POLITECNICO
MILANO 1863

School of Civil, Environmental and Land Management Engineering

M.Sc. programme in Civil Engineering for Risk Mitigation

Geospatial Data Processing to Support Seismic Emergency Management

WebGIS Services to Support Locational Choices of Shelters

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1. Introduction

1.1. Overview of the project

Disasters have been an enduring part of human history, encompassing a wide range of hazards such as earthquakes, floods, and fire outbreaks. Among these, earthquakes present the most formidable challenge due to their unpredictable timing, magnitude, and location (*Prediction and Perception of Natural Hazards - Google Books*, n.d.). Their devastating potential extends from erasing entire cities to inflicting significant casualties, economic losses, and social upheaval. Nonetheless, the extent of damage caused by earthquakes can be mitigated through effective disaster management planning (Bello & Aina, 2014). While it is impossible to prevent or predict some natural hazards like earthquakes, their adverse impacts can be minimized through a variety of actions and strategies. Implementing robust mitigation and preparedness measures can reduce communities' exposure to hazards and enhance their resilience to disasters(Lam & Kuipers, 2019).

In this report, we propose an emergency plan for shelters' location in the aftermath of a disaster in the city of Amatrice, Italy (Figure 1. Area of Interest: Amatrice city in Lazio region, Italy). Leveraging geospatial and demographic data, we will identify suitable locations for shelters during and after the disaster. Additionally, we will classify these shelters based on population demographics to cater to specific needs which might emerge after the earthquake. The objective of this plan is to facilitate prompt response and coordination among responsible agencies and stakeholders following the disaster's impact. Furthermore, we will discuss the possibility of implementing a new platform which can be used to replicate some of the tasks required for this project in a scalable and more efficient manner in the last chapter.

To enhance the visualization and accessibility of the computed data, we will develop a WebGIS portal. This platform will showcase the information through an infographic presentation, utilizing both software ArcGIS Online and GeoNode. The WebGIS portal will enable users to gain insights into the shelters' locations, demographic characteristics, and other relevant data, aiding in informed decision-making and resource allocation. Moreover, a dashboard has been developed to show infographic presentations of the status of the shelters in terms of: total number of evacuated people, shelters' capacity and filling rate.

Overall, this report aims to provide a comprehensive and practical approach to finding shelters' location in the context of seismic emergency management. By utilizing geospatial data and considering humanitarian and psychological consideration, we strive to develop an effective plan that optimizes the safety and well-being of individuals affected by earthquakes.

1.2. Problem Statement

The case study will focus on the town of Amatrice (Figure 1. Area of Interest: Amatrice city in Lazio region, Italy)., situated in central Italy. Amatrice is renowned for its susceptibility to earthquakes, being situated near the central Apennines, one of the most seismically active regions in Italy with a population of around 2300 inhabitants and spans an area of 174 km^2 (*Amatrice - Wikipedia*, n.d.). In 2016, a devastating Mw 6.2 earthquake struck the town (Figure 1. Area of Interest: Amatrice city in Lazio region, Italy)., causing significant damage to its infrastructure. The proposed shelter's location plan aims to address the specific challenges faced by Amatrice, considering its vulnerability to earthquakes and the impact of the previous seismic event. By incorporating different phases of the emergency-recovery plans, we will propose various shelter locations that can accommodate evolving needs in the aftermath of future events. To facilitate effective communication and aid in the process of the location choice for the civil protection and relevant authorities.

The WebGIS portal will serve as a platform to showcase the results of our work, it is important to note that the scenario we are proposing for building damage is general in nature and can be adapted to different damage scenarios that have been witnessed in the past or in may be faced in the future. By considering a range of potential damage scenarios, our shelters location plan will be applicable and adaptable to various seismic events and their corresponding impacts.

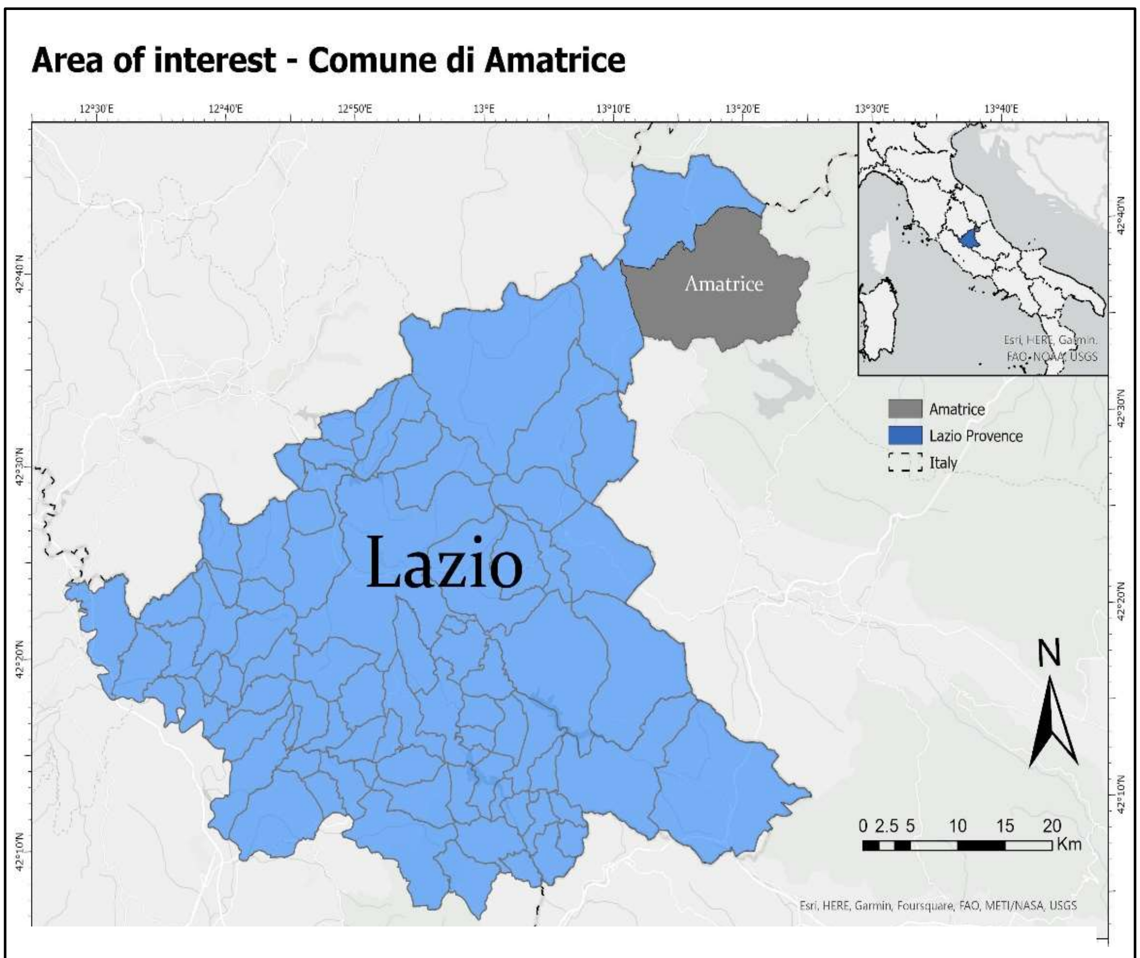


Figure 1. Area of Interest: Amatrice city in Lazio region, Italy

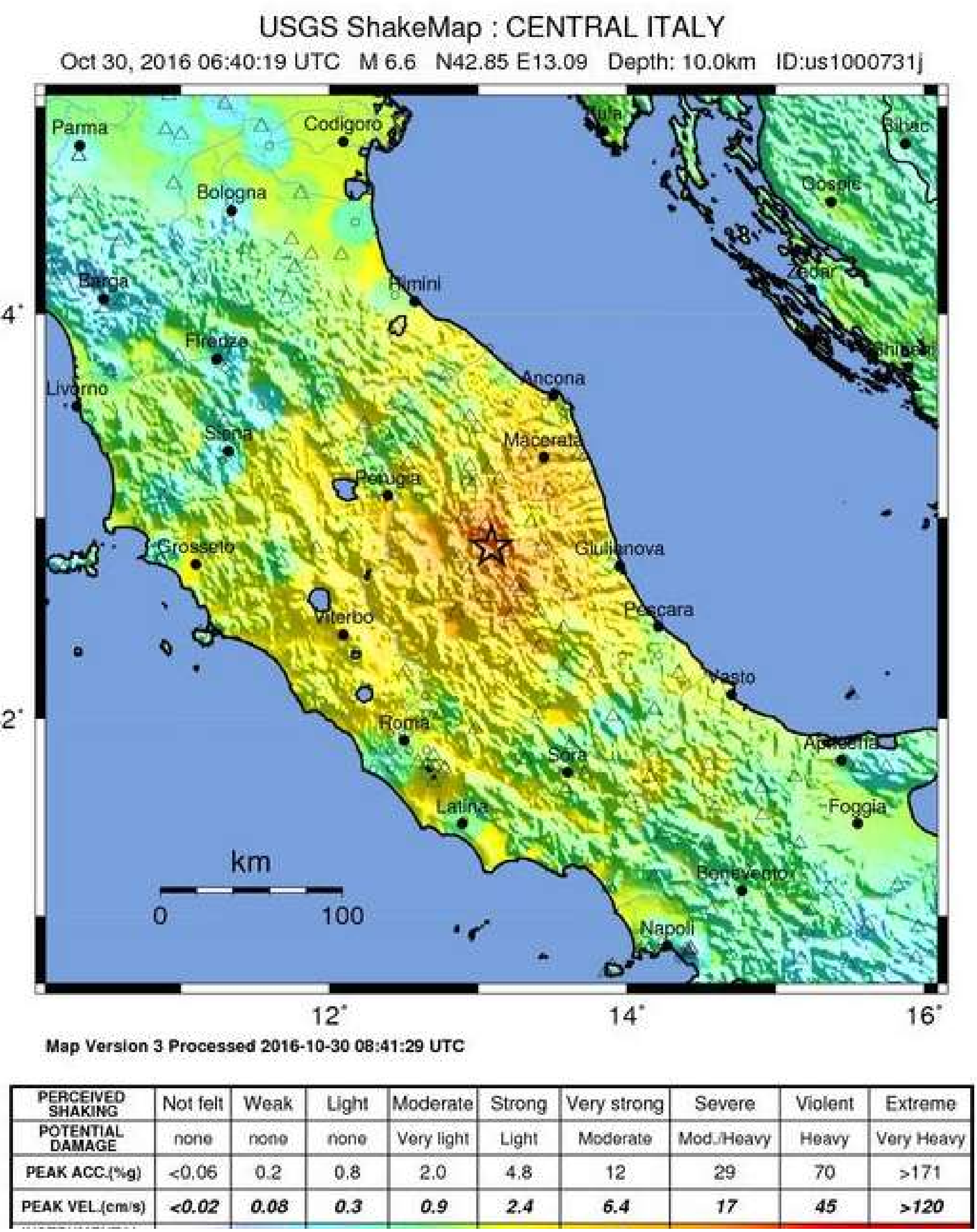


Figure 2. ShakeMap of 2016 Earthquake in Amatrice, Italy

1.3. Importance of the Location of Shelters During Emergency

Shelters and evacuation planning are critical components of disaster preparedness, both during and after a disaster. Shelters serve as temporary havens, providing relief and protection for individuals affected by disasters. They can either be purpose-built structures designed specifically for disaster relief or existing multi-purpose facilities, such as schools or gymnasiums, repurposed for temporary use in emergencies (Tamima et al., 2012). In our case study, we will focus on finding suitable locations for both temporary and permanent shelters (excluding the mutli-purpose facilities), considering the long-lasting effects of hazards and any potential induced hazards, while considering the accessibility to the essential needs. However, it is important to emphasize the significance of utilizing existing facilities that can be transformed into shelters, as previously mentioned.

1.4. Estimated Number of Evacuees

Accurate estimation of the number of evacuees plays a vital role in shelters location. Various models exist to estimate the number of evacuees based on different parameters, with one widely utilized model being HAZUS. HAZUS incorporates socio-economic factors to derive estimates (Schneider et al., 2006). In our case study, we will base our estimations on the highest possible estimate, considering the population of Amatrice and the anticipated number of NGO members and rescuers involved in humanitarian activities. This approach ensures sufficient capacity to accommodate all potential evacuees. Furthermore, we will propose a classification system for shelters, taking into consideration their safe deployment locations. This classification will be based on various demographic characteristics of the population affected by the disaster. By considering factors such as medical needs, privacy requirements, and proximity to damaged houses or properties, we aim to facilitate the evacuation process and ensure that the shelters cater to the specific needs of evacuees.

Total expected number of Evacuees: 2689(taken from the census layer) + 200 (for SAR and other NGOS) = 2889 Evacuees

1.5. Framework

The approach undertaken in this project involved four main phases. As depicted in the (Figure 3), the first two phases aimed to filter out unsuitable areas of land based on their geological characteristics and susceptibility to geohazards. To summarize our workflow, during the first phase, we eliminated portions of land unsuitable due to geological factors such as slope, soil type, and landcover. This left us with land areas that exhibited suitable geological characteristics for potential shelter locations. However, some of these areas were susceptible to geohazards, specifically floods, landslides, and presence of fault lines.

In the second phase, we further eliminated areas prone to the natural disasters, as well as those near fuel stations or electric grid network, due to the risk of fire or explosions and collapse of these grids. By the end of this phase, we had identified potential suitable areas in the event of an earthquake or any geohazards. Nevertheless, there are additional factors that can influence the suitability of an area for sheltering purposes. These factors fall into the categories of services and lifelines.

In the third phase, the level of the suitability of shelter areas was ranked by applying an increasing factor to the outcome of the previous phases. Considering the proximity to medical centres (hospitals) for healthcare access, proximity to police stations for security considerations, accessibility to water resources, and accessibility to the city's primary and secondary road network as well as the proximity to the high-density population zones.

Furthermore, in the fourth phase, further categorization was performed to the ranked suitable areas obtained from the third phase to highlight the most favourable ones with respect to: medical needs, road accessibility, and distance to the city centre. Identification of the areas for medical needs during emergency would help the user to efficiently distribute the elder and those who need medical assistance. The most accessible areas will help to accommodate those who don't have access to vehicles or with disabilities. Nonetheless, the areas in the proximity to the city centre were considered more favourable for the SAR teams for the reasons mentioned in (section 3.4).

A WebGIS application using ArcGIS online has been designed. The portal contains the crucial maps needed during the emergency namely, Ranked Suitable Areas, Classified Areas based on Needs and Suggested Areas for SAR Team. In addition, a dashboard has been developed to make use of the updated data during the emergency phase of the event. For instance, number of people to be evacuated, total evacuated and shelters' capacity. Since the ArcGIS online is a commercial product and need licencing, we have also published our results on the GeoNode platform as well, which acts a redundancy for the ArcGIS Online.

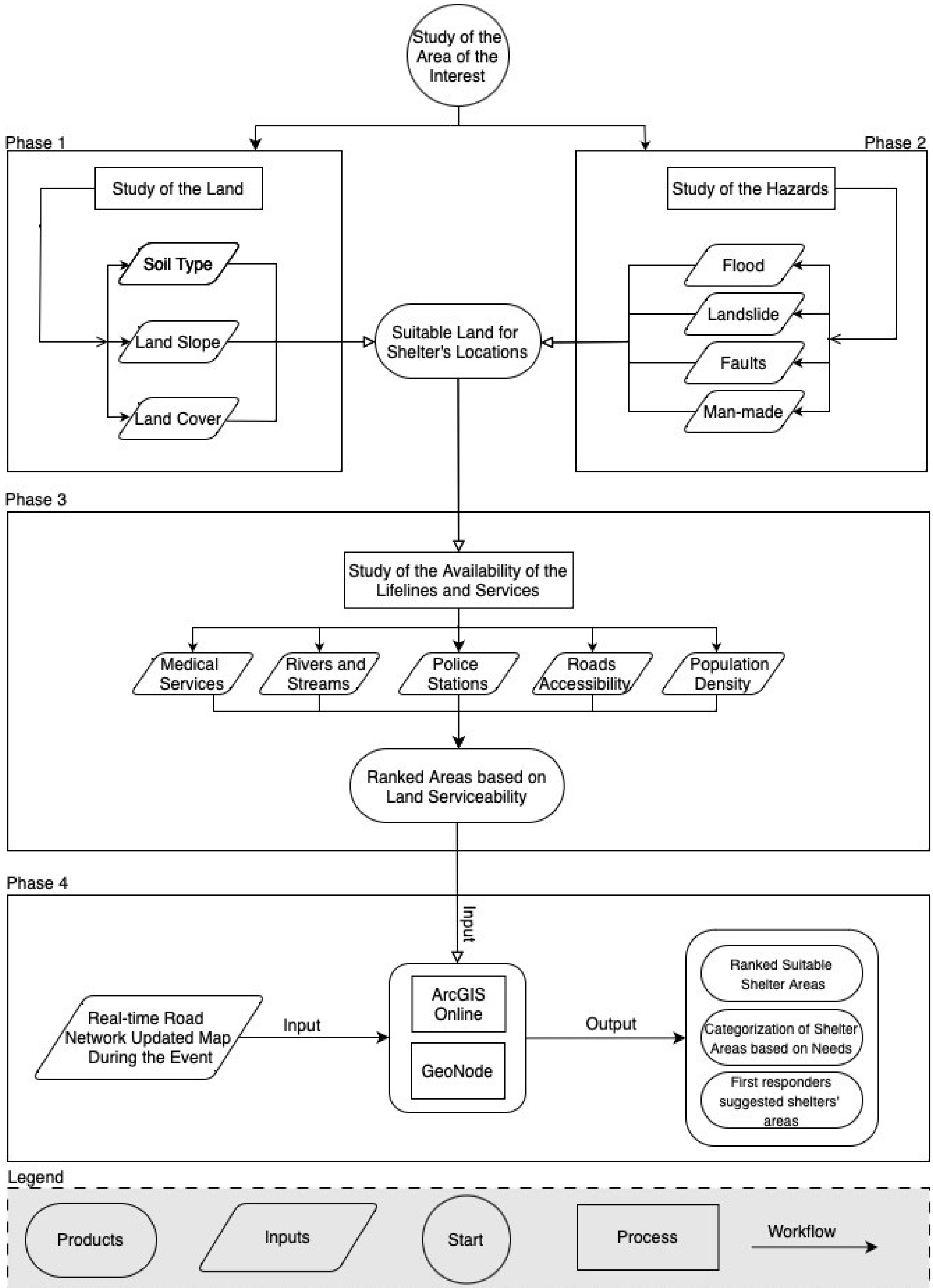


Figure 3. Framework and Workflow of the Project

1.6. Data

The data used in the framework of producing suitable areas for shelters in the city of Amatrice has been acquired from different sources. Further developing and conversion of these layers was needed to exploit the data using the different geo-processing tools in ArcGIS Pro and QGIS. Table 1 shows the metadata of each map used in this case study.

