



**RESILIENT COMMUNITIES THROUGH AWARENESS AND PREPAREDNESS  
AGAINST THE RISKS OF FIRE, FLOOD, AND LANDSLIDE**

## **CHAPTER 7. RESILIENCY METRICS/INDICATOR**

**Prepared by:** Prof. Selcuk Toprak, Prof. Banu Cetin, Assoc. Prof. Burak Aydogan,  
Assoc. Prof. Cigdem Balcik, Tahsin Gormus, Oguz Dal

**GEBZE TECHNICAL UNIVERSITY**



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## CHAPTER

# 7

## RESILIENCY METRICS/INDICATOR

Disasters occur worldwide and can be categorized into different types based on their causes. Natural Disasters are events caused by natural forces and processes such as meteorology and geology. They can be very large in scale and have potential to loss of life and property. Examples for natural disasters are floods, landslides, earthquakes, wild-fires, hurricanes and volcanic eruptions. Human-caused disasters are human originated disasters, as its name implies, and generally have regional impacts. Industrial accidents, transportation accidents, nuclear accidents, biological and environmental disasters can be an example for human-caused disasters. The occurrence of disasters varies depending on geographical location, climate, and human factors. Some regions are more prone to specific types of disasters due to their geographical features or climate patterns. Understanding the occurrence patterns and potential risks associated with different types of disasters is crucial for disaster preparedness, response, and mitigation efforts.

Every year, millions of individuals experience the impact of both natural and human-caused disasters. These disasters pose the risk of death and physical injury, and can lead to the loss of homes, possessions, and community infrastructure. Consequently, individuals affected by disasters have high risks of experiencing emotional and physical health problems. Stress reactions following a disaster exhibit similar patterns to those observed after any traumatic event. Disasters can trigger a wide range of mental and physical reactions, including responses to post-event problems and triggers associated with the traumatic experience.

Understanding the occurrence and impact of disasters is crucial for developing strategies to prevent, mitigate, and respond to such events. Governments, communities, and individuals play important roles in building resilience and minimizing the devastating effects of disasters.

## **7.1. Introduction to Disaster Resilience Metrics and Indicators**

### **7.1.1. Definition and importance of disaster resilience metrics and indicators**

Disasters strike with little warning, leaving behind destruction and complications that can be overwhelming for affected communities. In the face of such difficulties, the resilience of a community becomes paramount. Its ability to prepare, respond, and recover from disasters can significantly influence the extent of damage and the speed of rebuilding. Disaster resilience metrics and indicators play a pivotal role in understanding and enhancing a community's capacity to assess, withstand and adapt to these challenging situations.

In recent years, disasters have become more frequent and severe, fuelled by factors like climate change, population growth, and urbanization. Understanding and measuring disaster resilience have gained increasing importance as decision-makers, emergency managers, and volunteers seek to improve disaster response and recovery efforts. Resilience metrics offer valuable insights into a community's strengths and vulnerabilities, guiding resource allocation, preparedness planning, and long-term recovery strategies. By quantifying and analysing various aspects of resilience, stakeholders can identify gaps and implement targeted interventions to bolster a community's ability to bounce back from disasters stronger than before.

The adoption of disaster resilience metrics is a crucial step in transforming disaster management approaches from reactive to proactive. Traditional disaster response often focuses on immediate relief efforts, while overlooking the importance of resilience-building measures. By incorporating metrics and indicators into the disaster response and recovery

planning process, responders can make informed decisions based on empirical data, improving the overall effectiveness and efficiency of interventions. Moreover, these metrics can serve as benchmarks for progress evaluation, allowing for iterative improvements in disaster preparedness and response strategies.

### **7.1.2. Overview of the relationship between resilience and disaster management**

The resilience of a community in the face of disasters can be thought like a complex web, combined by multitude of components which together determine its ability to endure, respond, and recover. This assessment is not limited to measuring the community's capacity to merely bounce back; it extends to evaluating its capacity to adapt, learn, and improve in the aftermath of a flood. The evaluation of flood resilience demands a multi-dimensional approach that incorporates social, infrastructural, and ecological indicators.

In the disaster management field, the term "resilience" has become increasingly popular during the past twenty years. It is possible to evaluate resilience at the individual, household, community, and country level. In the disaster management field, the examination of resilience predominantly focuses on the community level. Within the field of disasters, the examination of individual resilience appears to be the next most common level of analysis, frequently studied within the psychological and medical literature (Doorn, 2017).

Resilience can be perceived and enhanced at different levels (International Federation of Red Cross and Red Crescent Societies (IFRC), 2014) (Figure 7.1):

- At the individual level, a person with resilience is in good health; possesses the necessary knowledge, competencies, abilities, and way of thinking to adjust to novel circumstances, enhance their own life as well as the lives of their friends, family, and community. A person who is resilient gains a sense of empowerment.
- At the household level, resilience is characterized by the presence of resilient individuals inside the home.
- At the community level, a community that is resilient helps to increase the resilience of the households and individuals it comprises.

- Local government, with its responsibilities encompassing infrastructure development, social services, maintenance, and the enforcement of legal regulations, has the potential to either enhance or diminish resilience across community, household, and individual levels.
- Resilience at the national government level encompasses several aspects such as laws, social security systems, policy, infrastructure, and governance issues. These factors have the potential to significantly influence the resilience of communities.
- Organizations like National Societies, along with their branches and volunteers, play a vital role in enhancing resilience across all levels by making essential contributions.
- On regional and global levels, the effects of conflicts, lack of security; food scarcity; extensive migration; disease outbreaks; economic recession; climate change and pollution; are both favorable and unfavorable outcomes of globalization and emerging technology. They all serve as background processes where the passed activities on one level might have possible unfavorable or advantageous on the other level.



Figure 7.1. Resilience at different levels (IFRC, 2014).

In the context of disaster risk management, roadmaps are established at specific intervals by governments and organizations with the aim of reducing disaster damages and enhancing community resilience against disasters. The most comprehensive of these roadmaps, which focuses on disaster risk reduction (DRR), is the Hyogo Framework for Action, prepared for

the period 2005-2015. Subsequently, as a continuation of this process, the Sendai Framework for Disaster Risk Reduction (2015-2030) has been published (Varol and Kırıkkaya, 2017).

In terms of disaster risk mitigation, the Hyogo Framework for action presents 5 priority actions. These actions are (UNISDR, 2005):

- Establishing disaster risk mitigation as a local and national priority with a robust institutional foundation.
- Identification, assessment, and monitoring of disaster risks, along with the enhancement of early warning systems.
- By utilizing knowledge, education, and innovation, forming a culture of resilience and safety across all levels.
- Decreasing risk factors (through appropriate risk management techniques)
- Enhancing disaster preparedness to ensure effective response across all levels.

The Sendai Framework 2015-2030 received official approval during the 3rd United Nations World Conference, which took place in Japan, on 18 March 2015. This marked a significant step in global disaster risk reduction efforts (UNISDR, 2015). There are 4 priority actions:

- Understanding disaster risk
- Enhancing disaster risk governance in order to effectively handle disaster risks.
- Making investments in disaster risk reduction to enhance resilience.
- Improving disaster preparedness to ensure an efficient response and to facilitate "Building Back Better" in the recovery, rehabilitation, and rebuilding phases.

### **7.1.3. Key concepts and terminology**

It is essential to establish a shared understanding of key concepts and terminology of resiliency metrics and indicators. Understanding these concepts is critical for accurate interpretation and application of resilience metrics in the context of specific disaster scenarios.

The role of disaster response volunteer is instrumental in supporting communities during times of crisis. By equipping themselves with the knowledge and skills to evaluate and utilize disaster resilience metrics, volunteers can contribute to more effective and sustainable disaster response efforts. Throughout this course, we will explore the metrics and indicators specific to three significant disaster types: floods, landslides, and fires. Each of these disasters presents

unique challenges, and understanding the specific resilience factors relevant to each scenario is vital in formulating targeted disaster response plans.

The word "resilience" comes from the Latin word "resilio," which means to bounce or jump back (Klein et al., 2003). Resilience is defined as the ability of a system and community to overcome disasters and emergencies with minimal damage and return to a state of equilibrium with the help of their psychological, sociological, and physical capacity (Varol and Kırıkkaya, 2017). Liu et al. (2017) define resilience as a layered system originating from multiple dimensions. Core resilience is made up of intra-individual elements, or trait-like features inside a person that promote resilience like physiology, gender, ethnicity, age and health behaviours. Internal resilience is made up of variables that may be fostered, improved, or gained through time by interpersonal interactions like friends, family, personal experiences and education. External resilience is made up of socio-ecological elements that aid in the development of resilience throughout an individual's lifetime. Components of this system may include social services, access to medical treatment, and other resources which have some kind of interaction with an individual.

Resilience holds significance across all countries due to the presence of vulnerable groups inside each country (IFRC, 2014). Vulnerability is related to social, environmental, economic, or physical factors that increase the susceptibility of a system, individual or community to the impacts of hazards. In general, the greater a community's or individual's resilience to disasters and the lower their vulnerability, the better their potential to cope with disasters (Varol and Kırıkkaya, 2017).

System resilience involves robustness, rapidity and enhancement when faced with natural hazards and disasters (Figure 7.2). A resilient system demonstrates robustness in its capacity to effectively absorb and withstand the effects of a hazard agent, hence leading to a decrease in the possible implications of a disaster. A resilient system is also capable of fast recovering after a disaster to achieve restoration levels in a reasonably short period of time. Ultimately, within the recovery phase, a resilient system boosts its capabilities through the enhancement of its mitigation status, reduction of existing vulnerabilities, and the improvement of its sustainability (Peacock, 2010).



