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ΜΕΤΑΠΤΥΧΙΑΚΗ ΔΙΑΤΡΙΒΗ

ASSESSMENT OF NATURAL HAZARDS (VOLCANIC, SEISMIC, LANDSLIDE, FLOOD AND WILDLAND FIRE) IN NISYROS ISLAND AND THE USE OF MODERN CARTOGRAPHY METHODS (WEB GIS)

ΔΗΜΗΤΡΗΣ ΚΑΡΑΠΑΝΟΣ
ΓΕΩΛΟΓΟΣ ΕΚΠΑ

ΤΡΙΜΕΛΗΣ ΕΠΙΤΡΟΠΗ

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ΑΘΗΝΑ 2016

ΕΘΝΙΚΟ ΚΑΙ ΚΑΠΟΔΙΣΤΡΙΑΚΟ ΠΑΝΕΠΙΣΤΗΜΙΟ ΑΘΗΝΩΝ

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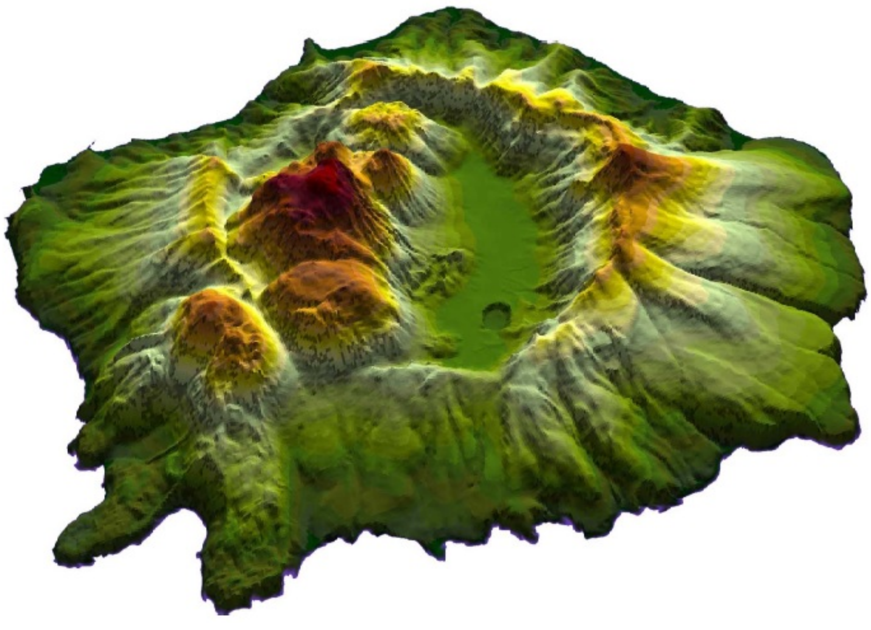

ΔΗΜΗΤΡΗΣ ΚΑΡΑΠΑΝΟΣ
ΓΕΩΛΟΓΟΣ ΕΚΠΑ

ΑΘΗΝΑ 2016

ΠΡΟΛΟΓΟΣ – ΕΥΧΑΡΙΣΤΙΕΣ

Με το πέρας της μεταπτυχιακής διατριβής, θα ήθελα αρχικά να ευχαριστήσω τον επιβλέποντα καθηγητή κο. Λέκκα Ευθύμιο για τις επιστημονικές πληροφορίες και τις εμπειρίες που μου παρείχε σχετικά με παλιές εργασίες του στη Νίσυρο, την κα. Νομικού Παρασκευή, Επίκουρη Καθηγήτρια Ε.Κ.Π.Α., για την εμπιστοσύνη της, το πλούσιο υλικό και τις πολύτιμες υποδείξεις κατά τη διάρκεια της διπλωματικής.

Θα ήθελα, επίσης, να ευχαριστήσω τον κο. Βασιλάκη Μανώλη, Επίκουρο Καθηγητή ΕΚΠΑ για την πολύτιμη βοήθειά του και τους εποικοδομητικούς διαλόγους σχετικά με το κομμάτι του Web GIS.

Επιπροσθέτως, θα ήθελα να ευχαριστήσω θερμά τη φίλη και συνάδελφο Μελάκη Μαρία για το χρόνο που μου αφιέρωσε και τις πολύ εύστοχες παρατηρήσεις της κατά τη διάρκεια μελέτης των φυσικών κινδύνων της Νισύρου.

Η παρούσα μεταπτυχιακή εργασία είχε ως αρχικό σχεδιασμό το χωρισμό της σε τρία αλληλένδετα μέρη. Το πρώτο μέρος ήταν η μελέτη και εκτίμηση των φυσικών κινδύνων της Νισύρου (ηφαιστειακός κίνδυνος, σεισμικός, κατολισθήσεις, πλημμύρες και δασικές πυρκαγιές). Το δεύτερο, η ανάρτηση των παραχθέντων χαρτών σε μια πλατφόρμα Web-GIS και το τρίτο μέρος και πιο καινοτόμο η κατασκευή μιας εφαρμογής για έξυπνα τηλέφωνα (smartphones). Τελικώς, κατασκευάστηκε web εφαρμογή η οποία είναι προσβάσιμη από οποιονδήποτε χρήστη μέσω έξυπνης συσκευής τηλεφώνου (smartphone), tablet και βέβαια ηλεκτρονικού υπολογιστή.

ΠΕΡΙΛΗΨΗ

Η Νίσυρος είναι ένα στρωματοηφαίστειο δομημένο από Τεταρτογενή ηφαιστειακούς σχηματισμούς. Τοποθετείται στο ανατολικότερο άκρο του Ελληνικού ενεργού ηφαιστειακού τόξου, έχει μια ιδιαίτερη ηφαιστειακή μορφή και παρουσιάζει γεωθερμικό ενδιαφέρον καθώς εμφανίζει ιδανικές συνθήκες για την ύπαρξη και εκμετάλλευση ενός γεωθερμικού πεδίου υψηλής ενθαλπίας.

Με την χρήση σύγχρονων λογισμικών κατασκευής και επεξεργασίας χαρτών, ερμηνείας δορυφορικών εικόνων, ανάλυση των γεωλογικών και μορφοτεκτονικών χαρακτηριστικών του ηφαιστείου της Νισύρου βάσει αποτελεσμάτων άλλων ερευνητών, έγινε προσπάθεια μελέτης των πιθανών κινδύνων που μπορεί να αντιμετωπίσει το νησί.

Λόγω των ιδιαίτερων γεωλογικών, τεκτονικών και μορφολογικών χαρακτηριστικών είναι δυνατόν να εκδηλωθούν οι παρακάτω κίνδυνοι:

- Ηφαιστειακός κίνδυνος.
- Σεισμικός κίνδυνος λόγω τεκτονικών κινήσεων στην ευρύτερη περιοχή της Νισύρου.
- Κατολισθήσεις που μπορεί να σχετίζονται με σεισμούς, μαγματισμό και ηφαιστειακή δραστηριότητα.
- Δασικές πυρκαγιές.
- Πλημμυρικά φαινόμενα.
- Ακραία καιρικά φαινόμενα όπως ο καύσωνας και καταιγίδες.

Επιχειρήθηκε στην παρούσα εργασία η ανάδειξη και προβολή της τεχνολογίας Web-GIS. Η εξέλιξη της τεχνολογίας Web-based GIS και η αρχιτεκτονική client-server έχουν διαδραματίσει σημαντικό ρόλο στο διαμοιρασμό των δεδομένων. Η ανάπτυξη και επέκταση του Διαδικτύου παρέχουν δύο βασικές ικανότητες που μπορούν να βοηθήσουν σημαντικά τους γεωεπιστήμονες. Πρώτον, το Web-GIS επιτρέπει την οπτική αλληλεπίδραση χρήστη-δεδομένων και δεύτερον, λόγω της σχεδόν πανταχού παρούσας φύσης του Διαδικτύου, τα γεωχωρικά δεδομένα μπορεί να είναι ευρέως προσβάσιμα.

Λέξεις - Κλειδιά: Νίσυρος, φυσικοί κίνδυνοι, Web GIS

ABSTRACT

Nisyros is a stratovolcano structured by Quaternary volcanic formations. Placed at the eastern edge of the Hellenic active volcanic arc, it has a special form of volcanic and geothermal characteristics interesting displays as ideal conditions for the existence and operation of a high-enthalpy geothermal field.

With the use of modern mapping and processing software, satellite images interpretation, analysis of geological and morphotectonic characteristics of the Nisyros volcano based on other researchers' results, was attempted a study of potential risks the island might face.

Because of the particular geological, tectonic and morphological characteristics, the following hazards could occur:

- Volcanic hazard.
- Seismic hazard due to tectonic movements in the wide region of Nisyros.
- Landslides that may be associated with earthquakes, magmatism and volcanic activity.
- Forest fires.
- Floods.
- Extreme weather events such as heat waves and storms.

An attempt in this thesis is to highlight and promote Web-GIS technology. The evolution of Web-based GIS technology and the client-server architecture have been an important role in data sharing. The development and expansion of the Internet provides two key capabilities which can significantly help geoscientists. First, the Web-GIS allows the visual interaction with data, and second, due to the almost ubiquitous nature of the Internet, the geospatial data can be widely accessible.

Keywords: Nisyros, natural hazards, Web GIS

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1.1 NATURAL HAZARDS

The United Nations International Strategy for Disaster Risk Reduction (UN-ISDR, 2004) defines disasters as a serious disruption of the functioning of a community or a society causing widespread human, material, economic or environmental losses which exceed the ability of the affected community or society to cope using its own resources. It is important to distinguish between the terms disaster, hazard and risk. Risk results from the combination of hazards, conditions of vulnerability and insufficient capacity or measures to reduce the potential negative consequences of risk (O'Keefe, Westgate and Wisner, 1976). When the hazard or threat becomes a reality, when it materializes, the risk becomes a disaster. For example, a certain river valley may be prone to flooding. There is risk if and only if a vulnerable society or property is located within this flood prone area. If the hazard materializes, that is, if the flood actually occurs, it will cause losses to the vulnerable society or property, thus creating a disaster.

Although the term 'natural disasters' in its' strict sense is not correct, as disasters are a consequence of the interaction between hazards and vulnerable societies, the term is used extensively in literature and also in daily use.

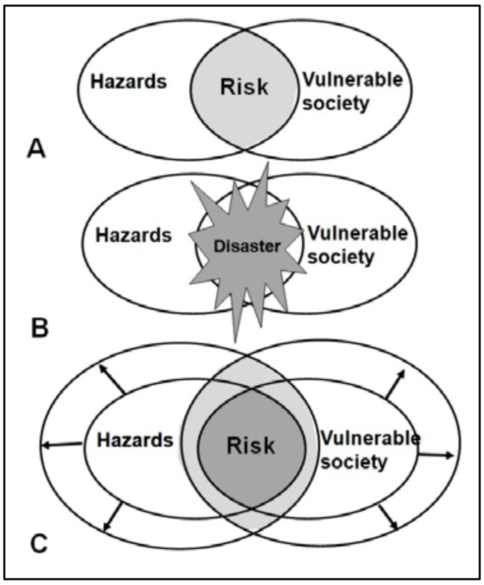


Figure 1: Schematic representation of the relation between hazards, vulnerable society, risk and disasters. A: risk indicates the expected losses to a vulnerable society as a result of hazards. B: A disaster occurs when the threat of a hazard become reality, and impacts on a vulnerable society. C: Future trends of increasing hazards and increasing vulnerability will lead to increasing risk. (source: CIESIN, 2005)

Natural disasters occur in many parts of the world, although each type of hazard is restricted to certain regions. Global studies on the distribution of hazards (e.g. MunichRe, 2010) indicate that geophysical disasters are closely related to plate tectonics. Earthquakes occur along active tectonic plate margins, and volcanos occur along subduction zones (e.g. around the margins of the Pacific plate, so-called 'Ring of Fire'). Tsunamis occur in the neighborhood of active plate margins, but their effects can be felt at considerable distances from their origin as the waves can travel long distances. Tropical cyclones (in North America called 'hurricanes' and in Asia called 'typhoons') occur in particular zones along the coast lines. Landslides occur in hilly and mountainous regions.

On the news headlines disasters appear almost every day. Most happen in far-away places, and are rapidly forgotten. Others keep the attention of the world media for a longer period of time. The events that receive maximum media attention are those that hit instantaneously and cause widespread losses and human suffering, such as earthquakes, floods and hurricanes. Recent examples are the Indian Ocean tsunami (2004), the earthquakes in Pakistan (2005), Indonesia (2006), China (2008) and Haiti (2010) and the hurricanes in the Caribbean and the USA (2005, 2008). On the other hand there are many serious geomorphologic hazards that have a slow onset such as drought, soil erosion, land degradation, desertification, glacial retreat, sea level rise, loss of biodiversity etc. They may cause much larger impacts on the long run but receive less media attention.

Earthquakes, volcanic eruptions and landslides, for all their dramatic impact, do not remotely match the scale of casualties that result from droughts, floods, and coastal storms (Sapir and Lechat 1986). This century to the end of 1990 there have been an estimated 1,52 million officially reported deaths from earthquakes. Almost half of this total has occurred in China, which also suffered the most devastating single event in the 1976 Tangshan earthquake which resulted in 242.000 deaths (Coburn and Spence 1992).

The seventeen most severe volcanic eruptions of this century have resulted in 75.000 deaths, with the most catastrophic eruption occurring in Mount Pelee in Martinique in 1902 when 29,000 were killed, and the second most severe event being the eruption of Nevado del Ruiz in Colombia in 1985 with the loss of 23.000 lives. Thus the remaining fifteen volcanic eruptions averaged 1.582 deaths per event (Wood 1986; United Nations 1985).

In the case of landslides, 40 sudden impact landslides have been reported this century causing 271.072 deaths. However this includes the most damaging landslide of this century, which took place in Gansu province, China in 1920, when 200,000 were reported killed. In 50 percent of these disasters less than a hundred were killed (Alexander 1989). Thus it can be seen that in global terms, landslides have relatively low casualty statistics relative to other hazards.

However, the data is misleading, since landslides often occur as a secondary consequence of another type of hazard, such as flooding, a cyclonic storm, or as a result of an earthquake. So, landslide casualties are often added to the total of deaths and injuries attributable to these broader events, and those specifically linked to landslides are probably under-reported.

To reduce disaster losses more efforts should be done on Disaster Risk Management, with a focus on hazard assessment, elements-at-risk mapping, vulnerability assessment and risk assessment, which all have an important spatial component. In a multi-hazard assessment the relationships between different hazards should be studied, especially for concatenated or cascading hazards. The use of Geographic Information Systems (GIS) has become an integrated, well developed and successful tool in disaster risk management. Hazard and risk assessments are carried out at different scales of analysis, ranging from a global scale to a community level. Each of these levels has its own objectives and spatial data requirements for hazard inventories, environmental data, triggering factors, and elements-at-risk. An overview is given of the use of spatial data with emphasis on remote sensing data, and of the approaches used for hazard assessment. This is illustrated with examples from different types of hazards, such as earthquakes, windstorms, drought, floods, volcanic eruptions, landslides and forest fires.

Top 10

Natural disasters by number of **deaths**

Earthquake, April	Nepal	8 831
Heat wave, June-August	France	3 275
Heat wave, May	India	2 248
Heat wave, June	Pakistan	1 229
Landslide, October	Guatemala	627
Heat wave, June-July	Belgium	410
Flood, November-December	India	325
Flood, July-August	India	293
Earthquake, October	Pakistan	280
Flood, January	Malawi	278

Total of **affected people** reported by country

Dem. Rep. of Korea	18 003 541
India	16 558 354
Ethiopia	10 210 600
Nepal	5 640 301
Bangladesh	4 452 553
Philippines	3 834 514
Malawi	3 438 995
China, P Rep	3 006 093
Guatemala	2 809 910
South Africa	2 700 000

Total of **economic damage** reported by country (in billion US$)

United States	24,88
China, P Rep	13,66
Nepal	5,17
United Kingdom	3,60
India	3,30
Chile	3,10
Australia	2,40
South Africa	2,00
Philippines	1,90
France	1,00

Figure 2: Disasters in numbers for the year 2015 (source: http://www.unisdr.org)

The last two decades have witnessed the increasing use of remote sensing for understanding the geophysical phenomena underlying natural hazards. The scientific knowledge gained along with the ability to disseminate timely geospatial information that can be integrated with demographic and socioeconomic data are contributing to comprehensive risk mitigation planning and improved disaster response.

According to Tierney (1992) we can distinguish three levels of impact:

- Primary: losses health damage (deaths, injuries causing epidemics, psychological disorders), private and public property damage (structures, buildings, historical monuments, temples).
- Secondary: injuries and damage to life lines (life line disruption), utilities and basic infrastructure networks such as electricity networks, water supply, telecommunications, sanitation, roads, railways, ports etc.
- Upper: changes in economic and political situation, reduction of natural resources, pollution, market destabilization and disruption of the social fabric, school closures, shops and private companies, long-term unemployment, reduced employment opportunities, creating homelessness and new living conditions (eg temporary accommodation of the population), reducing property values and rising rents, break cultural, educational and other activities etc.

Observations from Earth orbiting satellites are complementary to local and regional airborne observations, and to traditional in situ field measurements and ground-based sensor networks in seismology, volcanology, geomorphology and hydrology. The contributions of satellite remote sensing to solid Earth science, ranging from high-resolution topography (using e.g. Interferometric SAR, Lidar and digital photogrammetry) and geodesy to passive hyperspectral (such as ASTER, MODIS and Hyperion) and active microwave imaging, have transformed the discipline of Earth science.

The key to understanding the Earth's dynamics and system complexity is to integrate observations at local, regional and global scales, over a broad portion of the electromagnetic spectrum with increasingly refined spectral resolution, spatial resolution and over time scales that encompass phenomenological lifecycles with requisite sampling frequency.

Furthermore, assimilation of data and model outputs into decision support systems must meet operational requirements for accuracy, spatial coverage and timeliness in order to have positive impact on disaster risk management.

The Most Known Natural Disasters Databases:

- Emergency Disaster Database/EM-DAT (www.em-dat. be)
- Munich Reinsurance Company (NatCat) (mrnathan.munichre.com)
- Swiss Reinsurance Company (www.swissre.com)
- GLobal unique disaster IDEntifier number (GLIDE) (www.glidenumber.net)
- Emergency Management Australia/EMA (www.ema.gov.au/ema/emaDisasters.nsf)
- Canadian Disaster Database/CDD, (www.psepcsppcc.gc.ca/res/em/cdd/search-en.asp)
- Spatial Hazard Event and Losses Database for the United States/SHELDUS, (www.sheldus.org) και United States Storm and Hazard Database, (www.gesource.ac.uk/hazards/usastorms.html),
- Disaster Database Project, an independent database created and maintained by Dr. Walter Green at the University of Richmond. (http://learning.richmond.edu/disaster/index.cfm)

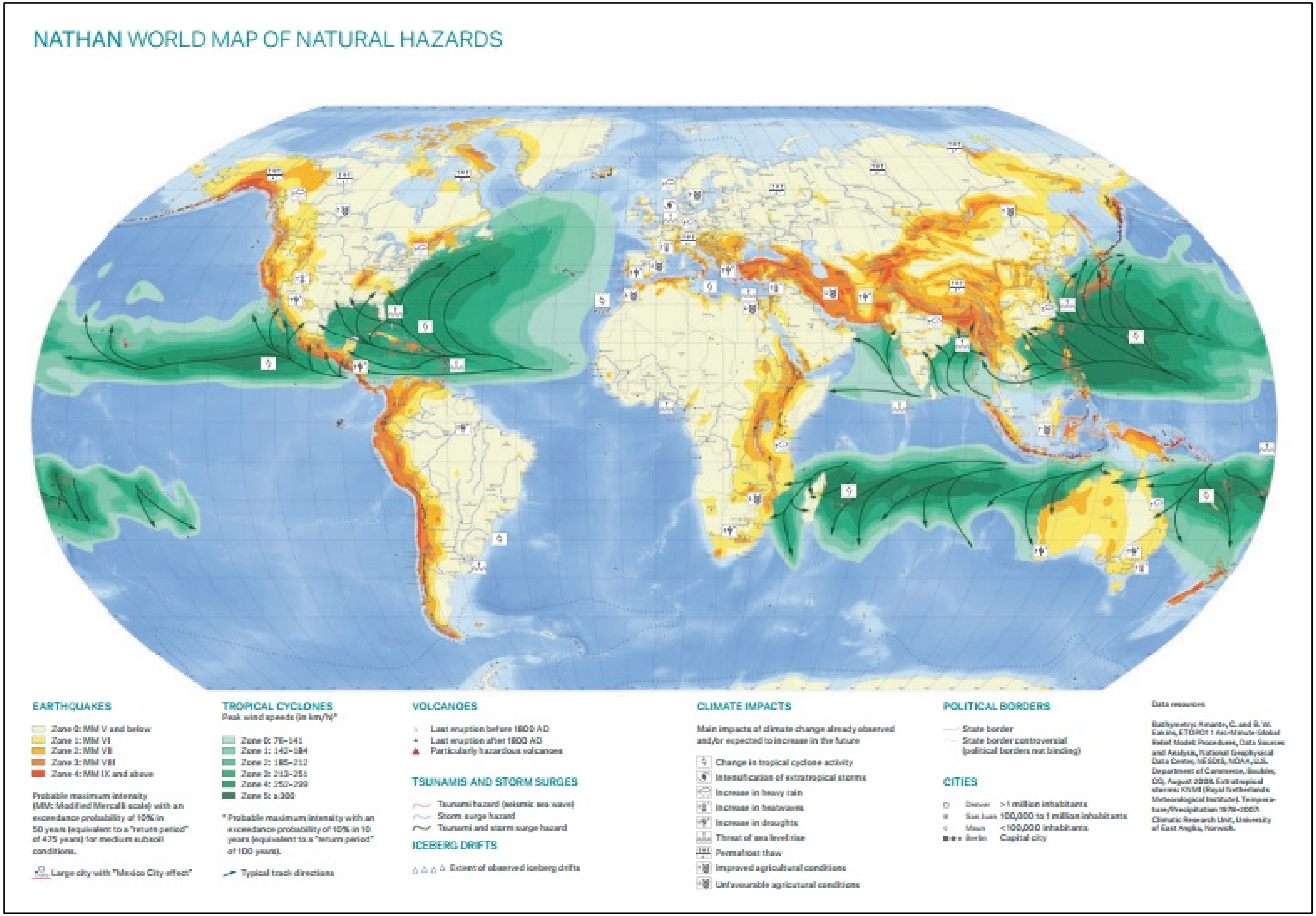


Figure 3: *Nathan World Map of Natural Hazards (source: Munich Re, 2011)*

1.2 METHODOLOGY

For the MSc. Thesis work were used:

- ❖ Map Sheets:
  - Hellenic Military Geographical Service – Nisyros Topographic Map
  - GEOWARN Project (2003) – Geological Map of Nisyros
- ❖ Satellite images:
  - Google Earth
  - ESRI ArcGIS Earth
- ❖ The ArcMap software version 10.1 of ESRI company
- ❖ Rainfall data from rainfall stations of the Hellenic National Meteorological Service at Kos town, Kos Airport, Astypalaia, Rhodes and Leros
- ❖ Digitized Contours (elevation 20m)
- ❖ Bibliographical and web references

Work done based on the maps was:

- ❖ Maps georeference to GGRS '87 Coordinate System
- ❖ Hydrographic network digitization
- ❖ Digitization of geological formations, tectonic contacts and volcanic domes
- ❖ Digitization of settlements and road network
- ❖ Hot springs digitization
- ❖ Fumarole spots digitization
- ❖ Editing digitized land use map (Corine 2000), and vegetation (Ministry for the Environment, Energy and Climate Change)

After the above data process, the following were produced:

- ❖ Digital Elevation Model
- ❖ Land Use Map
- ❖ Slope map
- ❖ Aspect map
- ❖ Thematic maps for hazards assessment with reference to volcanic, seismic, landslide, forest fire and floods.

