator. Most of the maps required multiple layers for their production.

We observed that some layers on several maps are the same, so they can utilize the same data on different maps after gathering data for the maps. For example, flood mapping relies heavily on water accumulation and temperature data and seismic records data are in use in five keymaps in the earthquake.

The timeframe represented by the maps varies on different maps. Some maps refer to weeks and months, while others display data and information which is related to the precise period of the map production. A transportation map shows us what is happening right now at the precise time of map production. Instead, a property damage historical map covers years of data, and the covered time does not always include the current time.

It was possible to estimate the amount of competence necessary to generate all maps of an event based on how maps are formed (simple overlay, processing, engineering knowledge) in these four events (avalanche, flood bathtub, snowfall, earthquake). We divide levels of skill required to produce each event's map into three categories (beginner, intermediate, expert). In this experiment, we discovered that beginners could generate a huge number of maps, and in some cases, such as a flood, they can create more than half of the maps. Knowing what level of knowledge is necessary for map production makes it easier to hire competent candidates and simplifies the process. However, this is a very rough approximation, and the ‘'level of skill necessary" is mostly determined by the event's location and specific features of the event.

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