Table 1. Data Used in the Project

Layer Name	Format	Source
DTM	TIFF	Regional Geoportal Lazio
Slope	Computed from DTM Layer	
Population	Shapefile	Regional Geoportal Lazio
Soil Type	Shapefile	BGR's IHME1500
Land Cover	Shapefile	Copernicus EU
Flood	Shapefile	Regional Geoportal Lazio
Landslide	TIFF	European Commission JRC
Faults	Shapefile	Regional Geoportal Lazio
Hospitals, Police Stations, Power Grid Networks, and Fuel Stations	Shapefile	OPEN STREET MAP

1.7. Weights Assignment

The distribution of relative weights among the different factors (layers) plays a vital role in obtaining satisfactory results. The weights assignment (shown in the table below), were used to obtain the final suitable areas for shelters (phase 3).

Phase	Layers	Classification	Interpretation	Suitability Weights	Main Weight
1st: Geological Criteria	Slope	$\theta \leq 2°$ & $\theta > 10°$	Unsuitable	0	7
		$2° < \theta \leq 4°$	Neutral	2	
		$4° < \theta \leq 10°$	Suitable	5	
	Soil Type	Limestones and Clays	Unsuitable	0	7
		Limestones and Marls	Neutral	3	
		Sandstones and Marls	Suitable	5	
	Landcover	Natural grasslands, Pastures, Discontinuous urban fabric	Unsuitable	0	7
		Sparsely vegetated areas, non-irrigated arable land, Land principally occupied by agriculture, with significant areas of natural vegetation.	Neutral	3	
		Water bodies, Mixed Forest, Coniferous Forest, Broad leaved Forest, Transitional woodland-shrub	Suitable	5	

2nd: Hazards Susceptability	Landslide	High & Very High Susceptibility Medium Susceptibility Very Low & Low Susceptibility	Hazardous Low Hazard Very Low Hazard	0 2 5	10
	Flood Hazard	Susceptible areas Un-susceptible areas	Unsuitable Suitable	0 1	-
	Faults	D < 500m D > 500m	Unsuitable Suitable	0 1	-
	Fuel Stations	D < 500m D > 500m	Unsuitable Suitable	0 1	-
	Power Plant	D < 500m D > 500m	Unsuitable Suitable	0 1	-
	Power towers	D < 250m D > 250m	Unsuitable Suitable	0 1	-
3rd: Serviceability and Lifelines Factors	Population Density	No. of People <20 21< No. of People < 50 No. of People > 51	Less suitable Neutral Suitable	1 1,23 1,35	-
	Roads	D ≤ 50 m 50 < D ≤ 300 300 < D ≤ 500 500 < D	Right of the road Favourable Neutral Less Favourable	0 1,70 1,47 1,23	-
	Hospital	≤ 500 m 500 < D ≤ 1000 m 1000 < D ≤ 2000 m 2000 < D	More Favourable Favourable Neutral Less Favourable	1,60 1,45 1,30 1,15	-
	Police	≤ 500 m 500 < D ≤ 1000 m 1000 < D ≤ 2000 m 2000 < D	More Favourable Favourable Neutral Less Favourable	1,50 1,38 1,25 1,13	-
	River & streams	≤ 50 m 50 < D ≤ 300 300 < D ≤ 600 m 600 < D	Water Body Favourable Neutral Less Favourable	0 1,25 1,17 1,08	-

2. Workflow and Corresponding Maps

The framework described in section 1.5 (Framework) outlines a workflow divided into four phases. These phases are designed to provide a structured approach to understand the workflow. In the subsequent section, detailed maps are presented, offering a more comprehensive explanation of each phase and the procedures involved in their development. Furthermore, the classification criterion and its corresponding weight used in each layer is explained above each layer.

2.1. Phase One: Geological Criteria to Find Suitable Land

During this phase, an analysis of the geological characteristics of the earth's surface in the Amatrice region was conducted. The study encompassed crucial factors such as slope, soil type, and land cover vegetation across various areas in Amatrice. To facilitate this analysis, corresponding maps were developed, assigning specific weights to each factor. By considering these weighted factors, areas that did not align with the desired geological characteristics were identified and subsequently excluded from consideration for shelter creation. This evaluation process ensured that only suitable locations were chosen to establish shelters, considering the geologically favourable attributes of the land.

2.1.1. Suitability of Land based on Land Slope

One of the crucial factors to consider when determining the suitability of a land area for choosing shelter location is the land slope. Extensive research conducted by (Liu et al., 2011) has identified that areas with slopes exceeding 10 degrees are deemed unsuitable for sheltering purposes due to the possibility of soil erosion. Consequently, these areas have been assigned a weight of 0 in our classification system to ensure their exclusion in subsequent stages. Conversely, to ensure effective drainage (*Camp Site Planning Minimum Standards | UNHCR*, n.d.). Corresponding categories and weights for each category is presented in Table 2.

Table 2. Land Slope Suitability Assigned Weights

Slope Range (degree)	Interpretation	Suitability Weight
$2 \leq \theta \leq 4$	Suitable	5
$4 < \theta < 10$	Neutral	2
$\theta \geq 10$	Unsuitable	0

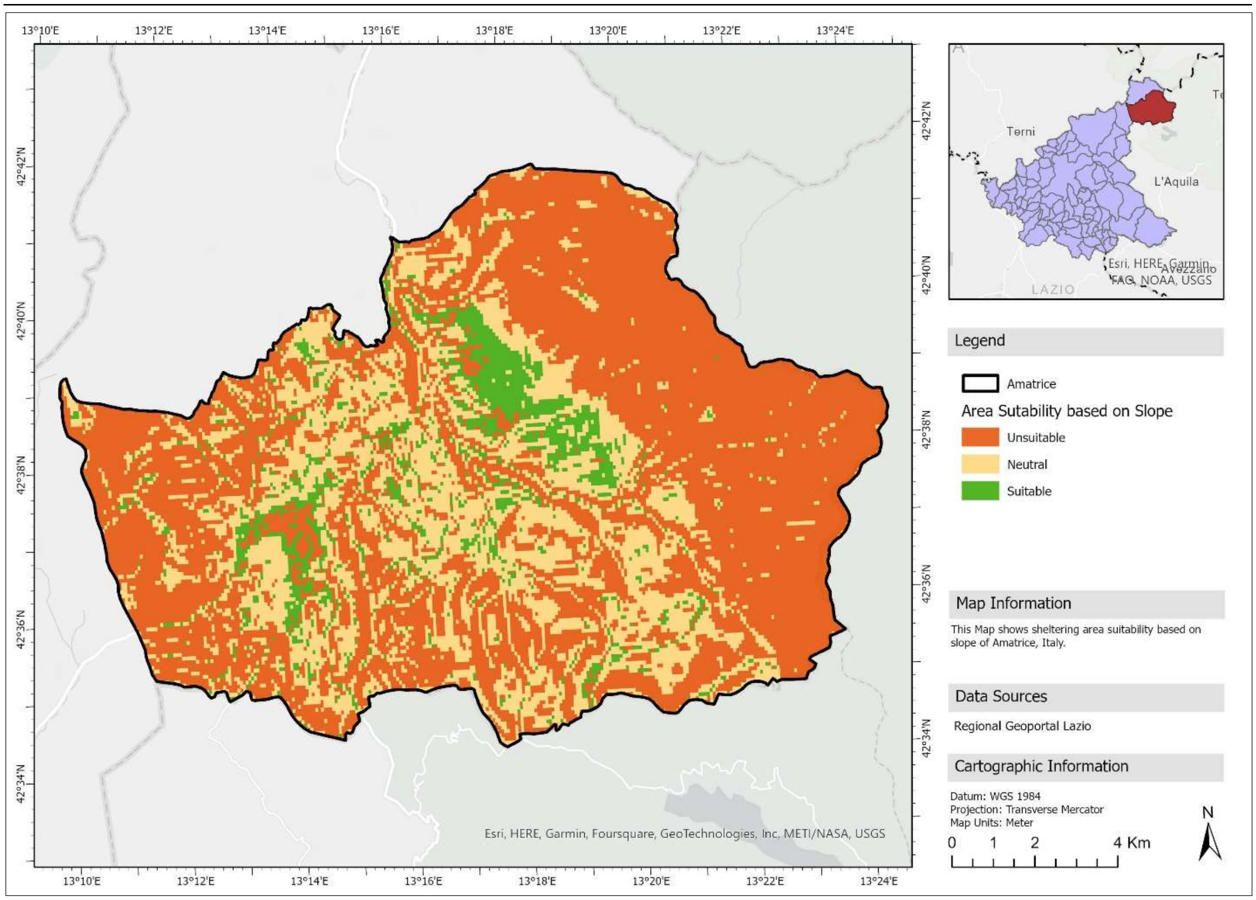


Figure 4. Land slope Suitability Map

2.1.2. Suitability of Land based on Soil Type

Soil permeability is a crucial factor to consider when determining suitable locations for shelters. The permeability of soil is influenced by various factors such as soil porosity, infiltration capacity, and soil saturation. Clay-rich soils, for example, have low permeability and infiltration, leading to high surface runoff. Consequently, it would not be advisable to construct shelters on such soil. Conversely, soils predominantly composed of sandstone exhibit higher permeability compared to clay soils, resulting in reduced surface runoff. Corresponding categories and weights for each category is presented in Table 3.

Table 3. Soil Type Suitability Assigned Weights

Soil Type	Interpretation	Suitability Weight
Sandstone and Marls	Suitable	5
Limestone and Marls	Neutral	3
Limestone and Clay	Unsuitable	0

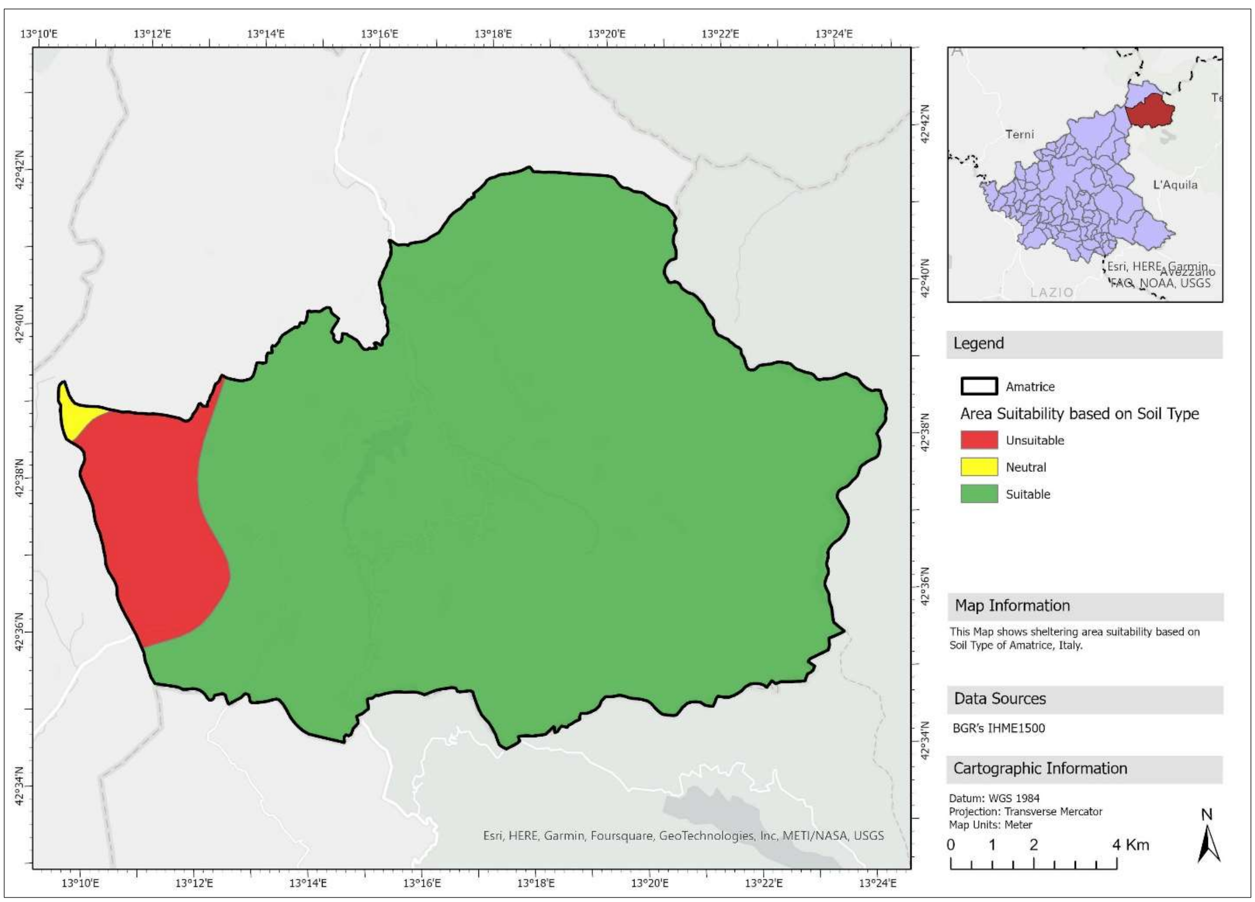


Figure 5. Soil Type Suitability Map

2.1.3. Suitability of Land based on Land cover

The type of land cover is another crucial factor to consider when selecting suitable locations for shelters. It is evident that areas densely covered by the trees and vegetation are unsuitable for sheltering purposes. Conversely, areas with moderate vegetation can serve as suitable sites for establishing shelters. These areas can effectively reduce dust and erosion, and compared to forested areas, they pose a lower risk of fire hazards. Taking into account the land cover in the designated area, we categorized it into three classes as outlined in table 3. categories and weights for each category is presented in Table 4.

Table 4. Landcover Suitability Assigned Weight

Landcover Type	Interpretation	Suitability Weight
Natural grasslands, Pastures, Discontinuous urban fabric	Suitable	5
Sparsely vegetated areas, non-irrigated arable land, Land principally occupied by agriculture, with significant areas of natural vegetation.	Neutral	3
Water bodies, Mixed Forest, Coniferous Forest, Broad leaved Forest, Transitional woodland-shrub	Unsuitable	0

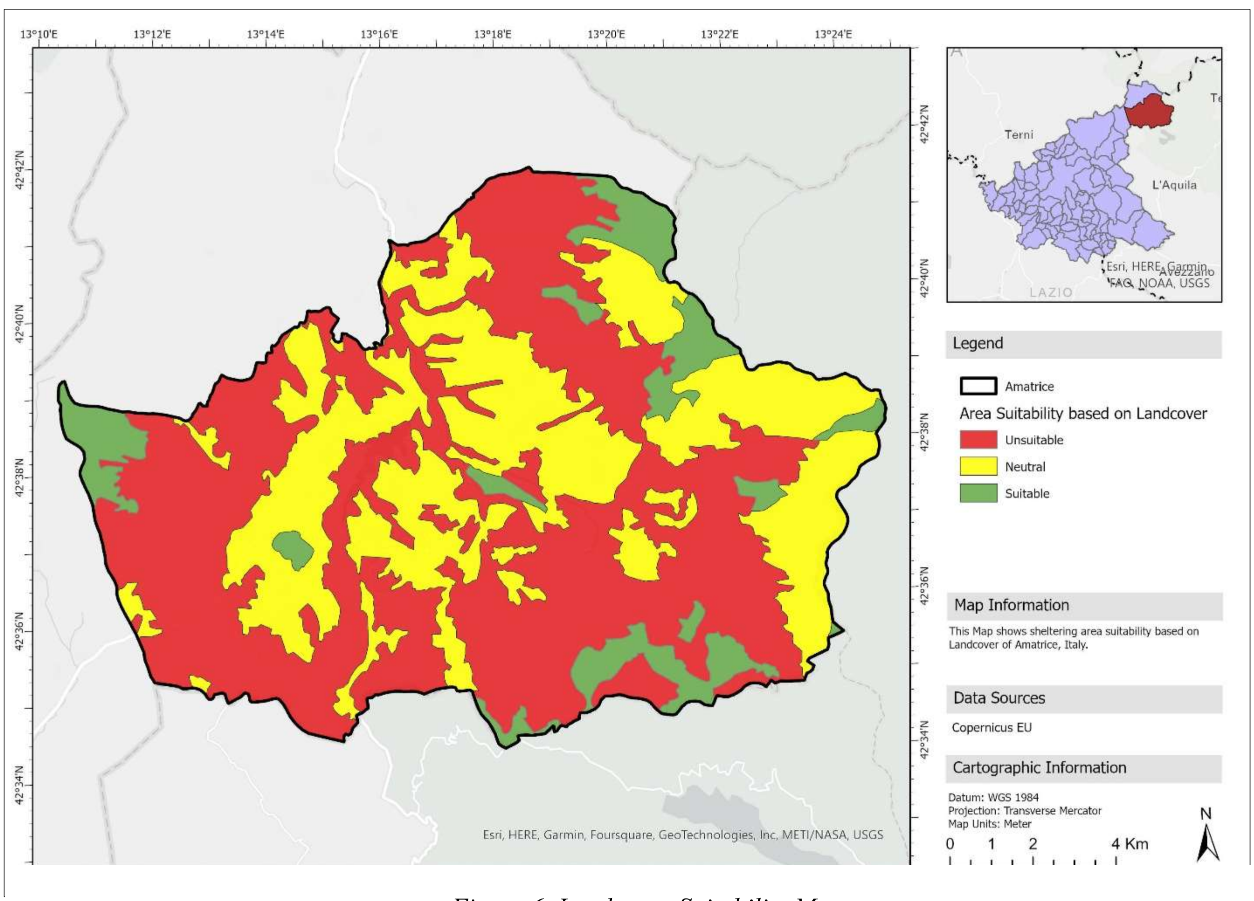


Figure 6. Landcover Suitability Map

2.1.4. Phase One Outcome

In the final step of Phase 1, all the layers explained in the sub-preceding sections including land slope, land cover, and soil type have been merged using GIS software while multiplying each of them by its corresponding weight *(section 1.7).* The Information that can be found in this final map is the suitable areas based on the geological characteristics of the area.