1.3 THE ISLAND OF NISYROS

Nisyros is the most characteristic and interesting volcanic form in Greece. Despite the particular geological and geothermal interest, the existing geological bibliography could be characterized as inadequate. Most scientific publications concerning Nisyros are mainly mineralogy and petrology containing only a few data on geological structure and tectonic evolution.

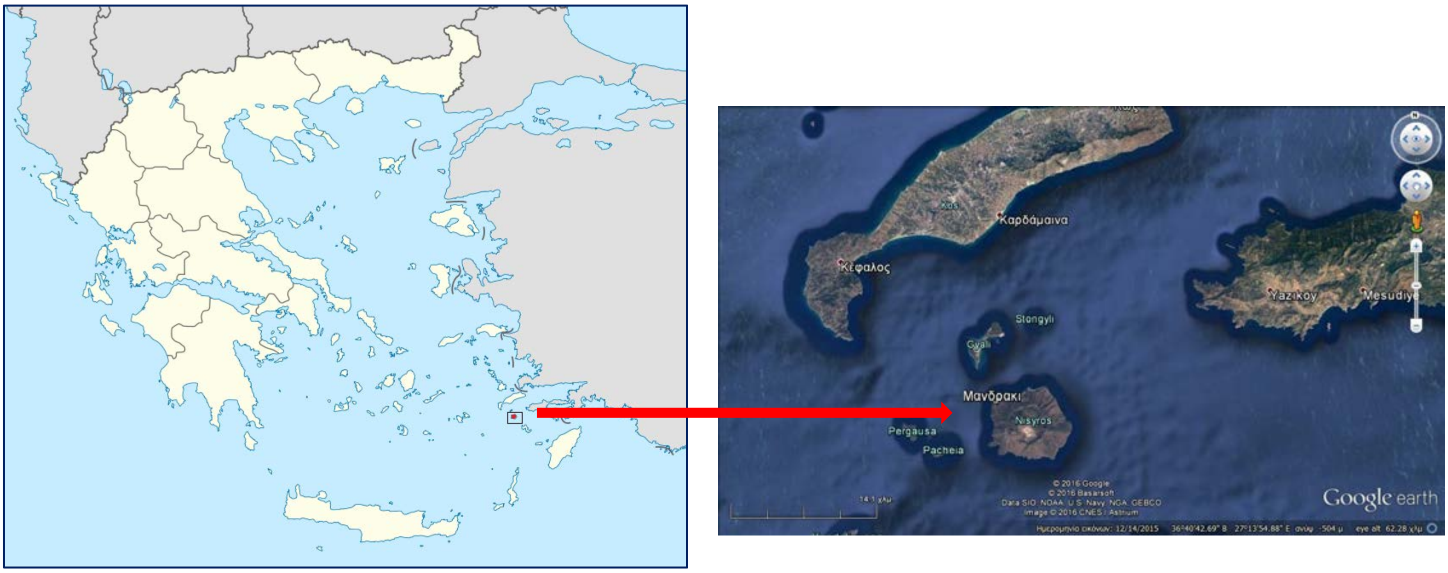


Figure 4: Location of Nisyros Lisand

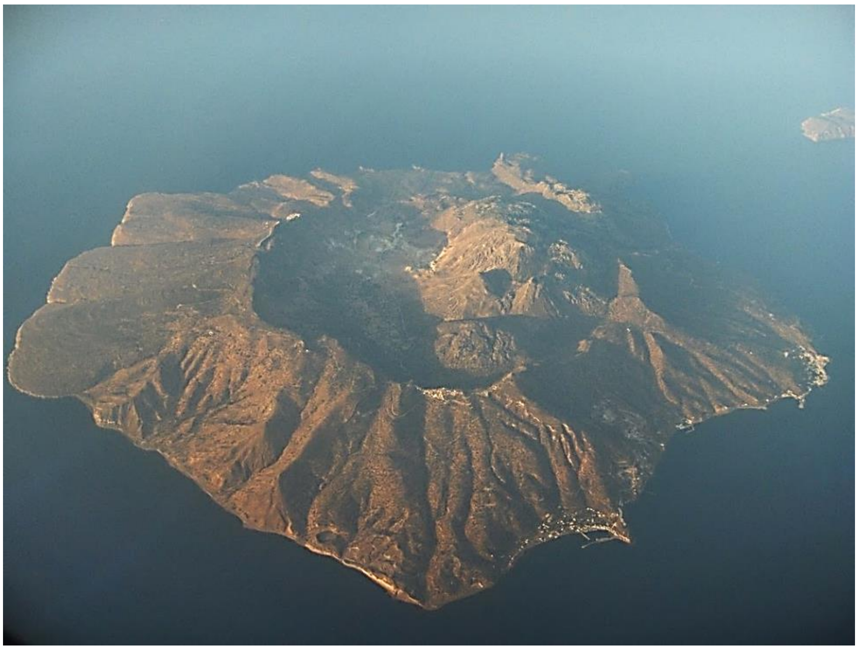


Figure 5: Aereal view of Nisyros volcano from northeast; the caldera with an approximate diameter of 3.6 km the filling of the western part with voluminous rhyodacitic domes up to 698 m (Profitis Illias); the almost circular structure and steep walls with a drop of 300 to 400 m between the northern and eastern rim down to the Lakki plain of 110 m above sea level. (source: P. Nomikou, D. Papnikolaou and V. J. Dietrich)

The first references to the geology of Nisyros belong to Martelli (1917), Desio (1931) and Georgallas (1958) where there are only general descriptive information. Although, the first extensive geological study Nisyros was made by Davis (1957) which concluded that there are two periods of pouring, each one of them had, initially, basic character and then eventually yield acid derivatives. The materials of the first volcanic period occur only in certain locations and then the cycle is closed with the formation of thick layers of volcanic cord. The second volcanic period gave a wide variety of petrological types such as andesites, tracheiandesites, dacites and rhyolites and then pumice.

Di Paola (1974) believes that there are two periods of the volcano evolution: 1st is the pre-calderic period where initially distinguished in a first underwater action and then into a gas action which gave a wide variety of rocks and the 2nd period is the post-calderic which gave rhyodacites occupied approximately 2/3 of the caldera and a part of the island as well outside the caldera.

These two publications do not agree with each other on key issues pairing of petrological formations and most important do not integrate the various rocks in a single stratigraphic structure.

The discipline in most scientific publications concerning Nisyros is mainly Mineralogy and Petrology with emphasis on the geothermal field and analysis of geochemical parameters of the hydrothermal system, while other publications exhibit geophysical characteristics and ground deformation.

1.4 GEOGRAPHY OF NISYROS

Nisyros spans an area of 50.055 km^2 (19.326 sq mi). with a total population of 1008 residents. The islets adjacent to Nisyros are Pacheia, Pergoussa, Kandelioussa, Agios Antonios and Stroggyli are not inhabited. The islet of Gyali has only 10 residents.

The islands closer to Nisyros are Kos on the north, Tilos on the south and Symi on the east. The Municipality of Nisyros includes Gyalí as well as the uninhabited Pacheiá, Pergoússa, Kandelioússa, Ágios Antónios, and Stroggýli.

1.5 HISTORICAL DATA

According to mythology Poseidon threw to the Giant Polyvotis a piece of rock from Kos Island during the fight between Gods and Giants. This rock created Nisyros and its volcano that is considered to be the moan of the wounded Giant. During the Persian Wars Nisyros together with Kos and Kalymnos were under the rule of the kingdom of Halicarnassus and fought in Xerxes' campaign against Greece. Nisyros history is linked to that of Rhodes and the rest Dodecanese. Nisyros joined Greece in 1948.

1.6 LIST OF VOLCANOES IN GREECE

This is a list of active and extinct volcanoes in Greece.

Name	Elevation		Location	Last eruption
	meters	feet	Coordinates	
Kos	430	1411	36.852°N 27.251°E	Pleistocene
Methana	760	2493	37.615°N 23.336°E	258 BCE
Milos	751	2464	36.699°N 24.439°E	140 CE
Nisyros	698	2290	36.586°N 27.160°E	1888
Poros	80	240	37.499°N 23.457°E	Pliocene
Santorini (Kolumbo)	-18	-60	36.517°N 25.492°E	1650
Santorini (Nea Kameni)	130	390	36.404°N 25.396°E	1950
Yali	180	591	36.671°N 27.140°E	Holocene

Table 1: List of volcanoes in Greece (source: http://www.greatdreams.com/blog-2012-3/dee-blog303.html)

VOLCANO	HISTORICAL ERUPTIONS
Methana	250 B.C.
Milos	80-205 A.D.
Nisyros	1888, 1873, 1871, 1830, 1422
Santorini	1950, 1939-41, 1928, 1925-6, 1866-7

Table 2: Historic Volcanic Eruptions in Greece

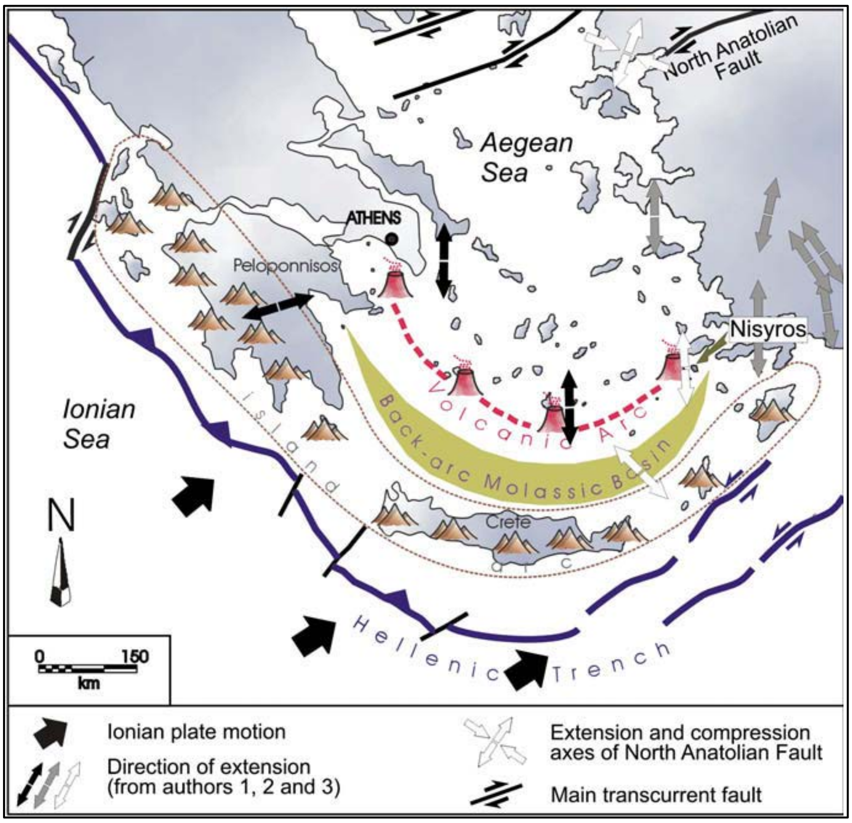


Figure 6: Geodynamic setting of the Aegean-Eastern Mediterranean Region. Red dashed line crosses the active volcanoes of the Hellenic Volcanic Arc.

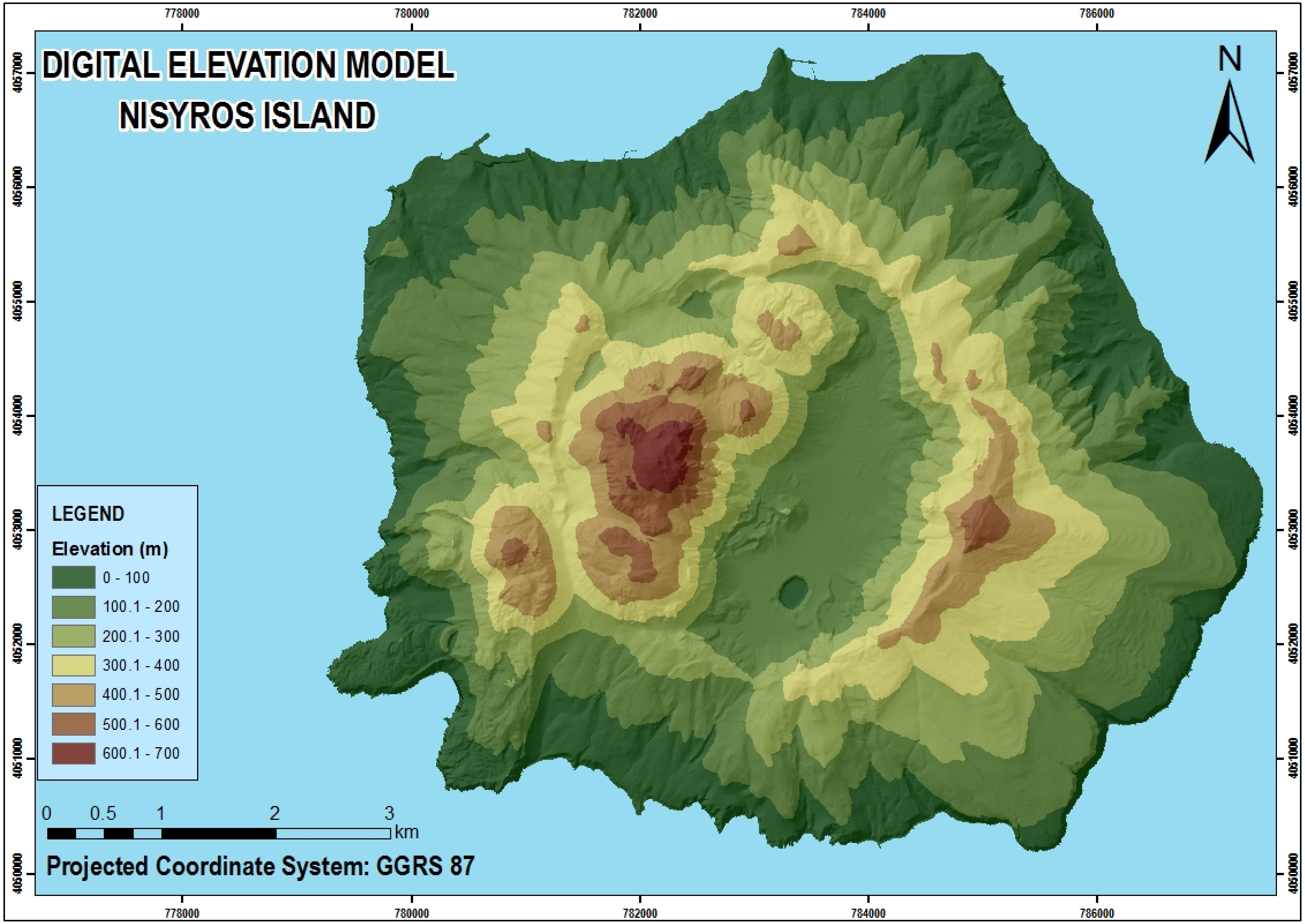


Figure 7: Digital Elevation Model of Nisyros island. The shape of the island reveals the characteristic circular, conical geometry of the active volcanoes, with the large caldera on the top of the volcanic cone.

Figure 8: Digital Elevation Model Satellite Image of Nisyros Island (Google Earth Pro, version 7.1)

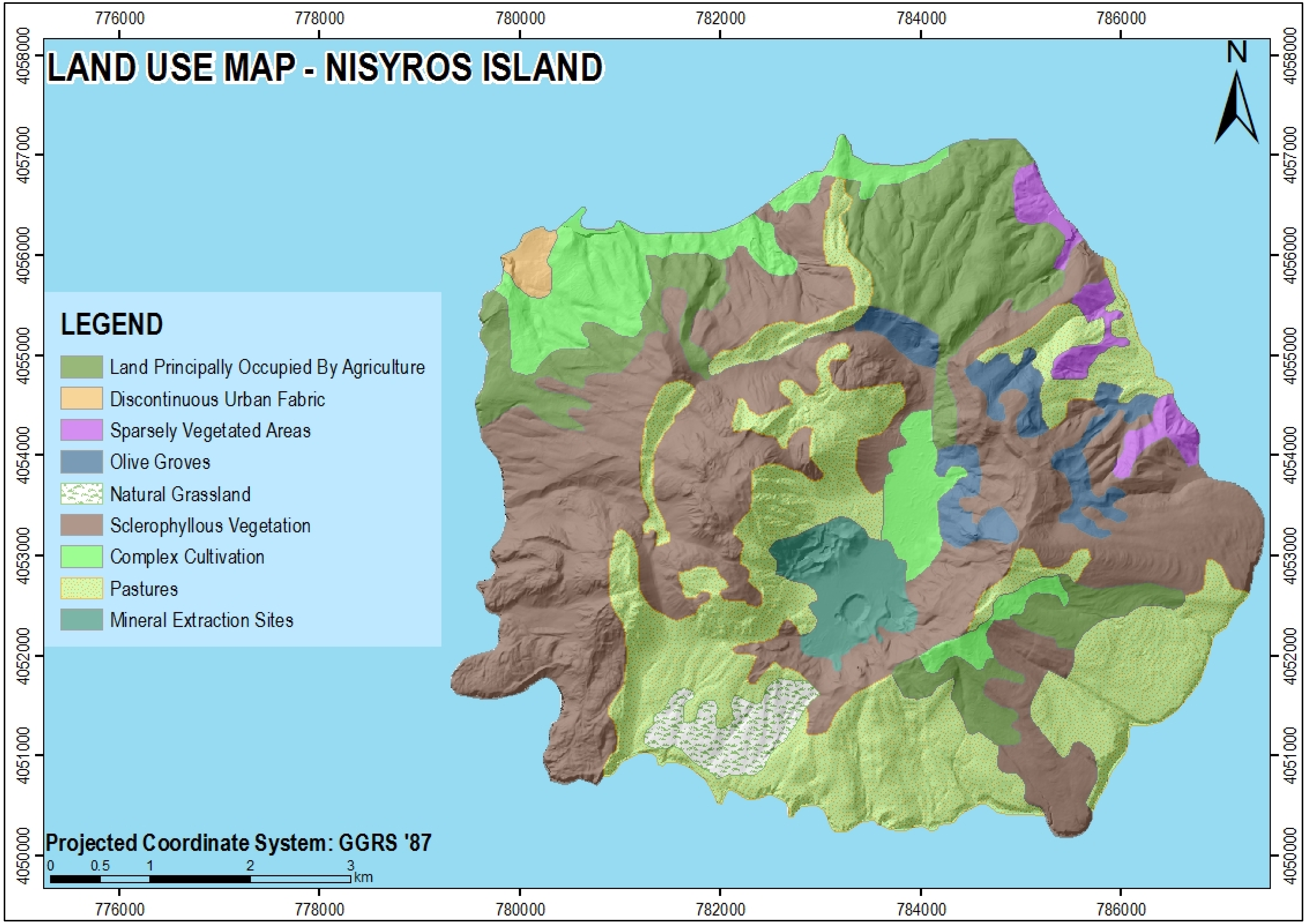


Figure 9: Land Use Map of Nisyros Island (source: CORINE 2000)