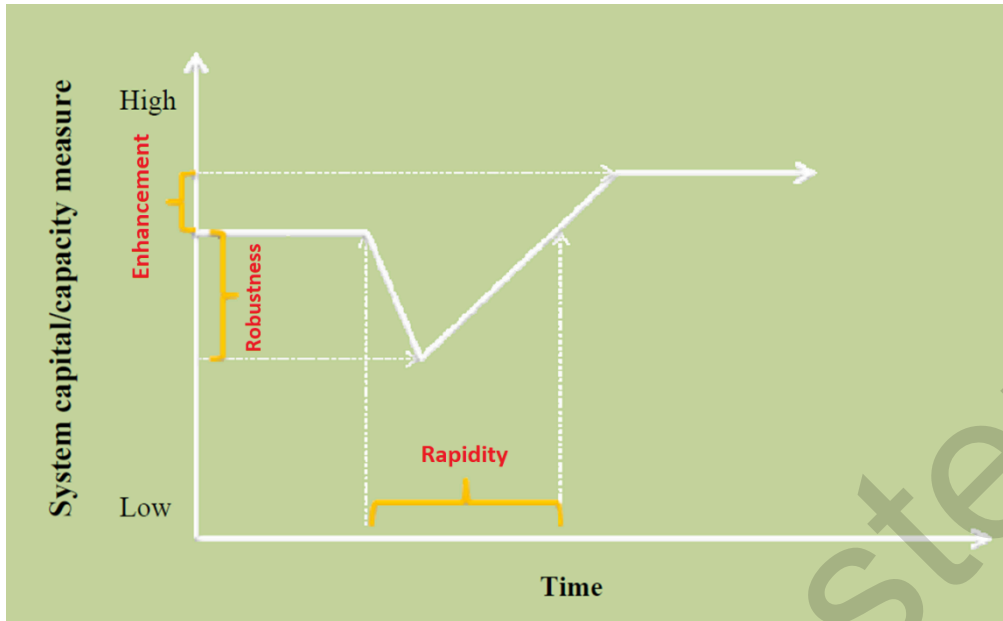


Figure 7.2. Crucial Aspects of Resilience (Peacock, 2010).

Figure 7.3 illustrates the theoretical path followed by two communities: (1) a community with higher resilience (solid line), and (2) a community with lower resilience (dotted line). These two paths depict the progressive transformation of communities with time across four stages: pre-disaster, disaster, restoration, and long-term recovery. The figure indicates that the community with higher resilience frequently encounters fewer adverse effects from disasters, whereas the community with lower resilience faces substantial disaster-related impacts and consequently undergoes more substantial fluctuations. Moreover, it is evident that the less resilient community will require a longer duration to return to its regular functioning (Mayunga, 2007).

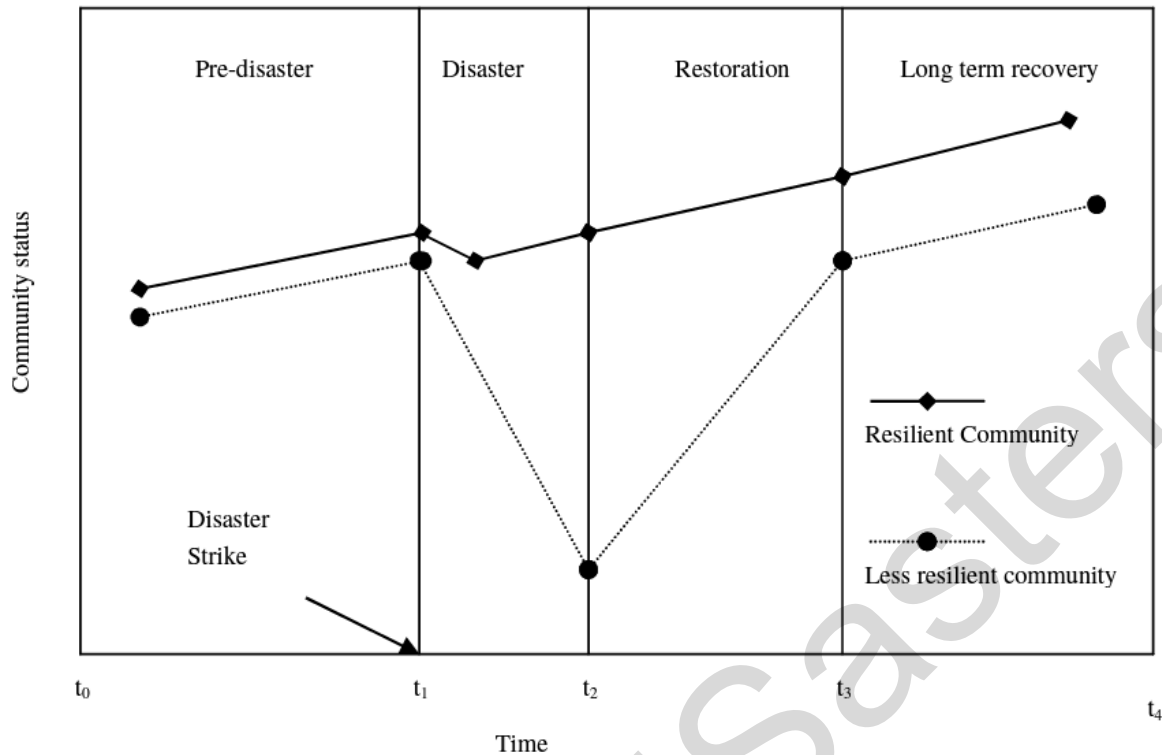


Figure 7.3. The theoretical path followed by resilient and less resilient communities (Zhang (2006), Mayunga (2007)).

## 7.2. Flood Resilience Metrics and Indicators

### 7.2.1. Understanding flood hazards and vulnerabilities

Floods are one of the most prominent disasters in the world and despite the scientific and technological developments, they are still damaging (Parker, 1999). Learning from the flood events and mapping the vulnerabilities have an important part in the disaster management (Kuang and Liao, 2020). The emergence of flood hazards stems from the combination of meteorological, geographical, and hydrological factors. From intense and sustained rainfall to the rapid release of water due to snowmelt, these factors combine to set the stage for what can become a calamitous event. Furthermore, the rupture of dams or the coastal storms in the form of storm surges, can transform tranquil landscapes into chaotic, inundated disaster zones within moments.

While flood hazards cast a broad shadow of uncertainty, vulnerabilities in the face of these events are intricately tied to a community's geographical location, demographic composition, and socio-economic fabric. Coastal regions with their proximity to the sea are affected by the storm surges. Areas nestled alongside rivers and lakes grapple with the imminent threat of waterways exceeding their banks. Urban spaces, often densely populated, are particularly

susceptible due to the prevalence of impermeable surfaces that hinder natural drainage. Socio-economic factors, such as poverty and inadequate housing, can amplify the impact of floods, rendering vulnerable populations even more defenceless against the flood.

Resilience and risk assessment reveals not only the weak links in the chain but also provides insights into the potential amplification of flood impacts due to specific contextual factors. By understanding these vulnerabilities, disaster response volunteers and stakeholders can tailor their resilience strategies to address the specific weaknesses within a community, making the difference between mere survival and robust recovery in the aftermath of a flood event.

### **7.2.2. Metrics and indicators for flood risk assessment**

Understanding the intricacies of flood risk assessment requires a thorough study, where hazards, vulnerabilities, and capacities intersect. This intricate choreography requires the integration of various metrics and indicators to obtain a comprehensive understanding of the dynamics at play.

#### *Quantifying Likelihood: Flood Frequency as a Metric*

At the heart of flood risk assessment lies the concept of flood frequency—a metric that quantifies the likelihood of a flood event occurring. This metric draws from historical data, providing insights into the frequency at which floods have occurred in the past. This historical context serves as a foundation for anticipating the future. The understanding of flood frequency educates disaster response stakeholders, enabling them to gauge the probability of floods and allocate resources accordingly. This metric, when combined with vulnerability indicators, paints a more complete picture of flood risk.

#### *Social Indicators*

Communities are the heart of resilience, and their readiness to face floods is often shaped by a range of social indicators. Community preparedness, a vital aspect of social resilience, hinges on factors such as awareness levels, education, and the community's capacity to mobilize resources during a flood event. A well-informed community, aware of evacuation routes and safety protocols, is more likely to navigate the challenges of a flood effectively. Social cohesion—the strength of relationships within the community—is a vital determinant of how well communities collectively respond and recover from floods. Strong social bonds often

translate into better information dissemination, support systems, and resource sharing during emergencies.

### Infrastructural Indicators

A community's physical infrastructure forms the backbone of its resilience. Assessing infrastructural indicators involves examining the robustness of critical facilities, drainage systems, flood barriers, and transportation networks. Structures designed to withstand floods contribute significantly to a community's ability to respond and recover. Flood-resistant buildings, proper drainage systems that channel water away, and strategically positioned flood barriers play a pivotal role in mitigating damage. Additionally, the accessibility of emergency shelters, healthcare facilities, and communication networks during floods greatly influences a community's ability to ease the after effects of the disaster.

### Ecological Indicators

The role of natural systems in enhancing the resilience cannot be overstated. Ecosystems, such as wetlands and forests, serve as buffers against floods, absorbing excess water and slowing down its movement. The health of these ecological indicators directly influences a community's resilience. A degraded ecosystem might fail to provide the flood mitigation services it once did, leading to increased vulnerability. Conversely, a well-preserved and managed natural environment can significantly reduce flood impacts. Recognizing the symbiotic relationship between communities and their surrounding ecosystems is crucial in developing holistic resilience strategies.

### Preparedness Indicators

Preparedness indicators encompass a range of factors that outline a community's readiness to face floods head-on. The existence of comprehensive emergency plans, complete with clear evacuation routes and communication protocols, serves as a blueprint for coordinated action. The presence and accessibility of emergency shelters, equipped to house and support displaced individuals, is vital in ensuring the safety and well-being of affected populations. Communities that have established early warning systems capable of detecting flood threats and disseminating timely alerts are better equipped to respond in a timely manner.