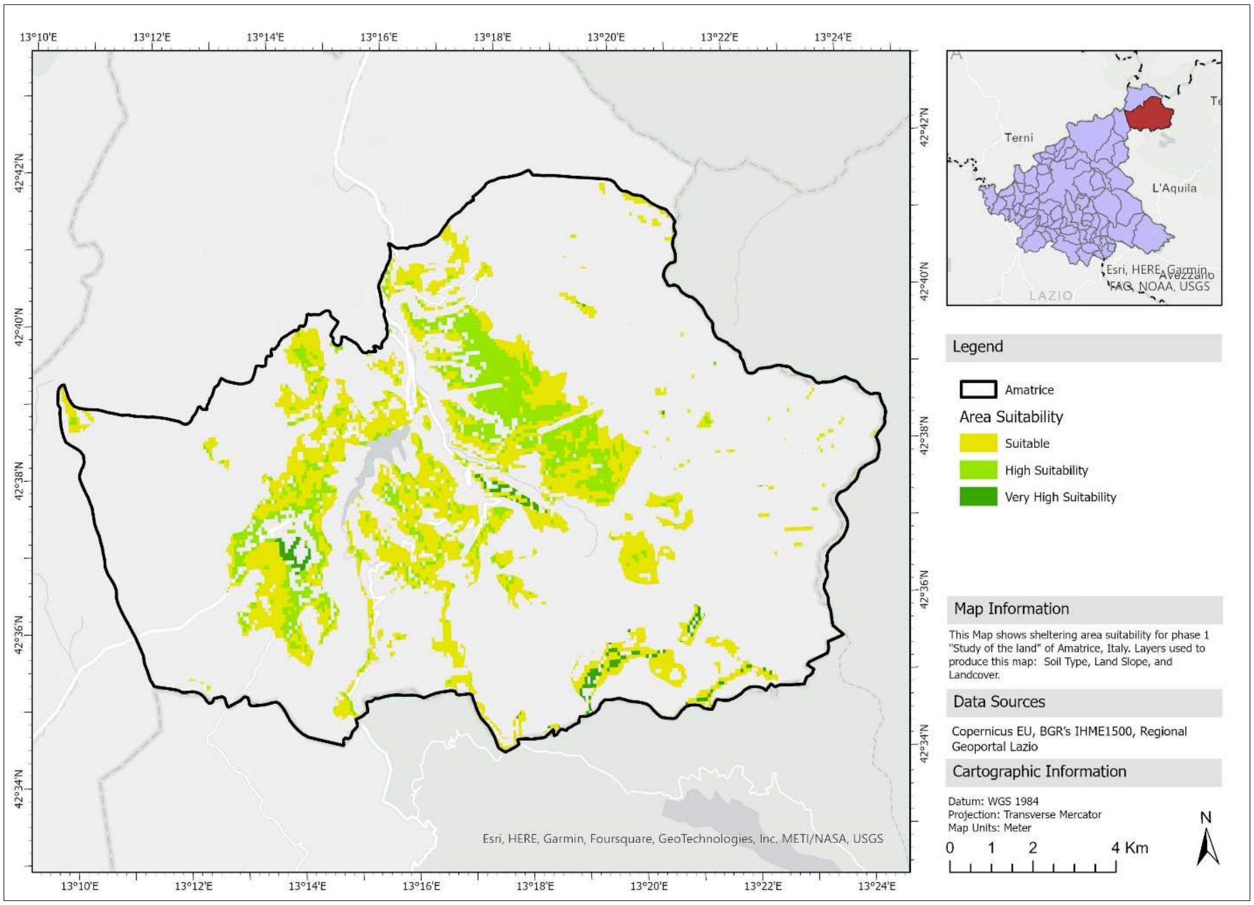


Figure 7. Outcome of the first phase Map

2.2. Phase Two: Hazards Susceptibility Criteria to Find Suitable Land

During this phase, an analysis of the potential natural and man-made hazards in the Amatrice region was conducted to consider the induced effects and multilevel hazards. The hazards which were investigated in this phase are of flood, landslide, fuel station, power plants, Power Towers, and earthquake faults. To perform this analysis, corresponding maps were developed, assigning weights to each factor. By considering these weighted factors, areas that are exposed to any kind of the previously mentioned hazards were identified and subsequently excluded from consideration for shelter creation. This evaluation process, conducted alongside the phase 1 assessments that consider the geological suitability of shelter locations, guarantees that the land is indeed suitable for the purpose of establishing shelters.

2.2.1. Susceptibility to Flood

Flooding events can cause significant losses of lives, extensive damage to infrastructure and disruption of essential services (Dall'Osso et al., 2009). For this reason, the flooding susceptibility layer was considered. The areas that are prone to flooding have been disregarded to highlight those areas that poses the opposite definition (Table 5).

Table 5. Flood Suitability Assigned Weight

Area Susceptibility	Interpretation	Suitability Weight
Un-susceptible areas	Suitable	1
Susceptible areas	Unsuitable	0

2.2.2. Susceptibility to Seismic Hazards

Studying the area for seismic hazards is an utmost importance. The damage caused by such hazard will be fatal to the city's infrastructure, buildings, and lifelines. Due to the unavailability of Earthquake Hazard Assessment layer for the city of Amatrice, we have used a layer that show the active faults in the area and disregarded the areas that lie around them (as a second alternative, shake map of a previous event could have been used to classify the areas for seismic susceptibility based on their recorded PGA) (Table 6).

Table 6. Seismic Hazard Suitability Assigned Weight

Area Susceptibility	Interpretation	Suitability Weight
Un-susceptible areas	Suitable	1
Susceptible areas	Unsuitable	0

2.2.3. Susceptibility to Man-Made Hazards

Man-Made hazards can vary from infrastructure collapses to industrial accidents. Considering these areas that happen to have a potential hazardous effect in case of damage due to natural disaster (e.g., earthquake, flooding) is crucial. To avoid secondary damage to evacuees, potential shelter areas that fall within 500 meters of earthquake faults or high-risk areas such as gas stations and powerplants to be excluded from the suitable areas for shelters (Sustainability 2017, 9, 2098). Also, shelters that fall within 250 meters of power towers are to be excluded. (Table 7).

Table 7.Man-made Hazard Suitability Assigned Weight

Area Susceptibility	Interpretation	Suitability Weight
Not Susceptible Areas	Suitable	1
Susceptible areas	Unsuitable	0

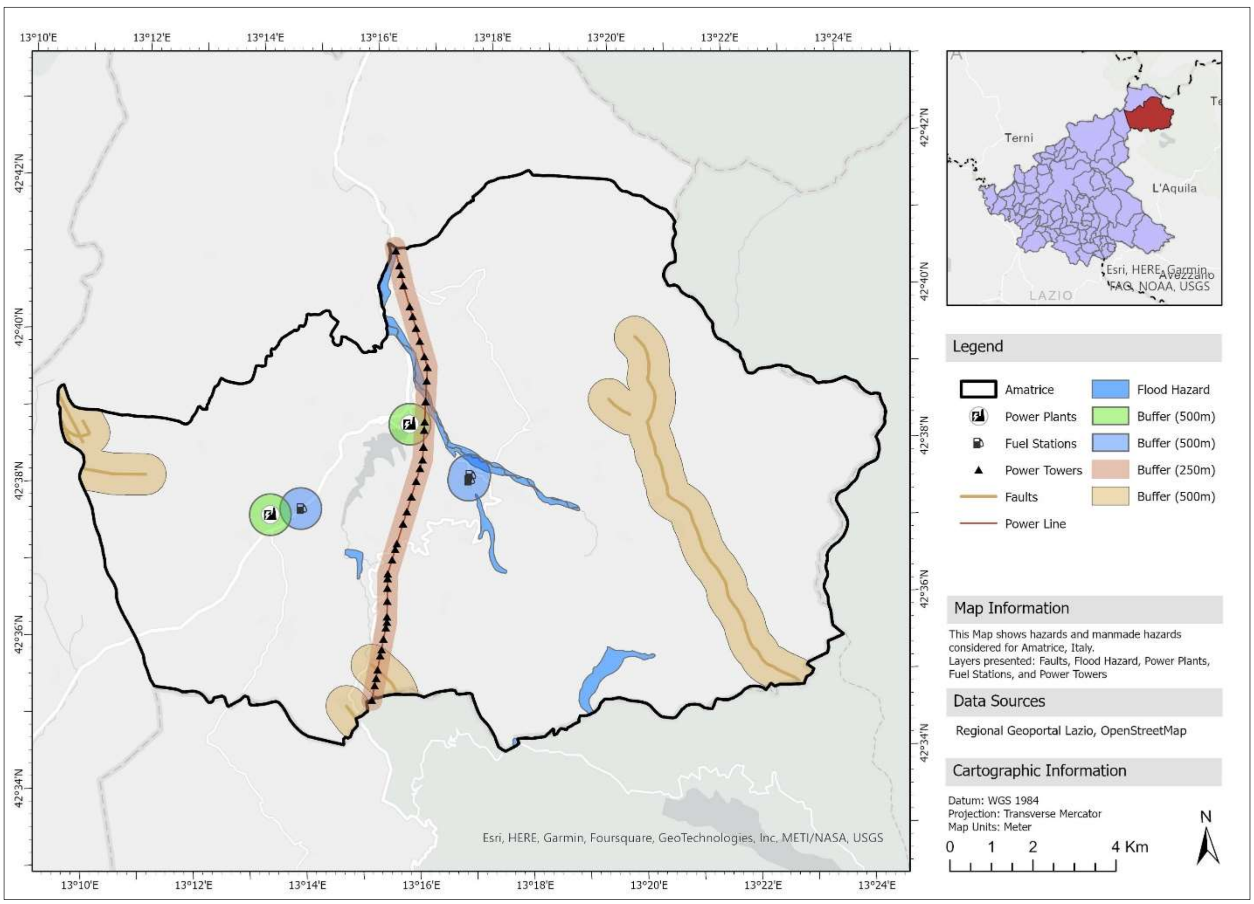


Figure 8. Man-made Hazard Suitability Map

2.2.4. Susceptibility to Landslides

Landslides can have a significant impact on the overall hazard and subsequent damage caused by the earthquake. The assessment of landslide's susceptibility will allow for a comprehensive understanding of the suitability of the area in the second phase. The areas that have been disregarded are those that pose a high and very high susceptibility. The areas that are considered poses medium or low are used and given weight (Table 8).

Table 8. Landslide Hazard Suitability Assigned Weights

Area Susceptibility	Interpretation	Suitability Weight
Very Low & Low Susceptibility	Very Low Hazard	5
Medium Susceptibility	Low Hazard	2
High & Very High Susceptibility	Hazardous	0

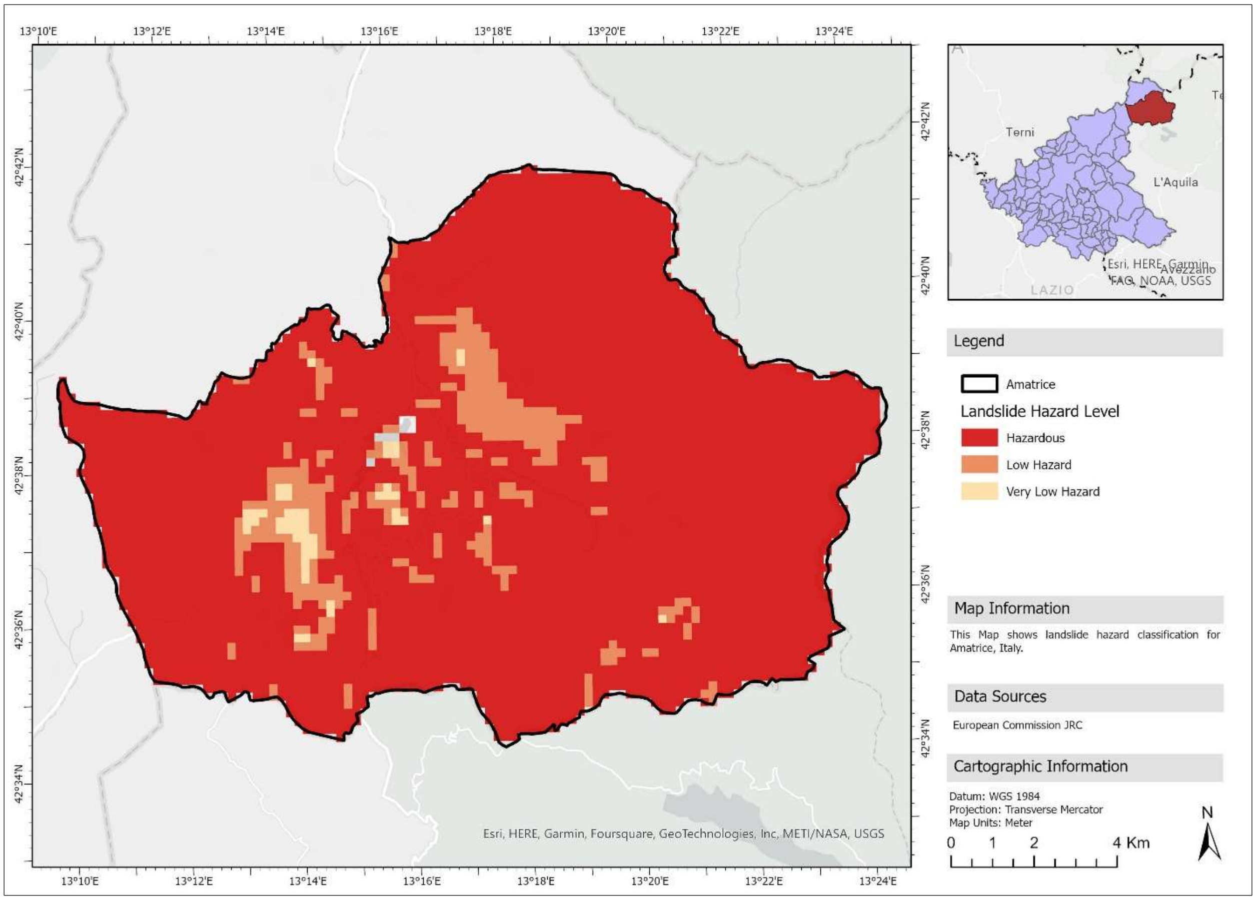


Figure 9. Landslide Hazard Suitability Map

2.2.5. Phase Two Outcome

The outcome of phase two map shows hazard classification after considering natural and man-made hazards. In which hazardous area is to be deemed unsuitable for shelters, assigned a score of zero, and thus removed when combined with phase one. The map demonstrates the areas that would be safe from hazards during the time of emergency. The layer is an outcome of merging the last five previous layers and multiplying each layer by its corresponding weight.

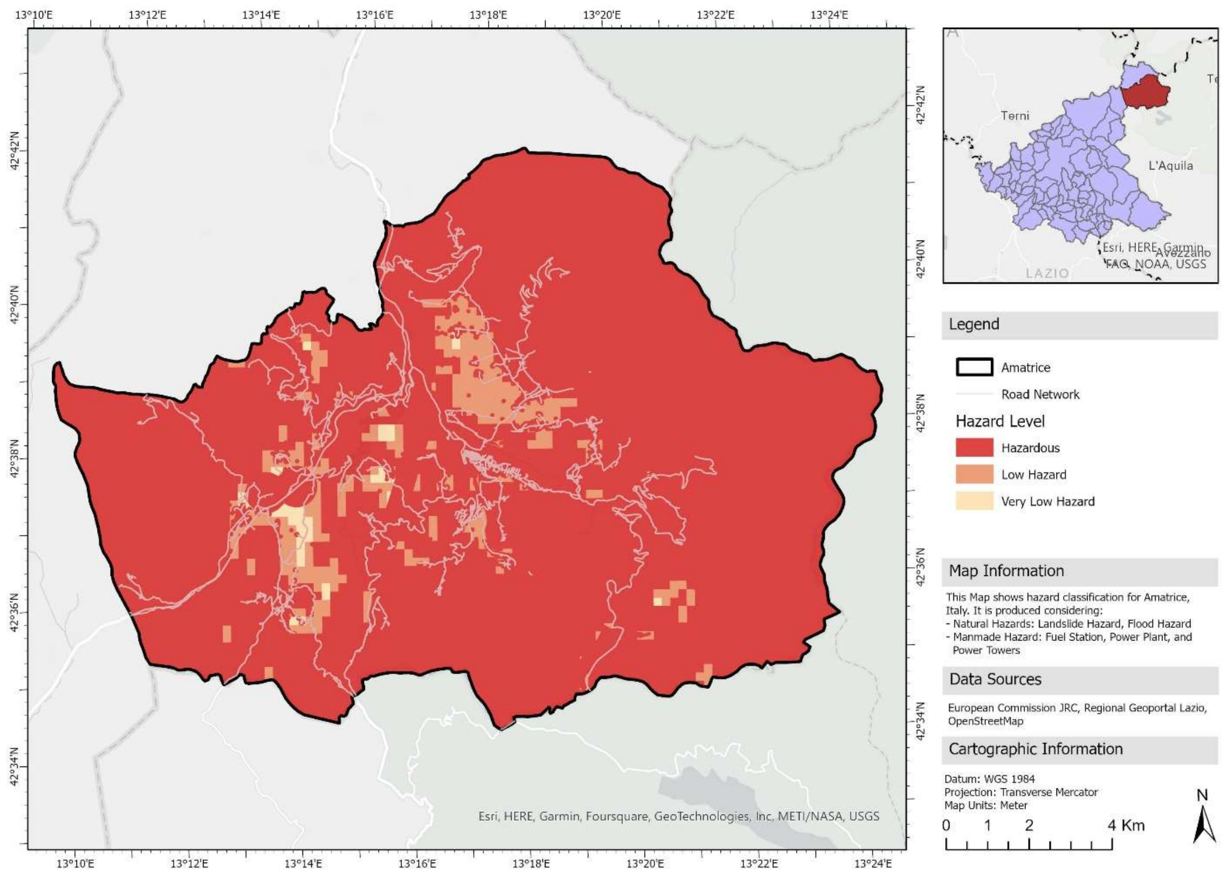


Figure 10. Phase 2 Outcome Map

2.2.6. Phase One and Two Outcome

Upon reaching this phase, the map produced would show the shelter's area locations that are suitable according to geological characteristics and hazard classification of the whole area. The outcome of hazard classification phase will be used in such that the hazardous areas will be excluded, while low and very low hazard areas will be taken in consideration and their scores to be multiplied with phase one results. This layer will be further processed in phase three to rank these areas in terms of the essential needs for medical assistance, accessibility, safety, and distance to the population areas.