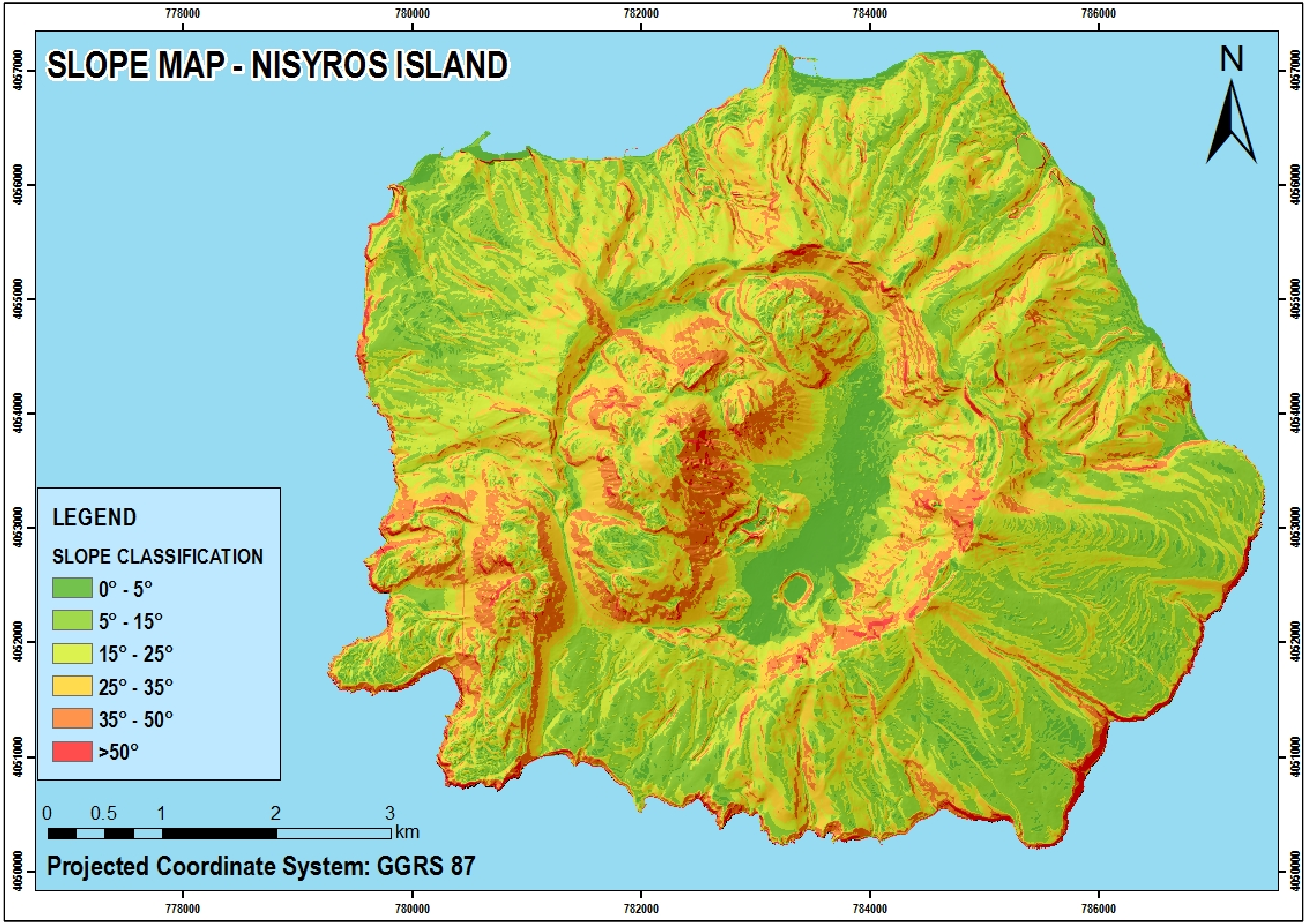


Figure 10: Slope Map. Morphological slopes are intense (>30°) because of the steep terrain posed by successive lava spills

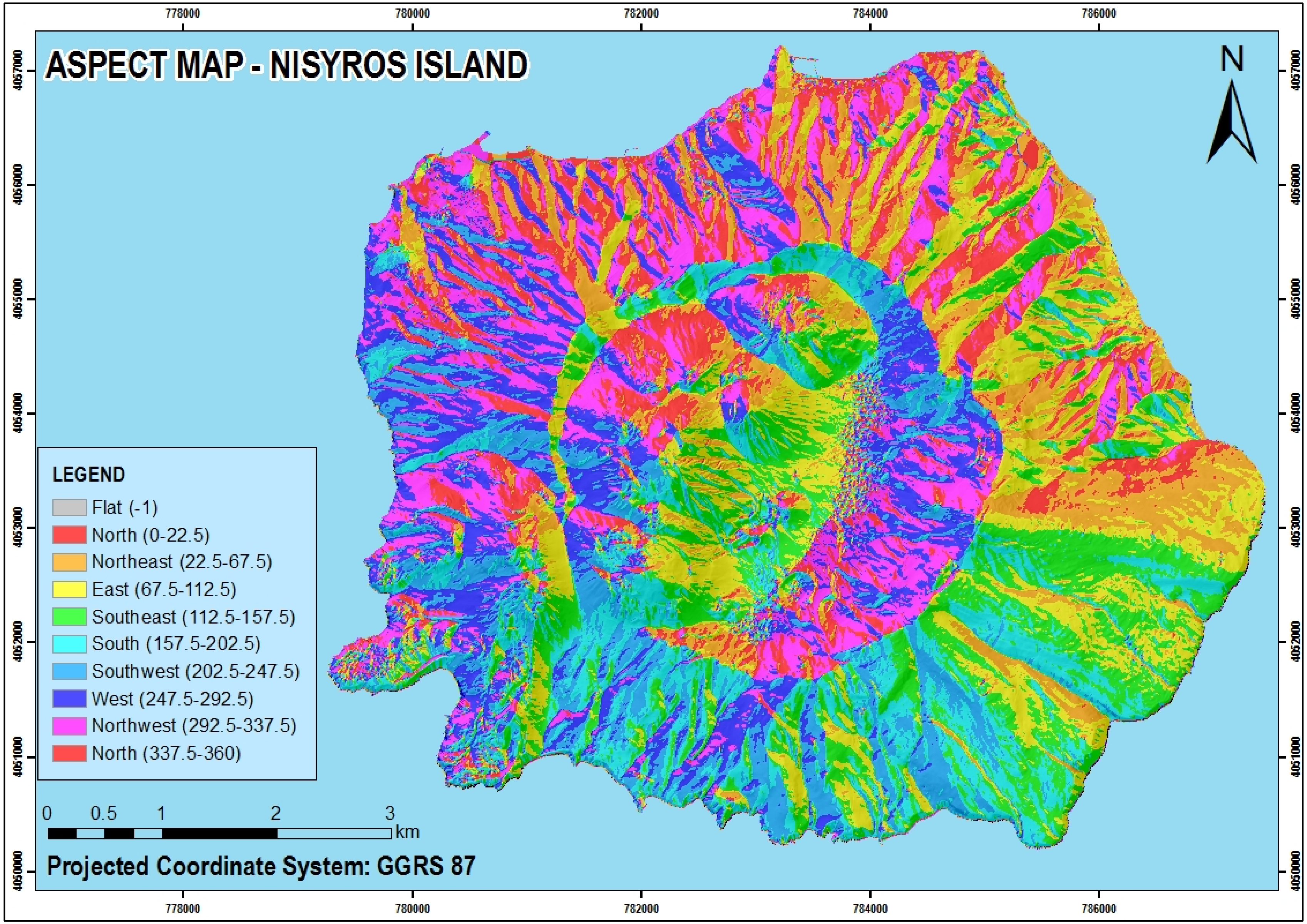


Figure 11: Aspect Map

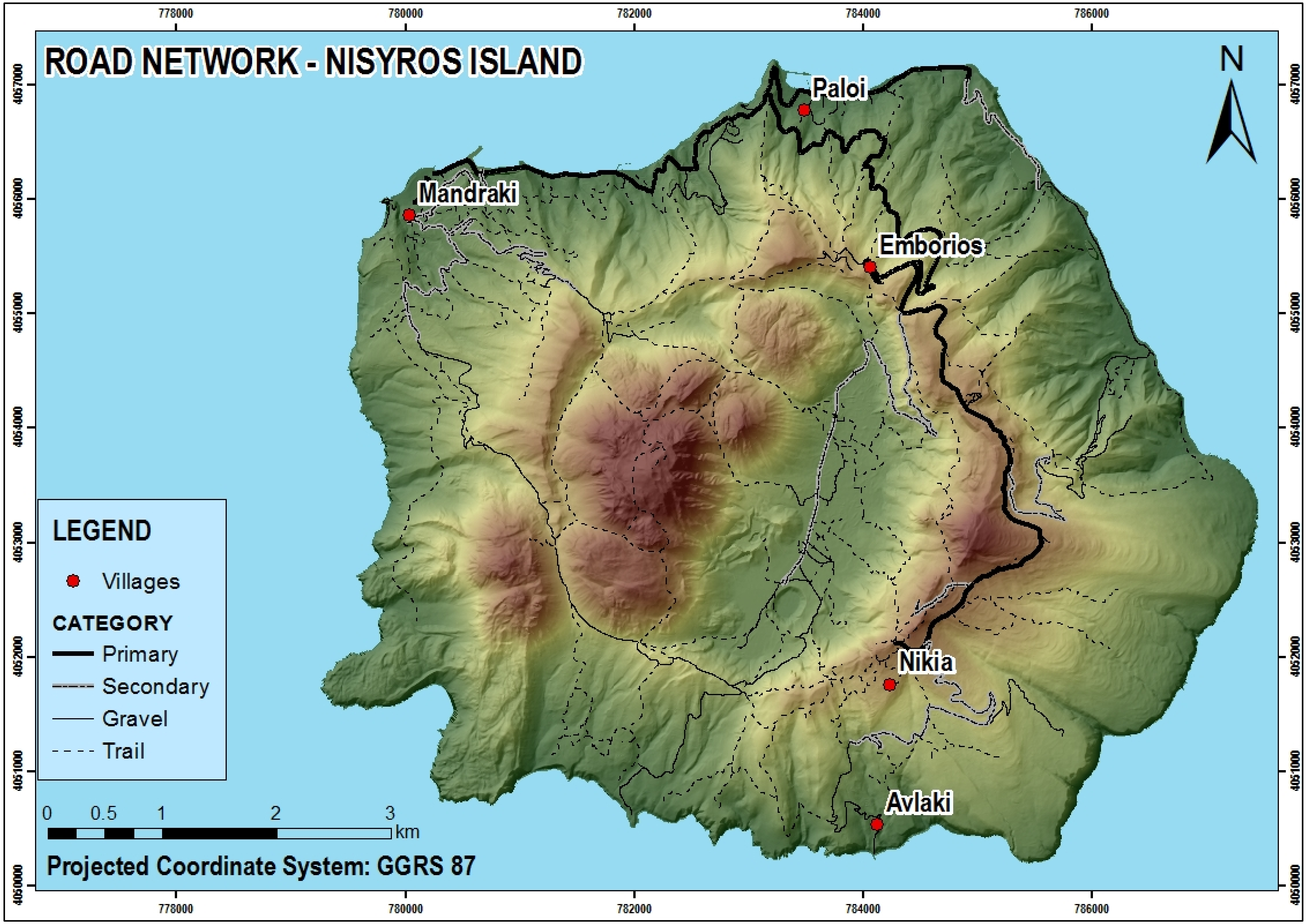


Figure 12: Nisyros Island Road Network and location of the Villages

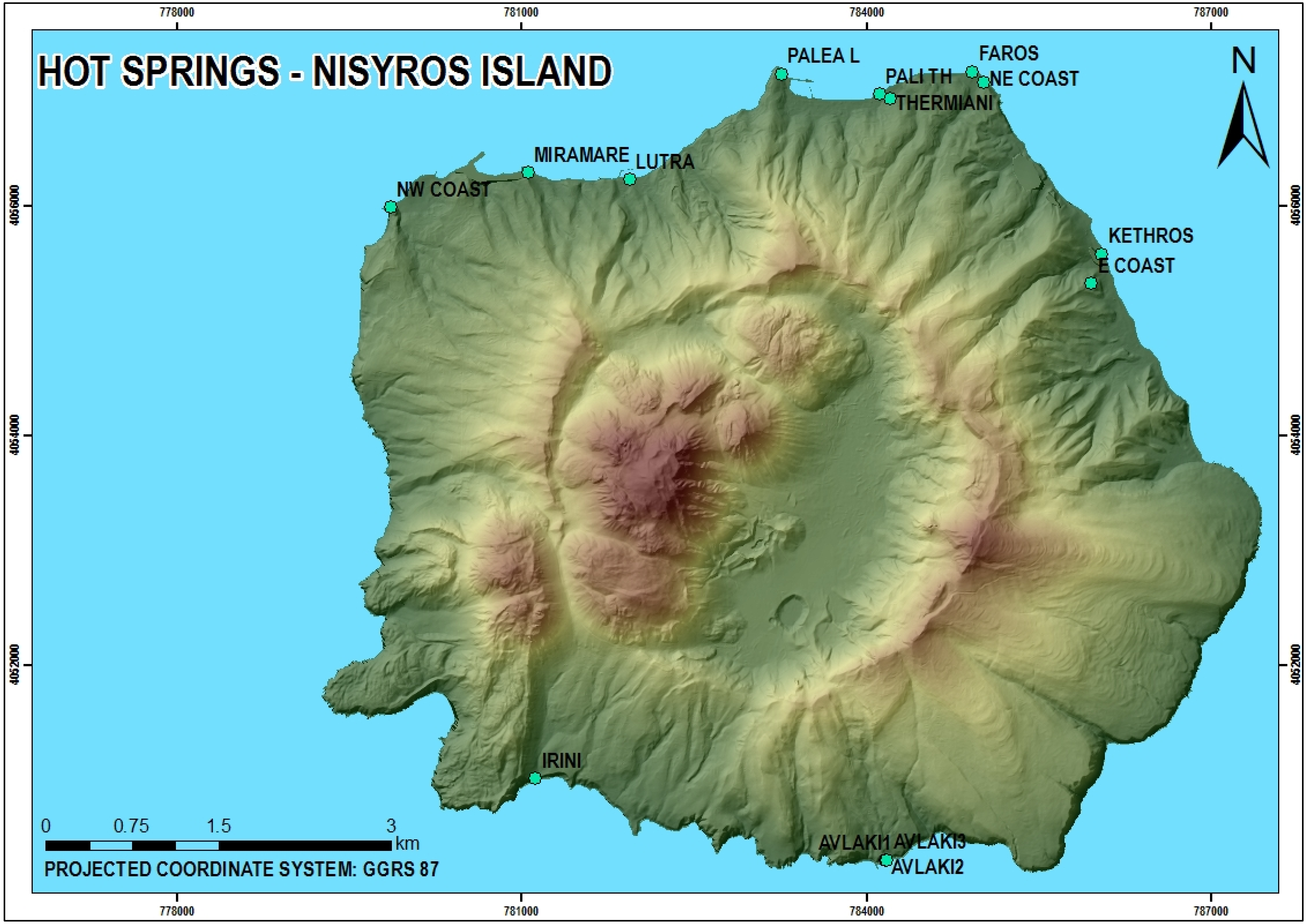


Figure 13: Nisyros Island hot springs

Figure 14: View of the caldera of Nisyros with the domes of Profitis Elias and the Stefanos crater

1.7 THE HELLENIC VOLCANIC ARC

The development of the Hellenic Volcanic Arc (Figure 6) is the result of the subduction of the East Mediterranean oceanic lithosphere below the European continental plate, at least during the last 45 Ma (Papanikolaou, 1993). The present day geodynamic structure of the Hellenic Arc includes the Hellenic Trench, which is a 1500 km-long arcuate trough extending from the Ionian Sea in Western Greece to the Lybian Sea, south of Crete and ending southeast of Rhodos Island. It also includes the parallel structures of the Peloponnese–Crete–Dodekanese island arc and the back-arc mollasic basin of the Cretan Sea. Finally, the Aegean island arc is developed parallel to the Hellenic Trench in a more internal position along the islands to the north of the Cretan basin.

Recent volcanoes occur on Soussaki, Methana, Aegina and Poros to the west, on Milos and Santorini in the centre and on Kos and Nisyros to the east. Submarine volcanoes have also been found in the Epidauros Basin in the western Saronikos Gulf (Pavlakis et al., 1990). The volcanoes of the Hellenic Arc were especially active in the Late Pleistocene–Holocene, with some eruptions known in historical times (Fytikas et al., 1976; Liritsis et al., 1996).

The eastern sector of the Hellenic Volcanic Arc, including the islands of Kos, Yali and Nisyros, resulted from the northeastward directed subduction of the Eastern Mediterranean lithosphere below the active Hellenic margin of the European plate. It is a very active sector, featuring the largest volumes of volcanic products in Late Pleistocene–Holocene times. Major magmatic activity began at least 0.16 Ma ago (Keller et al.,1990), producing the largest eruption in the Eastern Mediterranean represented by the ‘‘Kos ignimbrite’’, which covered an area of more than 3000 km2. The centre of this eruption is not known with accuracy but it is probably located in the submarine area north of the Yali islet, a few kilometres northwest of Nisyros (Nomikou, 2004).

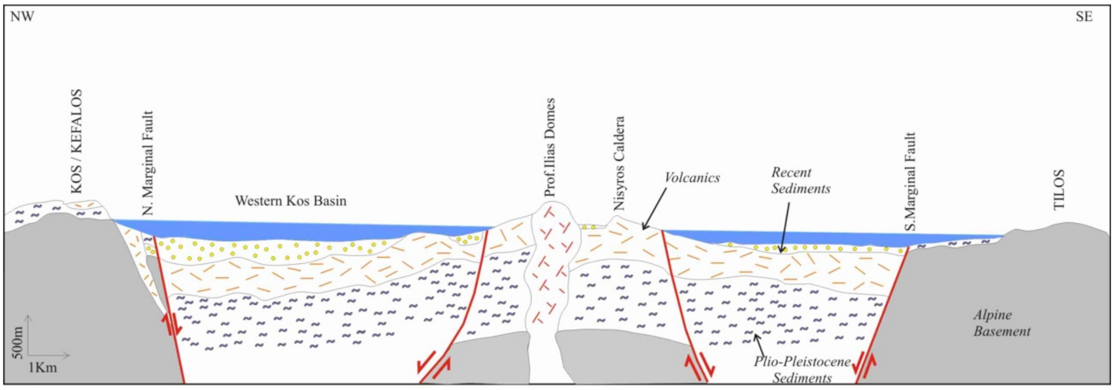


Figure 15: The general structure of the regional neotectonic graben between Kos and Tilos islands (Papanikolaou and Nomikou, 2001)

1.8 THE GEODYNAMIC SETTING OF NISYROS

The island of Nisyros is exclusively made of Quaternary volcanic rocks, represented by alternating lava flows, pyroclastic layers and more viscous lava domes, ranging in age from 200 to 25 ka. Nisyros forms a truncated cone with a base diameter of 8 km and a central caldera, 4 km in diameter. Basement rocks made of carbonates and marbles were found at depth of 600m in a well located in the northwestern part of the caldera and at 1000m below the southeastern part by geothermal drillings (Geotermica Italiana, 1983, 1984). The infilling of the caldera above this basement is made of lacustrine, alluvial and tephra deposits. The evolution of this volcano has been described first by Martelli (1917), Desio (1931), Davis (1967) and Di Paola (1974), and more recently it has been divided into five major stages (Papanikolaou et al., 1991; Nomikou, 2003; Vanderkluysen et al., 2005; Volentik et al., 2005):

1) an underwater volcano, with erupting basaltic and andesitic pillow-lavas, built up the lower volcanic rocks visible on the northern coast near Mandraki;
2) A 500–700m high stratovolcano grew on top of these partly submarine lavas for a period of more than 100 ka;
3) after several eruptive phases of gas and steam explosions, two major rhyodacitic plinian eruptions covered the whole island with pyroclastic flows and pumice falls;
4) subsequently, a major central, vertical collapse of the volcano leaved a large caldera at <20 ka BP (Limburg and Varekamp,1991); and
5) during pre-historic times, the western part of the caldera depression was filled with a series of rhyodacitic domes, the highest of which, Profitis Ilias, rises 698 m a.s.l.

No volcanic activity is known to have occurred on the island after the formation of the domes for at least 25 ka; the only reported historical explosions are related with the formation of several phreatic craters inside the caldera, such as Alexandros, Polyvotis, Stephanos, Phlegethon and Achelous, which are still emitting fumaroles. Violent earthquakes, gas detonations, steam blasts and mudflows accompanied the most recent hydrothermal eruptions in 1871–1873 and 1887 AD (Marini et al., 1993). During this activity some people were slightly injured and minor damages were caused to the houses.

According to Papanikolaou et al (1991), the pre-caldera period is characterised by a succession of 4 lavas and 4 pyroclastic flows (A,B,C,D) that formed the stratovolcano. This succession was followed by the rhyolites of Nikia in the southern part of Nisyros and by pumice deposits. The post-caldera period comprises the white pumice and the Profitis Ilias rhyodacites.

The geological map of Nisyros has been simplified based on the "GEOWARN" Project (2003). The legend of the geological map includes the following formations:

1. Alluvium, coastal deposits: They are mainly observed in the northern coastal areas of Nisyros. They contain coarse and finer materials from the erosion of the volcanic formations of the island and they overlay unconformably the volcanic formations.
2. Scree-Talus Cone: They occur mainly along the internal slopes of the Nisyros caldera and along some active fault zones. They contain breccias.
3. Caldera deposits: They are fine grained materials deposited on the horizontal area of the caldera.
4. Prophitis Ilias dacites: These are massive volcanic domes and flows result of the recent post-caldera volcanic activity. They build the top of Mt. Prophitis Ilias and they interrupt the continuity of the caldera rim at its western part.
5. White pumice: It is usually coarse-grained pumice with white colour.
6. Nikia Rhyolites: They constitute a huge lava flow towards the southeast, covering a little less than ¼ of the external slopes of the caldera.
7. Pumice with volcanic breccia: This pumice formation is underlying the Nikia Rhyolites.
8. Pyroclastics and Lavas: 4 different types each.
9. Scoriae: These rocks are not stratigraphically bounded to a certain formation because they are alterations of lavas belonging to different lava formations. Their colour is usually red, or black.

1.9 NEOTECTONIC STRUCTURE OF NISYROS

Several active faults were mapped on Nisyros by Papanikolaou et al in 1991 and during 2000-2002. Major faults have throws close to 100m whilst minor ones have throws of only a few tens of meters. The major fault zones are shown on the tectonic map (1:10.000 scale) delivered at the end of 2001, and are:

F1 Fault zone. It is one of the most important fault zones with a N50E strike and 70-80 SE dip, and a throw reaching 100 m. Judging by the formations cut by this fault zone we can assume that it has been reactivated repeatedly, both during the flow of lavas C and D and after the extrusion of Profitis Ilias lavas.