### Response Indicators

A community's response during a flood event can be the difference between order and chaos. Resilience metrics allow stakeholders to assess the effectiveness of this response through response indicators. These indicators reflect the speed, efficiency, and effectiveness of emergency services, evacuation efforts, and communication systems during a flood. The coordination among response agencies and the community's capacity to adapt to evolving situations are also critical factors in measuring response effectiveness. Regular drills and simulation exercises, by providing firsthand experience, enhance the practical application of these response indicators.

### Quantitative Indicators/Metrics

According to review by Bulti et al. (2019) about community flood resilience assessment frameworks, number of resilience dimensions considered in the selected studies were between 4 and 8 where the majority of them have 8 dimensions. By considering different factors covering resilience dimensions, financial, institutional, and physical comprehensiveness of the studies were relatively better where the community competences, technical and environmental issues are not relatively well covered.

The main resilience indicators addressed by those studies were (Bulti et al., 2019):

- Natural factors: natural assets/resources, conservation of natural resources.
- Infrastructural factors: physical facilities and infrastructures, protective infrastructure, efficiency and maintenance of infrastructures, land use and structural design.
- Socio-economic factors: financial structure, security, and dynamism, human composition, socio-economic status, education attainment, especial need for assistance, social networks, knowledge and skill in relation to past events, peace and security, social support, collective action and decision making, critical reflection and problem-solving skills, flexibility and creativity, collective efficacy and empowerment, quality of life.
- Institutional factors: executive, local institutions, partnership, regulations, education and training, community participation and engagement.
- Technical factors: early-warning systems, emergency response, recovery plans, contingency plans, resource management plan, hazard exposure and mapping.

The studies and frameworks, which consists of indices, scorecards and toolkits are valuable tools for assessing and enhancing the community resilience in terms of disasters. Each framework differs in the scope or the methodology. A list of studies for flood resiliency metrics and indicators are provided in Table 7.1 as listed by Bulti et al. (2019).

Table 7.1. The list of community resilience framework studies (Bulti et al., 2019).

<b>Name of the developed framework</b>	<b>Year</b>	<b>Scope</b>	<b>Method</b>
Coastal Community Resilience Toolkit	2007	US	Toolkit
Community and Regional Resilience Initiative	2008	US	Index
Community Disaster Resilience Framework	2009	US	Index
The PEOPLES Resilience Framework	2010	US	Index
Baseline Disaster Resilience Indicators	2010	US	Index
Coastal Community Resilience Index	2010	US	Index
Flood Resilience Index	2013	Europe & Asia	Index
Community Disaster Resilience Scorecard	2013	Australia	Scorecard
Resilient Communities Scorecard	2013	US	Scorecard
Community Resilience Measurement Framework	2013	Global	Model
ARUP's City Resilience Framework	2014	Global	Index
IFRC Framework for Community Resilience	2014	Global	Toolkit
Australian Natural Disaster Index	2016	Australia	Index
ResilSIM	2016	US	Model
Community Flood Resilience Measurement Tool	2017	Global	Index
Community Disaster Resilience Index	2017	Latvia	Index
Maine Flood Resilience Checklist	2017	US	Scorecard

Among these studies, Community Resilience Measurement Framework measures the community resilience on a global scale. It considers a wide range of factors that contribute to resilience, considering regional and cultural variations. ARUP's City Resilience Framework focused on cities worldwide, assessing the resilience of urban areas. It considers factors such as infrastructure, governance, social services, and community engagement. IFRC Framework for Community Resilience offers guidelines and tools for assessing community resilience globally. It emphasizes the importance of community involvement in resilience-building efforts. Community Flood Resilience Measurement Tool considers factors like early warning systems, evacuation plans, and post-disaster recovery capacities. In Europe and Asia scale,

Flood Resilience Index considers factors such as flood preparedness, infrastructure resilience, and community engagement (Bulti et al., 2019).

Beyond metrics that quantify hazards and impacts, indicators of vulnerability shed light on a community's capacity to withstand floods. Population density in flood-prone areas, infrastructure susceptibility, and the presence of early warning systems are just a few examples of indicators that offer insights into a community's preparedness. These indicators serve as early warning signs of potential vulnerabilities that might exacerbate the impact of a flood event. By combining these metrics and indicators, stakeholders gain a comprehensive understanding of flood risk—empowering them to make informed decisions, plan interventions, and allocate resources effectively to reduce vulnerability and enhance resilience.

### **7.2.3. Assessing the resilience of flood-prone communities and infrastructure**

The resilience of a community in the face of floods is similar to a complex web, combined by different aspects that together determine its ability to endure, respond, and recover. This assessment is not limited to measuring the community's capacity to merely bounce back; it extends to evaluating its capacity to adapt, learn, and improve in the aftermath of a flood. The evaluation of flood resilience demands a multi-dimensional approach that incorporates social, infrastructural, and ecological indicators.

The study of Karrasch et al. (2021) explains the flood resiliency in a context of a flood resiliency rose as shown in Figure 7.4.

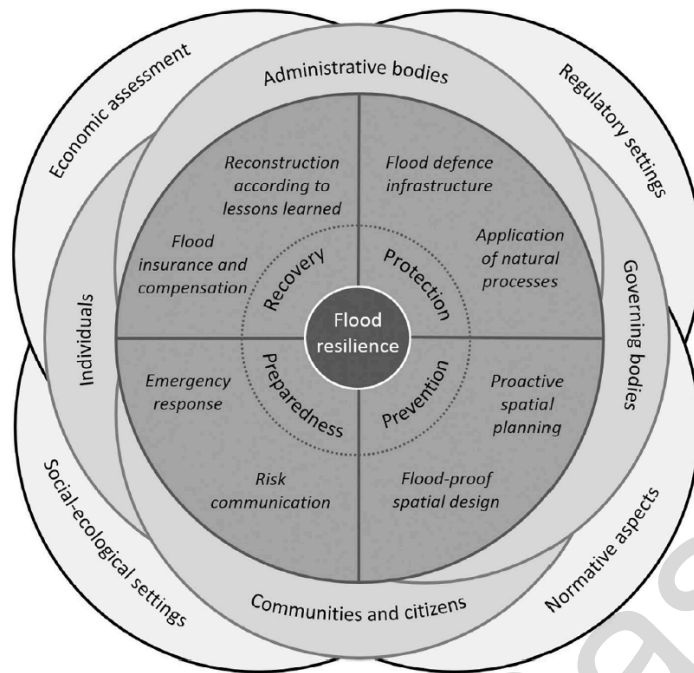


Figure 7.4. Flood Resiliency Rose (Karrasch et al., 2021).

In the study, the flood resiliency is elaborated using a two-step approach combining the theoretical and practical perspectives. Three level of operations are defined using the scientific concepts and relevant policy documents. The first level combining protection, prevention, preparedness, and recovery measures by an extended multi-layer approach. In the second step, surveys conducted in Belgium, Denmark, Netherlands, and the United Kingdom is used to validate the definitions and the practical applicability of the resiliency rose (Karrasch et al., 2021).

The spatial scale on assessing the flood resilience can be household-scale, community-scale, city-scale, and national-scale (McClymont et al., 2020). Household-scale methods are the most common approach for resilience measurement, and the majority of those studies were focused on the flood impact assessment. At the community-scale, social perspectives are more prevalent, as well as the physical urban systems, and flood mitigation strategies. City-scale methods focus on technical tools to measure resilience at city scale. Among them, Balica et al. (2009) used flood vulnerability indicators including physical and social vulnerability of a city. In the national-scale, studies focus more on the strategic perspective rather than the social one (McClymont et al., 2020).



#### 7.2.4. Case studies and best practices in flood resilience measurement

This part of the unit will cover the aspect and summary of a case study carried out in Sg. Kedah Basin, Malaysia. The research introduces a novel approach for assessing flood susceptibility and risk in paddy fields using a Multi-Criteria Decision Making approach. The study focuses on the specific context of paddy cultivation, which experiences different growth stages (vegetation, reproductive, and ripening) with varying water requirements. By integrating flood inundation and damage, the research establishes a flood vulnerability index for paddy fields that considers all growth periods. The risk assessment also factors in inundation duration and depth, which are specific to each location and paddy seed variety, offering insights that prior studies have overlooked. The parameters used in the calculation is given in Table 7.2.

The resulting risk indices are categorized into five classes, ranging from very low to very high risk. The research produces a comprehensive flood risk map (Fig. 7.5) that can be utilized by authorities and stakeholders to evaluate flood risk levels effectively, particularly in areas where rice is a crucial staple crop.

Table 7.2. Criteria used in the flood resilience index calculation (A. Anuar et al., 2023).