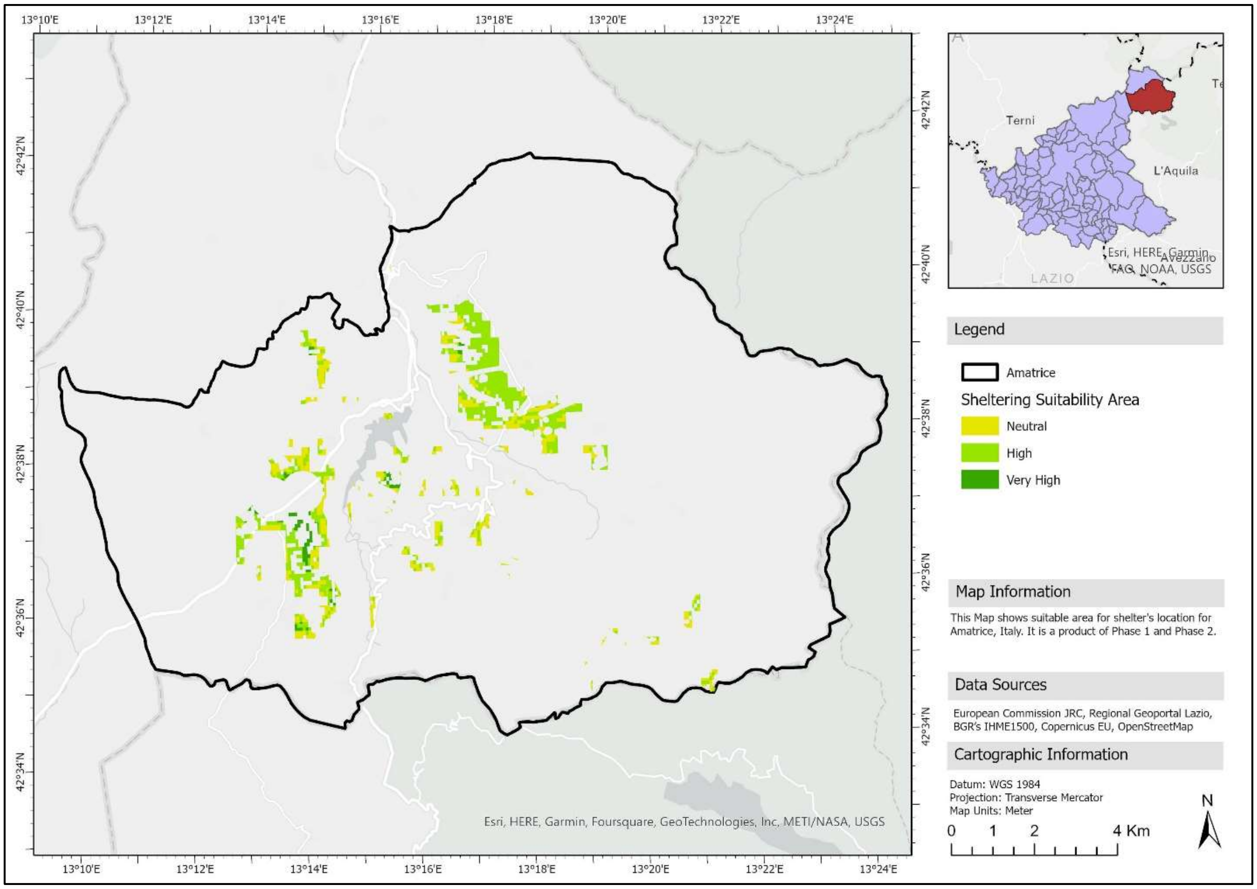


Figure 11. Phase One and Two Outcome Map

2.3. Phase Three: Ranking the Areas based on the Serviceability and Lifelines

As explained before, during the first two phases the approach was to eliminate unsuitable areas due to the geological characteristics of the land, and its susceptibility to different hazards by assigning (multiplying) weights to them accordingly. Consequently, at the end of second phase, the areas of the land which are suitable for sheltering purposes remains, irrespective of their accessibility to services and lifelines.

In the third phase of this case study, and in order to take into account the proximity of the suitable lands to different services and lifelines, the relative-weights from the outcome of phase one and two were multiplied by increasing factors according to their closeness to the services. The closer the area to a service the higher factor it will be multiplied to.

The considered factors are the proximity to: roads, medical services, water sources, police stations and population density zones.

2.3.1. Ranking the Areas based on Accessibility

The accessibility has been assessed based on the distance to the roads from the suitable areas developed in the outcome of phase 1 & 2. Buffering zones with different distances around the road network were analysed. The areas overlapping these zones were assigned different weights (Table 9). Moreover, the suitable areas that were not accessible by the road network were excluded in this phase.

Table 9. Accessibility Assessment Weights

Road Buffering zones (m)	Interpretation	Weight
$D > 500$	Less Favourable	1,23
$300 < D < 500$	Neutral	1,47
$50 < D < 300$	Favourable	1,70
$D < 50$	Right of the road	0

2.3.2. Ranking the Areas based on Proximity to Medical Services

Medical service access is a very important aspect to consider when locating a shelter. In the city of Amatrice, we have 2 medical services centres. Buffering circles around these two areas have been made and the suitable areas from the previous phase outcome is being overlapped and given weights (Table 10).

Table 10. Hospitals Proximity Assessment Weights

Hospitals Buffering zones (m)	Interpretation	Weight
$D > 2000$	Less Favourable	1,15
$1000 < D < 2000$	Neutral	1,30
$500 < D < 1000$	Favourable	1,45
$D < 500$	More Favourable	1,60

2.3.3. Ranking the Areas based on Proximity to Water Sources

Water resources expressed in the available river and water streams can be beneficial for the evacuees in order to find a sustainable water source, especially during the early phases of constructing the emergency shelter. Nonetheless, the assigned factor was given the lowest weight compared to the other factors, as shown in the table (Table 11).

Table 11. Water Resources Proximity Desirability Assigned Weights

Water Buffering Circles(m)	Interpretation	Desirability Weight
D > 600	Less Favourable	1,08
300 < D < 600	Neutral	1,17
50 < D < 300	Favourable	1,25
D < 50	Water Body	0

2.3.4. Ranking the Areas based on Proximity to Police Stations

Placing shelters close to police stations would provide a level of security to the places placed around them. Buffering circles with different radii have been performed and each class has been given a weight to it (Table 12).

Table 12. Police Station Proximity Desirability Assigned Weights

Police Station Buffering Circles(m)	Interpretation	Desirability Weight
D > 2000	Less Favourable	1,13
1000 < D < 2000	Neutral	1,25
500 < D < 1000	Favourable	1,38
D < 500	More Favourable	1,50

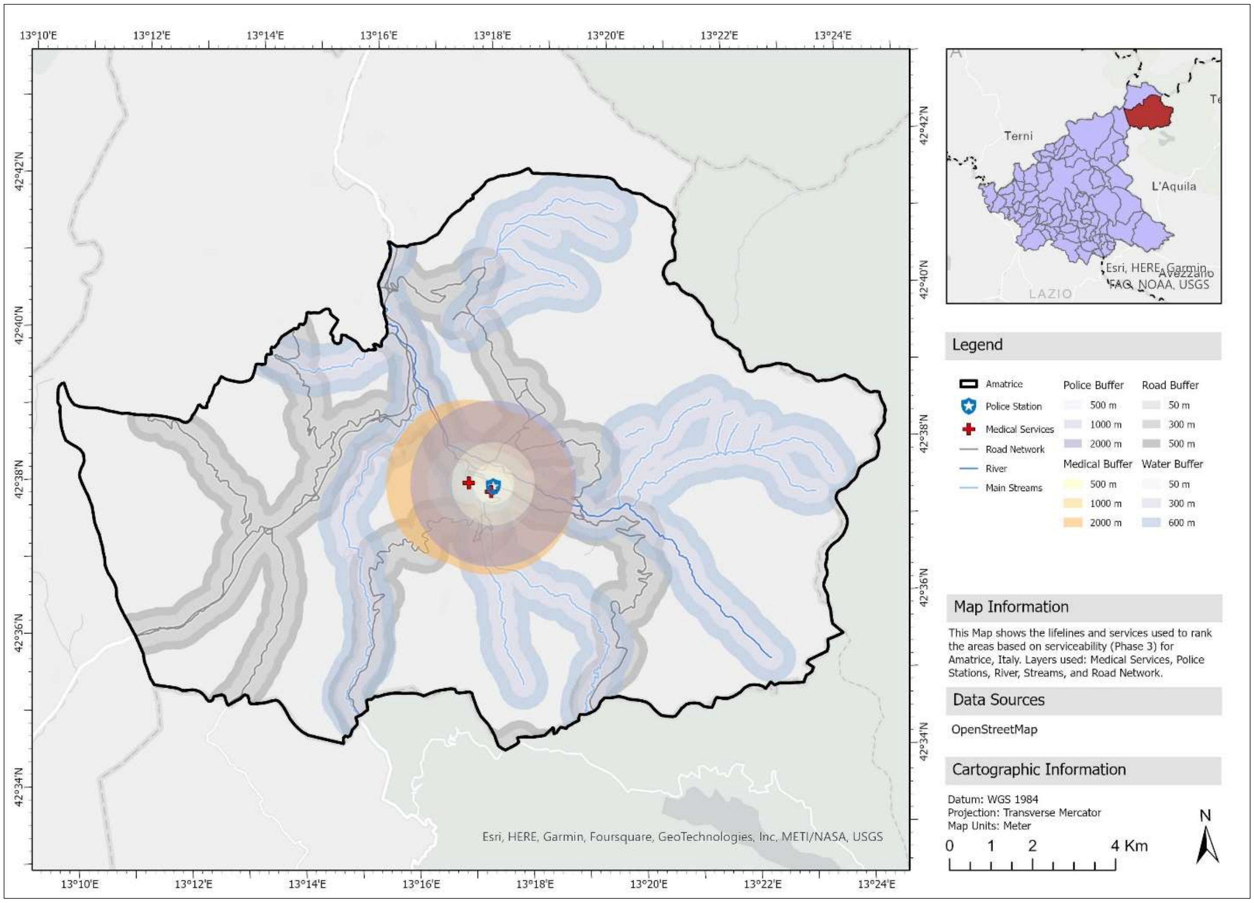


Figure 12. Phase 3 Buffering Map

2.3.5. Ranking the Areas based on Proximity to Population Densities

The suitable areas have been overlapped over the population areas. The areas have been classified based on the population density number corresponding to the overlapped suitable areas, after removing the areas that overlap with actual residential buildings (Table 13).

Table 13. Proximity Population Densities Assigned Weights

Population Densities' Zones	Interpretation	Desirability Weight
number of People < 20	Less suitable	1
21< number of People < 50	Neutral	1.23
number of People > 51	Suitable	1.35

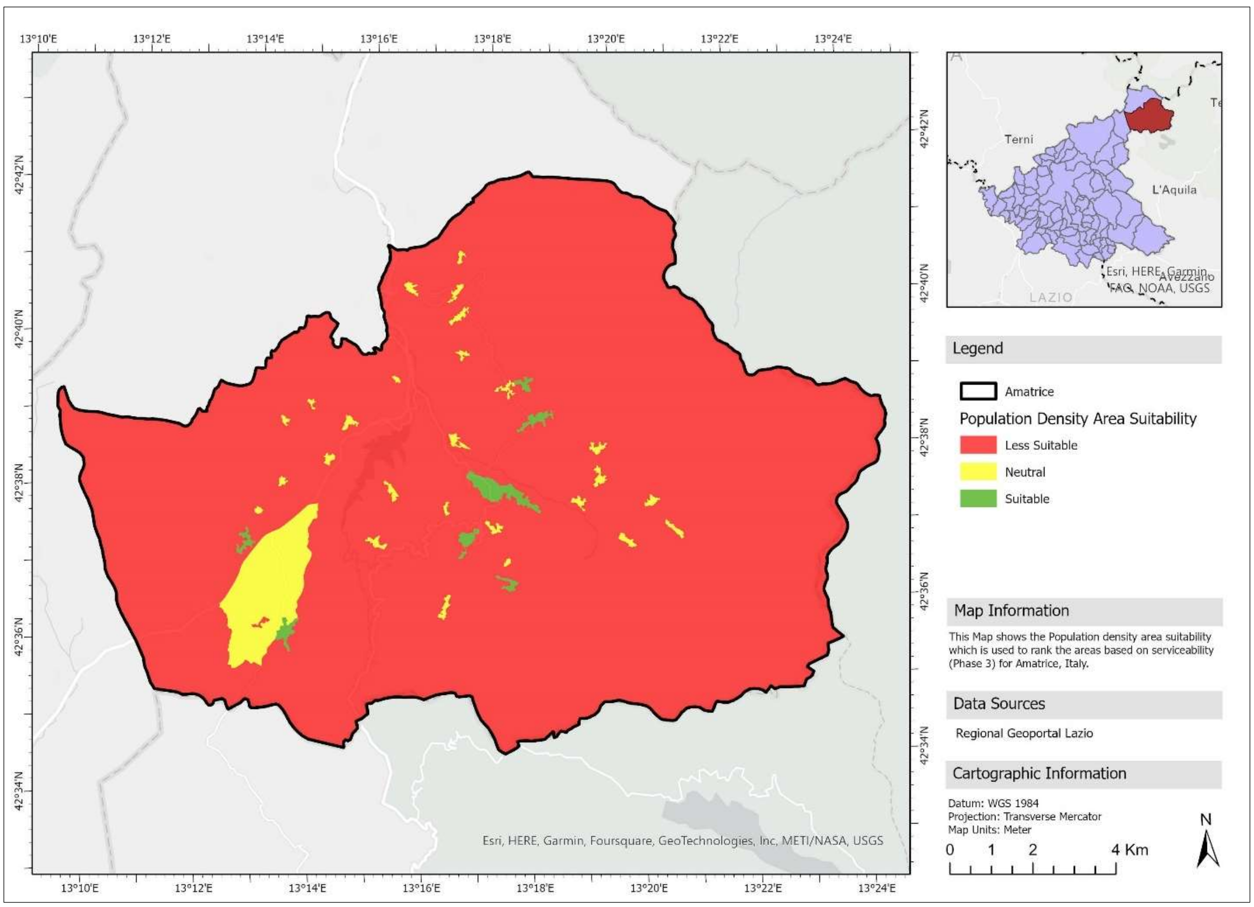


Figure 13. Phase 3 Population Density Map

2.3.6. Phase Three Outcome

Following the process of assigning the increasing factors to different services and lifelines in the third phase, the ranked areas based on serviceability map was obtained as shown in (Figure 14.. Classified Suitable Areas based on needs).

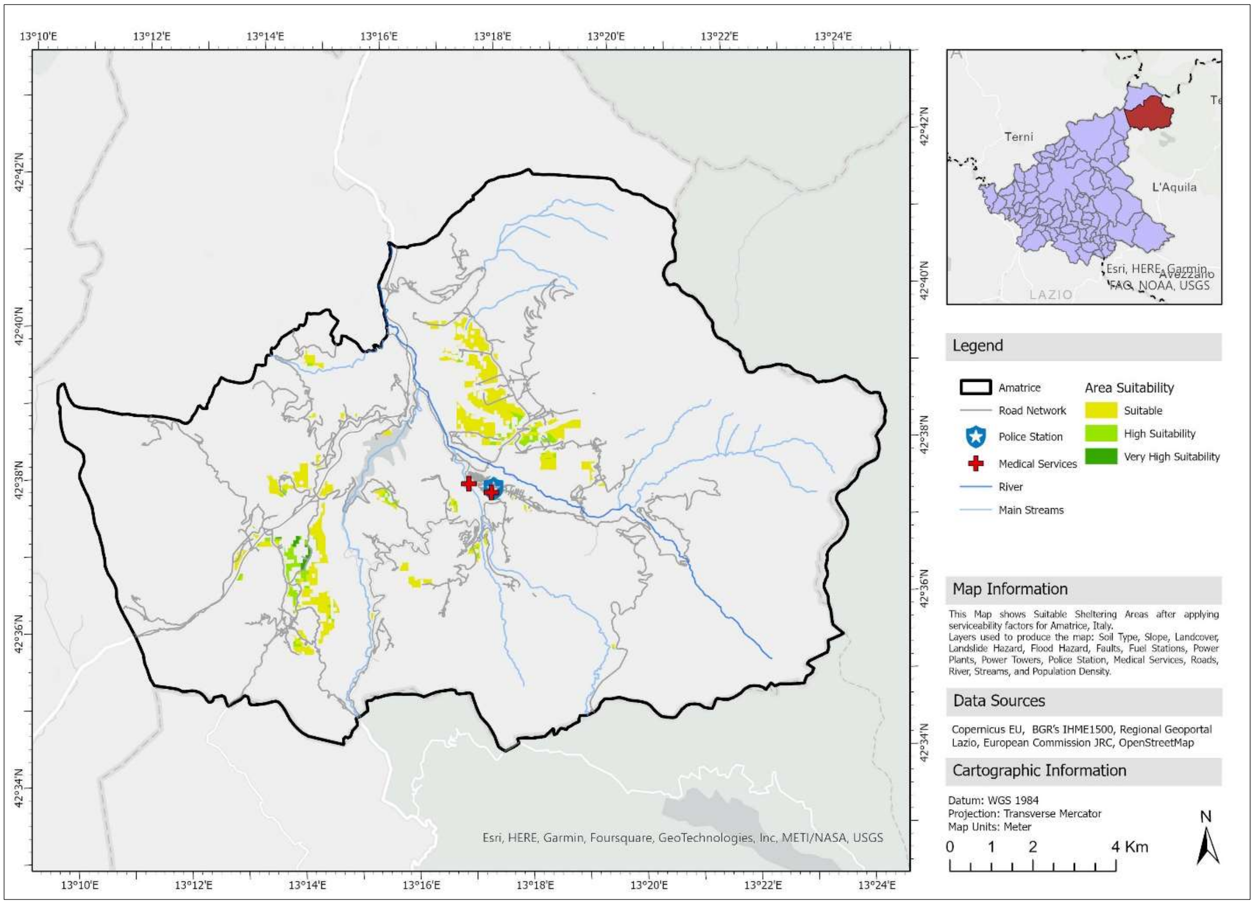


Figure 14.. Classified Suitable Areas based on needs

2.4. Phase Four: Final outcomes

The main objective of this case study is to support locational choices of shelters, which was achieved in the first three phases. At the end of the third phase, a map of Amatrice region was obtained from which the unsuitable parts of the land were eliminated, and the suitable parts were classified into different ranks according to the proximity to different services. In the Fourth phase, we took one further step to support the decision makers with selecting the most suitable location in case of the need to build up more than one shelter in Amatrice. At this step, we have produced three different maps as listed below:

- ***Map #1****: Suitable shelter areas classified according to proximity to the services and lifelines:*
  This map is the final outcome of the three phases which were explained meticulously in the previous parts. It can be served to give a general idea of the possible lands among which the decision makers can choose to locate the emergency shelters.

- ***Map #2****: Categorization of the shelters based on different needs:*
  The content of this map is similar to the previous one. Nevertheless, it only shows the shelter areas that lies within a serviceability limit of different services as kind of categorizations for the needs that might emerge during the emergency. This categorization will support the decision makers to decide upon those needs.

- ***Map #3****: First responders suggested shelter areas:*
  One of the needs that will emerge in occurrence of severe earthquakes is the need of the Emergency Responders for sheltering Emergency Responders are the people coming from neighbouring cities with large trucks and loaders to help the Search and Rescue operations. Those people need to be close to the population zones.