F2 Fault Zone. This is located in the southern part of the island roughly 1Km east of F2 and strikes N30E and dips 70-80 WNW. Its total offset is about 120m.

F3 Fault Zone. F3 is located in the northwestern part of the island and trends N40W with dips of 70-80 to the NE. It juxtaposes different formations both within and outside the caldera. Offset morphotectonic indicators point to a throw of 70-90 m.

F4 Fault Zone. This zone defines a graben, striking N20W, consisting of two conjugate faults with opposing dips. This fault zone is younger than the previous three as it cuts the Nikia rhyolites whilst older formations show no evidence of any prior deformation.

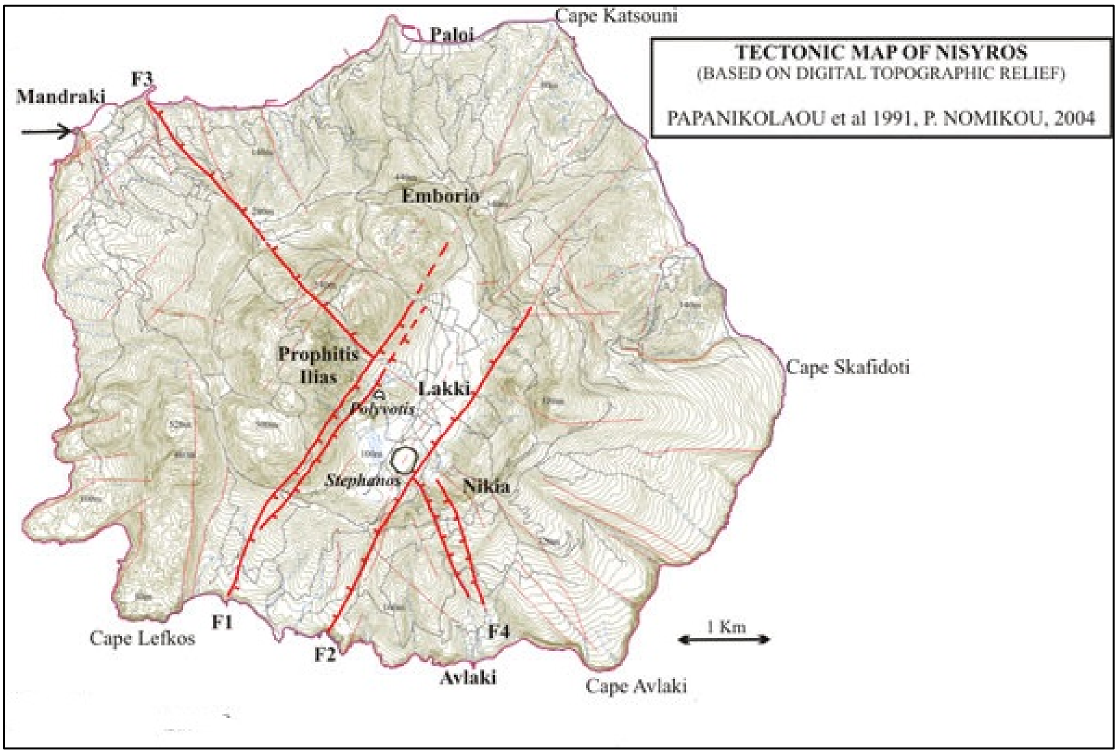


Figure 16: Tectonic Map of Nisyros (source: Papanikolaou D., et al 1991, Nomikou P., 2004)

The resulting neotectonic structure of Nisyros comprises of five blocks, each one with a kinematic character of relative uplift-horst-or relative subsidence-graben. The NW-SE fault zone of Profitis Ilias-Mandraki (F3) implies an extension in the NE-SW direction, whereas the NE-SW fault zones of Ag.Irini (F1 and F2) implies an extension in the NW-SE.

G.P.S. stations were established on Nisyros Island over all five neotectonic blocks, aiming to a monitoring of the crustal deformation. Measurements started in June 1997 and they showed very important displacements, both in the horizontal and the vertical axes, of the order of 10 to 40 mm/per year (Lagios et al, 1998,2000, Nomikou et al, 1999).

Additionally:

i. the maximum uplift was observed in a NW-SE direction running parallel to the major Profitis Ilias-Mandraki fault and
ii. the horizontal displacement of the block west of the Profitis Ilias-Mandraki fault zone is directed towards the SW whereas the block to the east is directed towards the east.

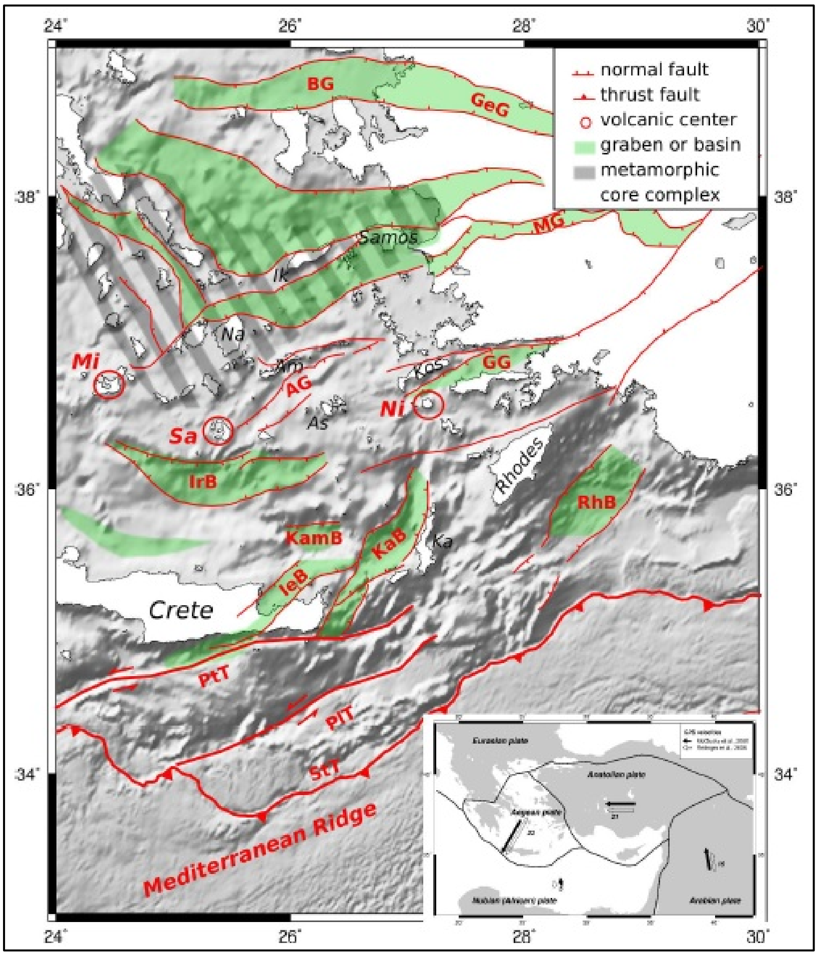


Figure 17: General tectonic map of the eastern HSZ (Chamot-Rooke et al., 2005). Volcanic centers: Milos volcano (Mi), Santorini volcano (Sa), Nisyros volcano (Ni). Major graben and basins: Bergama graben (BG), Gediz graben (GeG), Menderes graben (MG), Amorgos graben (AG), G¨okova graben (GG), Iraklion basin (IrB), Kamilonisi basin (KamB), Ierapetra basin (IeB), Karpathos basin (KaB) and Rhodes basin (RhB). Major fault system (since Miocene): Ptolemy trench (PtT), Pliny trench (PlT) and Strabo trench (StT). Islands: Ikaria (Ik), Naxos (Na), Amorgos (Am), Asytpalea (As) and Karpathos (Ka). Small figure: plate motion-values and -directions relative to the Eurasian plate from GPS-experiments (McClusky et al., 2000; Reilinger et al., 2006).

The HSZ is the seismically most active region of the Mediterranean and has been always affected by strong earthquakes. Many studies of seismicity by permanent and temporary networks were undertaken to better understand the active tectonics the HSZ. Works focused on a regional scale on the entire HSZ (Comninakis & Papazachos, 1972; Makropoulos & Burton, 1984; Papadopoulos et al., 1986; Papazachos, 1990; Hanuˇs & Vanˇek, 1993; Hatzfeld, 1993; Hatzfeld et al., 1993; Papazachos & Kiratzi, 1996).

At the Nisyros volcanic complex, at the time span from 1996 to 1998, a period of high seismic activity was located within the upper crust beneath the volcanic complex (Papadopoulos et al., 1998; Sachpazi et al., 2002). During this period more than 1600 earthquakes with magnitudes up to MS 5.3 were located. Accompanied by a ground uplift of up to 14 cm at the western flank of the volcano, a horizontal extension to W, E and S and variations of geothermal parameters of fumaroles (Caliro et al., 2005; Lagios et al., 2005), the episode of seismic unrest was interpreted as an intrusion of a magmatic body into the shallow crust.

1.10 GEODYNAMIC ACTIVITY IN THE KOS-YALI-NISYROS-TILOS VOLCANIC FIELD

The eastern sector of the Hellenic island arc, including the islands of Kos, Yali and Nisyros, seems to be geodynamically very active, since it comprises the largest volumes of volcanic products. High geodynamic activity in the Kos-Yali-Nisyros-Tilos volcanic field started in the Pliocene (approx. 2.6-2.8 million years) with phreato-magmatic eruption of ignimbrites.

Figure 19 shows a magmato-tectonic model to demonstrate the close relationship between magmatism/volcanism, seismicity and structural configuration in the eastern sector of the Aegean volcanic arc. The increase of geodynamic activity can only be understood if the processes of magma generation, emplacement, fluid behaviour and tectonic environment are known.

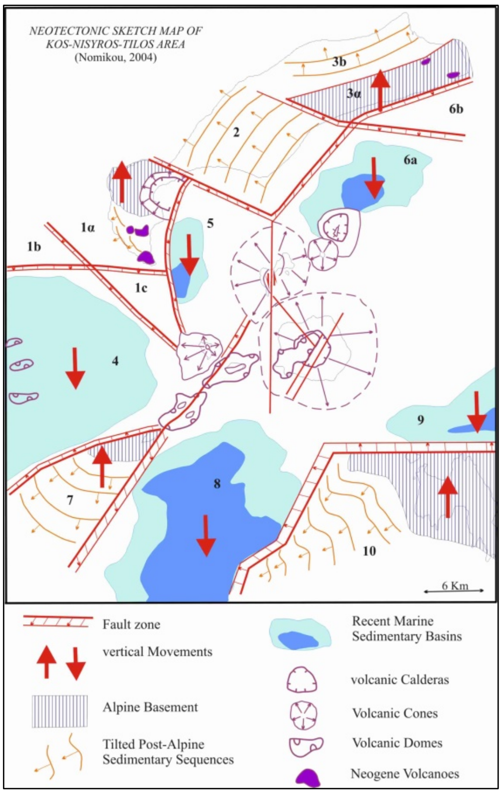


Figure 18: *Neotectonic Sketch Map of the Kos-Nisyros-Tilos area. The neotectonic blocks are shown together with their general kinematic character of uplift, subsidence or tilt as well as the volcanic structures. The main outcrops of the Alpine formations are shown at the uplifted blocks whereas the basinal areas of actual marine basins are shown at the subsided blocks and the general dip of the sedimentary sequences is shown at the tilted blocks. (Nomikou E., 2004)*

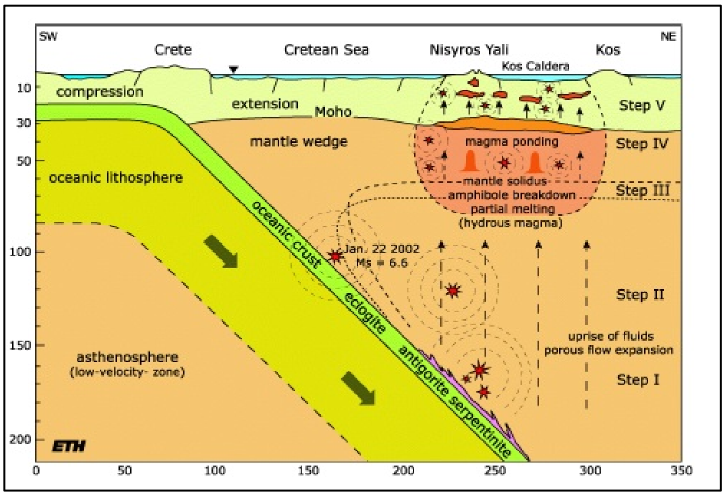


Figure 19: *The Magmato-Tectonic Model of the eastern sector of the Aegean volcanic arc in a SW-NE cross-section from Crete to Kos(source: GEOWARN Project)*

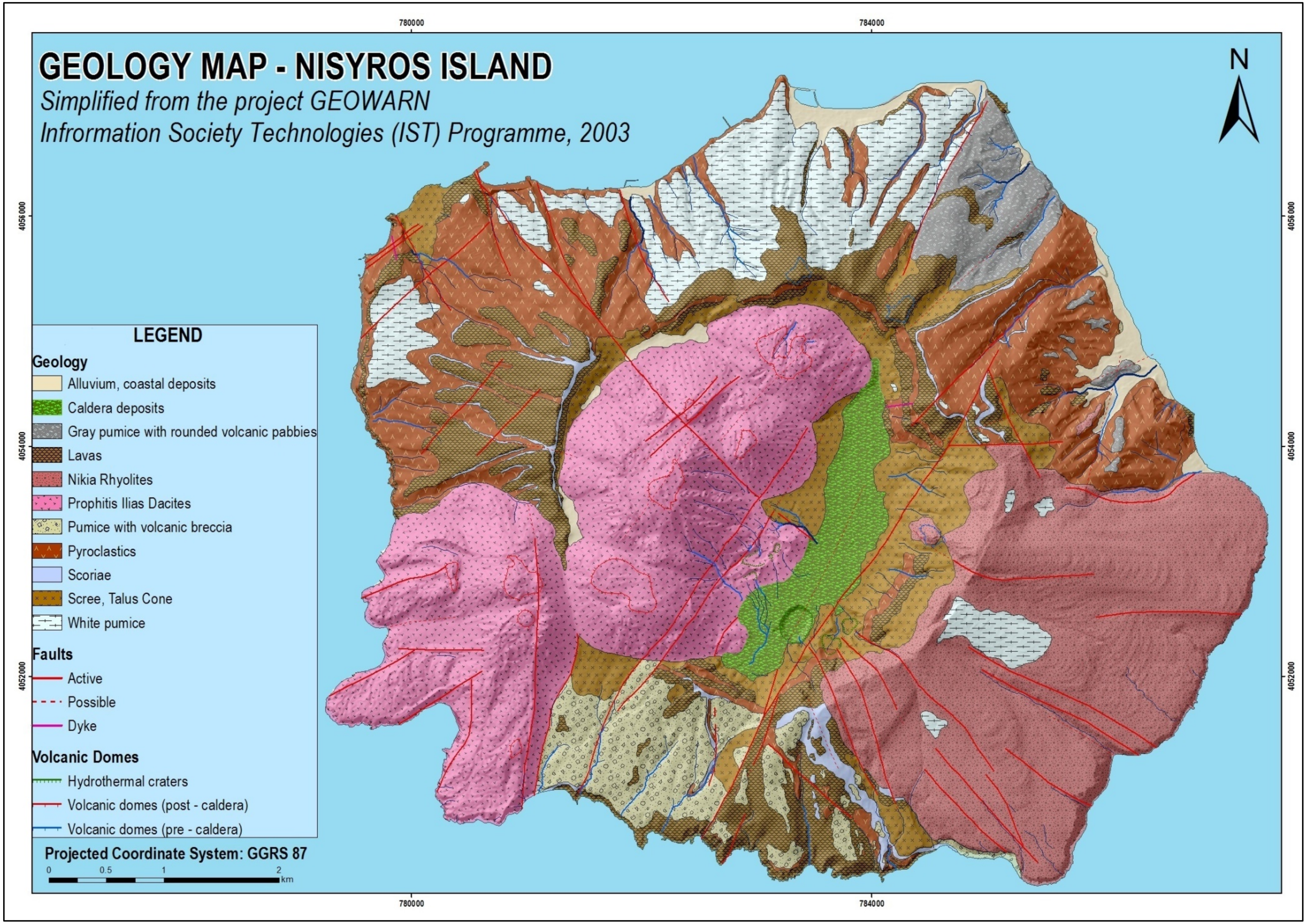


Figure 20: Geological Map of Nisyros Island

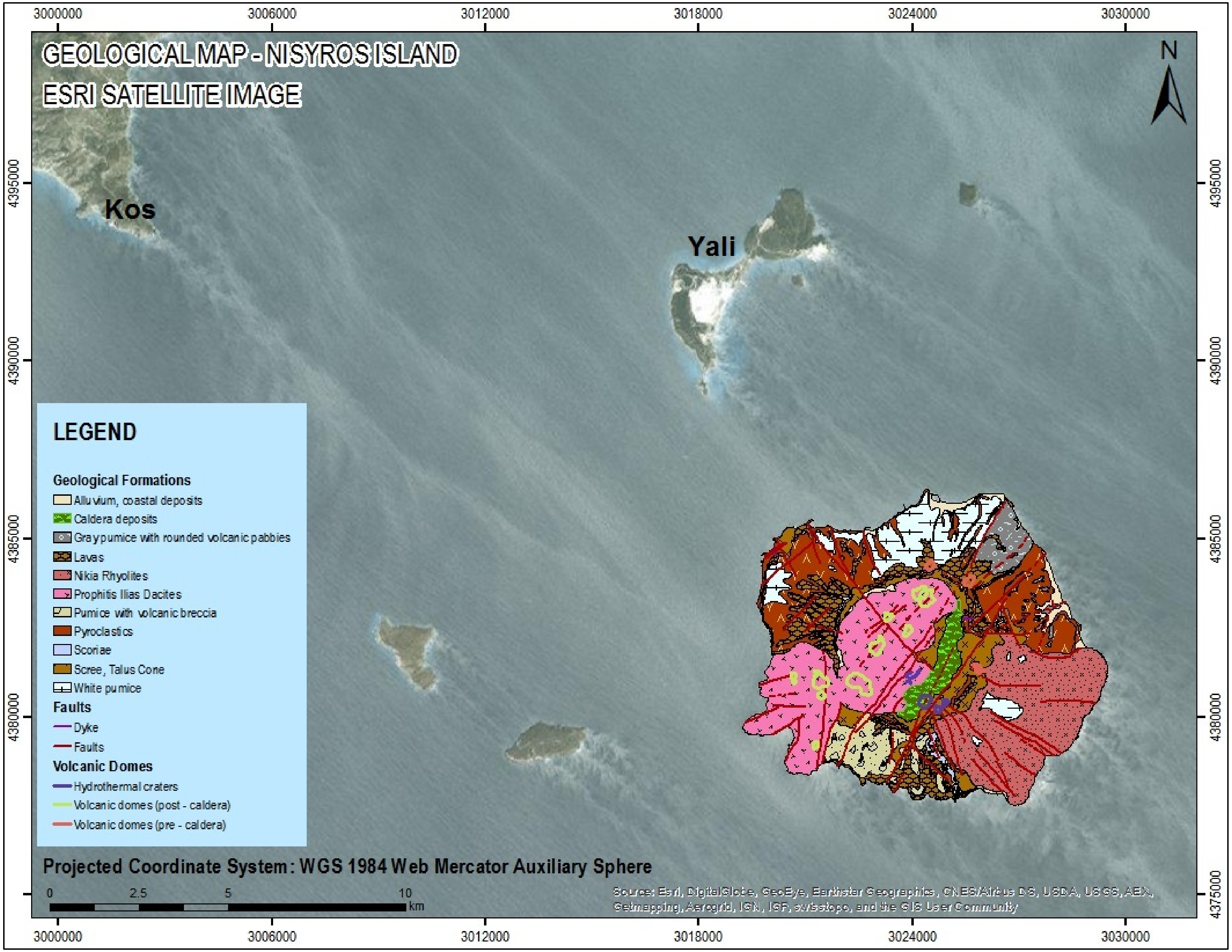


Figure 21: Geological map Satellite Image of Nisyros Island (ESRI Satellite Image)

2. VOLCANIC HAZARD

2.1 THE VOLCANISM IN THE PLATE TECTONICS CONTEXT
2.2 TYPES OF VOLCANOES
2.3 THE VOLCANIC HISTORY OF NISYROS ISLAND
2.4 A BRIEF SUMMARY OF THE GEOLOGICAL EVOLUTION OF NISYROS
2.5 GAS AND HYDROTHERMAL EXPLOSIONS WITHIN THE CALDERA
2.6 FUMAROLIC ACTIVITY
2.7 PRELIMINARY PHENOMENA
2.8 VOLCANIC RISK ASSESSMENT
2.9 THE CONCEPT OF VOLCANIC ERUPTION SCENARIOS WITHIN THE KOS-YALI-NISYROS-TILOS VOLCANIC FIELD
2.10 CONCLUSIONS

2.1 THE VOLCANISM IN THE PLATE TECTONICS CONTEXT

The plate boundaries and the hot spots often coincide with volcanic activity. About 80% of the Earth's volcanoes surrounding the Pacific Ocean, where several oceanic plates subduct beneath the neighboring mainland. Another 15% of volcanoes are also above subduction zones in the seas of the Mediterranean and Caribbean. The remainder of volcanoes are scattered along the mid-ocean ridges divergent margins of the plates (e.g. in the case of Iceland, where the mid-Atlantic ridge emerges and active volcanoes are shown), and over hot spots located inside oceanic or continental plates (eg Hawaii volcanoes National Park and Yellowstone respectively). Each type of volcano, depending on its tectonic placement within the framework of plate tectonics (Figure 22), presents its own special characteristics (type of explosion, morphological characteristics etc.).