Criteria	Unit	1	2	3	4	5
Total annual rainfall	mm/year	0-1000	1000-1500	1500-2500	2500-3500	>3500
Slope	%	>32,1	24,1-32	16,1-24	8,1-16	<8
Soil type	Class	<0,4 (Very Well drained)	0,4-0,54 (Well drained)	0,55-0,69 (Imperfectly drained)	0,70-0,84 (Poorly drained)	> 0,84 (Water body)
Elevation	m	>400	300-400	200-300	100-200	<100
Distance from the river	m	>1000	501-1000	301-500	51-300	<50
Land Use/land cover	Class	Forest	Agriculture / open land with cover	Open land without cover	Infrastructure and utility / residential	Water body / commercial and services / Transportation / Industrial

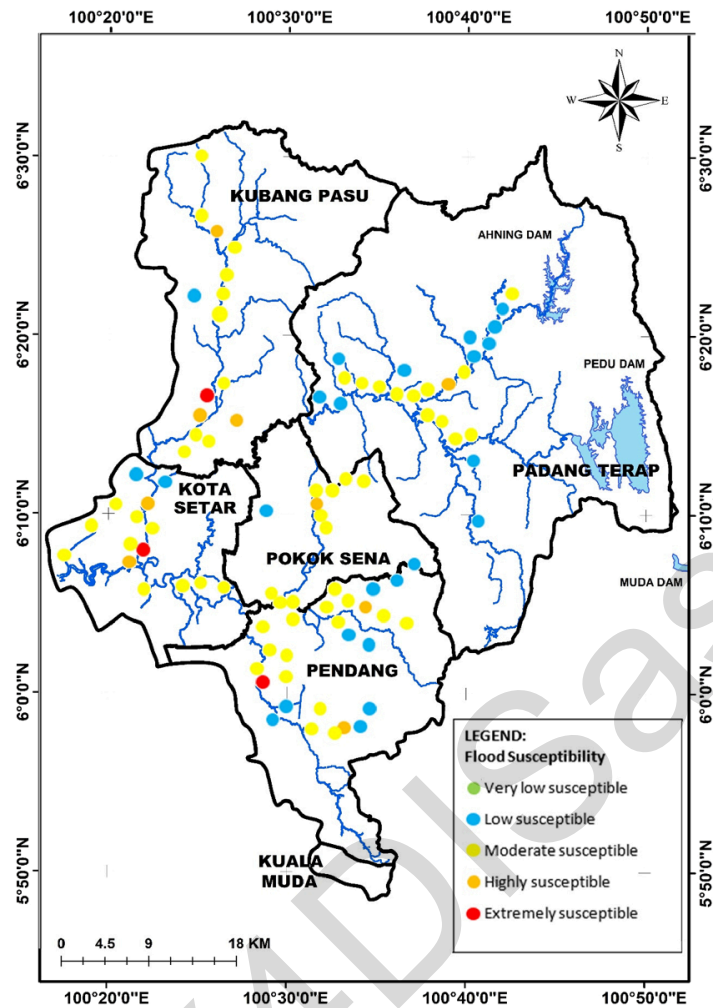


Figure 7.5. Flood susceptibility index map for the Sg. Kedah basin (A. Anuar et al., 2023).

Aroca-Jiménez et al. (2023) implemented a collection of vast databases including social, cultural, institutional, physical, ecosystem, and economic indicators to compute Integrated Multidimensional Resilience Index (IMRI) in Spain. The general methodology and concept is explained in the workflow given in Fig. 7.6.

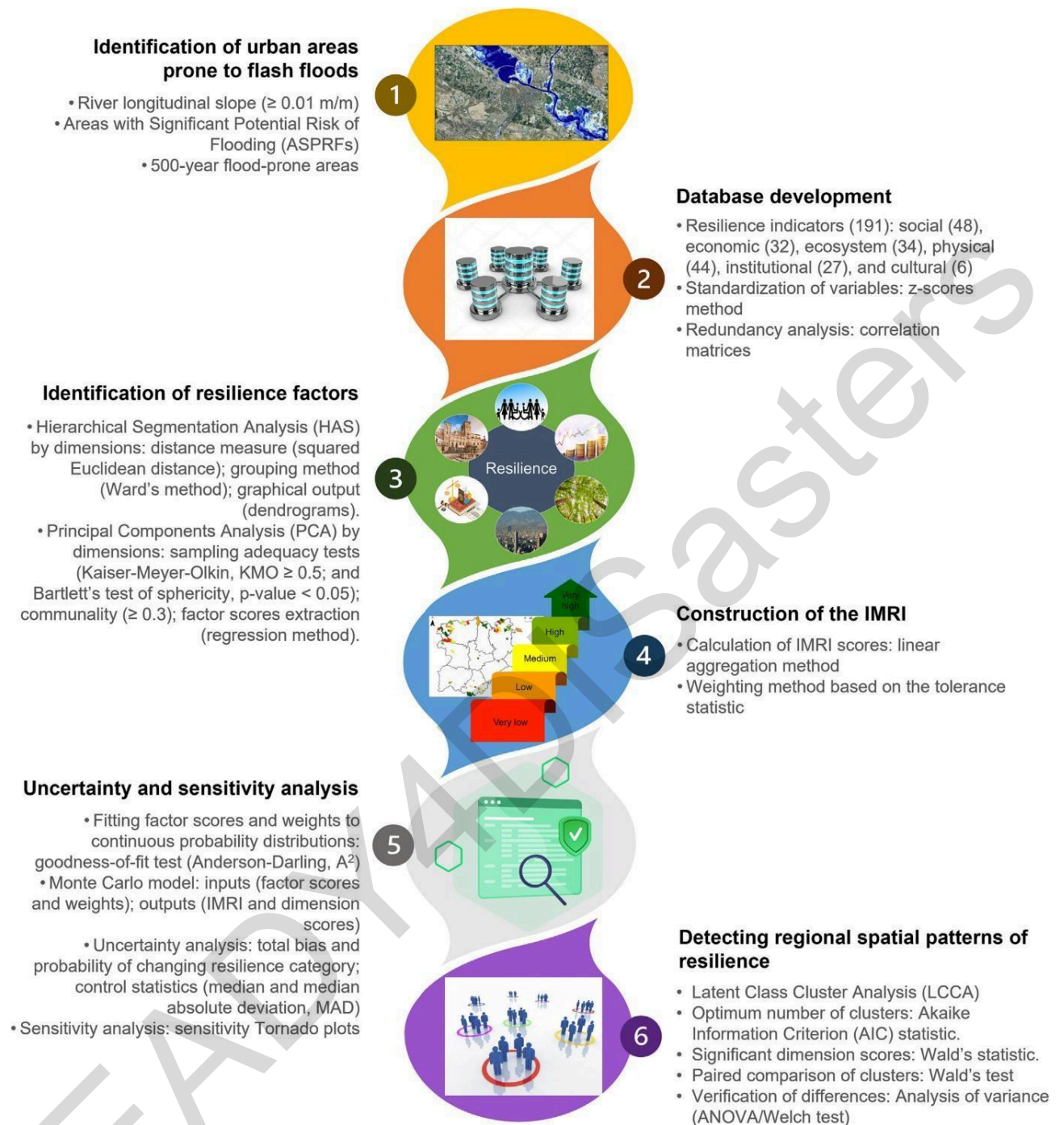


Figure 7.6. Graphical overview of stages to compute IMRI to quantify flood resilience (Aroca-Jiménez et al., 2023).

The methodology included identification of the flood prone areas, database development according to the selected sites, identification of the resilience factors, construction of the resilience index, uncertainty analysis, and finally obtaining the results of the study as spatial distribution of resilience. The aggregated index resulted in the map shows in Fig. 7.7 where it is also possible to see the contribution of each of the main parameter groups to the IMRI, as the main indicator of the total resilience against floods.

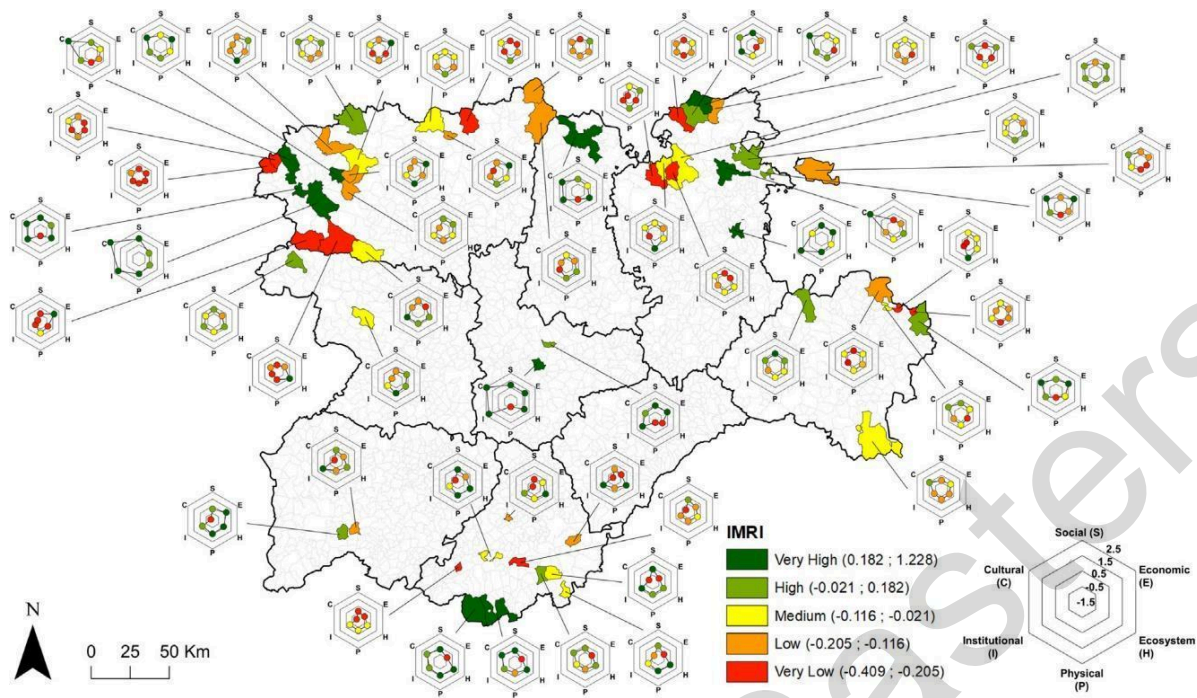


Figure 7.7. IMRI scores disaggregated by dimensions for selected locations (Aroca-Jiménez et al., 2023).

### 7.3. Landslide Resilience Metrics and Indicators

#### 7.3.1. Understanding landslide hazards and vulnerabilities

Landslides, often characterized by their silent yet devastating nature, underscore the delicate balance between geological processes and human habitation. These events result from a complex interplay of factors, including geological conditions, land use practices, and rainfall patterns. The understanding and application of landslide resilience metrics and indicators are critical components in deciphering this intricate puzzle. By doing so, we can enhance communities' capacity to withstand and recover from the impact of these natural disasters.