2.4.1. Categorized Suitable Areas based on different demographic needs

This layer displays a categorization of the suitable areas according to their proximity to medical services, police station, and high populated areas. In which those factors were taken in consideration to present areas with high medical service priority and areas with better suitability for families and elderly to be close to residential areas with high population density.

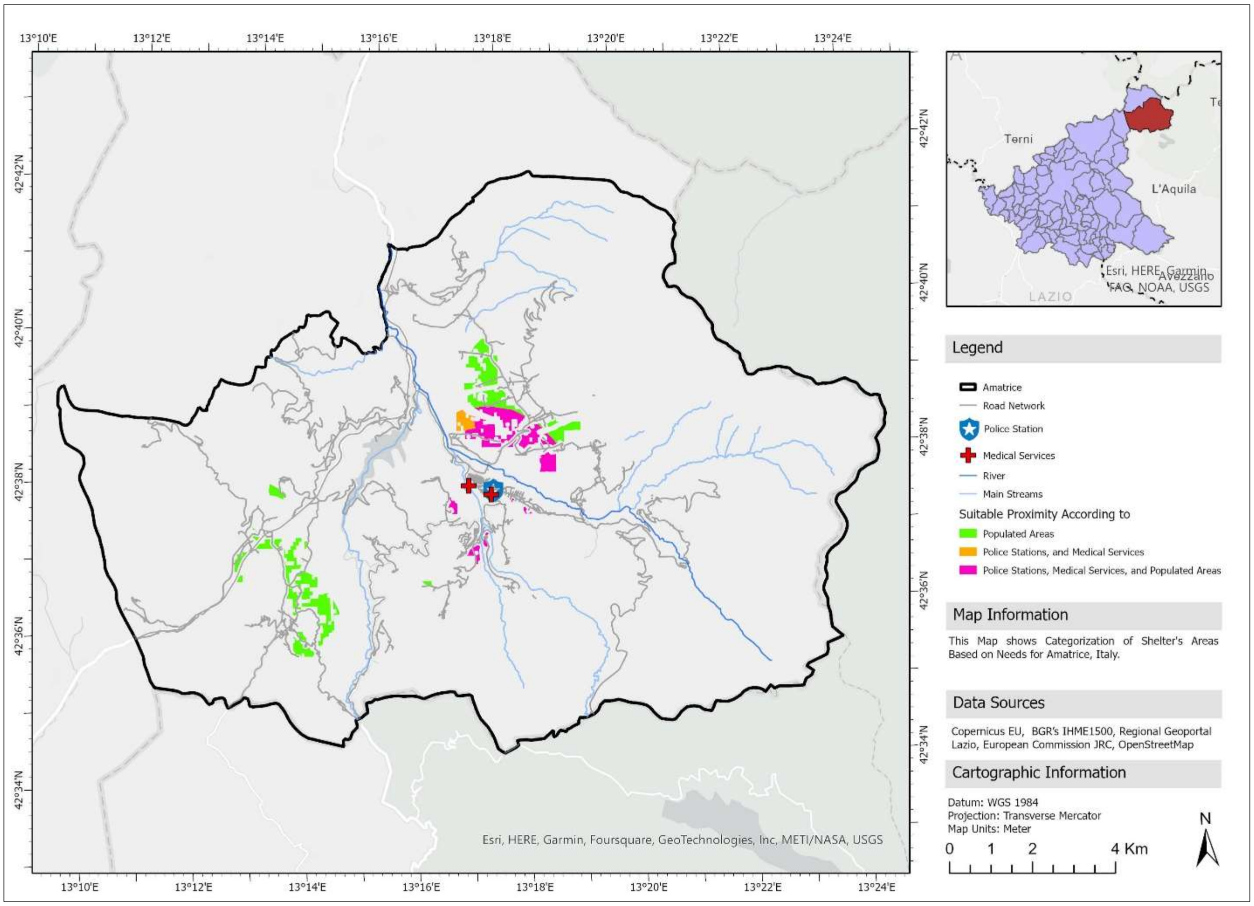


Figure 15. Classified Suitable Areas based on needs

2.4.2. First Responders Suggested shelter areas:

In this layer, we highlighted the suitable areas from phase 3 that lie around the city centre and close to the essential service needs. The Search and Rescue teams would be operating all over the city. Accommodating them in an area with good accessibility will immensely increase the efficiency of their work.

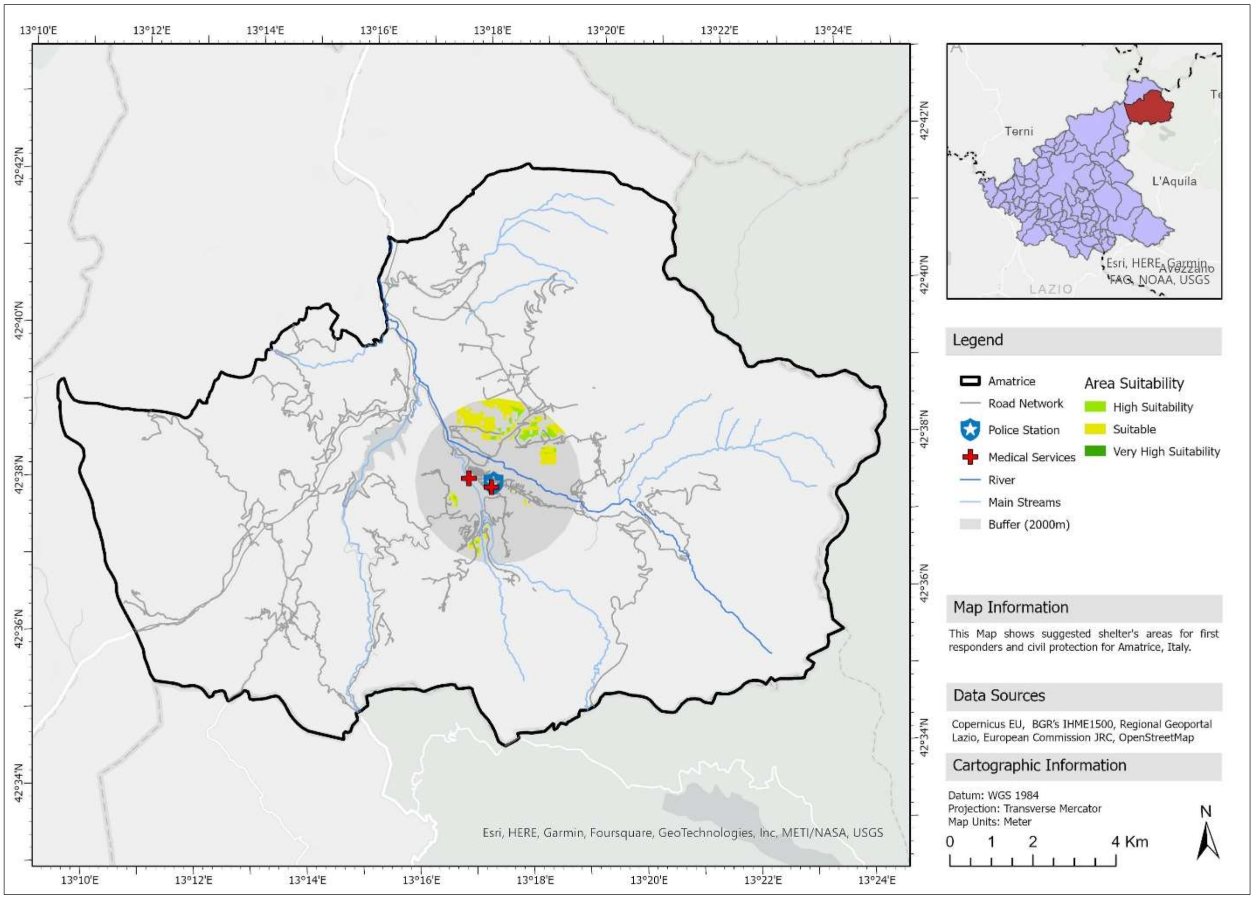


Figure 16. Classified Suitable Areas for Emergency Responders

2.4.3. Real-time Road Network Status:

The Real-time Road network status would be a great benefit to the authorities. Monitoring the conditions of the road during the event (Emergency Phase) would help them to assess the accessibility of the suggested suitable sheltering areas in real-time, and to disregard the areas with limited accessibility due to a damage. Moreover, it will help them to provide alternative shelter locations to avoid bottle-neck traffic. Upon obtaining this map, it will be possible to update it on the WebGIS platforms during the emergency as discussed in the following section.

3. WebGIS design:

To make our work easily accessible to end users, we have decided to publish the final maps online. This enables decision makers to conveniently utilize these maps when determining the optimal locations for placing shelters in the aftermath of the events. Using WebGIS tools offers several advantages over traditional printed maps which are discussed as following:

Dynamic and Interactive: WebGIS allows for dynamic exploration of spatial data, offering interactive features such as zooming, panning, and layer toggling. This enhances the decision-making process by enabling users to analyze different data layers and explore various scenarios.

- *Real-Time Access: WebGIS provides up-to-date information by incorporating real-time data updates. Decision makers can access the most current and relevant information, ensuring that their decisions are based on the latest data available.*

By leveraging these advantages, WebGIS tools provide a more efficient, accurate, and accessible means of utilizing spatial data for decision making. To present our final products on a WebGIS platform, we explored two options: ArcGIS Online and GeoNode. These platforms were introduced to us during the lectures, and each offers its own set of advantages and disadvantages, which are discussed in detail below.

3.1. ArcGIS Online

ArcGIS Online is a powerful cloud-based platform that offers a user-friendly interface, making it accessible to users with various levels of technical expertise. It provides a wide range of ready-to-use templates and configurable tools, allowing for the creation of interactive web maps, applications, and dashboards with ease. The platform excels in data integration and analysis capabilities, enabling seamless incorporation of geospatial data and performing complex spatial analysis task. However, it's important to consider that ArcGIS Online is a proprietary software that requires licensing, which. Additionally, while the platform offers extensive functionality, customization options may be limited compared to open-source alternatives.

3.1.1. ArcGIS Online: Instant App

On ArcGIS online portal, the user can access the web application designed for the support in locating the suitable sheltering upon an earthquake emergency in Amatrice. The application can be accessed on a shared group between the developer and the stakeholders, including all the metadata and item information.

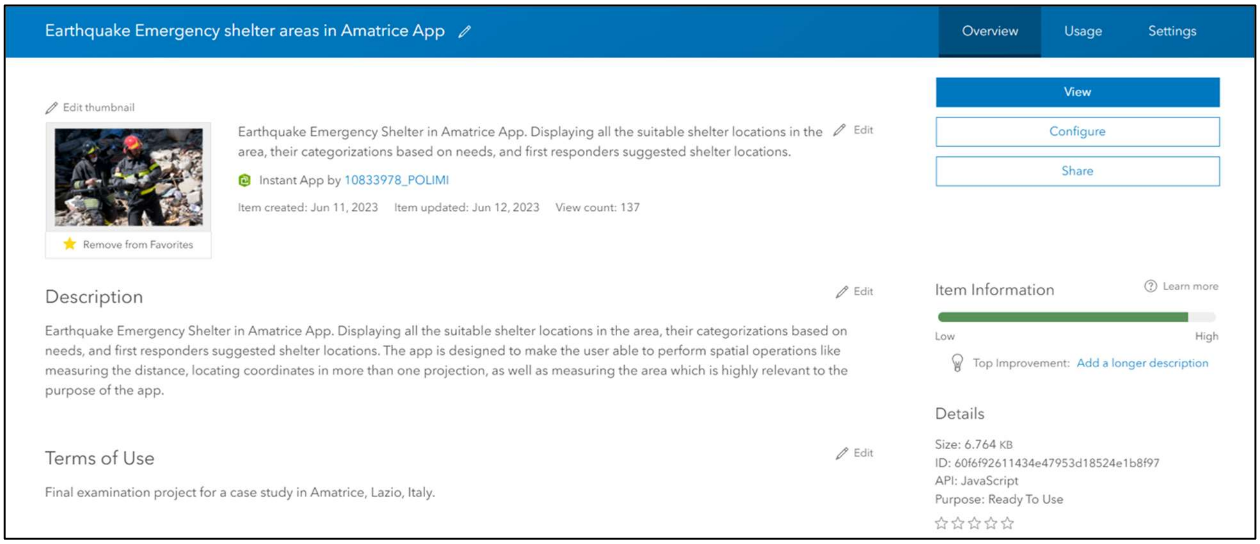


Figure 17. ArcGIS Online Instant Map Welcome

3.1.2. Interface and maps

By starting the application, an introduction panel will appear to guide the users on how to use the application as shown in the figure below

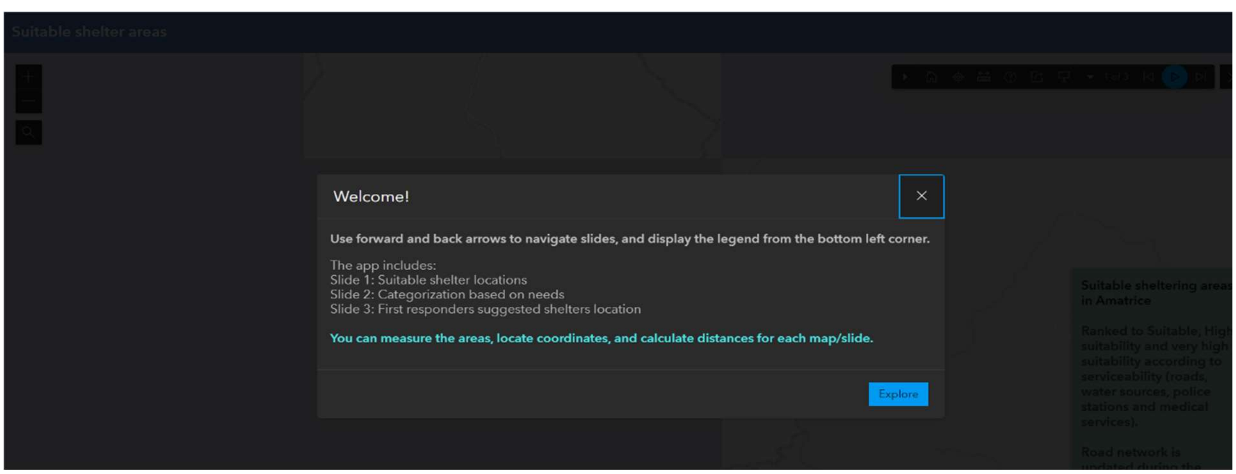


Figure 18. ArcGIS Online Instant Map Welcome Page

The application includes the following maps: Suitable shelter areas, Categorization of shelter areas based on needs, and First responders suggested shelters' location, along with a text panel describing the map information as shown in figures (19), (20), and (21).

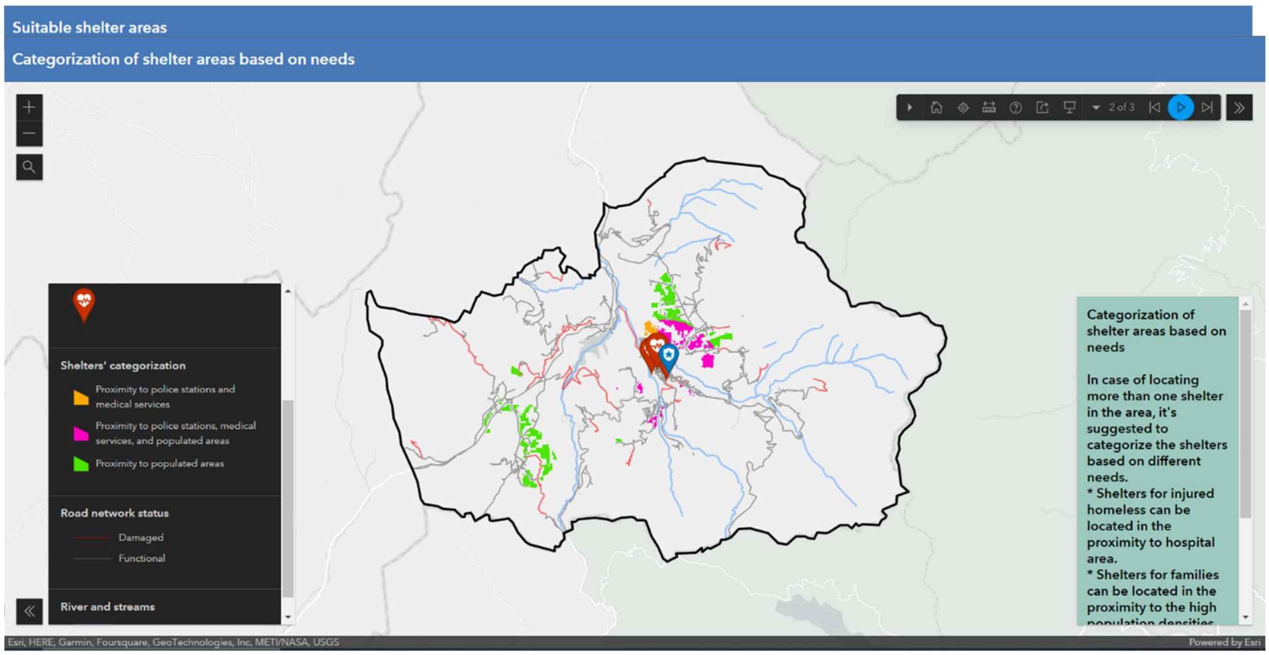


Figure 19. ArcGIS Online Instant Map: Map #1

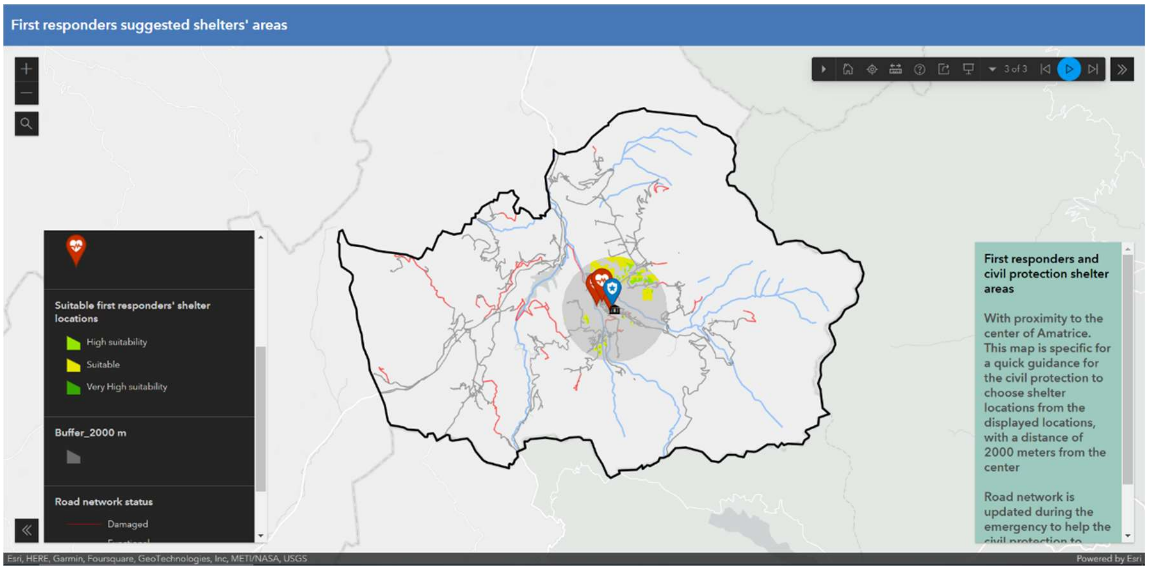


Figure 20. ArcGIS Online Instant Map: Map #3

3.1.2.2. Application functions and features

With interactive tools, the users can exploit several functions relevant to the requirements by using the control panel on the top right corner.