The subduction zones favor explosive pyroclastic volcanism, due to intermediate or acid composition magmas generated there. So then the volcanism associated with subduction zones characterized by steep composite cones, which consist mainly of andesites.

Type of explosive volcanism observed in intra-continental hot spots areas, as well as in mainland taphrogenesis areas. As mentioned, in both these cases the acid or an intermediate composition rock base of the continental crust melted due to the contact with the hot, basic composition, magma rising from the mantle. Pouring acidic viscous magmas forming lava dome, calderas and volcanic ash deposits, characteristic of intra-continental taphrogenesis zones and hot spots. In continental zones tafrogenesis but in hot spots discharged and basic lavas recommendation, not necessarily simultaneously with acidic spills.

This type of dual volcanism (bimodal volcanism), found for example in the Basin and Range area of southwestern North America.

On the plates divergent zones (such as Iceland) in continental taphrogenesis zones (like in East Africa), and to the hot spots which developed within ocean plates (such as Hawaii), basaltic lavas effusions with low viscosity, create plateau lava and volcanoes with minor morphological slopes.

In tectonic plates, the only case that very rarely, if not at all, volcanic activity is observed is the one of transform faults, such as the San Andreas fault. In these cases nor any plate subduct to give andesitic lavas, nor remove to give vent to a basic composition lava from the mantle.

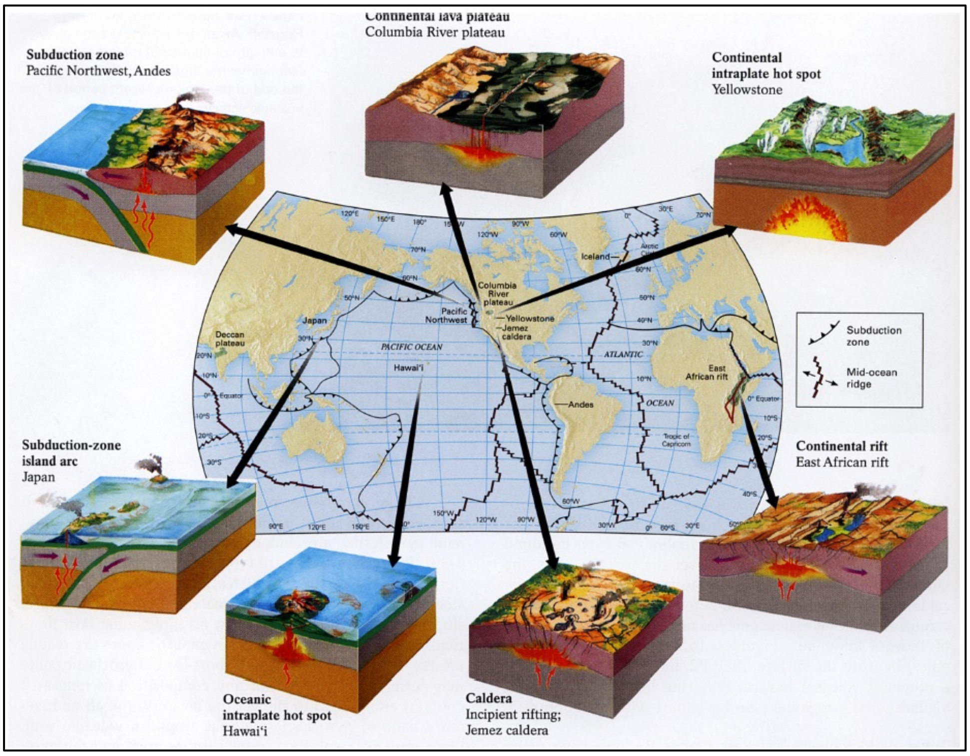


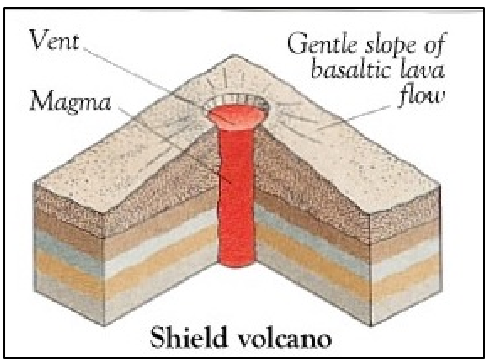
Figure 22: The distribution of volcanoes worldwide, which provides a link between the tectonic framework of the lithospheric plates and active volcanism. Noted the identification of volcanic activity with the boundaries of the plates, the most typical case of volcanoes surrounding the Pacific Ocean, and called "ring of fire" (source: Dynamic Geology, Undregraduate Courses, Faculty of Geology, National and Kapodistrian University of Athens).

2.2 TYPES OF VOLCANOES

Volcanoes exist in a number of forms, which are determined by the composition of their magma. Each particular volcanic form has a characteristic eruption style. The information and graphics in the table below summarise the most common types of volcanoes.

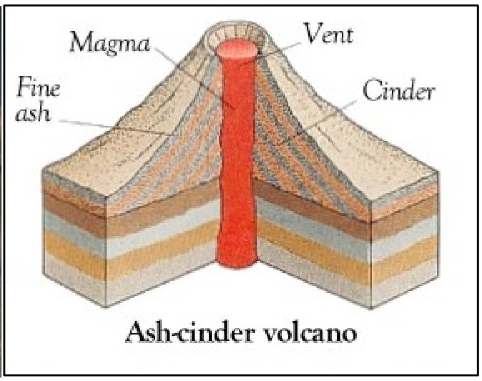
SHIELD VOLCANO

- Eruption Style: gentle, lots of magma, lava fountains and bombs.
- Magma: hot, low viscosity (runny),fast moving.
- Gas: low levels, can escape from magma.
- Shape: wide and low with gently sloping sides (from layers of lava flows cooling).
- Example: Mauna Loa, Hawaii.



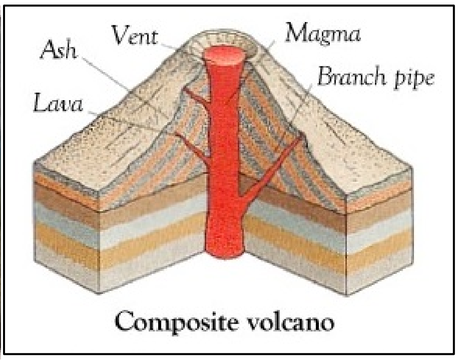
CINDER CONE

- **Eruption Style:** mildly explosive, erupt lava from breach in side or base of volcano, gas-filled lava cools to become cinders.
- **Magma:** hot, low viscosity, hot soft.
- **Gas:** expands and forms bubbles in lava, high levels.
- **Shape:** steep sides, small crater, surrounded by debris of small red or black basalt rocks with little holes (rock solidifies around bubblies).
- **Example:** Paricutin, Mexico.



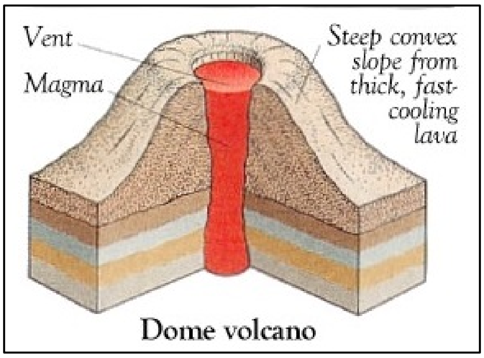
COMPOSITE VOLCANO/ STRATOVOLCANO

- **Eruption Style:** explosive, violent, lava flows, lahar, pyroclastic flows, cinders and ash clouds.
- **Magma:** slightly cooler, thick and sticky, very viscous, foams and explodes violently.
- **Gas:** high levels, pressure from gas bubbles trying to escape.
- **Shape:** regular shape, steep sided cones, rough landscape, layers of lava, rock and ash make it all.
- **Example:** Mount Fuji, Japan.



LAVA DOME

- **Eruption Style:** slow, can be violent, lava does not flow far
- **Magma:** highly viscous.
- **Gas:** low levels.
- **Shape:** hardened, thick layers of rock.
- **Example:** Mount St. Helens, USA.



2.3 THE VOLCANIC HISTORY OF NISYROS ISLAND

The Basal Volcanic Complex (ca. 160,000 to 100,000 years)

I. Basaltic to andesitic pillow lava of Panagia Spiliani

The Early-Caldera Stratovolcano (ca. 100,000 to 30,000 years):

II. Lakki Pyroclastics and Avlaki Complex (Mandraki – Avlaki lavas)
III. The Melisseri - Evangelistra - Afionas Complex (The Emborios Complex)
IV. The Ellinika - Kyra - Lies Pyroclastic Complex
V. The Argos - Stavros Complex

The Main Caldera Formation (30,000 to 15,000 years ?)

VI. The First Caldera Phase (?30,000 to 20,000 years ?)
VII. The Second Caldera Phase (20,000 to <15,000 years ?)

2.4 A BRIEF SUMMARY OF THE GEOLOGICAL EVOLUTION OF NISYROS

The island of Nisyros is a Quaternary composite stratovolcano located at the easternmost end of the Aegean volcanic arc, in the Dodecanese archipelago, south of Kos. The island is almost circular, with an average diameter of 8 km, covering an area of about 42 km2. It lies above a basement of Mesozoic limestone (Geotermica Italiana. 1983 and 1984) and a thinned crust, with the Moho located at a depth of about 27km (Makris and Stobbe 1984). Nisyros began its evolution with the submarine accumulation of basaltic-andesitic pillow lavas and hyaloclastites and eventually emerged above sea level allowing the development of a subaerial edifice.

The volcanic edifice of Nisyros with a summit caldera of a 4km average diameter is the result of a large variety of explosive and effusive eruptions producing calc-alkaline pyroclastic deposits and lavas from basaltic andesitic, dacitic, rhyodacitic, and rhyolitic composition. According to previous studies, the volcanic history has been generally assigned to four major episodes: starting with shallow marine to subaerial basaltic to andesitic volcanism followed by moderate andesitic explosive and effusive activity, building up a first major strato-cone surrounded by several satellite eruption centers (scoria and tuff cones). The present morphology of the island is finally due to two major rhyolitic plinian explosive phases each accompanied with consecutive effusive voluminous lava flows and domes, which may have followed the caldera collapses.

In 1996–1998, Nisyros showed signs of unrest with a seismic crisis accompanied by intense ground deformation and increased activity and geochemical variations of the island's fumaroles (Papadopoulos et al., 1998; Sachpazi et al., 2002; Lagios et al., 2005; Caliro et al., 2005). During this period, more than 1600 earthquakes occurred (Papadopoulos et al., 1998). Sachpazi et al. (2002) suggest that these events were compatible with the intrusion of a magmatic body at shallow depth within the crust of the Nisyros region, rather than fissure vents.

2.5 GAS AND HYDROTHERMAL EXPLOSIONS WITHIN THE CALDERA

In 1414 reported possible vapor splashing, hot water and sulfur gases release. The most recent hydroclastic eruptions in 1873 and 1888 were accompanied by earthquakes, gas detonations and fire. The latter effects are due to high gas emanations of H_2S, CO_2, H_2 and CH_4 from fracture zones, which cut the caldera.

2.6 FUMAROLIC ACTIVITY

Two types of fumarolic activity occur within the caldera crater field:

1. Degassing and steaming mud pools are present in the central parts of Stefanos and Polyvotis craters. They vary in size from a few centimeters to a meter in diameter and are the results of boiling and steam from the uppermost level of the upper hydrothermal cell. Their activity is dependent on the seasonal rainfall and. The gases with temperatures close to 100°C and are rich in H_2S, CO_2, H_2 and CH_4. The boiling muddy waters are close to sulfuric acids with a pH between 1.5 and 3.

2. The second type of fumaroles is bound to disseminated channels and fissures within the walls and rims of the craters as well as along major fracture zones. The gases with temperatures of a few degrees below or close to 100°C are also rich in H_2S, CO_2, H_2 and CH. They seem to originate from the deeper parts of the hydrothermal system.

Kinvig, Winson and Gottsmann (2010) performed a detailed and systematic assessment of the volcanic threat of Nisyros using a threat analysis protocol established as part of the USGS National Volcano Early Warning System (NVEWS). The evaluation involves a methodical assessment of fifteen hazard and exposure factors, and is based on a score system, whereby the higher the score, the higher the threat is. They draw their analysis from published data as well as from results of their research on Nisyros over the past years. They ended up that in comparison to US volcanoes both scores place Nisyros in the "Very High Threat (VHT)" category, grouping it with volcanoes such as Redoubt, Mount Ranier and Crater Lake.

Volcano Monitoring	State	Aviation - Threat	Threat	Required Monitoring	Current Monitoring	Status
Kilauea	HI	46	324	4	4	Erupting
Mt. St. Helens	WA	56	267	4	4	Erupting
Nisyros (Extreme)	–	41.6	262	4	1	Unrest
Rainier	WA	35	244	4	2	
Hood	OR	26	213	4	2	
Shasta	CA	37	210	4	2	
South Sister	OR	26	194	4	2	
Lassen Volcanic Center	CA	31	186	4	2	
Mauna Loa	HI	4	170	4	3	Unrest
Redoubt	AK	44	164	4	3	
Nisyros (Conservative)	-	31.32	163	4	1	Unrest
Crater Lake	OR	35	161	4	1	
Baker	WA	14	156	4	2	
Glacier Peak	WA	35	155	4	1	
Makushin	AK	34	152	4	3	
Spurr	AK	44	130	4	3	Unrest
Long Valley Caldera	CA	29	128	4	4	0
Newberry Volcano	OR	28	126	4	2	2
Augustine	AK	44	123	4	3	1

Table 3: Threat score for Nisyros in relation to 18 volcanoes that make up the "Very High Threat" group in the United States. Following Ewert (2007) the volcanoes that are currently displaying unrest or that are already erupting are shown in the "Status" section. The scores for Nisyros are displayed for comparison.

The scores generated by assessing the volcanic threat that Nisyros poses are more useful when seen in context with other volcanoes that have been assessed using the same scheme. Ewert et al. (2005) used the scores for the overall threat score and the aviation threat score to divide the US volcanoes into five threat groups from "Very High" to "Very Low". Both of the scores attained by Nisyros place the volcano in the "Very High Threat" category. For illustration, Table 3 shows the rank that these scores would give Nisyros among the 18 US volcanoes in this category.

2.7 PRELIMINARY PHENOMENA

1. Earthquake activity
    - Increased seismic activity at local level
    - Muffled roar
2. Soil deformations
    - Bulges or upward movements in the volcanic cone
    - Slope changes near the volcano

3. Hydrothermal phenomena
    - Increased supply of hot springs
    - Increased gases release in the fumarole
    - Hot springs or gases warming in fumarole
    - Destruction of vegetation on the slopes of the volcano
4. Chemical changes
    - Changes in the chemical composition of the emitted gases

Before volcanic eruption, there is an increase in temperature. These thermal anomalies are detected in the soil, hot springs, and the crater fumarole, where the gas temperatures rise. The thermal anomalies are observed using telescopes and infrared sensors on satellites. The increase in temperature causes changes in rock formations to a point where they lose their magnetic qualities and gravitational properties, while their electrical conductivity gets disrupted.

2.8 VOLCANIC RISK ASSESSMENT

Assessment and management of volcanic risk are important scientific and economic issues, especially in densely populated areas threatened by volcanoes. The best treatment of these aspects requires accurate assessment and mitigation programs, the development of effective tools for prediction and management of crisis and the promotion of sustainable development within such regions.

Evaluation of volcanic risk is extremely complex because it can involve different hazardous phenomena including pyroclastic and lava flows, fallout of ash and tephra, earthquakes and landslides. Volcanic hazard assessment implies many steps, usually computed with different tools. This fact can be the origin of many errors, both made by the different operators or due to the transfer between different systems. It also could make all the procedure a high time-consuming process, therefore reducing the available time for a quick response in the case of a volcanic unrest.

The devastation of volcanic activity may be due to:

- Toxic gases: Numerous gases as carbon dioxide vapors, carbon monoxide, hydrogen sulphide, etc. Both are emitted both during volcanic activity, and during interim periods.
- Pyroclastic Activity: It is a characteristic activity of magma with high silicon content. During pyroclastic activity all kinds of volcanic suspensions are observed, which are ejected from a volcanic conduit to the atmosphere. The explosions are quite intense and their speed, in some cases, outstrip the speed of sound. The materials can be transported over long distances and can cover hundreds of square kilometers. The pyroclastic activity has a direct impact on the environment and in particular flora and fauna, while disasters in residential areas and in construction are important.
- Fires: Fires caused to the surrounding area of the volcano, from the high temperatures that prevail and which can reach several hundred degrees of Celsius Nonetheless, the risk of fire due to the volcanic activity is extremely low.
- Mud Flows: Caused when reached saturation in large volumes of volcanic ashes and other volcanic products, so there is moving to lower altitudes with high speeds.

- Lava Flows: They take place when the magma reaches the surface and overflow the crater covering the sides of the volcano. They move quite slowly especially when exhibiting large viscosity thus give people the possibility of reaction and precaution. Several methods have been adopted at times to divert handle flows as bombings, hydraulic cooling and wall construction-dams. These methods do not intended to block large flows but precaution and inhibition some lava flows progression.

2.9 THE CONCEPT OF VOLCANIC ERUPTION SCENARIOS WITHIN THE KOS-YALI-NISYROS-TILOS VOLCANIC FIELD

The GEOWARN Product Early Warning System and Emergency Plan for Nisyros and the surrounding volcanic field, indicates that earthquakes, volcanic eruptions, and hydrothermal explosions are seen as primary hazards; and landslides, tsunamis, rock falls, and mudflows are considered secondary hazards resulting from earthquakes and volcanic activity.

Three major types of primary volcanic eruption scenarios can be considered (Figure 24):

- "Strombolian eruptive activity": eruptive activity during a short period of time (days to weeks). Strombolian eruptions are distinct bursts of fluid lava (usually basalt or basaltic andesite) from the mouth of a magma-filled summit conduit.
- "Vulcanian eruptive activity": explosive eruptive activity (phreatomagmatic) during a short to intermediate period of time (weeks to months). Vulcanian eruption is a short, violent, relatively small explosion of viscous magma (usually andesite, dacite, or rhyolite).
- "Plinian eruptive activity": strong to extreme explosive eruptive activity (phreatomagmatic) during an intermediate to long period of time (months to a few years). The largest and most violent of all the types of volcanic eruptions are Plinian eruptions. They are caused by the fragmentation of gassy magma, and are usually associated with very viscous magmas (dacite and rhyolite).