Arising from abrupt ground movement, landslides can swiftly lead to catastrophic consequences. Geological factors, such as the composition of soil, slope angles, and geological formations, significantly influence the susceptibility to landslides. Human activities, including deforestation, urbanization, and improper construction practices, can further exacerbate these hazards. Identifying and assessing these vulnerabilities are paramount in effectively evaluating the resilience of communities and infrastructure against potential landslide events. This analysis helps to create a targeted strategy for mitigation and resilience-building, tailored to the specific vulnerabilities present.

### **7.3.2. Metrics and indicators for landslide risk assessment**

Landslide risk assessment involves a thorough understanding of both the likelihood of a landslide event occurring and its potential consequences. In this endeavour, resilience metrics offer a combination of quantitative and qualitative measures that prove invaluable.

#### *Geotechnical Indicators*

A pivotal aspect of landslide resilience lies in comprehending slope stability. Geotechnical indicators delve into the physical properties of the terrain, providing insights into its propensity for instability. Soil type, compaction, and water content are among the factors that influence slope stability. Engineering techniques, such as slope stability analysis and continuous monitoring of soil moisture content, play a significant role in assessing the potential for instability. By integrating these geotechnical indicators with historical landslide data, stakeholders can identify regions with a heightened risk of landslides. This knowledge empowers targeted interventions and adaptive measures to strengthen the stability of these areas.

#### *Preparedness Indicators*

Preparedness indicators encompass a spectrum of factors that outline a community's readiness to confront landslides. At the core of this preparedness is the establishment of early warning systems capable of detecting potential landslide triggers and issuing timely alerts to those at risk. These systems, integrated with meteorological data and ground movement monitoring, provide valuable lead time for communities to initiate response measures and evacuate if necessary. Beyond technological systems, the presence of well-defined evacuation plans, clear communication protocols, and designated safe areas for displaced individuals are critical components of landslide preparedness.

Landslide risk communication and regular community drills also contribute significantly to preparedness. Engaging with the public, educating them about the risks associated with landslides, and providing them with actionable information enhances their ability to respond effectively. Moreover, simulation exercises allow communities to practice their response strategies in a controlled environment, enabling them to fine-tune their procedures and enhance coordination among various stakeholders.

#### *Response Indicators*

Effective response during a landslide event is a complex management event itself that demands well-coordinated efforts. Resilience metrics play a pivotal role in assessing the efficiency and effectiveness of these response mechanisms.

Response indicators encompass a range of factors, including the speed and agility of emergency services, the efficiency of evacuation procedures, and the ability to manage and share information in real time. The capacity to adapt to rapidly evolving situations during a landslide event showcases a community's resilience. Timely decision-making, effective communication among response agencies, and the ability to mobilize resources efficiently are indicative of a robust response strategy.

Real-time data collection during and after a landslide event provides a valuable information that can be instrumental in evaluating the efficiency of the response. Post-event analysis allows stakeholders to identify strengths and areas for improvement, facilitating a continuous cycle of learning and enhancement. By leveraging this data, communities can refine their response protocols, allocate resources more effectively, and ensure a higher degree of readiness for subsequent events.

#### *Infrastructure Resilience Indicators*

The resilience of infrastructure in landslide-prone regions is a pivotal determinant of the impact of these events. Critical infrastructure, including roads, bridges, buildings, and landfills must be designed to withstand the forces exerted by landslides (e.g., Toprak and Dal, 2022). Metrics that evaluate the structural integrity of infrastructure under potential landslide conditions offer insights into their resilience. Moreover, the integration of early warning systems, emergency response plans, and community awareness amplifies the overall resilience of areas susceptible to landslides. Evaluating infrastructure resilience in accordance with the geotechnical indicators presents a holistic view of landslide resilience, where physical stability converges with preparedness and responsiveness.

#### *Quantitative Indicators/Metrics*

Bera et al (2020) classifies resilience into four components: social, environmental, physical and economic. Quantitative indicators under these components are listed below:

i) Environmental: distance from active slide, distance from drainage, degree of slope, temporal probability of landslide, density of landslide, built-up area density

- ii) Social: Ratio of dependent population, ratio of female population, ratio of disabled population, ratio of literate population, years of residence, distance from nearest house
- iii) Economic: Monthly income, ratio of employed population, livelihood diversity, assets for emergency time
- iv) Physical: Accessibility of roads during rainy season, distance from market, distance from hospital, distance from health centre, distance from nearest emergency shelter

### **7.3.3. Assessing the resilience of landslide-prone areas and slope stability**

Historical landslide frequency serves as a cornerstone metric in landslide risk assessment. Analysing past events helps to anticipate future probabilities, a crucial aspect of preparedness. Precipitation patterns, particularly intense rainfall, contribute significantly to landslide occurrences. This metric aids in identifying periods of heightened risk. Terrain slope, a terrain-related metric, complements this by indicating areas prone to instability. Alongside these metrics, indicators such as the presence of erosion control measures, land use planning, and the condition of vegetation cover provide additional layers of insight. By integrating these metrics and indicators, stakeholders gain a comprehensive understanding of the landscape's potential for landslides, guiding informed decisions in mitigation and response planning.

### **7.3.4. Case studies and best practices in landslide resilience measurement**

A case study about landslide risk assessment was conducted in a location with a high incidence of landslides, the Rivière Aux Vases basin, Quebec, Canada (Regmi and Agrawal, 2022). The main aim is to devise a straightforward methodology based on a qualitative approach in order to make a dependable assessment of landslide hazard risk in a given area with the aid of geographic information system (GIS). This study examines four key data points: geology, topography, land usage, and hydrology, along with their related factors, to assess the causes of landslides (Table 7.3). Additionally, critical infrastructure (Table 7.4) and demographic information (Table 7.5) are taken into account for evaluating potential losses. The combination of these data points is employed in assessing landslide risks within the Aux Vases watershed.

Table 7.3. Landslide-causing variables that lead to landslide risk.

Variable Type	Variables
Geological variables	Rock Type
	Soil Type
Topographic variables	Altitude
	Plan curvature
	Slope aspects
	Slope gradient
Land Usage variables	Land Use
Hydrological variables	Drainage density
	Proximity to the river

According to the Table 7.3, soil type is one of the most important variables for landslides. Clay soil has most of the slope instabilities in this study. Slope aspect is another important variable. Slope aspect indicates the compass direction of the steepest incline on the terrain. It is predominantly influenced by the alignment of fractures or breaks in the terrain. This, consequently, has implications for the level of rainfall received and the degree of sunlight exposure, ultimately influencing the stability of the slope. Also, the slope gradient affects local-scale moisture content and pore pressure, as well as the regional hydraulic behavior on a larger scale. Land use type may be also effective because forested areas help maintain a steady flow of water, allowing for regular infiltration. In contrast, cultivated land can lead to slope instability due to the saturation of the soil cover. Moreover, greater drainage density indicates imperviousness of underlying soil or rock strata, indicating slope instability. Furthermore, Runoff is a significant factor in initiating landslides. As the likelihood of erosion diminishes farther from the river along its banks, the occurrence of landslides becomes more concentrated in close proximity to the river.

Table 7.4. Critical Infrastructure and Lack of Coping Capacity Relationship.

Critical Infrastructure (CI)	Distance from communities	Lack of Coping Capacity (LoCC)
Hospital	<6km	0
	>6km	1
Police Station	<10km	0
	>10 km	1
School	<6km	0
	>6km	1
Roads	<200 m	0
	>200 m	1
Transmission Lines	< 1 km	0
	> 1 km	1
Recreational Facilities	< 1 km	0
	> 1 km	1



Coping capacity necessitates ongoing awareness, resources, early warnings, and effective management, both in regular circumstances and during disasters. The measure of coping capacity is the capability of individuals, organizations, and systems to utilize existing skills and resources in order to deal with unfavorable conditions. According to Table 7.4, if LoCC value of each critical infrastructure is equal to 1, due to the deficiency in disaster preparedness/response resulting from the lack of access to institutional support and vital infrastructure in the area, the consequences of disasters may be more severe. Also, distance from communities for each critical infrastructure is determined. For example, the presence of a police station within a 10 km range is regarded as beneficial. The assessment of the region's capacity to respond to disasters and emergencies heavily relies on the availability of these critical infrastructures. As a result, LoCC value is calculated by summing the LoCC value for each critical infrastructure.

Table 7.5. Demographic variables for vulnerability evaluation.

<b>Variable</b>	<b>Vulnerability defining attributes</b>
Population density	Higher population density (more vulnerable)
Age	Very old (>65 years) and young (<14 years)
Education	No certificate or degree
Language Barrier	Unable to speak either French or English
Family income	Under \$50 K per year
Immigration Status	Immigrants
Living Condition	Living in rented places

According to the Table 7.5, ages less than 14 and more than 65 years are more vulnerable to disasters because of mobility problems, their dependency on others and insufficient physical strength. In addition, inability to communicate effectively in the dominant language of the area puts individuals at a greater risk during disasters compared to those who are proficient. This is due to their struggle in accessing, comprehending, and responding to information or alerts disseminated through public media channels. Actually, there are many other different factors like unemployment, people with disabilities etc. which effects the vulnerability. However, they have not been incorporated into this case study because the purpose of this methodology is to create a straightforward framework for evaluating vulnerability within the context of disaster risk and community resilience. Additionally, due to lack of sufficient information, the status of buildings is not also included in the scope of vulnerability in this study.

In this study, a landslide inventory map is prepared which displays where landslides have occurred, along with their time of occurrence and their type. Then, landslide susceptibility map is created by using bivariate method of frequency ratio (FR) method. In this method, Fr value is calculated for each variable. While calculating this value, the number of pixels including landslides for each classes/variables are used. The sum of the FR values of all variables shown in Table 7.3 gives the Landslide Susceptibility Index value. Landslide susceptibility maps depict the likelihood of future landslides by considering the inherent characteristics of a location. After that, LoCC (lack of Critical Infrastructure) and V (population vulnerability) values are calculated with the help of Table 7.4 and demographic variables in Table 7.5. Later on, landslide susceptibility, vulnerability and LoCC maps are prepared with these calculations. Landslide risk map of the region is obtained as shown in Figure 7.8.