3.1.2.2.1. Measuring the area

Upon choosing a suitable shelter area using the provided information on each map, the chosen area can be measured as shown in the figure below.

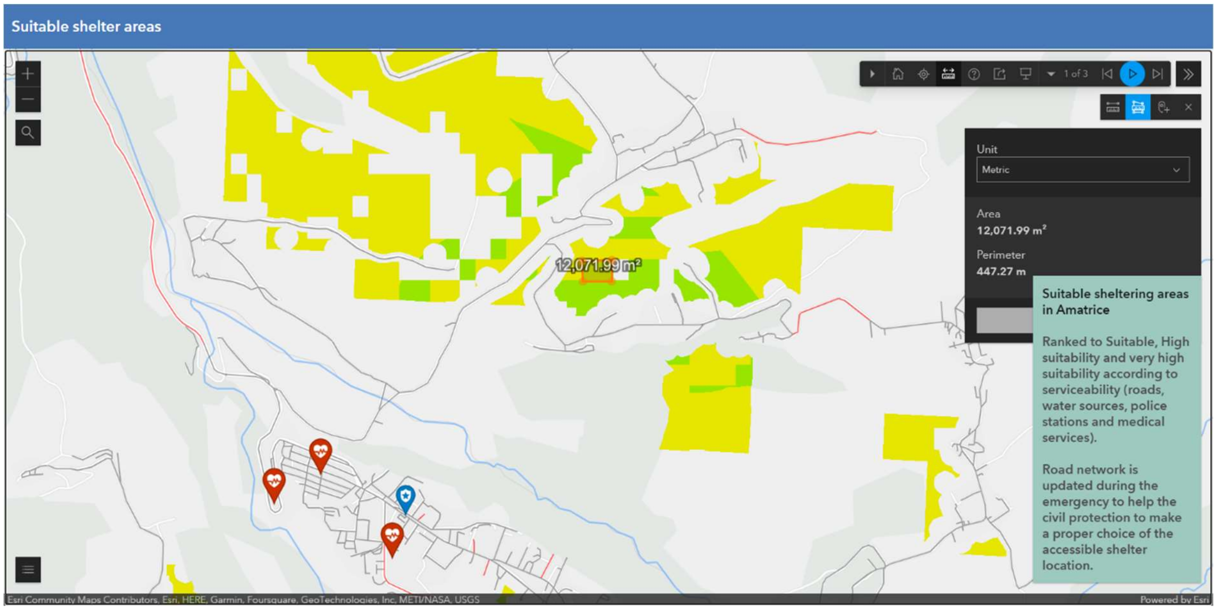


Figure 21. ArcGIS Online Instant Map: Distance Measuring Tool

3.1.2.2.2. Measuring distances

This function is useful to locate the distance of the chosen area for logistical and security reasons. It's also possible to determine the road distance by following the real-time road network displayed on the map.

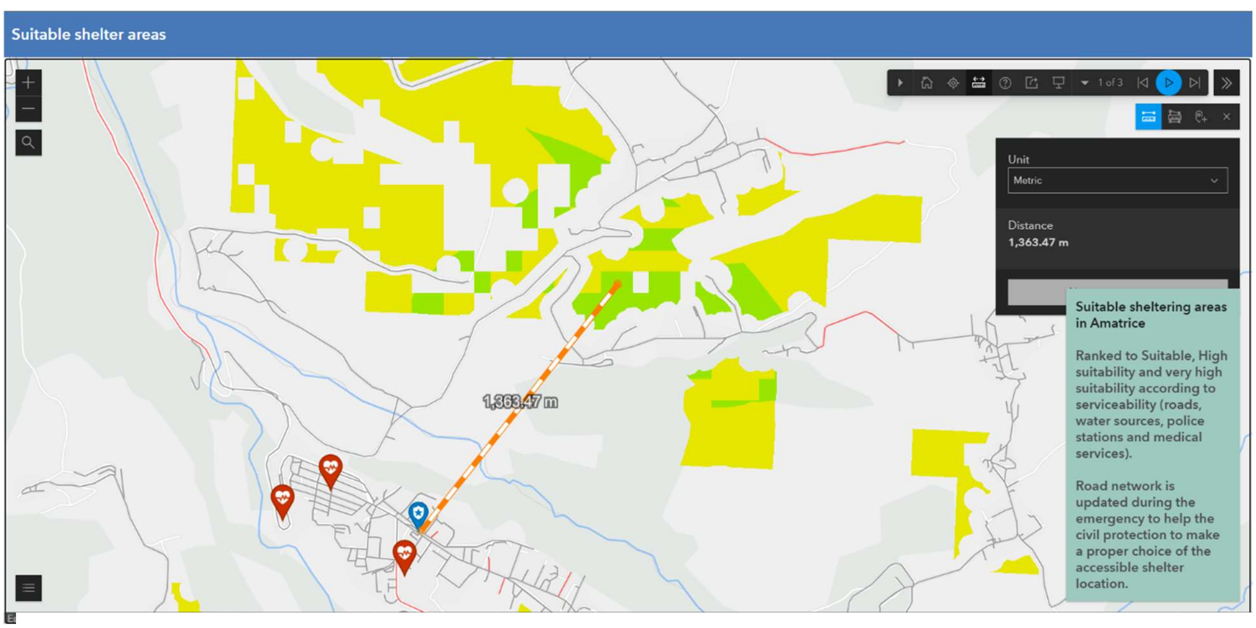


Figure 22. ArcGIS Online Instant Map: Distance Measuring Tool

3.1.2.2.3. Locating the coordinates

In addition to the possibility of locating the user on the map. It also is possible to locate any point on the map by moving the cursor on the screen, using the available projections in the figure below. This feature is highly important as it facilitates the coordination between different teams on the field, especially during a severe earthquake, where most of the landmarks are damage.

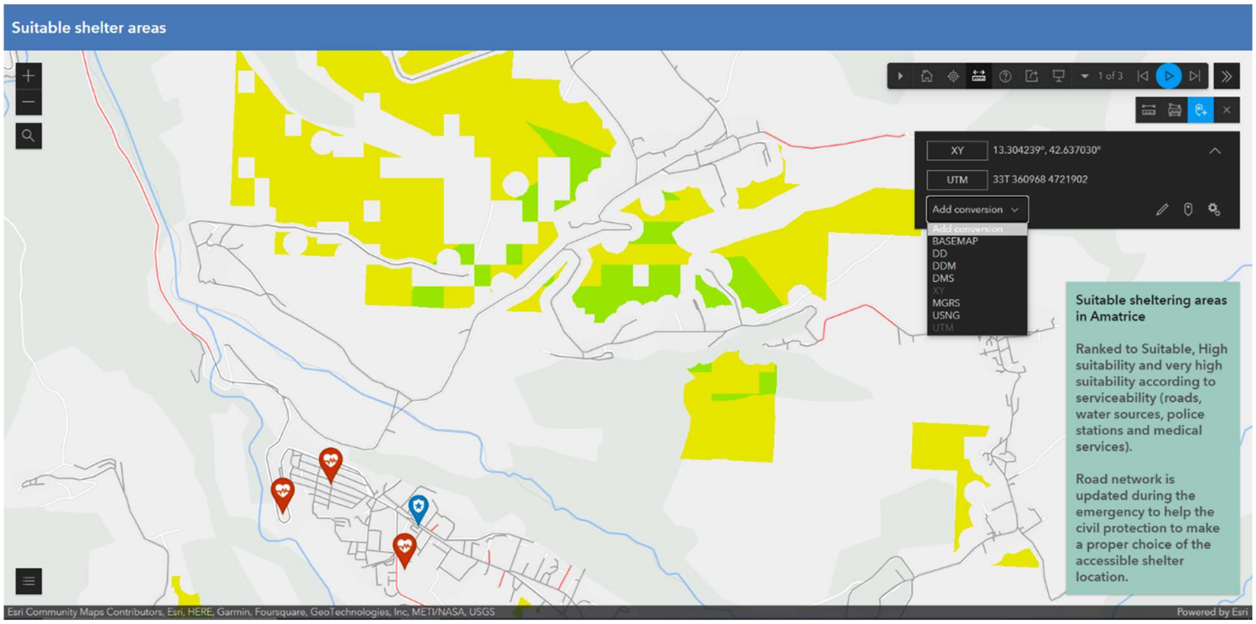


Figure 23. ArcGIS Online Instant Map: Locating and Coordinating Tool

Furthermore, for a better user experience and to guarantee the consistency between the different displayed maps, the information of the suitable shelter areas map is available on the rest of the maps by selecting any of the polygons in the second and third map.

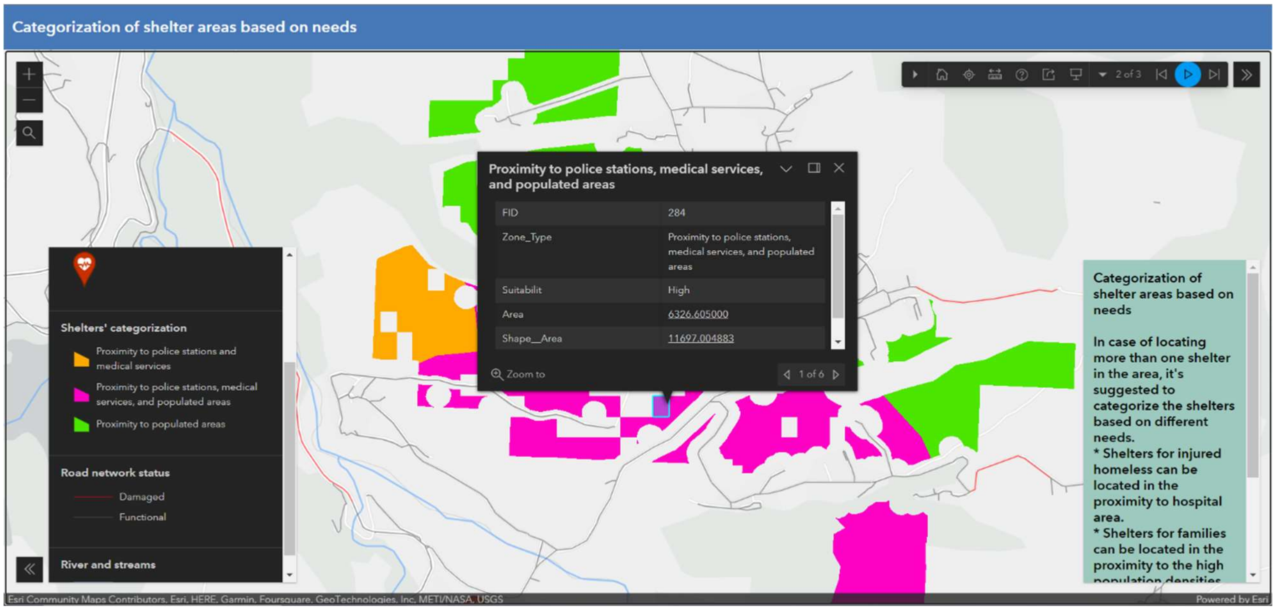


Figure 24. ArcGIS Online Instant Map: General Information of Polygons.

3.1.3. ArcGIS Online: Dashboard

In this dashboard, we introduce a pie chart that categorizes the shelter locations into "suitable," "high suitable," and "very high suitable" areas. When you click on each category, the corresponding areas are highlighted on the main map. Additionally, we include a key performance indicator (KPI) that displays the exact area in square meters when you select "suitable," "high suitable," or "very high suitable" on the pie chart. Furthermore, we incorporate a smaller map on the left side of the dashboard, showing the Emergency Access Routes of Amatrice. This map is synchronized with the main map, meaning that when you zoom in or out on the Emergency Access Routes map, the main map zooms accordingly, and viceversa. Lastly, we include markers for the Police Station and Medical Services on the dashboard. When you click on either of these markers, the main map zooms in to display the exact location of the respective facility.

This feature allows users to quickly locate essential services within the area of interest and facilitates efficient emergency response. By combining these elements in the ArcGIS Online dashboard, users can

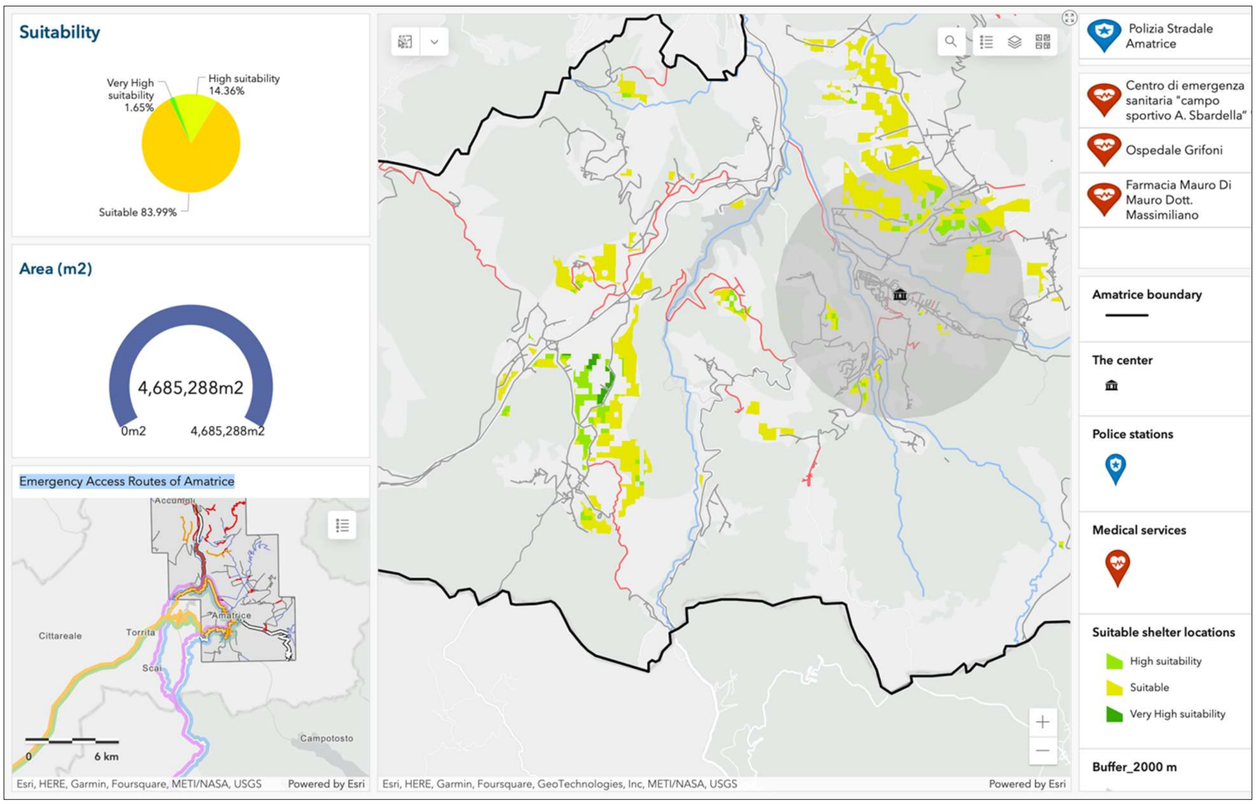


Figure 25. Figure ArcGIS Online Dashboard: Interface.

This feature allows users to quickly locate essential services within the area of interest and facilitates efficient emergency response. By combining these elements in the ArcGIS Online dashboard, users can easily identify suitable shelter locations, assess their area in square meters, visualize emergency access routes, and locate essential facilities, thus improving decision-making processes and enhancing the overall preparedness and response to seismic events in the region.

3.1.3.1. ArcGIS Online Implementation: Insight

Insights on ArcGIS Online offers numerous benefits for data analysis and visualization. Within Insights, we include the road status, categorizing it as either functional or damaged, and represent this information through a bar chart that further categorizes roads into primary, residential, secondary, pedestrian, and other types. Additionally, we incorporate a map displaying the suitability of areas for shelter, accompanied by a dot plot indicating the availability of suitable, high suitable, and very high suitable areas. Moreover, we provide another map highlighting the population distribution in Amatrice, along with a table that compares the number of available areas within each category (suitable, high suitable, and very high suitable) and the corresponding number of people that can be accommodated in those areas. The table takes into account a minimum area per person of 4.5 m2. This comprehensive approach in Insights facilitates data exploration, spatial analysis, and reporting, enabling users to gain valuable insights, make informed decisions, and effectively plan for shelter allocation and population management in Amatrice.