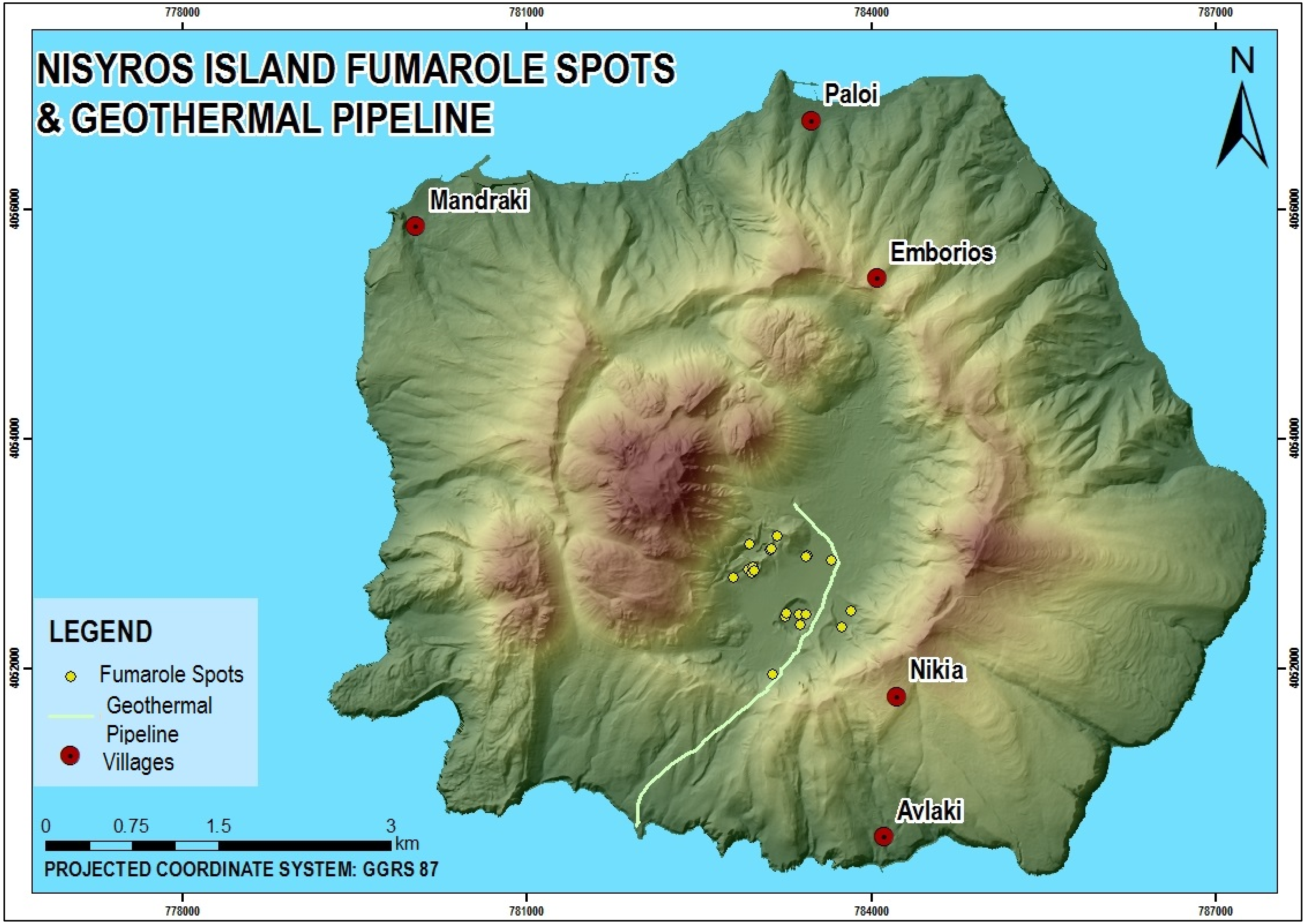


Figure 23: Fumarole Spots and Geothermal Pipeline

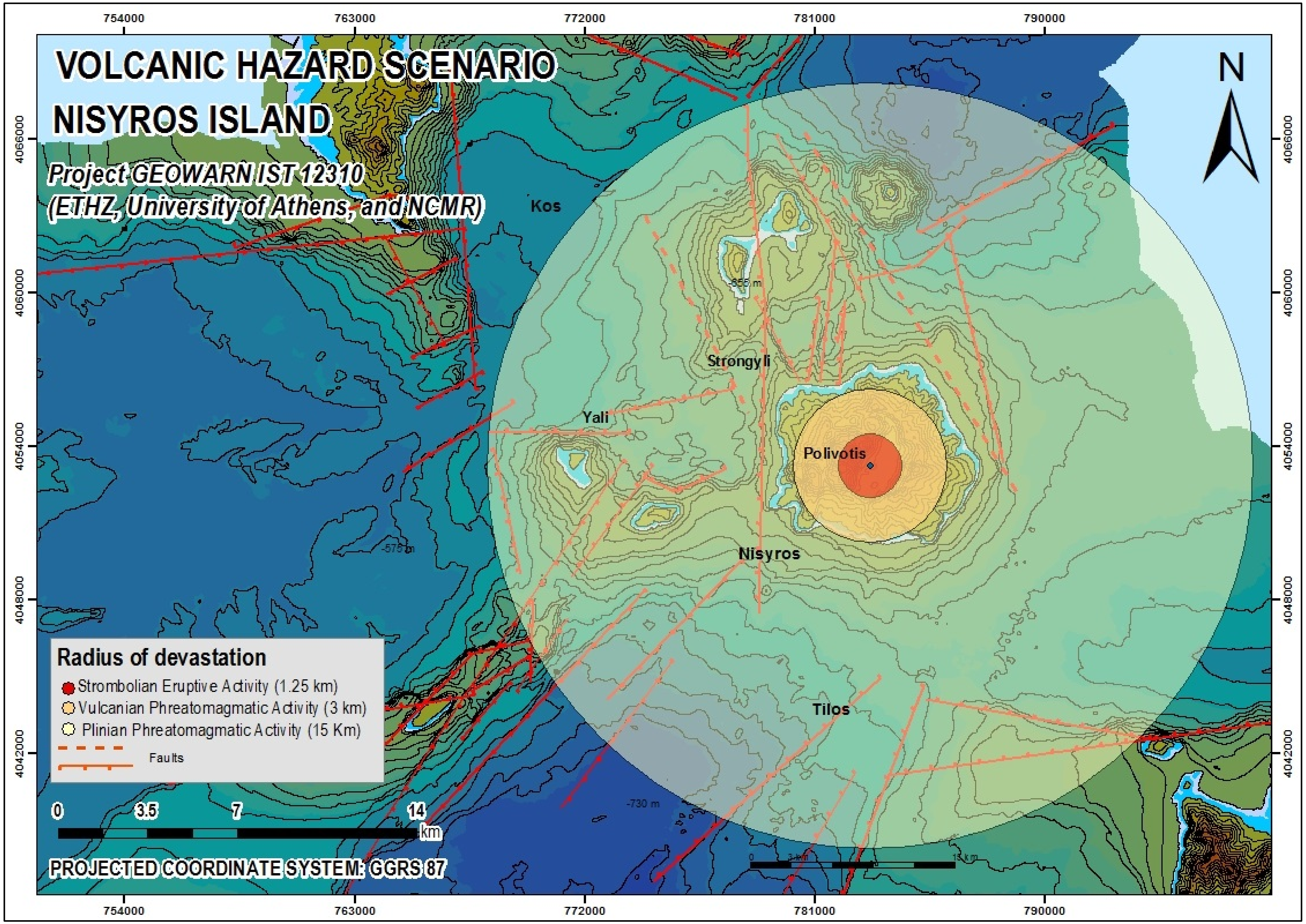


Figure 24: Volcanic Hazard Scenario (processed map based on the GEOWARN Project, 2003)

2.10 CONCLUSIONS

Long-dormant volcanoes like Nisyros require rapid hazard assessment, given that possible onset of eruption may be within days to months of the start of unrest. Assessments have to be made promptly to inform decision making, emergency management services and planning for a future eruption. It is recommended a blueprint for rapid ash and gas assessment for other long-dormant volcanoes.

However, the level of hazard is also influenced by the intensity of the event, the altitude over which the volcanic material is released, distance from the vent and the occurrence of precipitation.

Adequate supplies of dust masks are recommended for citizens and tourists and regular monitoring of the air quality (ash and gas concentrations) during the eruption is advised. The combination of fine ash and gas with dry, hot or windy weather may also require further precautions to be undertaken, such as partial or full evacuation. In addition to the health impacts of fine ash exposure, agriculture is likely to be adversely affected by fine ash and acid rain, especially in the growing seasons of spring and early summer.

Volcanic activity in the last thousand years happens within the caldera of the Nisyros volcano, particularly in the southeast part, where all relatively recent craters reserved.

So based on the above, there is a serious risk of phreatic or hydrothermal explosion, similar to those of the previous century pyroclastic activity and poisonous gases release. The last lava effusion occurred 10,000 years ago, when the Prophitis Ilias domes created, so the risk of extensive lava flow with the current data appears to be low.

Consequently, the hazard is considered to be high.

In conclusion, the main measure of protection for Nisyros is the correct information for residents and tourists especially during the summer months, for risks during their visit to the craters.

3. LANDSLIDE HAZARD

3.1 THE CONSEPT OF LANDSLIDE DISASTER
3.2 FACTORS INFLUENCING LANDSLIDES
3.3 GEOGRAPHIC INFORMATION SYSTEMS (GIS) & MULTI-CRITERIA DECISION ANALYSIS FOR LANDSLIDE HAZARD ASSESSMENT
3.4 LANDSLIDE HAZARD INVESTIGATION OF TRIGGERING FACTORS IN NISYROS ISLAND
3.5 **THE** WEIGHTED LINEAR (WLC) METHOD
3.6 LANDSLIDE SUSCEPTIBILITY MAPS
3.7 LANDSLIDE HAZARD MAP
3.8 LOCATION OF METEOROGICAL STATIONS OF HELLENIC NATIONAL METEOROGICAL SERVICE (HNMS) AND THE AVERAGE ANNUAL PRECIPITATION
3.9 LANDSLIDE REMEDIATION WORKS AT THE PANAGIA SPILIANI MONASTERY
3.10 CONCLUSIONS

3.1 THE CONCEPT OFLANDSLIDE DISASTER

The generalized term "landslide" encompasses all downward movements along a soil or rock slope, which occur mainly as a result of shear failure within the limits of the landslide mass (Skempton & Hutchinson, 1969). Landslide is an important geological hazard that causes damage to natural and social environment. Many authors have given different definitions on the the landslide term. Varnes and IAEG (1984) defined landslides as 'almost all varieties of mass movements on slope including some such as rock falls, topples and debris flow that involve little or no true sliding'. Brusden (1984) considered landslides as a unique form of mass transport and a process which do not require a transportation medium such as water, air or ice. Crozier (1986) defined landslides as 'the outward and downward gravitational movement of the earth material without the aid of running water as a transporting agent. According to Hutchinson (1988), 'A landslide in its strict sense is a relatively rapid mass wasting process that causes the down slope movement of mass of rock, debris or earth triggered by variety of external stimulus'. A recent definition by Courture R (2011) simply states that 'landslide is a movement of mass of soil (earth or debris) or rock down a slope'. This concept of landslide is more broaden with respect to the type of material that moves down slope.

Wanting to describe in simple words the term landslide we could define the phenomenon, as the mass movement of a slope (rock or soil) whose center of gravity is moved downwards and outwards. Another equally simple definition is the slope segment piece which is separated from the fixed portion in a well-defined surface.

Landslide processes are part of the normal geomorphic cycles of landscape development. They become hazardous when they interfere with human activities. They are especially serious in developing countries where environmental protection and management are harder to sustain. Over 95% of all disasters and fatalities related to landslide in particular, and mass movement in general occur in developing countries (Hansen, 1984, Chung, 1995). Up to 0.5% of the GNP of these countries have been lost by landslides (Fournier D'Albe, 1976). In the world, annual economic losses due to landslides are estimated to be in the order of two to five billions of US Dollars (Schuster, 1994).

The stability of the slopes and the type of landslide affected by many factors, including geological - geotechnical conditions, hydrogeological conditions, topography, climate and land use. The classification of landslides can be done in many ways, the most important of which are the basis of the material (soil or rock), movement (activation, flow, creep) and other features, such as speed, depth of burglary and the content water.

Landslide hazard mitigation is the principal goal of landslide hazard assessment, which results in the production of hazard and risk maps. Natural hazard mapping includes delineating the occurrences of phenomena such as landslides, flooding, earthquakes, and volcanism in the past, and prediction about the occurrences of such phenomena in the future (Varnes, 1984). It also concerns defining zones in terms of the probability of occurrences of potentially damaging phenomena within a certain span of time. During hazard mapping, information in the form of DEM, and from thematic maps on geology, geomorphology, land-use, topography and drainage network of the area are required depending on the scale of the hazard map to be produced.

3.2 FACTORS INFLUENCING LANDSLIDES

- Geological (structure and geometry of geological formations, ground or rock type).
- Topographic - geomorphological (slope geometry, land surface slope, aspect slope).
- Hydrological, climatic and hydrogeological factors.
- Mechanical (human intervention through charging enforcement at the top of the slope. e.g. embankments, buildings, seismic loading, digging at the base of slopes for opening roads ...)
- The groundwater level and/or the surface water.

The role of water is often decisive as exercised hydrostatic pressures reduce the stability of the slope, while on the rocky slopes, the rotation of the water phase increases the range of discontinuities and facilitate the movement of water at deeper points. Furthermore, when the water moves between permeable layer acts as a lubricant.

For the classification of landslides, various proposals have been suggested, at times, by many researchers. In each case classification is given particular emphasis to one or some of the factors of landslide, such as the type, speed, age and movement reasons, the type of material, the geometry of the phenomenon in relation or not with the geological structure and morphology.

One of the most comprehensive classifications which have been proposed is the classification by Varnes, taking into account several factors such as the type of movement, the type of transformed materials, the type of motion, etc.

The landslide classification based on Varnes' system (1978) has two terms:

- the first term describes the material type,
- the second term describes the type of movement.

TYPE OF MOVEMENT		TYPE OF MATERIAL		
		BEDROCK	ENGINEERING SOILS	
			Predominantly coarse	Predominantly fine
FALLS		Rock fall	Debris fall	Earth fall
TOPPLES		Rock topple	Debris topple	Earth topple
SLIDES	ROTATIONAL	Rock slide	Debris slide	Earth slide
	TRANSLATIONAL			
LATERAL SPREADS		Rock spread	Debris spread	Earth spread
FLOWS		Rock flow	Debris flow	Earth flow
		(deep creep)	(soil creep)	
COMPLEX	Combination of two or more principal types of movement			

Table 4: Classification of slope movements based on the material type (Varnes, 1978)

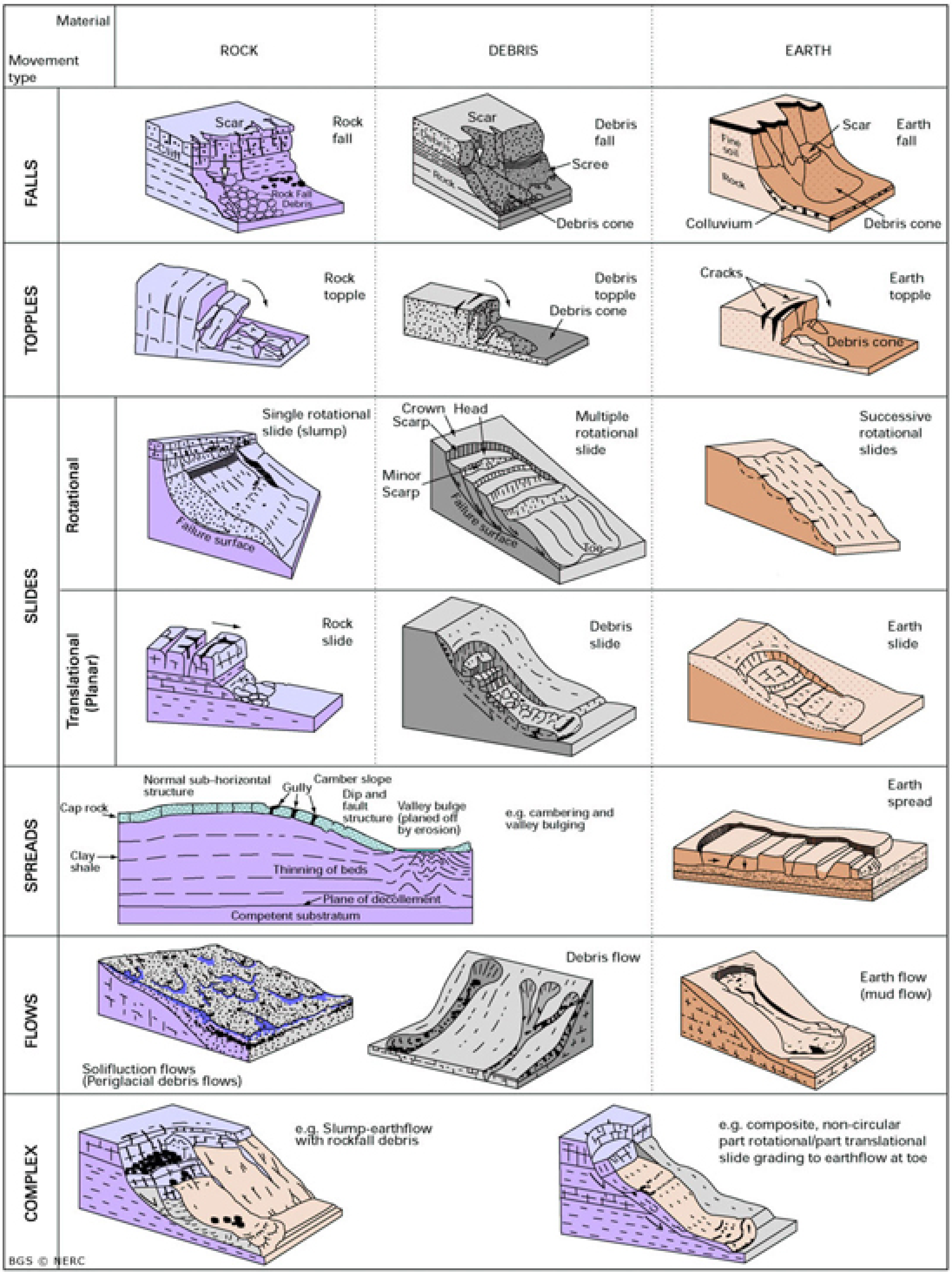


Figure 25: Classification of slope movements base on the type of movement (Varnes, 1978)

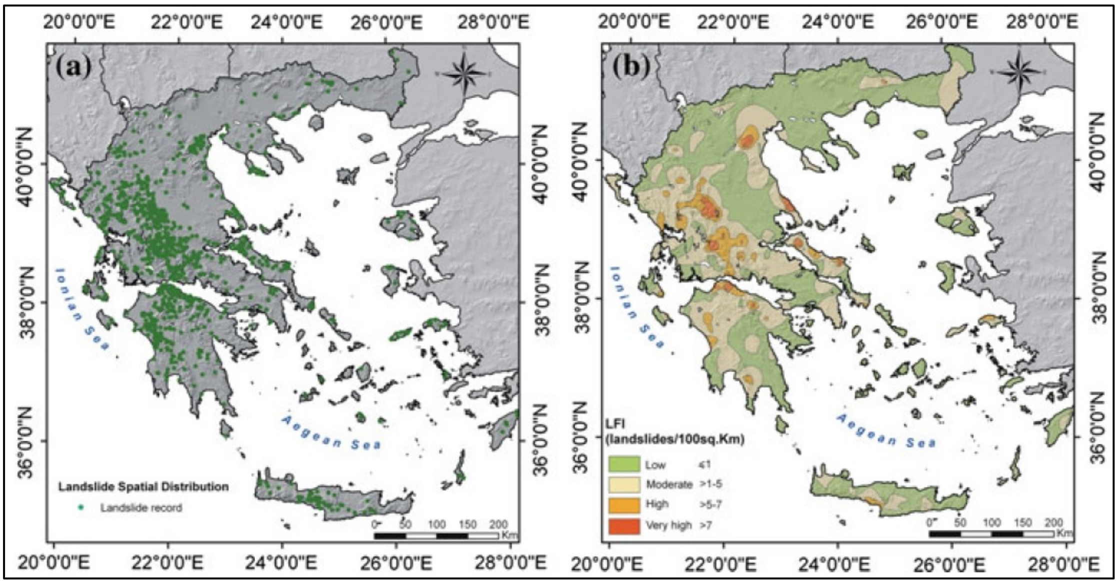


Figure 26: a) historical landslide events map showing the spatial distribution of the recorded events, b) Landslide Frequency Index (N. Sabatakakis, G. Koukis, E. Vassiliades, S. Lainas, Natural Hazards 2013)

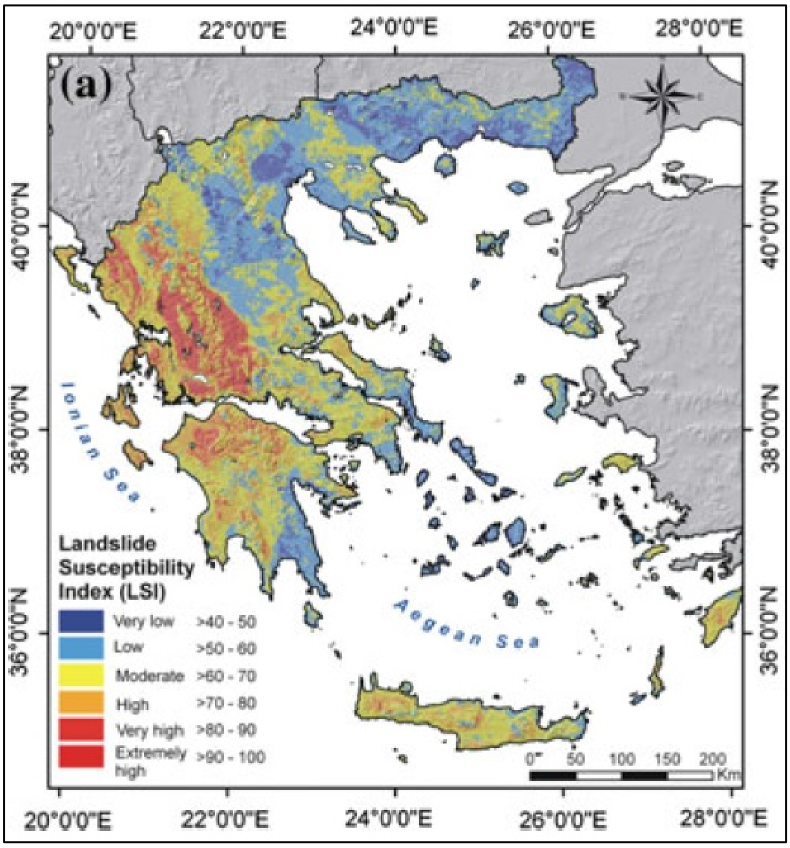


Figure 27: Landslide Sensitivity Index distribution zones in Greece (N. Sabatakakis, G. Koukis, E. Vassiliades, S. Lainas, Natural Hazards 2013)

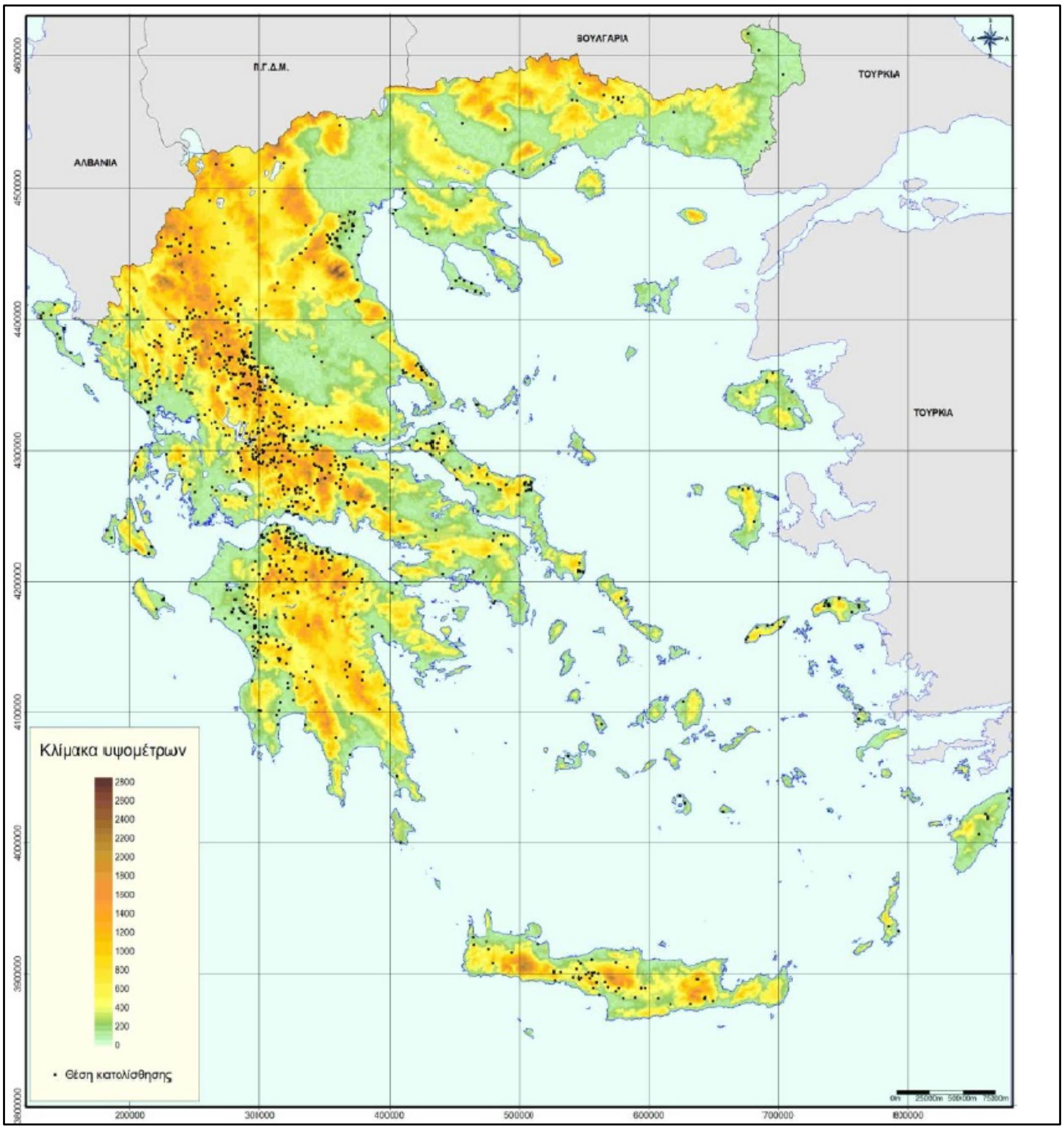


Figure 28: Topographic map with the locations of 1238 recorded landslides in Greece (Vassiliades, 2010)

The lithological-geotechnical context of Nisyros, because of the morphological characteristics it bears as a volcano, it could be favoring landslides. Below, it is given brief information on the geotechnical behaviour of the geological formations.