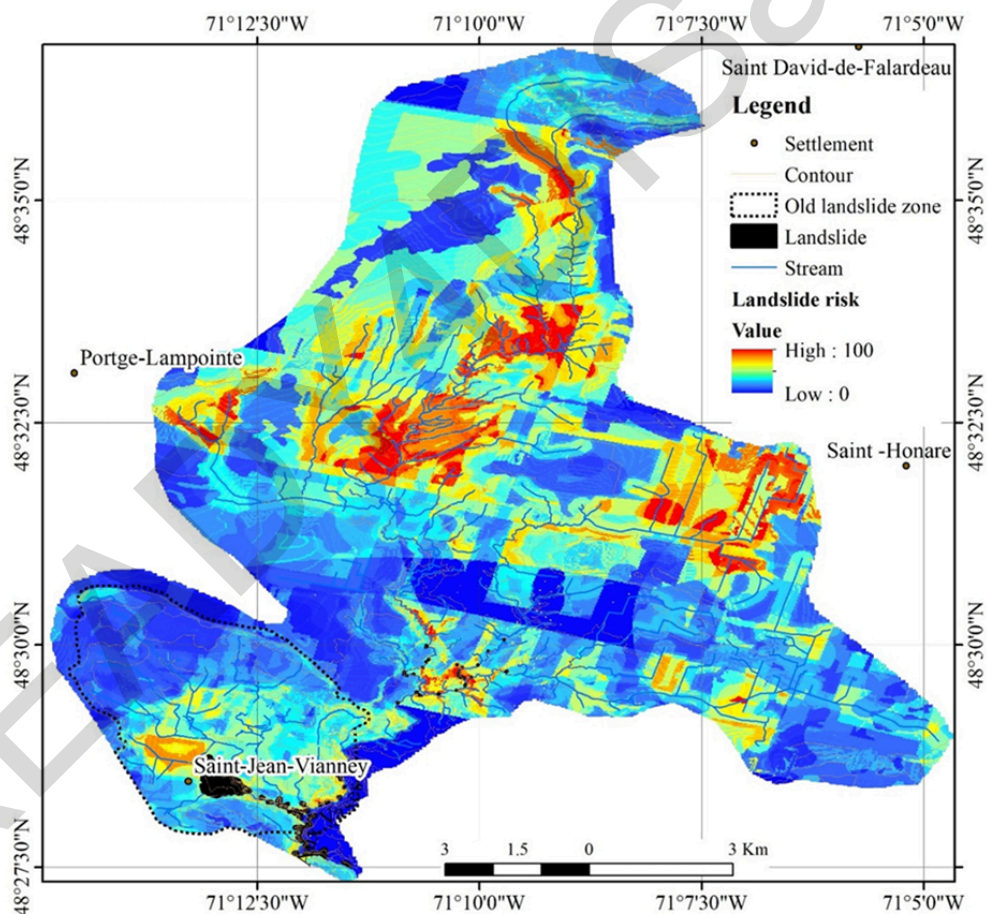


Figure 7.8. Landslide risk map of the region (Regmi and Agrawal, 2022).

According to this case study, it can be said that evaluating landslide risks is crucial in reducing potential loss of life and property within the studied region. It provides communities

with valuable insights to make informed choices for risk mitigation and enhancing their ability to cope. With this process, it is possible to have more resilient communities. This kind of study can be carried out in any place in the world. Indicators about topography, geology, land use and hydrological properties of the region can effect the landslide, so the result can be different in any other places, countries. These studies must be even repeated in the same area again regularly because some indicators can change with time in the community or region. In addition, the data used in these kind of studies must be up to date.

#### **7.4. Fire Resilience Metrics and Indicators**

##### **7.4.1. Understanding fire hazards and vulnerabilities**

As one of the most common and devastating natural disasters, fires demand comprehensive strategies for disaster preparedness. The assessment of fire resilience requires a dedicated set of metrics and indicators, tailored to present the detailed description of fire dynamics across different settings – from urban environments to industrial complexes. This exploration into fire resilience explains the intricacies of understanding, measuring, and improving a community's ability to withstand, respond to and recover from fires. Fires, whether sparked by human activities or natural causes, pose a significant risk across various landscapes. A key element in bolstering fire resilience is understanding the hazards and vulnerabilities unique to different types of fires.

In urban areas, factors such as building density, construction materials, and population distribution contribute to varying degrees of fire risk. In contrast, industrial sites introduce their own complexities, including the presence of hazardous materials and complex processes that can escalate fire hazards. Recognizing these vulnerabilities has a high level of importance in shaping effective fire resilience strategies.

##### **7.4.2. Metrics and indicators for fire risk assessment**

The evaluation of fire risk necessitates a multifaceted approach that can encompass the diverse characteristics of fires in different contexts. Metrics and indicators serve as indispensable tools for quantifying and qualifying fire risks. Within urban settings, these metrics could encompass the response time of fire services, availability and efficiency of fire detection and suppression systems, as well as the accessibility of evacuation routes. In industrial environments, additional metrics might include evaluating the types and quantities of hazardous materials present, the efficacy of emergency response protocols, and the

incorporation of fire-resistant infrastructure. Furthermore, the role of community engagement and education in fire resilience cannot be understated. Metrics that measure public awareness, participation in fire safety programs, and the presence of community-driven fire response plans offer insights into a community's readiness and capacity to respond effectively to fires. By studying these metrics and combining knowledge from them, stakeholders gain a comprehensive perspective on fire risks, enabling strategic resource allocation, informed decision-making, and the implementation of measures aimed at enhancing fire resilience. Understanding the indicators for fire resilience results with safer communities that are better equipped to navigate the challenges posed by fires.

### *Infrastructure and Industrial Site Indicators*

In the pursuit of fire resilience, the resilience of infrastructure stands as a crucial pillar. This encompasses the designs of buildings, materials used, and the capacity to respond effectively to fires. In industrial environments, where operations are often intricate and hazardous materials may be present, this aspect becomes even more critical.

Metrics evaluating building designs, fire suppression systems, and evacuation plans play a fundamental role in assessing a community's fire resilience. In industrial contexts, specialized indicators may encompass the availability of containment measures for hazardous materials, efficiency of emergency shutdown procedures, and protocols to prevent the rapid spread of fire in interconnected processes.

The integration of these metrics offers a comprehensive understanding of how well a community is positioned to handle fires. By investigating infrastructure resilience, especially in industrial settings with their unique complexities, stakeholders can develop more targeted and effective strategies for minimizing fire impacts.

### *Community Engagement Indicators*

A robust community engagement strategy is a cornerstone of fire resilience across a variety of landscapes. Metrics that gauge public awareness, participation in fire safety programs, and the establishment of community-driven fire response plans provide insights into a community's readiness to respond to fires.

Educating residents about fire risks, evacuation protocols, and emergency contacts empowers individuals to take an active role in mitigating the effects of fires. Moreover, involving the

community in the formulation of fire response plans fosters a culture of preparedness and collective responsibility.

In urban areas, this might translate into initiatives that encourage fire drills, public education campaigns, and fostering partnerships with local fire departments. In industrial environments, community engagement could involve ensuring that employees are well-informed about fire safety procedures and that industrial facilities have open lines of communication with neighbouring communities.

By evaluating these community engagement metrics, stakeholders gain a clearer understanding of how effectively a community can respond to fires. The collective involvement of residents and employees in fire resilience initiatives contributes to a safer, more resilient environment for everyone.

#### Quantitative Indicators/Metrics

The practical insights gleaned from case studies underscore the multifaceted nature of fire resilience metrics and their application. By understanding the challenges faced by different settings, we gain invaluable lessons that can be adapted and integrated into fire preparedness and response strategies across various contexts.

The methods used in the fire risk assessment can be classified into two groups as Geographical Information System (GIS) aided spatial functions and Multi-Criteria Decision Analysis (MCDA) methods. Parameters involved in the process of applying these methods can be classified into four main groups (Sari, 2021):

- i)** Topographical parameters: Elevation, slope, aspect, indices such as Compound Topography Index (Vadrevu et al., 2010).
- ii)** Climatic parameters: Average temperature, average precipitation, evaporation, solar radiation, wetness, wind.
- iii)** Forest structure parameters: Vegetation type, biomass density, fuel types.
- iv)** Socio-economic parameters: Distance to roads, distance to rivers, land use, population density, distance to power lines, distance to rail roads.

### 7.4.3. Assessing the resilience of communities and ecosystems in fire-prone regions

In urban areas, the significance of fire resilience is amplified due to the concentration of buildings, infrastructure, and populations. Cities such as New York stand as examples of comprehensive fire resilience strategies. These strategies encompass a spectrum of measures, including stringent fire codes, innovative building designs, and coordinated emergency response plans. Fire-resistant materials, state-of-the-art sprinkler systems, and well-defined evacuation routes are essential components. The urban case study underscores the importance of metrics that cater to the unique challenges of densely populated areas, where the rapid spread of fires can lead to widespread devastation.

Industrial environments, often housing intricate processes and hazardous materials, require specialized fire resilience strategies to ensure the safety of personnel, operations, and surrounding communities. Industrial plants, particularly those dealing with petrochemicals, serve as examples of meticulously planned fire resilience. Metrics in these settings might gauge the proximity of hazardous materials to potential ignition sources, the presence of rapid response systems, and the effectiveness of emergency shutdown procedures. The industrial case study underscores the necessity of integrating metrics that reflect the complexities of industrial operations into fire resilience assessments.