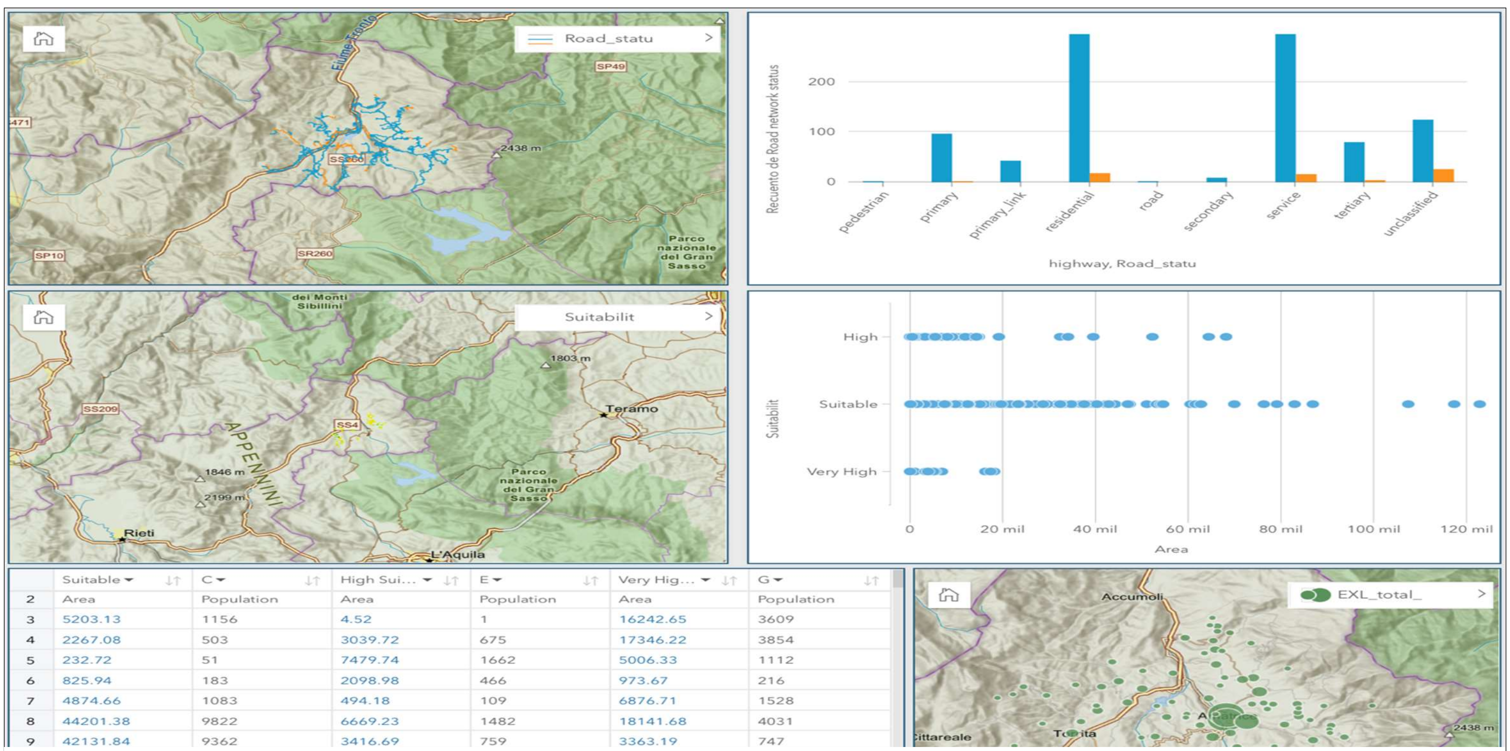


Figure 26. ArcGIS Online: Dashboard Functionalities

3.2. GeoNode:

GeoNode, an open-source platform, focuses on data sharing and collaboration, providing users with flexibility and customization options. It offers a customizable and extensible framework, allowing users to create and manage geospatial data catalogues, maps, and applications tailored to their specific needs. One of the key advantages of GeoNode is its cost-effectiveness, as it does not entail licensing costs, making it a favorable choice for projects with limited budgets. The platform emphasizes data sharing and collaboration, enabling community engagement and participation. However, it's worth noting that GeoNode may require more technical expertise for initial setup and configuration, which may present a learning curve for users less familiar with open-source platforms. While GeoNode offers extensive customization possibilities, achieving specific functionality may require additional development effort.

3.2.1. GeoNode Implementation

In GeoNode, users can easily check and download layers, maps, documents, create their own groups, and more. We will use some figures to elaborate on GeoNode. The following Figure 29 shows the overview of the whole GeoNode page, including the function area, searching box, featured datasets and some other provided information.

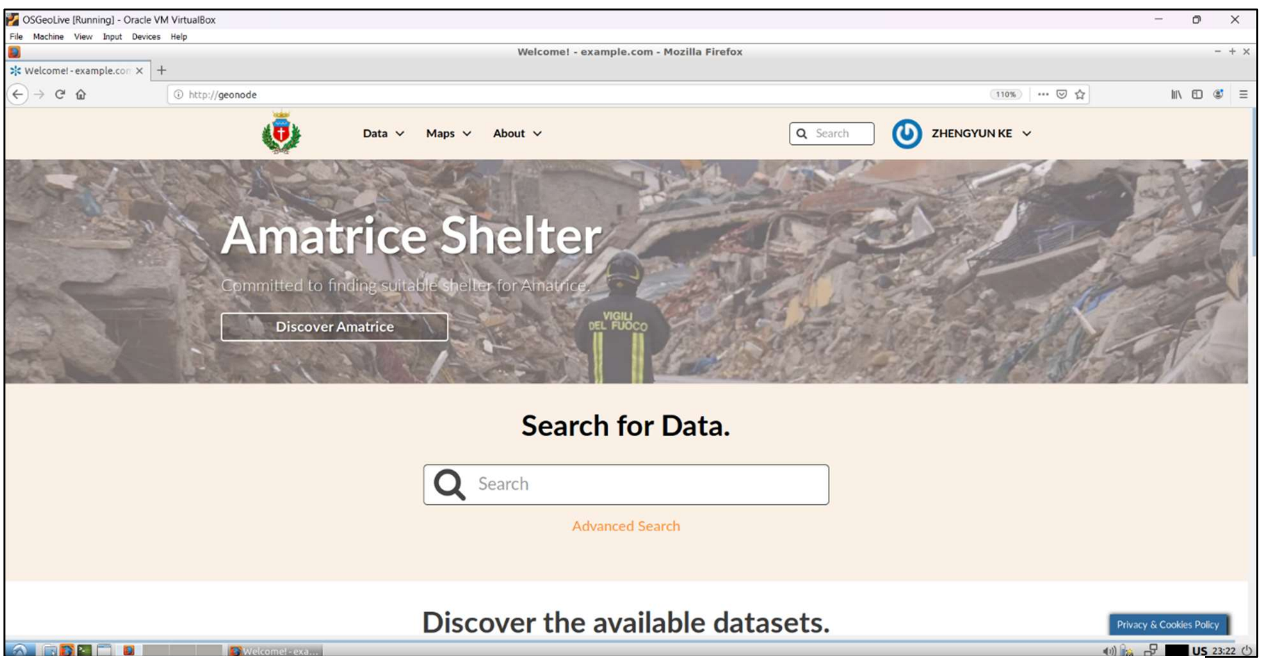


Figure 27

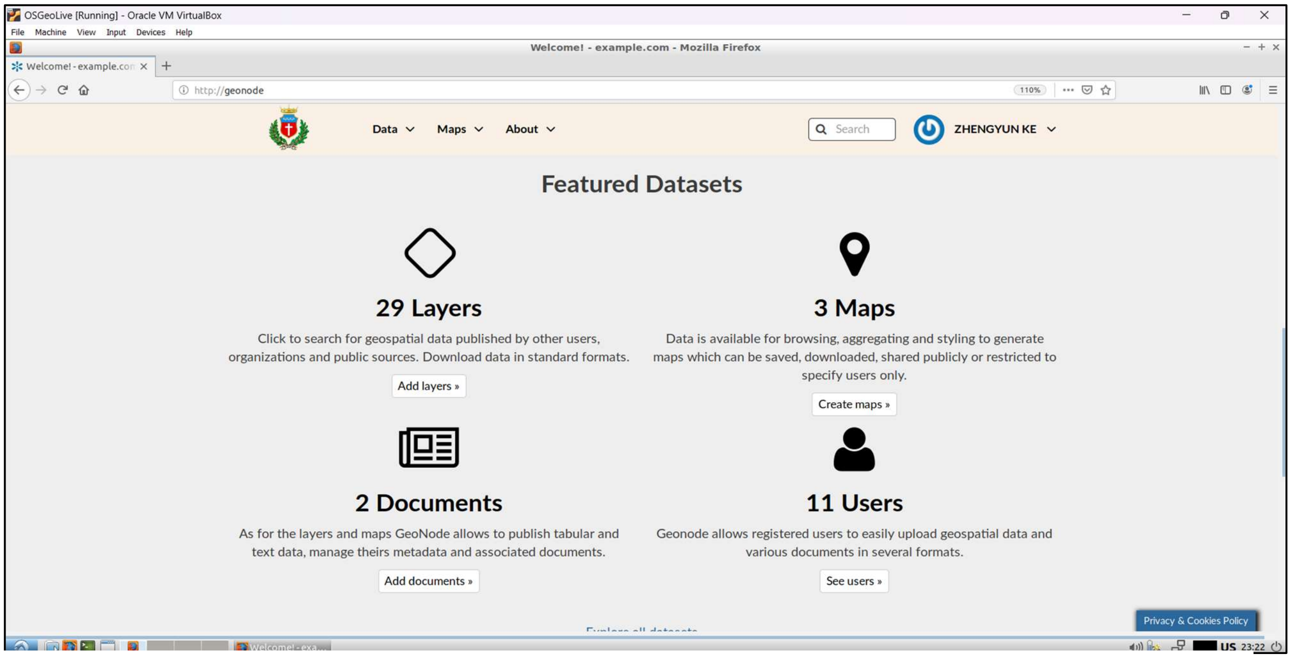


Figure 28

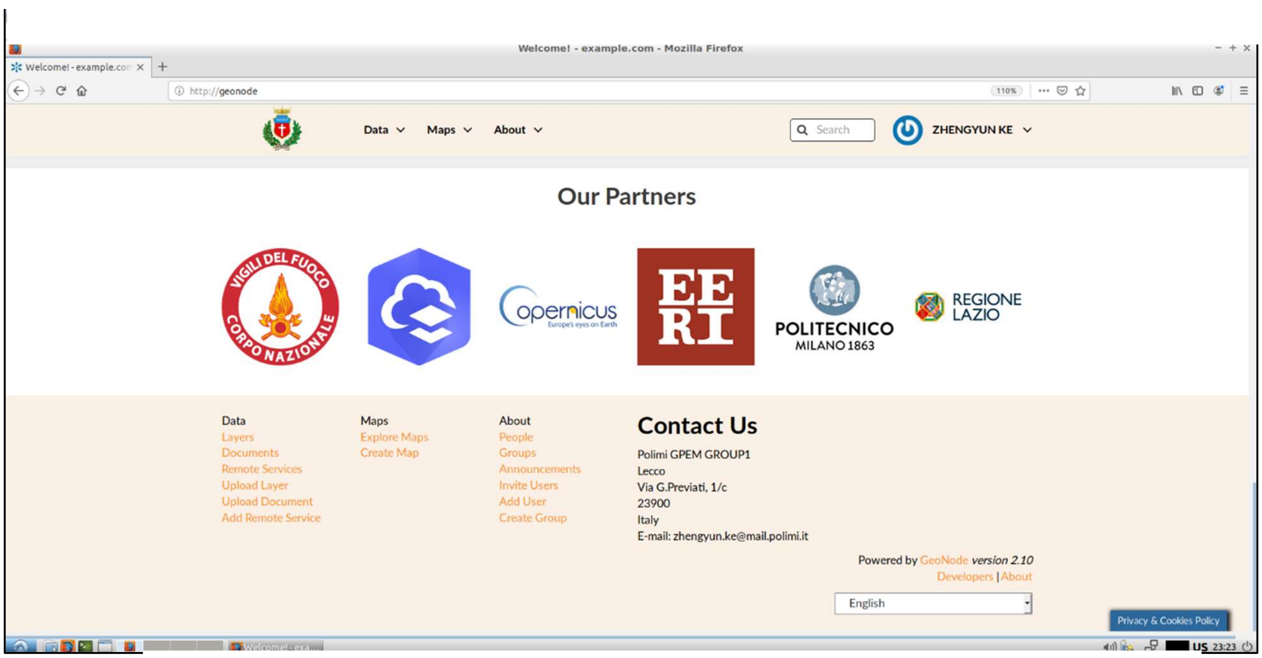


Figure 27,28 and 29: GeoNode: Website overview.

To meet the aesthetic needs of users, we modify the "Inspectors" code for the better website appearance, shown as (figure 30)

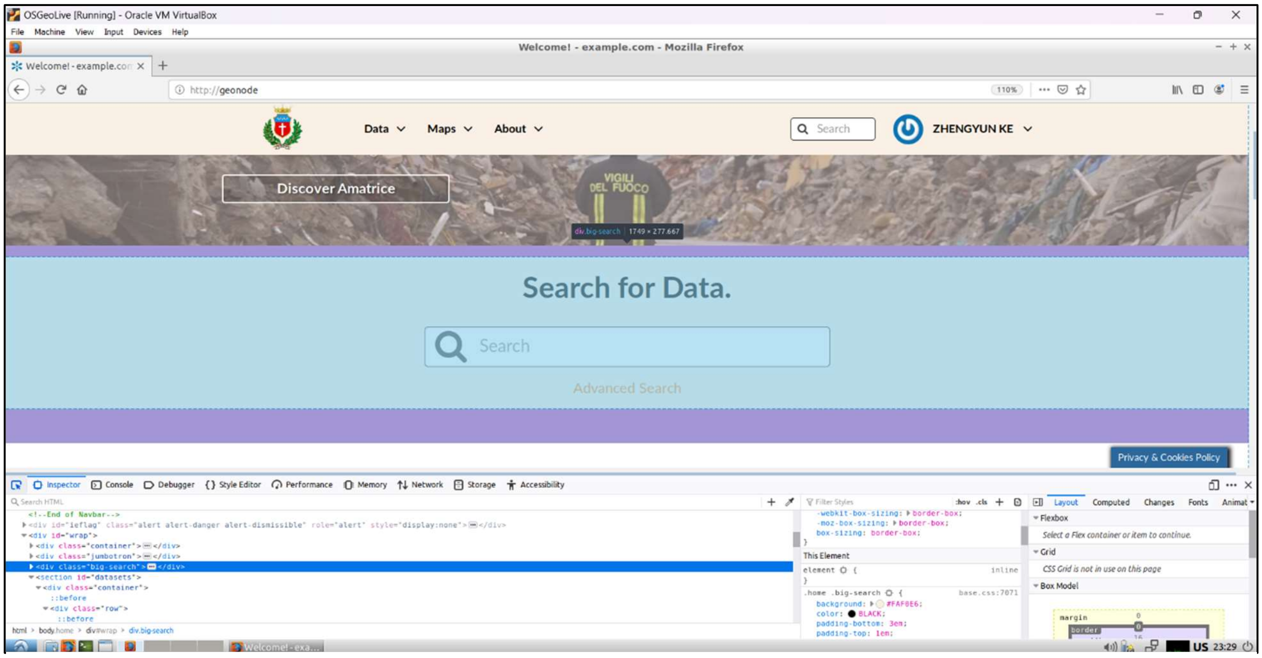


Figure 30. GeoNode: Web design through Inspector

Layers are updated and can be easily checked in the GeoNode. In total 10 layers already exist about Amatrice Shelters here, including police station position, medical services, and road network, etc. All of those layers can be download by users and modify by designers. An example demonstrated as figure 31. To make it more friendly to users, the metadata offers all necessary information about each layer and helpful guide the user to utilize layers as figure 32 depicted:

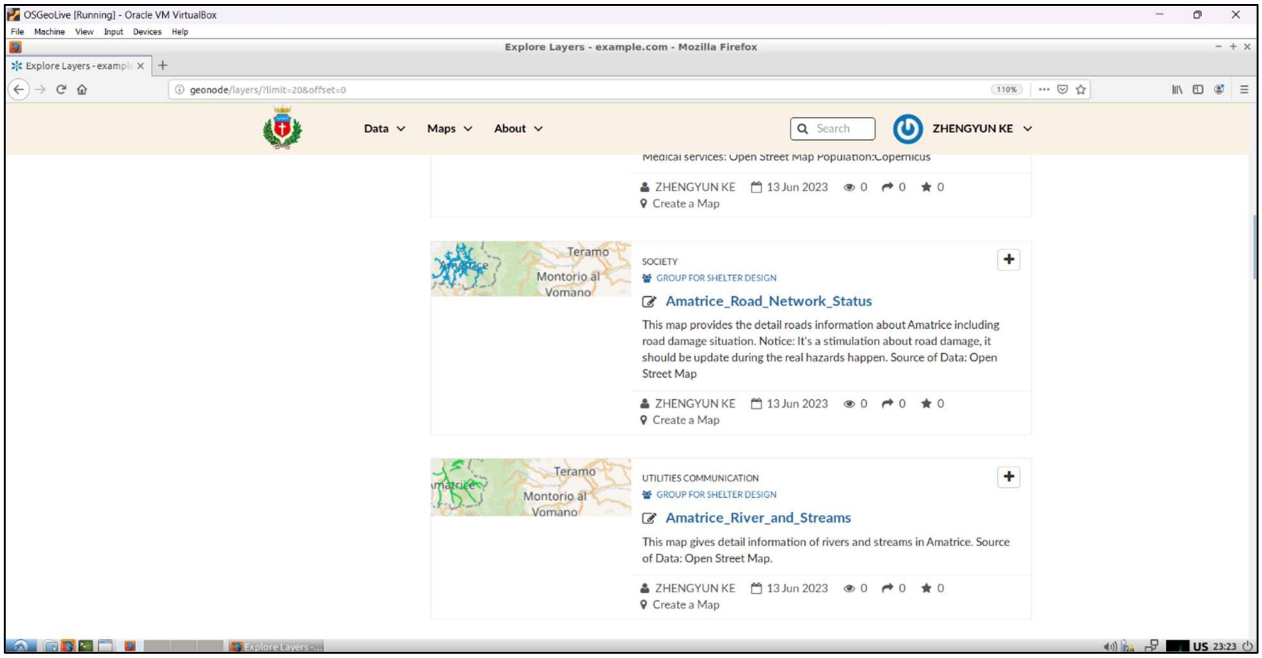


Figure 31. GeoNode: An example of updated layers

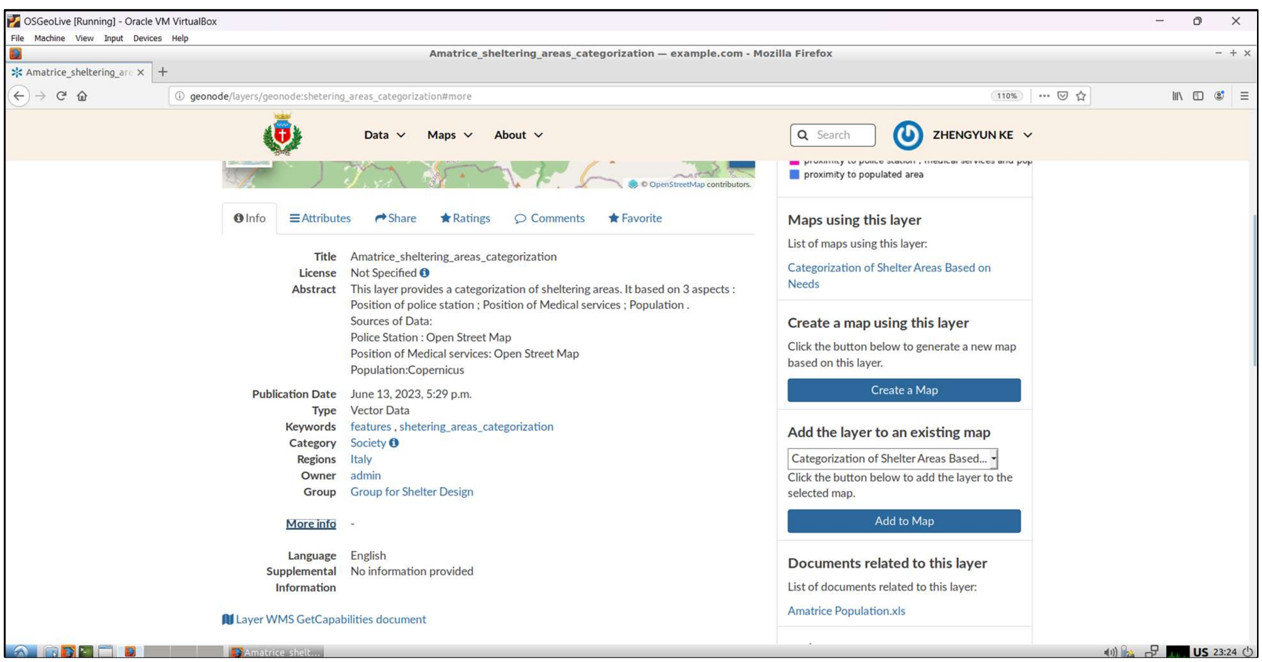


Figure 32. GeoNode: Detailed information about each layer

Using already updated layers, the map can be created and display the useful information for users. It's quite easy for delating or adding layers, adjusting the opacity of layers, changing background of layers, printing layers and so on. GeoNode gives us a chance to easily display shelter maps for users.