- Lavas: They are usually in the form of structures, domes, streams and rarely veins. It basically hard rock developed with a dense network of discontinuities resulting from their rapid cooling. Classified as rock formations to carry out excavation is necessary to use powerful mechanical means or explosives.
- Pyroclastic Rocks: They are mostly layered formations, characterized by relative ease of weathering and erosion, with good to moderate strength.
- Volcanic Ashes: Where intercalations of volcanic ashes are found, special attention is necessary, as this is a form of moderate strength.
- Scree: The scree consists of loosely to moderate bonded conglomerates, gravels with little clay.

3.3 LANDSLIDE HAZARD ASSESSMENT

In this study, several spatial data such lithological map, slope map, aspect map, road network map, faults map and land use map of Nisyros island have been collectively considered to produce the landslide hazard map. The data were superimposed using a common geographic reference grid, using GIS techniques. Then, to produce the landslide hazard map, the value of each grid cell in the overlays were summed and divided by the total number of event controlling parameters using the following formula (Papatheodorou):

Risk map = (([azimuth] <= [slope aspect] + 20) + ([azimuth] <= [slope aspect] - 20) + ([slope inclination] >= [layers slope]))

However, the final map obtained for the landslide risk from this condition was deemed unreliable and quite simplified. This is due to the fact that this approach does not take into account many of the important parameters that affect landslides.

For more reliable results, the method that used was the Multi-Criteria Decision Analysis which is based on the “Analytic Hierarchy Process” (Saaty 1980) and the Weighted Linear Combination (WLC) Method.

3.4 GEOGRAPHIC INFORMATION SYSTEMS (GIS) & MULTI-CRITERIA DECISION ANALYSIS FOR LANDSLIDE HAZARD ASSESSMENT

So, for the landslide hazard assessment of this case-study, the Multi-Criteria Decision Analysis method was implemented in combination with the use of GIS. This method is based on “Analytic Hierarchy Process” (Saaty 1980) and the “Weighted Linear Combination Method”.

The aim is, through the combination of different levels of information where each one represents a landslide enhancing factor, categorized based on a uniform scale and certain "significance weight", to construct a final landslide hazard map.

The choice of this method was made because it is a fast and economical method of risk assessment, while requires data that are immediately available from various carriers and the Internet.

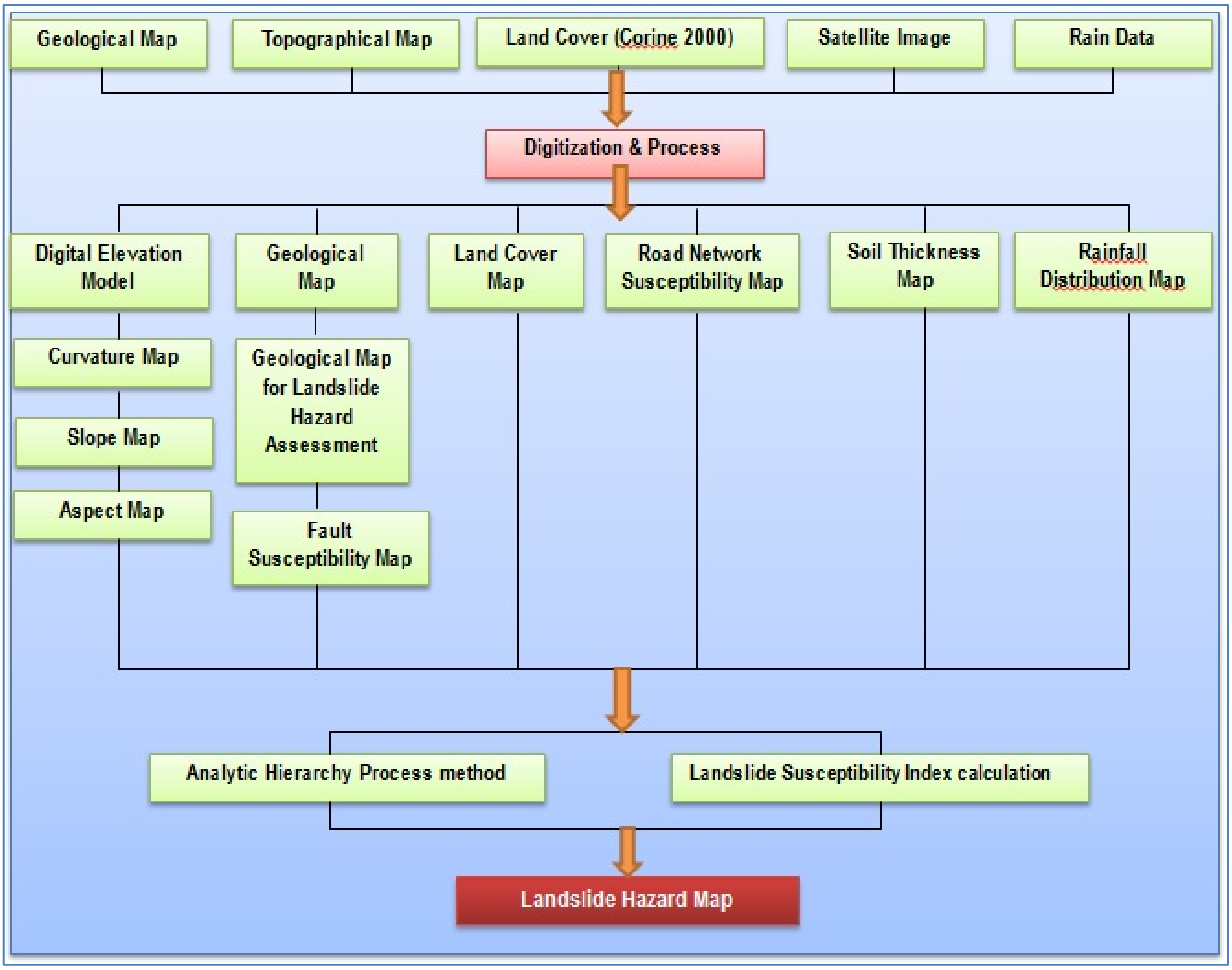


Figure 29: Multi-Criteria Decision Analysis flow chart for landslide hazard assessment

For the implementation of this method were digitized data taken from the Hellenic Military Geographical Service (maps scale 1:50000), geological maps based on the GEOWARN Project, the European Land Cover Program (CORINE 2000), the European Soil Geographical Database and annual rainfall data from rainfall stations.

Utilizing the above data using G.I.S, ten thematic maps were created where each one represents a factor that controls/enhances landslide susceptibility. Each thematic map transformed into raster form, divided into classes which with the Weighted Linear Combination method were normalized to a scale 0-100. Then, using the Analytical Hierarchical Process (AHP) for each of the 10 factors, a materiality weight was defined, according to its key role to landslide susceptibility.

In the final step, the thematic maps multiplied with the proportional weight of each and added to give the final landslide hazard map.

3.5 LANDSLIDE HAZARD INVESTIGATION OF TRIGGERING FACTORS IN NISYROS ISLAND

The factors selected as most important for the production of the final hazard map based on available data and the specific characteristics of Nisyros Island are:

- geological formations types
- morphological slopes
- soil layer thickness
- land use
- the distance from faults
- the distance from the road network
- curvature
- aspect slopes
- rainfall

Geological Formations Type

The type of geological formations and their mechanical behavior is a very decisive factor for the stability of slopes. According to the classification made, greater susceptibility show the scree while the alluvial show the lower (usually located in flat areas).

Morphological Slopes

Morphological slopes are a key factor to the landslides. It determines the flow of surface water and groundwater, while controlling and territorial horizon moisture content. Also, it is a critical factor as influencing the shear strength of the cluster responsible for the slippage. The slope map derived from the Digital Elevation Model into degrees. The classification used is as follows:

i)< 5^o , ii) 5^o –15^o, iii) 15^o – 30^o , iv) 30^o – 45^o v) >45^o.

In general, we can consider that as morphological slope increases, landslide susceptibility increases too. It has been observed, though, that at very large gradients (>45^o), formations which are coherent and rocky, generally ensure stability of slopes to slip, but are prone to collapses. The slope angle is an essential component of landslide analysis. As the slope angle increases, shear stress in soil or other unconsolidated material generally increases as well. Gentle slopes are expected to have a low frequency of landslides because of generally lower shear stresses associated with low gradients.

Soil Layer Thickness

In case of soil layer thickness, the landslide occurrence probability value is lower dependent on the thickness increasing. When there is heavy rain, the soil is thicker and there is more space, so the soil can contain more water

The soil layer thickness determines its ability to bind more or less water and create slip conditions between its contact with the underlying bedrock. The distribution data of soil layer thickness were obtained by the European Soil Geographical Database, scale 1: 1.000.000.

Land use

A key factor to the appearance of landslides is the land use and the anthropogenic interventions. It is generally accepted that the type and density of vegetation controls the flow and infiltration of surface water after a rainfall, while providing mechanical support territories with the root system, affecting the stability of slopes.

Therefore, areas with sparse or no vegetation are more sensitive to the effects of atmospheric factors and as a result have frequently volatility relative to forests and areas with dense vegetation. Rural areas and arable land are generally considered to have a lower risk of landslide, since they usually grow at low morphological slopes and precautions are taken by the owners where there are problem.

Aspect Slopes

A factor taken into consideration is the aspect slopes which are exposed to wind and sunlight for long periods during the year may show greater susceptibility to landslides. In the study area the North and Northeast aspects make the slopes more vulnerable to landslides.

Distance from the Road Network

The development of roads causes an imbalance to the formations, thus increasing their susceptibility to landslides.

The road network map below, presents a 50m zone of effectiveness (Figure 36) either side of the road, where the susceptibility is enhanced. Beyond this distance we consider the existence of the road network does not affect the balance of the formations.

Distance from faults

Generally, large fault zones are characterized by abrupt morphological discontinuities forming cliffs. The geological formations that are located in a short distance are usually tectonic fatigued and have a reduced resistance to any disturbance either by human interference, or by atmospheric action. Particularly, if the fault zone is characterized active, there are frequent changes in the relief in the form of landslides.

A thematic map was created (Figure 37) with a high susceptibility effectiveness zone up to 150m distance from any fault and a second zone of low susceptibility between 150 - 300m. Beyond 300m it is considered that the formations are not affected by the faults (Ladas, 2007).

Curvature

One commonly used parameter in landslide-hazard analysis that is in need of further investigation is plan curvature. Plan curvature is the curvature of the hillside in a horizontal plane or the curvature of the contours on a topographic map. Hillsides can be subdivided into regions of concave outward plan curvature called hollows, convex outward plan curvature called noses, and straight contours called planar regions. Statistical analysis of plan-curvature and landslide datasets indicate that hillsides with planar plan curvature have the highest probability for landslides in regions dominated by earth flows and earth slides in clayey soils. The probability of landslides decreases as the hillsides become more concave or convex. Hollows have a slightly higher probability for landslides than noses. In hollows landslide material converges into the narrow region at the base of the slope. The convergence combined with the cohesive nature of fine-grained soils creates a buttressing effect that slows soil movement and increases the stability of the hillside within the hollow. Statistical approaches that attempt to determine landslide hazard need to account for the complex relationship between plan curvature, type of landslide, and landslide susceptibility.

Curvature values represent the morphology of topography. A positive curvature indicates that the surface is upwardly convex at that cell. A negative curvature indicates that the surface is upwardly concave at that cell. A value of zero indicates that the surface is flat. In the case of curvature, the more negative the value, the higher the probability of landslide occurrence. In particular, for negative values, the lower the value, the higher the landslide probability. From the result, curvature is related to landslide occurrence.

Rainfall

The rainfall parameter is very important because their intensity and frequency affect the stability of slopes. When there is heavy rain, the poorer drainage there is to control water flow, the more water is contained in the soil. For this reason, landslide probability is higher. The climate in Nisyros is characterized as dry. The rainfall data listed below were taken by the Hellenic National Meteorological Service (HNMS).

STATION	STATION CODE	HEIGHT (m)	CARRIER	PERIOD OF OPERATION	AVERAGE ANNUAL PRECIPITATION (mm)
KOS	16742	50	HNMS	1981-2008	88
KOS-POLI	16740	127	HNMS	1961-1981	74
LEROS	16768	11	HNMS	1986-2004	42
RODOS	16749	11	HNMS	1955-2013	80

Table 5: Rainfall data taken by Meteorological Stations adjacent to Nisyros island (source: Hellenic National Meteorological Service)

3.6 **THE** WEIGHTED LINEAR COMBINATION (WLC) METHOD

The implementation of a multi-criteria assessment method (Voogd, 1983 and Carver, 1991) requires the combination of several factors - criteria for extracting a final result. The approach of Weighted Linear Combination is the best known and most commonly used method, with high reliability when using data in raster format (Eastman, 2006). The information levels must be apart from the importance weight and a categorization into a single scale that can be combined. The scale used is from 0-100 and the normalization of initial classes in the thematic maps was held based on the formula:

$$X = (R / Rmax) * \text{standardized range}$$

where X is the normalized value, R is the initial categorized class value, Rmax the maximum value of the categorized classes and standardized range is equal to 100.

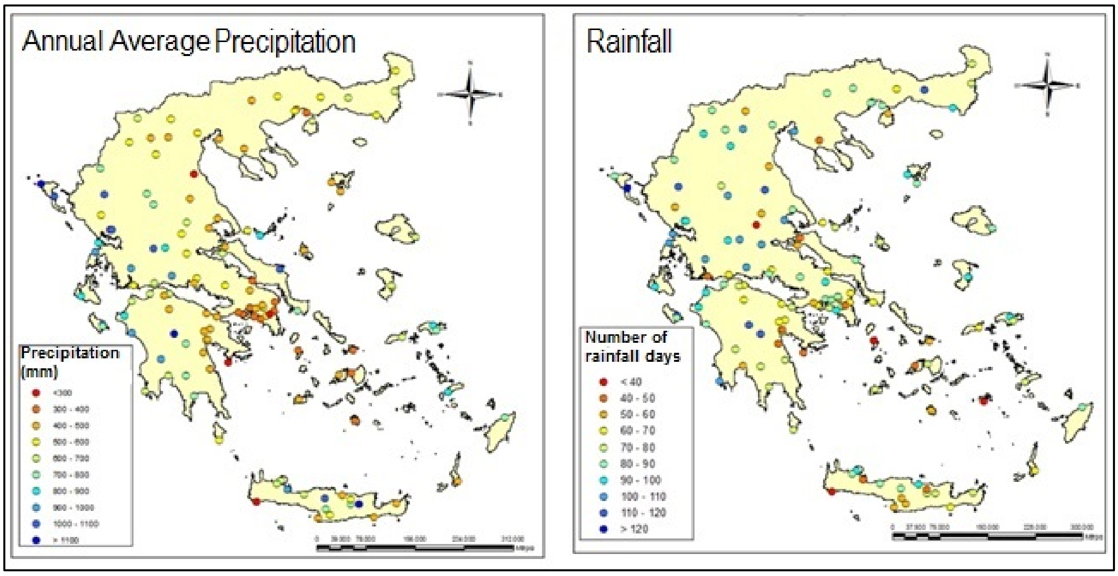


Figure 30: Annual average precipitation and rainfall days (source: Farmaki, E., 2012)

3.7 LANDSLIDE SUSCEPTIBILITY MAPS

In these maps, each polygon or each event controlling parameter represent an area assumed to have similar degree of vulnerability to landslide. They were weighted and have been given numeric values (priority values) according to their relative vulnerability.

Factors	Materiality weight	Classes	Landslide Susceptibility (0-5)	Normalized Values
Lithology	0,25	Scree, Talus Cone	5	100
		Various Pumice deposits, Caldera deposits	4	80
		Pyroclastics	3	60
		Lavas	2	40
		Nikia Rhyolites, Scoriae	1	20
		Alluvium, Coastal deposits	0	0
Slope (°)	0,20	>45°	5	100
		30°-45°	4	80
		15°-30°	3	60
		5°-15°	2	40
		<5°	1	20
Land Use	0,15	Olive Groves-Pastures	5	100
		Grassland	4	80
		Forest Land	3	60
		Agricultural Land	2	40
		Barren Land	1	20
Distance from road network	0,10	<50m	1	100
		>50m	0	0
Distance from faults	0,10	<150m	2	100
		150-300m	1	50
		>300m	0	0
Soil layer thickness	0,06	Very Deep (>120cm)	4	100
		Deep (80-120cm)	3	75
		Moderate (40-80cm)	2	50
		Shallow (<40cm)	1	25
Curvature	0,06	Concave (<-1,5)	3	100
		Less Concave (-1,5 - -0,1)	2	66
		Flat (0)	1	33
		Convex (>0)	0	0
Rainfall distribution	0,05	1000-1200mm	4	100
		800-1000mm	3	75
		400-800mm	2	50
		<400mm	1	25
Aspect	0,03	N and NE directions (0°-22,5° / 22,5°-67,5°)	1	100
		Other directions (67,5°-360°)	0	0

Table 6: Factors materiality weight and classes with respective classification

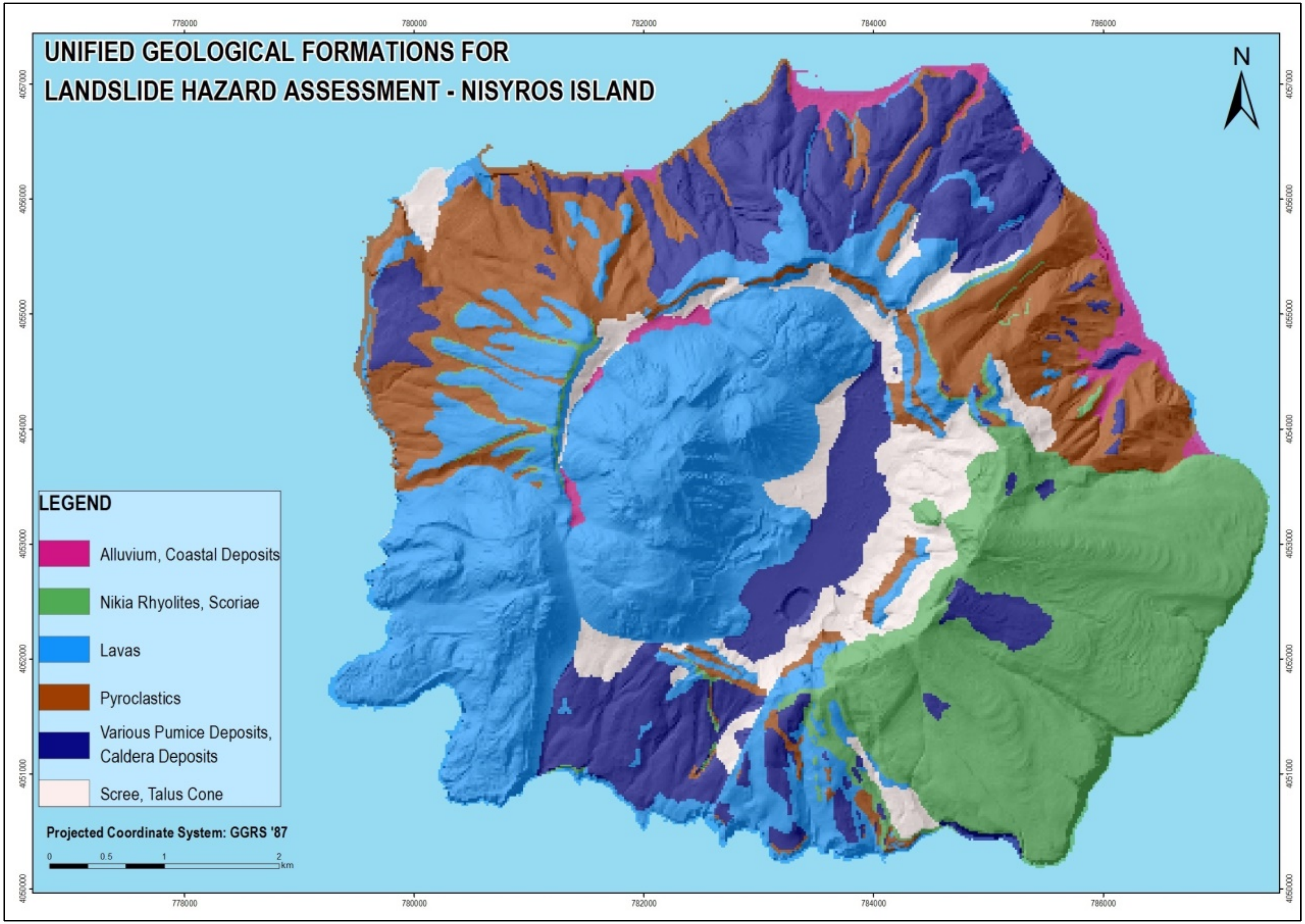


Figure 31: Unified geological formations for landslide hazard assessment

Figure 32: Soil layer thickness satellite image (processed by Google Earth, version 7.1)