### 7.4.4. Case studies and best practices in fire resilience measurement

Here, a quantification study based on a fire resilience metric will be presented briefly to give the readers the grasp of the application of metrics and indicators in fire susceptibility. The research by Sari (2021) focuses on assessing forest fire susceptibility in the Muğla province of Turkey, an area prone to forest fires due to its sensitive ecosystems and climatic conditions. The study aims to create forest fire susceptibility zones by integrating various factors like environmental, forestry, topographic, economic, and meteorological parameters. The researcher employs GIS aided MCDA techniques, with the Analytical Hierarchy Process (AHP) used to calculate the weight of each criterion. The parameters and their corresponding classes for the calculation is given in Table 7.6.

Table 7.6. Criteria used in the fire resilience index calculation (Sari, 2021).

Criteria	Unit	Low			Moderate			Extreme		
		1	2	3	4	5	6	7	8	9
Aspect	Class	N	NW	NE	W	Flat	E	SW	SE	S

Slope	%	0	5	10	15	20	25	30	40	50
Elevation	Meter	0	100	300	500	1000	1500	2000	2500	2700
Com.Topo.In.	Class	12	9	6	3	0	3	6	9	12
Wetness	%	10	20	30	40	50	60	70	80	90
Humidity	%	74	74	70	66	62	58	54	50	46
Wind	m/sc	2	2,5	3	3,5	4	4,5	5	5,5	6,5
Temperature	Celcius	25	25,5	26	26,5	27	27,5	28	28,5	29
Precipitation	Kg/m^2	0,05	0,15	0,30	0,45	0,60	0,75	0,90	1,05	1,38
Land Use	Class	Wetland		Urban		Agriculture		Pastures		Forests
Dist.Settlement	Meter	120	105	90	75	60	45	30	15	0
Dist.Buildings	Meter	80	70	60	50	40	30	20	10	0
Dist.Water	Meter	0	30	45	60	75	90	105	120	120
Dist.Powerlines	Meter	120	105	90	75	60	45	30	15	0
Dist.Roads	Meter	120	105	90	75	60	45	30	15	0
Forest Type	Class	Non Forest	-	-	-	Broad Lv.	-	-	-	Conifer
Forest Density	%	10	20	30	40	50	60	70	80	90

The formulation included parameters and their respective weights in the calculation. The weights matrix is prepared with the AHP approach, which will not be further elaborated here for simplicity. The generated maps are validated using actual forest fire locations, showing accuracy rates of around 89% for AHP susceptibility map. The prepared fire susceptibility map together with the actual fire locations is given in Figure 7.9.

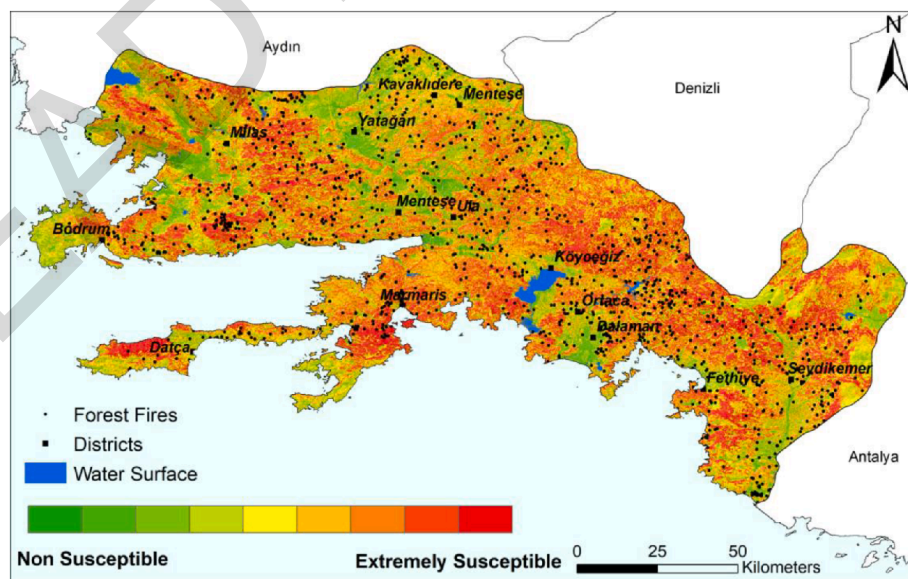


Figure 7.9. Forest fire data distribution and AHP forest fire susceptibility map (Sari, 2021).

This research shows that comprehensive and accurate forest fire susceptibility maps can be helpful to aid decision-making in fire management and prevention strategies.

In urban areas, the significance of fire resilience is amplified due to the concentration of buildings, infrastructure, and populations. Cities such as New York stand as examples of comprehensive fire resilience strategies. These strategies encompass a spectrum of measures, including stringent fire codes, innovative building designs, and coordinated emergency response plans. Fire-resistant materials, state-of-the-art sprinkler systems, and well-defined evacuation routes are essential components. The urban case study underscores the importance of metrics that cater to the unique challenges of densely populated areas, where the rapid spread of fires can lead to widespread devastation.

## **7.5. Applying Metrics and Indicators in Disaster Preparedness and Response**

### **7.5.1. Integrating Resilience Metrics and Indicators in Preparedness Planning**

In the realm of disaster management, the adage "prevention is better than cure" holds immense significance. Disaster preparedness is the linchpin of effective response and recovery efforts. Integrating resilience metrics and indicators into preparedness planning is a forward-looking approach that empowers communities and authorities to anticipate, strategize, and fortify their defences against impending disasters.

#### *The Power of Proactive Preparedness*

Disaster preparedness entails a series of coordinated activities and strategies aimed at reducing the impact of disasters. This includes planning for evacuation, resource allocation, emergency response, and community engagement. At the heart of these efforts lies the integration of resilience metrics and indicators, which transform preparedness planning from a reactive endeavour into a proactive one.

#### *Anticipating Vulnerabilities*

Resilience metrics and indicators serve as powerful tools for anticipating vulnerabilities. By analysing historical data, assessing physical and socio-economic dimensions, and utilizing predictive modelling, authorities can identify areas and communities at higher risk of specific disasters, such as floods, earthquakes, or hurricanes. This anticipatory approach allows for targeted preparedness measures, such as reinforcing critical infrastructure, enhancing early warning systems, and streamlining evacuation plans for the most vulnerable populations.



### Tailoring Preparedness Strategies

Not all disasters are created equal, and neither should preparedness strategies be uniform. Resilience metrics and indicators enable the tailoring of preparedness plans to the specific needs and risks of a community. For instance, in flood-prone areas, metrics related to flood depth, frequency, and historical impacts inform the design of flood-resistant infrastructure and the creation of effective evacuation routes. In earthquake-prone regions, indicators related to building resilience and earthquake preparedness become paramount.

### Resource Allocation and Optimization

Efficient resource allocation is a cornerstone of disaster preparedness. Resilience metrics and indicators guide authorities in optimizing the allocation of resources by quantifying vulnerabilities and risks. For example, if a coastal community faces the dual threats of hurricanes and rising sea levels, metrics related to storm surge vulnerability and sea-level rise projections inform resource allocation for the reinforcement of coastal defences. This ensures that resources are directed where they are most needed, maximizing the effectiveness of preparedness efforts.

### Community Engagement and Empowerment

Engaging communities in preparedness planning is vital for its success. Resilience metrics and indicators provide tangible evidence of vulnerabilities and risks, making it easier to communicate the importance of preparedness to residents. By involving communities in data collection, risk assessments, and the formulation of preparedness plans, a sense of shared responsibility is nurtured. This active engagement empowers individuals to take ownership of their safety, participate in drills, and support the implementation of preparedness strategies.

### Continuous Improvement Through Evaluation

The integration of resilience metrics and indicators does not end with the creation of preparedness plans; it continues throughout the entire disaster management cycle. After each preparedness exercise or response, data is collected and analysed using these metrics to evaluate the effectiveness of strategies. This iterative process allows for continuous improvement, ensuring that preparedness plans evolve in response to changing risk landscapes, population dynamics, and technological advancements.

### **7.5.2. Using metrics and indicators for early warning systems**

The effective management of disasters, particularly in the context of hydrometeorological events, is a global imperative. Timely and accurate information, coupled with efficient response mechanisms, can significantly reduce the impact of disasters on communities. One key component in this endeavor is the development and evaluation of early warning systems (EWS). These systems are designed to provide advance notice of impending disasters, allowing authorities and communities to take proactive measures to mitigate risks and minimize the potential for loss of life and property.

However, assessing the effectiveness of early warning systems is a complex challenge. To address this, the study by de Moraes (2023) proposes a novel methodology. This methodology aims to objectively evaluate the key elements universally accepted as constituents of an early warning system. Metrics and indicators play a pivotal role in this evaluation process. They provide quantifiable measures of the performance of early warning systems, helping disaster management authorities identify strengths and weaknesses. By analysing these metrics, decision-makers can make informed improvements to the system, ultimately enhancing its ability to protect communities from the impacts of hydrometeorological disasters.

To illustrate the practical application of this methodology, de Moraes (2023) investigates two distinct disasters in Petrópolis, Brazil, occurring 11 years apart. During this interval, Brazil implemented several measures for disaster risk reduction. The disparities in the impacts of these disasters shed light on the effectiveness of public actions and the enduring influence of vulnerability. Furthermore, this study, for the first time, brings mathematical rigor to the evaluation of disaster risk. By treating the disaster risk equation as a theorem, the research underscores the pivotal role of vulnerability as the linchpin in determining the impact of disasters.

In summary, the study provides a comprehensive framework for assessing early warning systems using metrics and indicators, with a specific focus on hydrometeorological disasters. Such an approach is invaluable in disaster management, as it enables decision-makers to refine strategies, enhance preparedness, and safeguard communities in the face of evolving climate challenges.

### **7.5.3. Assessing response capacity and effectiveness through metrics**

Assessing the response capacity and effectiveness of disaster management systems is a critical component of ensuring the safety and resilience of communities in the face of natural and man-made disasters. Metrics play a pivotal role in this assessment, providing a quantitative framework to evaluate the readiness and efficiency of response efforts.