Three maps are available as suggested shelter areas for Amatrice, and you can check the more details of map through figure 33.

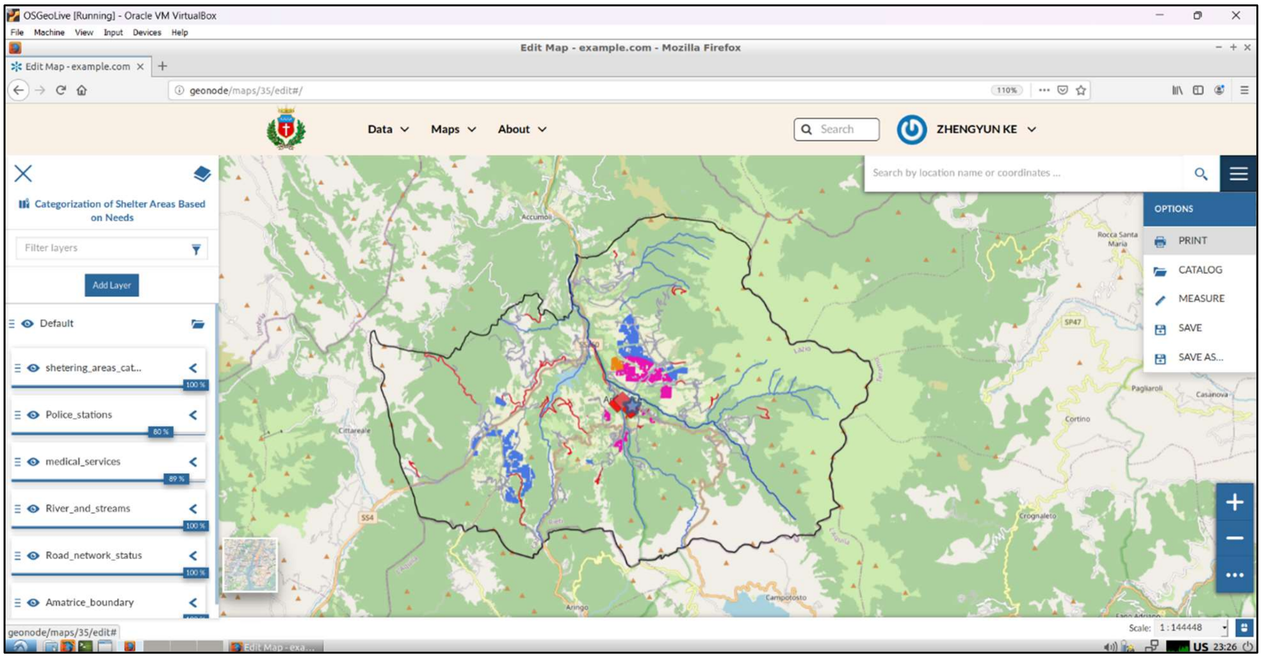


Figure 33. Categorization of Shelters Areas Based on Needs

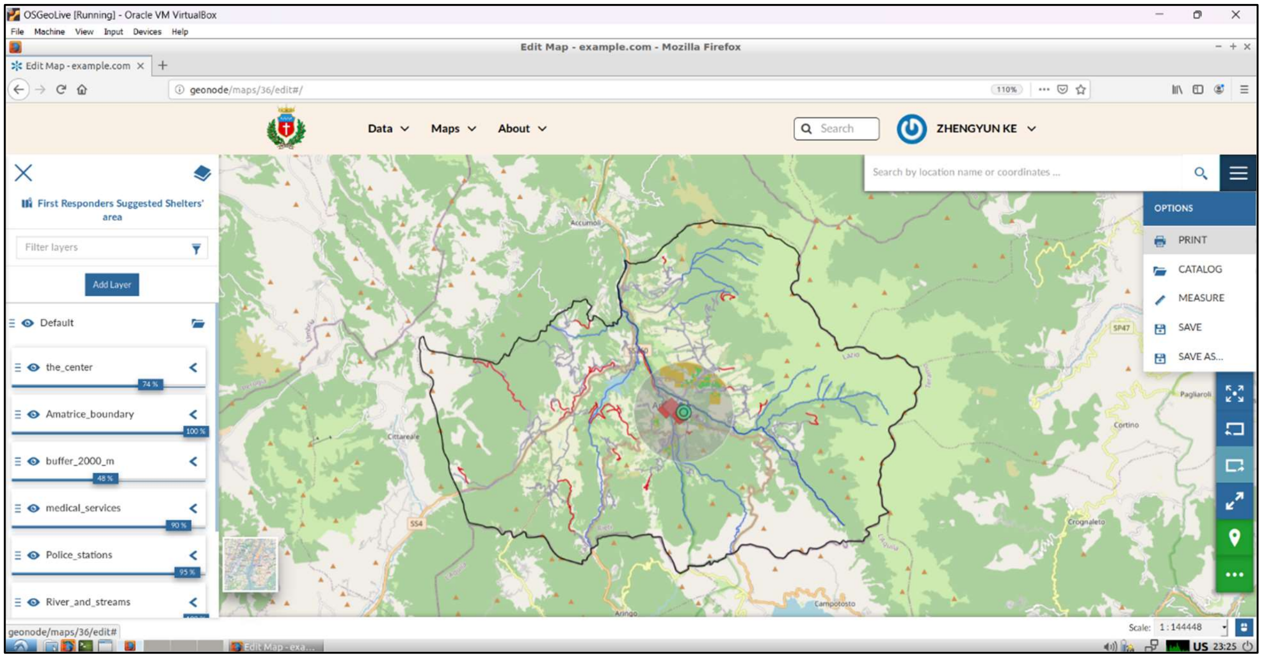


Figure 34. Map for First Responders Suggested Areas

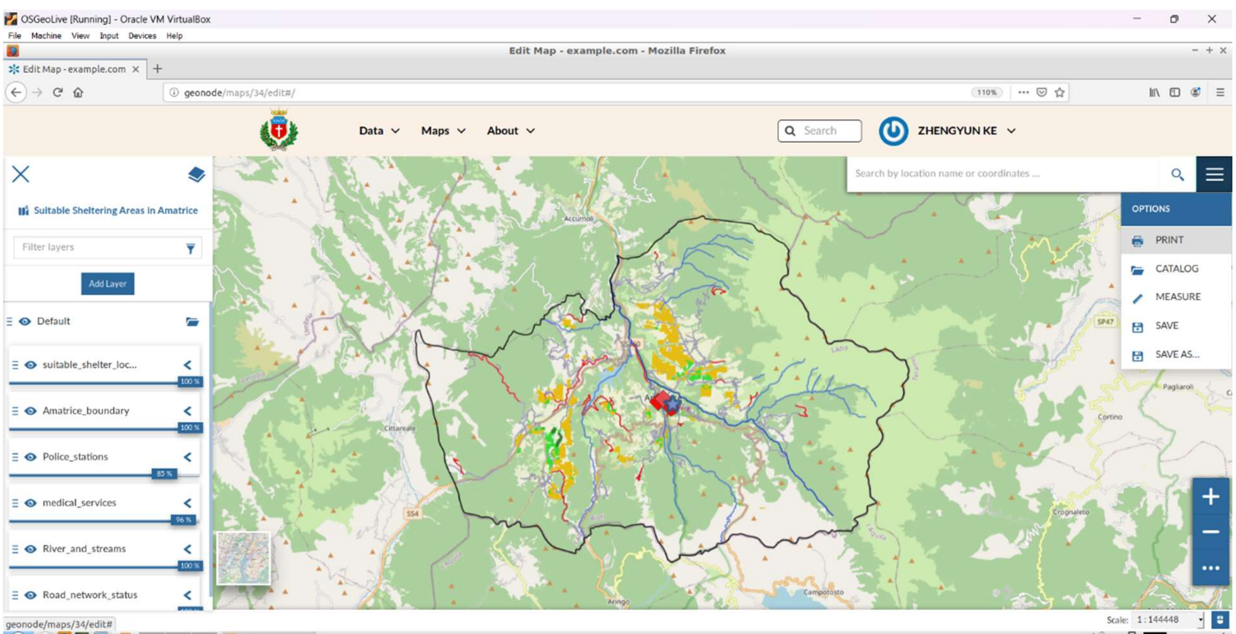


Figure 35. Suitable Areas for Sheltering in Amatrice

As a supplement, an Excel table about population has also been updated in GeoNode Documents depicted as figure 34. Similarly, the table has abstract and label. If users have more specific requirements, this will facilitate them to search for data and proceed with the next steps.

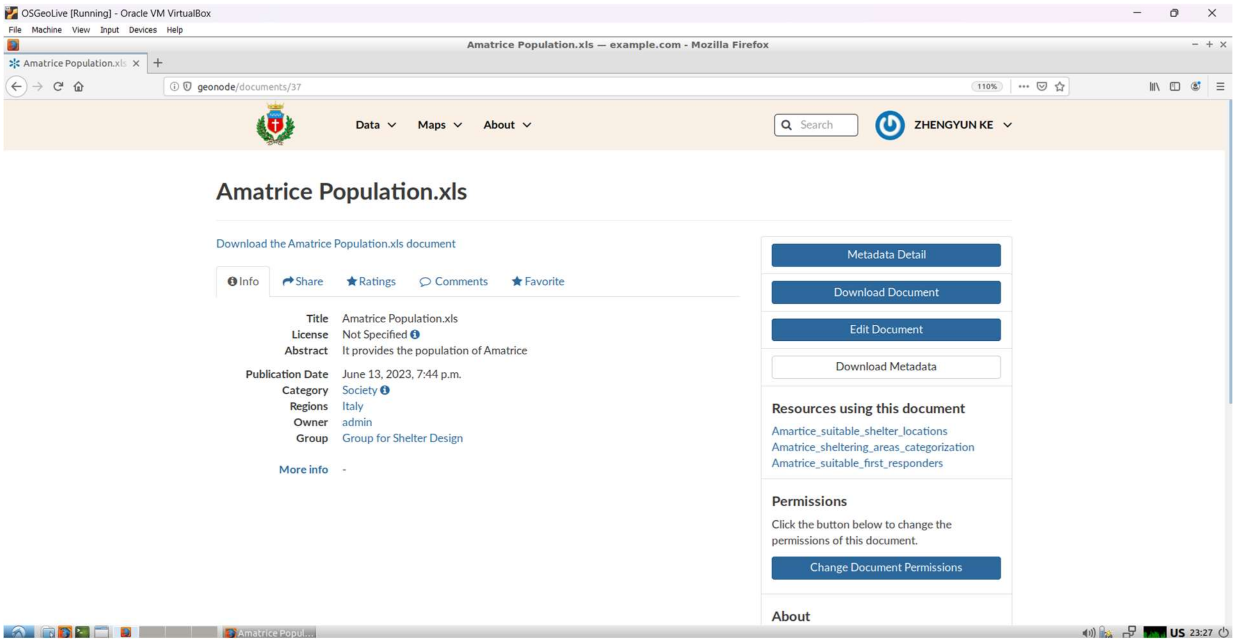


Figure 36. Example of Uploaded Document

3.2.2. Some Remarks on GeoNode

- *GeoNode is a open-source website. Its advantage is that it is more convenient to search for data, download layers, and create maps. But it relies heavily on other map processing software like Qgis and Arcgis. This makes it difficult to make some changes directly using GeoNode and operation steps are more cumbersome.*

- *Not all designs can be performed on GeoNode, even if the inspector is modified, it cannot be saved, which brings some limitations to the operation. Luckily this does not affect its core functions.*

- *It's important to keep interaction with users to know their requirements exactly and fulfil their necessities, which will bloom the efficiency of work.*

4. Google Earth Engine and Use Cases

4.1. Introduction

Google Earth Engine is a powerful cloud-based geospatial analysis platform that revolutionizes the way we process, analyze, and visualize vast amounts of satellite imagery and geospatial data. With its scalable infrastructure, extensive data catalog, and built-in analysis capabilities, Google Earth Engine offers a seamless and efficient solution for conducting some spatial analyses, monitoring environmental changes, and creating interactive visualizations on a global scale.

4.2. Inefficiencies of the normal workflow

After completing the project and presenting the results using WebGIS software, it has become evident that conducting the same task for every town in the country can be a resource-intensive and inefficient process. Several inefficiencies were encountered throughout the project, which are outlined below.

a. Scalability: Manual downloading and processing of maps and data sources hinder scalability. Replicating steps for other cities becomes time-consuming, limiting efficient project scaling.

b. Computational Cost: Processing raster layers is computationally expensive, especially for larger areas. Personal computers may lack the necessary capabilities, further limiting scalability.

c. Updatability: The Earth's surface changes, requiring updated data. GEE allows seamless integration of updated satellite imagery, enabling flexibility without redoing the entire process.

d. Compatibility: GEE performs computations on cloud-based infrastructure, reducing hardware limitations. It offers accessibility and flexibility for spatial analysis compared to traditional GIS software.

e. Licensing and Integration: ArcGIS Pro offers integration with WebGIS but requires a purchased license. QGIS is open source but lacks webmap integration, requiring additional steps. GEE combines advantages of being open source, free, and easy webmap publishing.

4.3. Limitations of the Google Earth Engine Platform

Despite the numerous benefits and advantages of the Google Earth Engine (GEE) platform discussed earlier, it is important to acknowledge that it may have some limitations in the context of our specific project. These limitations can serve as areas for future research and improvement, offering opportunities to enhance the platform's capabilities and address the following inefficiencies:

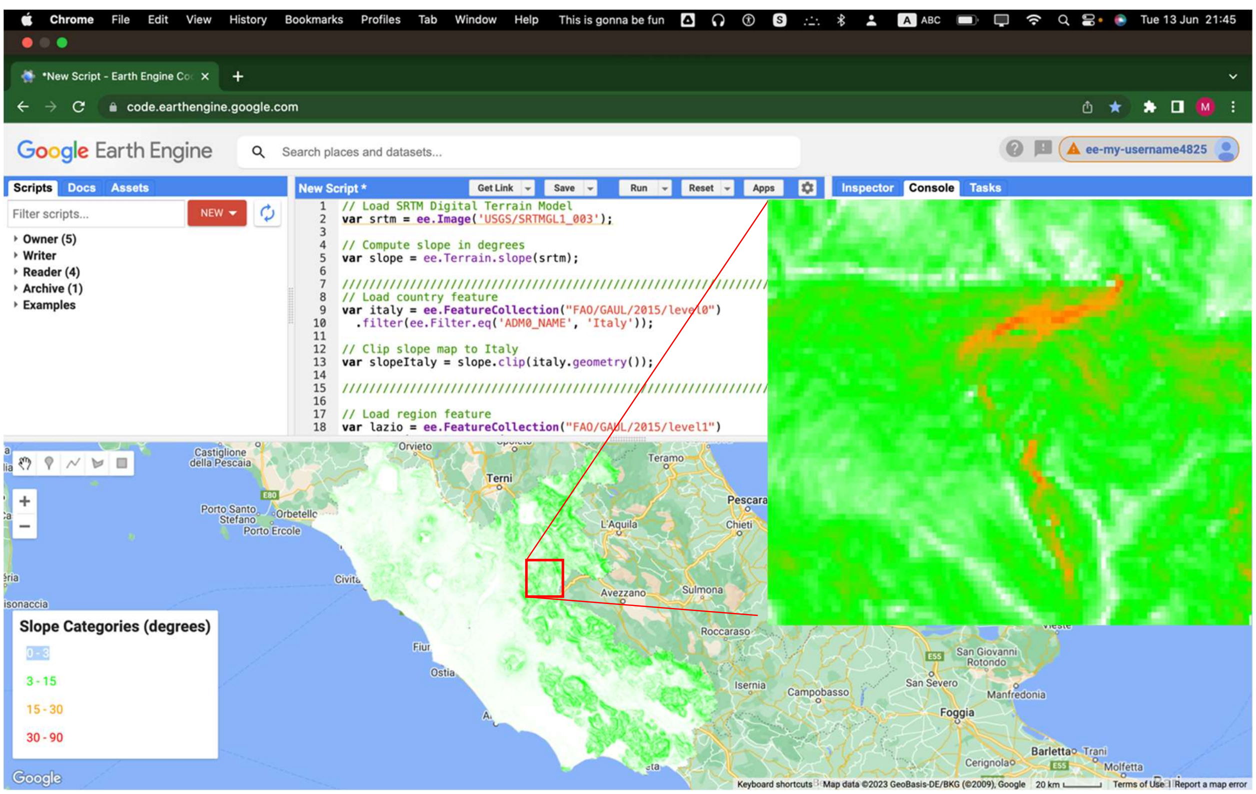
a. Connectivity and Reliability: GEE relies on stable internet connectivity, which may hinder users with limited access or connectivity issues from utilizing the platform effectively for spatial analysis tasks.

b. Learning Curve: Effective use of GEE requires users to possess coding skills in Java or Python, creating a knowledge gap for GIS operators who may not have the necessary programming expertise.

c. Advanced Spatial Analysis: While GEE offers basic spatial analysis capabilities, dedicated GIS software provides a more extensive range of tools and functions for complex spatial analyses, including geoprocessing operations, spatial statistics, network analysis, and 3D modeling.

4.4. GEE Platform Use Case

To provide a concise example highlighting the capabilities of the Google Earth Engine platform, we have created a simple map demonstrating the categorization of slopes using coding in GEE. This map showcases how GEE enables users to efficiently process and visualize geospatial data for specific analysis tasks.



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