Response capacity metrics encompass a wide range of factors, including the availability of resources such as emergency personnel, equipment, and medical supplies. By quantifying these resources and their distribution, authorities can identify gaps and allocate resources strategically to enhance response capacity. Additionally, metrics can assess the efficiency of communication and coordination among response agencies, ensuring that information flows seamlessly during a crisis.

Effectiveness metrics delve into the outcomes of response efforts. They help measure the success of evacuation plans, the speed of medical care delivery, and the overall impact on saving lives and reducing injuries and property damage. By analysing these metrics, authorities can identify areas for improvement, streamline response procedures, and allocate resources where they will have the most significant impact.

Incorporating metrics into disaster response evaluation fosters a culture of continuous improvement. It enables responders and decision-makers to learn from past events, adapt strategies to evolving threats, and ultimately enhance the resilience of communities. Furthermore, metrics provide a basis for benchmarking response efforts, enabling authorities to compare their performance with best practices regionally, nationally, and internationally. In an era marked by the increasing frequency and intensity of disasters, the role of metrics in assessing response capacity and effectiveness is indispensable in safeguarding lives and livelihoods.

## **7.6. Recovery and Reconstruction Metrics and Indicators**

### **7.6.1. Metrics and indicators for assessing post-disaster recovery and reconstruction**

The process of post-disaster recovery and reconstruction is a multifaceted and dynamic endeavour that involves rebuilding not only physical infrastructure but also the social, economic, and environmental fabric of affected communities. It is essential to evaluate the progress and effectiveness of recovery efforts, and this evaluation is made possible through the application of metrics and indicators. Metrics and indicators provide a structured approach

to measuring the various dimensions of recovery, enabling policymakers, researchers, and practitioners to gain valuable insights into the recovery process's complexities.

Here are some common categories and examples of metrics and indicators used in post-disaster recovery and reconstruction assessment:

**1. Infrastructure Resilience Metrics:**

- Percentage of damaged infrastructure repaired or replaced.
- Time taken to restore critical infrastructure (e.g., roads, bridges, utilities).
- Resilience of new infrastructure, considering updated building codes and materials.

**2. Economic Recovery Metrics:**

- Employment rates and income levels in the affected area.
- Gross Domestic Product (GDP) growth or contraction.
- Business recovery rates, including the number of reopened businesses.

**3. Housing Recovery Indicators:**

- Percentage of damaged or destroyed housing units repaired or rebuilt.
- Availability of temporary housing solutions.
- Housing affordability, including rent and mortgage costs.

**4. Social Recovery and Well-being Indicators:**

- Access to healthcare services and facilities.
- Educational enrollment and attendance rates.
- Community cohesion and social support systems.

**5. Environmental Recovery Metrics:**

- Ecological restoration progress, including reforestation and wetland rehabilitation.
- Reduction in environmental pollution and hazardous materials.
- Implementation of sustainable land use and building practices.

**6. Public Health and Safety Indicators:**

- Disease outbreaks and public health emergencies.
- Availability of clean water and sanitation.
- Resilience of healthcare systems and facilities.

**7. Community Engagement and Participation Indicators:**

- Participation in community planning and decision-making processes.
- Community-based disaster risk reduction initiatives.

- Use of public feedback and satisfaction surveys.

#### **8. Risk Reduction Metrics:**

- Implementation of disaster risk reduction measures.
- Compliance with updated building codes and zoning regulations.
- Reduction in the exposure and vulnerability of communities to future disasters.

#### **9. Recovery Financing Metrics:**

- Allocation and utilization of recovery funds.
- Efficiency in fund disbursement and project implementation.
- Monitoring and evaluation of financial transparency.

#### **10. Psychosocial and Mental Health Indicators:**

- Post-disaster mental health services and support.
- Prevalence of psychological distress and trauma.
- Access to counseling and support services.

#### **11. Resilience Index:**

- Development and monitoring of a comprehensive resilience index that combines various factors, such as economic, social, environmental, and infrastructural, to assess the overall resilience of the affected area.

These metrics and indicators help governments, organizations, and communities assess the progress of recovery and reconstruction efforts and make informed decisions to enhance resilience and reduce vulnerabilities in the face of future disasters. The specific metrics and indicators chosen for assessment may vary based on the disaster type, the region, and the goals of the recovery and reconstruction program.

#### **7.6.2. Monitoring progress and evaluating the effectiveness of recovery efforts**

In the aftermath of a disaster, monitoring progress and evaluating the effectiveness of recovery efforts are vital competences for decision-makers, planners, and emergency responders. These competences are guided by a commitment to data-driven decision-making, adherence to recovery principles, and a deep familiarity with relevant monitoring systems, such as landslide maps.

Data and feedback lie at the heart of effective disaster response and recovery. Decision-makers need to harness available data sources, including satellite imagery, ground assessments, and community feedback, to gain real-time insights into the evolving situation. By continuously collecting and analysing data, they can make informed choices about

resource allocation, prioritize the most urgent needs, and adapt strategies as circumstances change. Moreover, feedback from affected communities is invaluable; it provides a ground-level perspective on the recovery process, allowing for adjustments that align with the community's specific needs and aspirations. Through regular data collection and feedback mechanisms, responders ensure that their efforts remain responsive, relevant, and effective.

Coordination and management of recovery efforts should be guided by well-established recovery principles. These principles, which encompass inclusivity, sustainability, and building back better, provide a roadmap for decision-makers to navigate the complex landscape of post-disaster recovery. Inclusivity ensures that the voices and needs of all community members, including the most vulnerable, are considered and integrated into recovery planning. Sustainability entails a commitment to environmentally sound practices and long-term resilience. Building back better signifies a proactive approach to recovery, aiming not only to restore what was lost but also to enhance the community's overall resilience to future disasters. Competence in recovery principles allows decision-makers to strike a balance between immediate needs and the long-term well-being of communities.

Familiarity with landslide maps, flood maps and monitoring systems is especially crucial in regions prone to landslides, floods and other geological hazards. These maps, typically based on geological data, historical events, and terrain analysis, provide essential information about areas at risk. Decision-makers and planners must not only be aware of the existence of these maps but also understand how to interpret them. Monitoring systems, which may include sensors, remote sensing technologies, and community-based reporting, enable real-time tracking of landslide and geological activity. Competence in using these systems empowers responders to anticipate and respond swiftly to flood or landslide threats, reducing the potential for further harm during the recovery process.

In conclusion, the competences of data-driven decision-making, adherence to recovery principles, and familiarity with monitoring systems are pivotal in the effective response and recovery from disasters. By honing these competences, disaster management professionals can better serve affected communities, minimize risks, and work towards a more resilient and sustainable future.

### **7.6.3. Lessons learned from past disasters**

Understanding the complexities of disaster risk management and response strategies is an essential competency for professionals in the field. This comprehension is derived from the invaluable lessons learned through the analysis of past disasters. These experiences serve as a profound source of knowledge, enabling disaster management professionals to adapt their approaches effectively. This competency equips them to make informed decisions, uphold safety and security during disaster response activities, and collaborate efficiently within diverse teams in high-stress environments.

#### *Comprehending Disaster Risk Management Principles and Strategies*

The study of past disasters provides a comprehensive view of disaster risk management principles and strategies. It delves into the intricate web of factors that contribute to disaster vulnerability and resilience. By examining real-world case studies, professionals gain insights into the various components of disaster risk reduction, including risk assessment, early warning systems, and community engagement. They come to appreciate how pre-existing vulnerabilities, coupled with inadequate planning and response efforts, can intensify the impact of disasters. Lessons from previous events underscore the significance of interdisciplinary collaboration, holistic risk reduction, and the importance of addressing underlying social and economic factors. This deep understanding of disaster risk management principles is rooted in the practical applications and consequences of these principles.

#### *Maintaining a Secure and Safe Environment during Disaster Response Activities*

In disaster management, ensuring the safety and security of all involved parties is paramount. Past disasters vividly illustrate the chaotic and high-stress environments that often emerge in the wake of a catastrophe. Disaster management professionals must possess the competence to establish incident command systems, implement protective measures, and provide comprehensive training to responders. This extends to mastering the art of effective communication, risk assessment, and the proper utilization of personal protective equipment (PPE) to mitigate potential hazards (FEMA, 2017). Moreover, lessons from previous events highlight the necessity of tailoring response strategies to the unique characteristics of each disaster scenario, whether it involves natural calamities, public health crises, or technological accidents. Professionals who internalize these lessons are better equipped to create and maintain secure and safe environments for all stakeholders.

#### *Working Collaboratively with Diverse Teams in High-Stress Environments*

Collaboration is a cornerstone of effective disaster response, and past disasters provide invaluable insights into the challenges and merits of teamwork. Responding to disasters necessitates the seamless coordination of diverse teams, including first responders, medical personnel, volunteers, and government agencies, within high-stress contexts. The competency to work collaboratively involves an understanding of interagency dynamics, communication protocols, and the distinct roles and responsibilities of various stakeholders. Lessons from past disasters emphasize the criticality of clear leadership, well-defined roles, and the adaptability to swiftly changing circumstances. Furthermore, they underscore the significance of cultural competence and sensitivity when engaging with diverse populations. Disaster management professionals who grasp these lessons are better prepared to facilitate collaboration, manage conflicts effectively, and harness the strengths of diverse teams, thereby enhancing the overall effectiveness of disaster response efforts.

In conclusion, the ability to extract valuable lessons from past disasters is foundational for professionals in disaster risk management. It equips them with a profound understanding of disaster risk management principles and strategies, underscores the importance of maintaining safety during response activities, and enhances their capacity to collaborate effectively with diverse teams in high-stress environments. By continually seeking and applying these lessons, disaster management professionals can contribute significantly to the resilience and well-being of communities facing the ever-present threat of disasters.



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