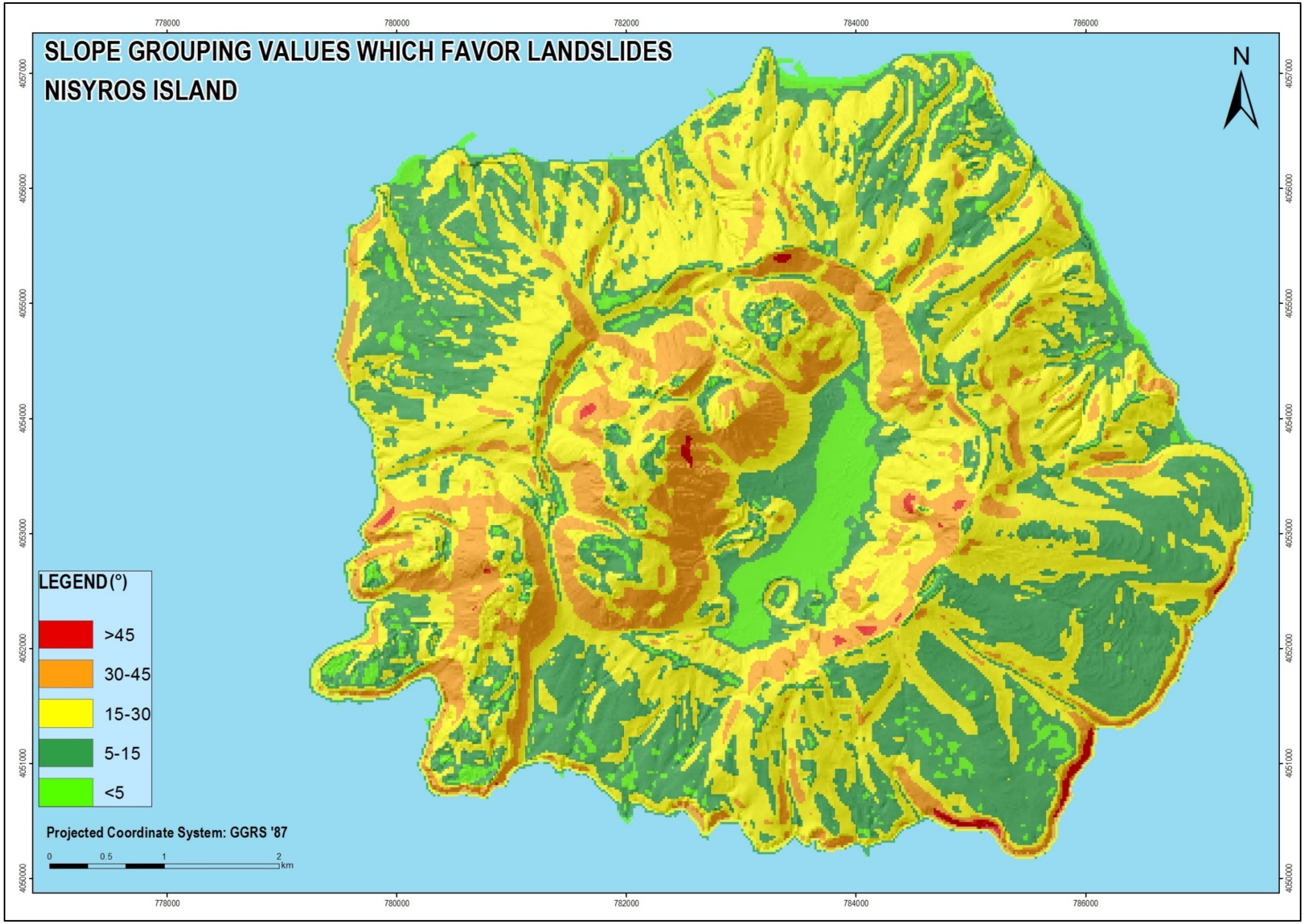


Figure 33: Slope grouping values which favor landslides

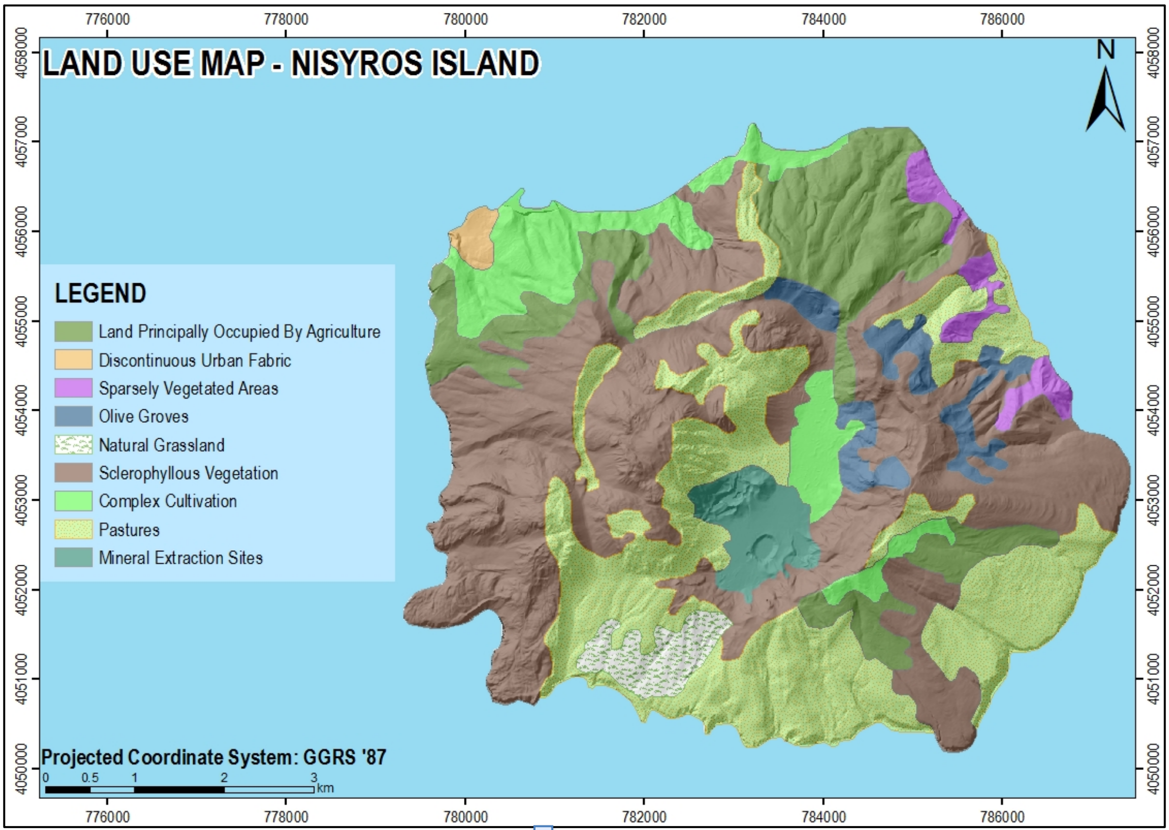


Figure 34: Land Use Map (Corine 2000)

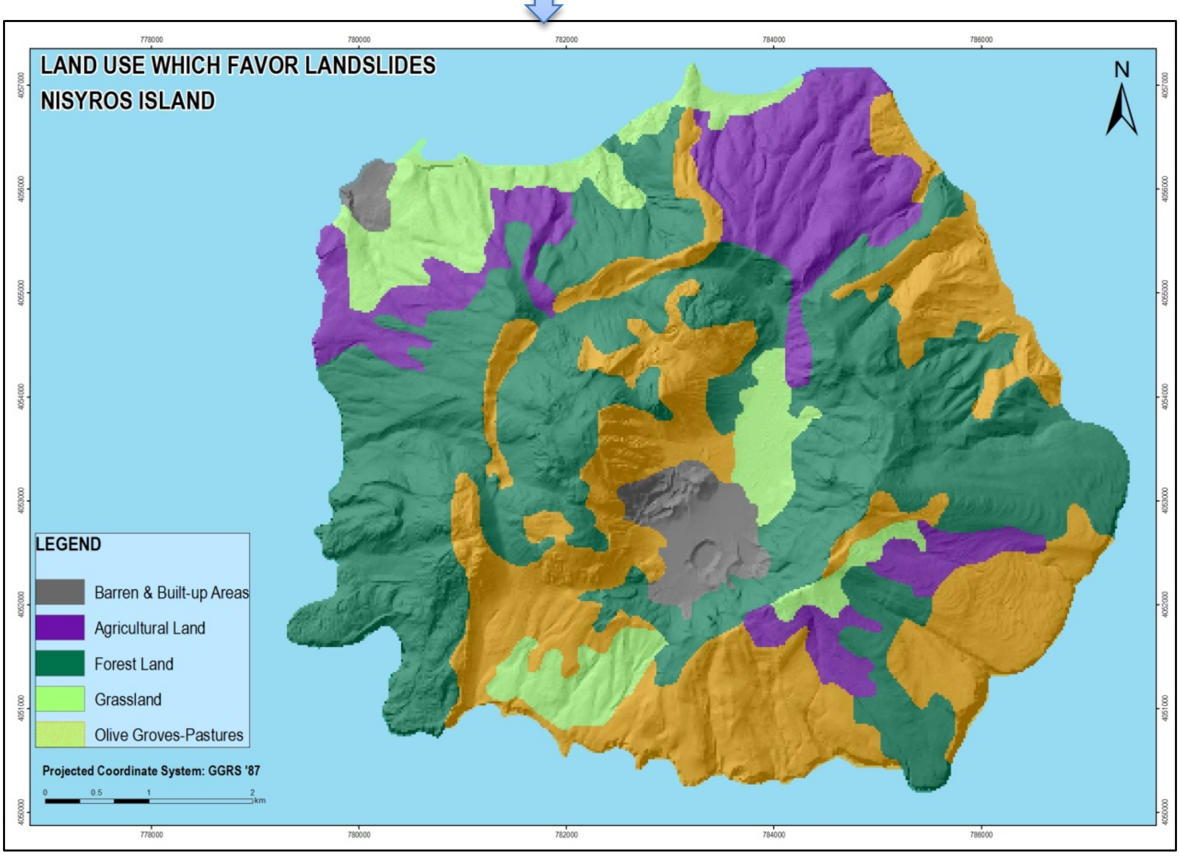


Figure 35: Land Use which favor landslides

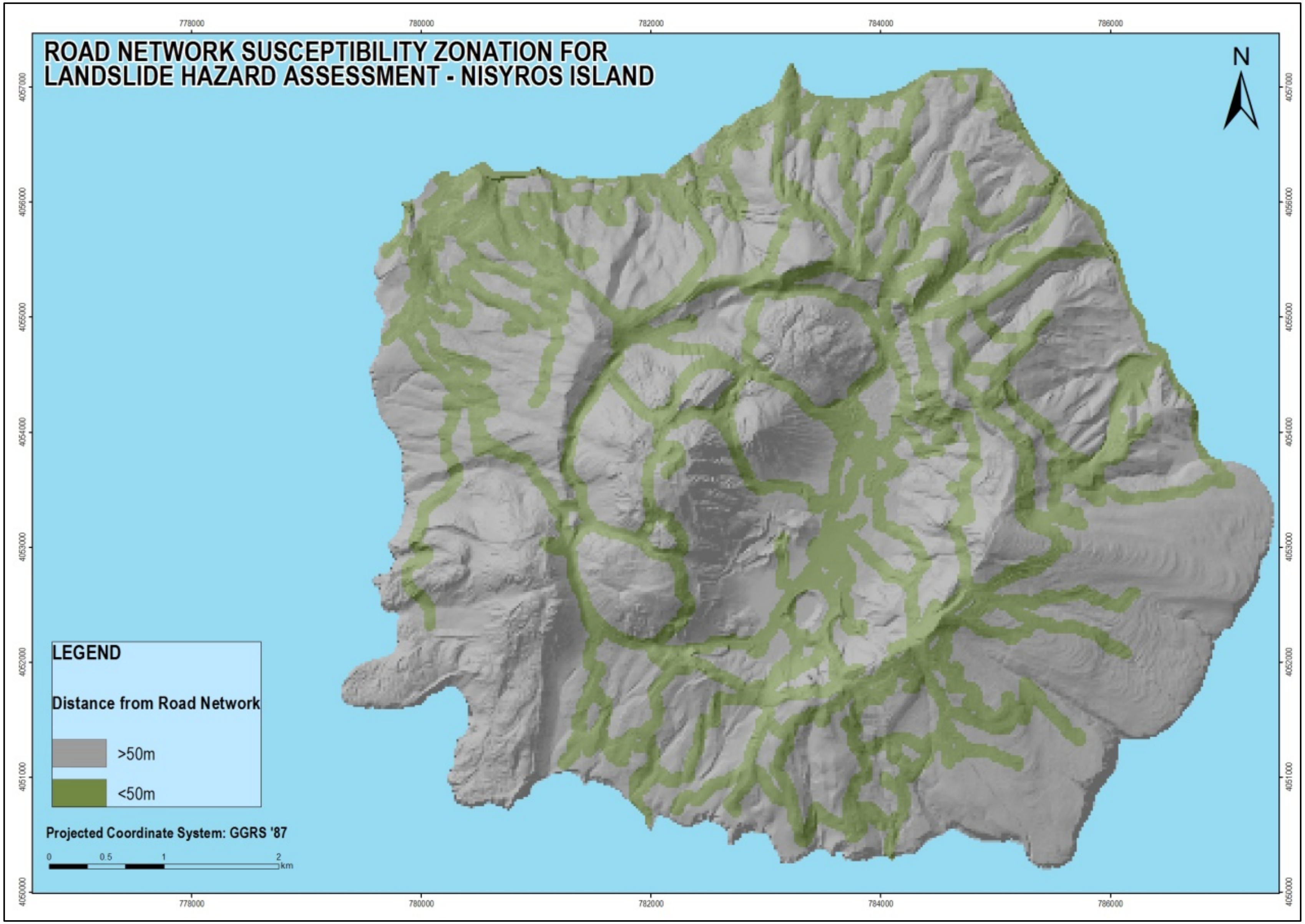


Figure 36: Road network susceptibility zonation for landslide hazard assessment

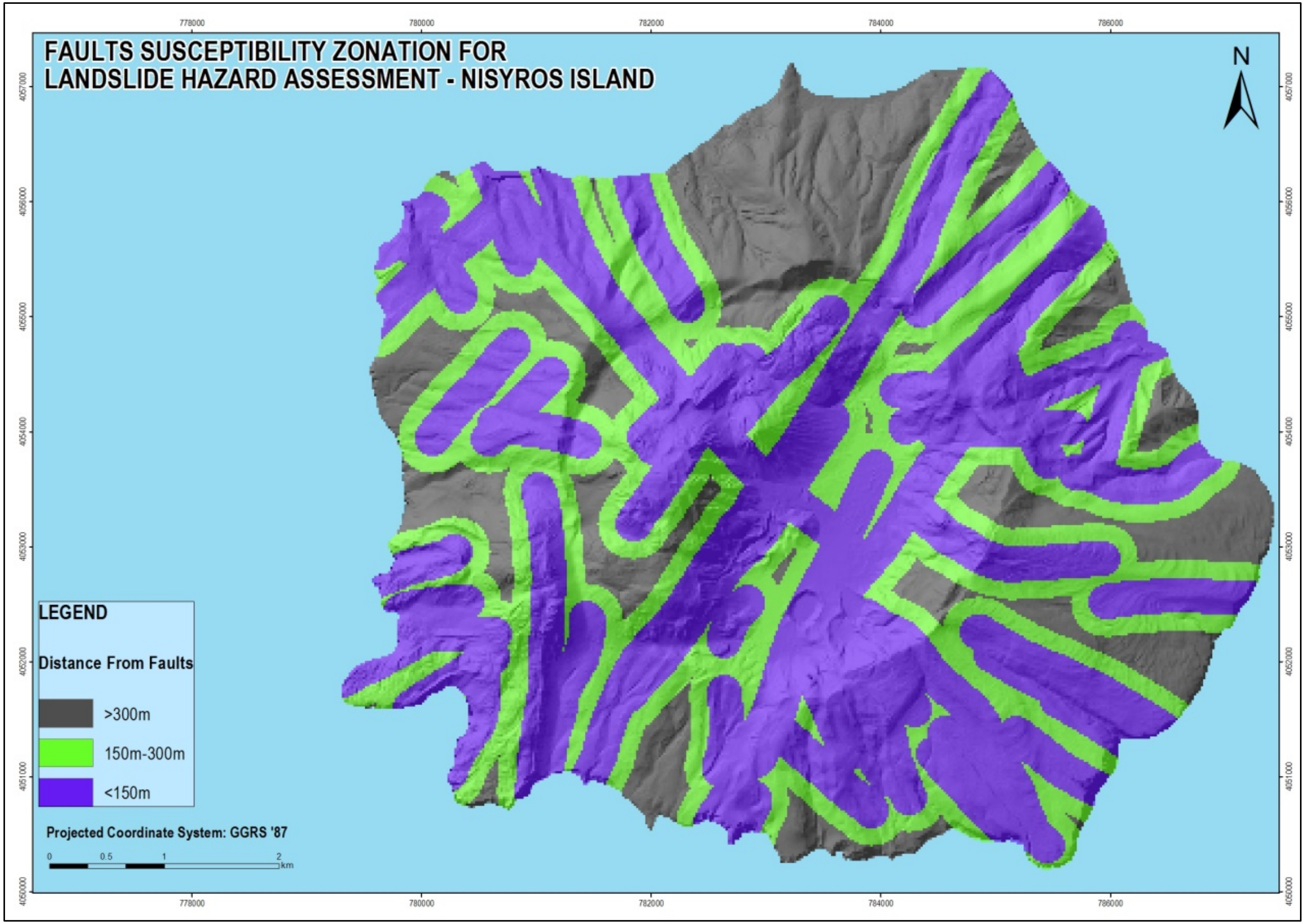


Figure 37: Fault susceptibility zonation for landslide hazard assessment

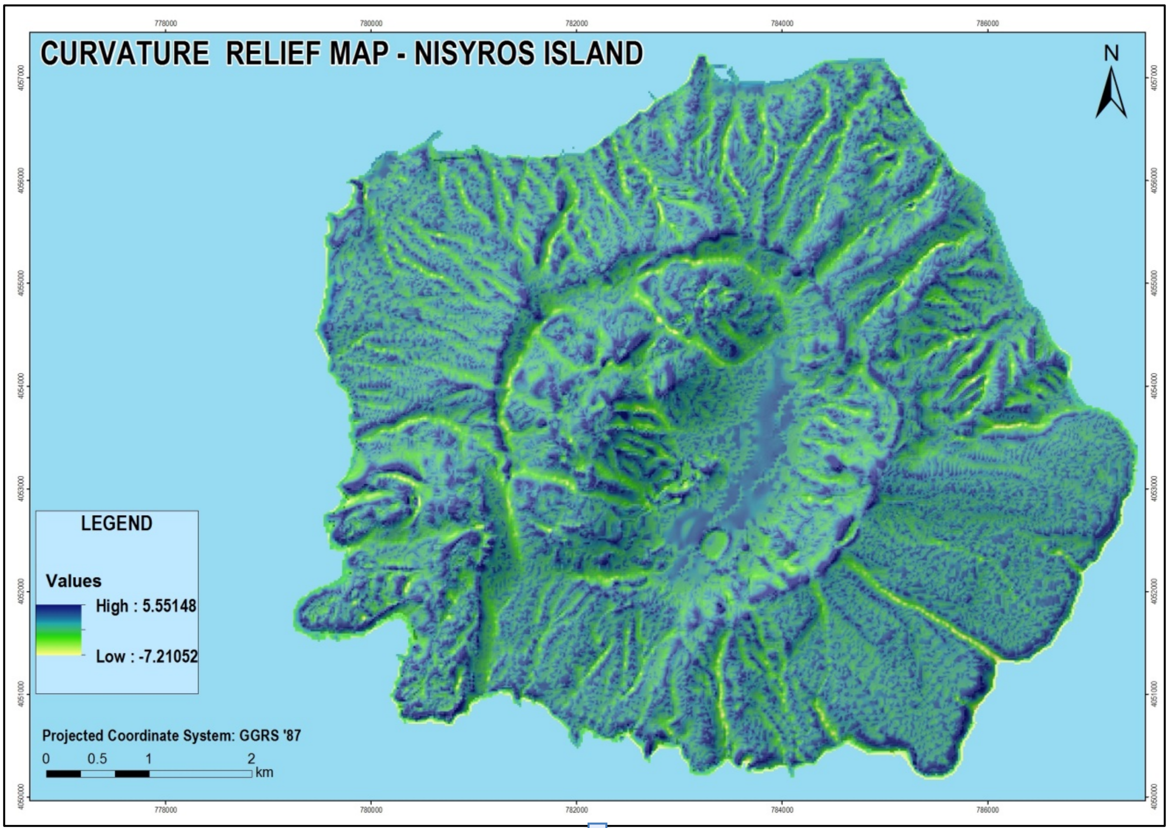


Figure 38: Curvature Relief Map of Nisyros

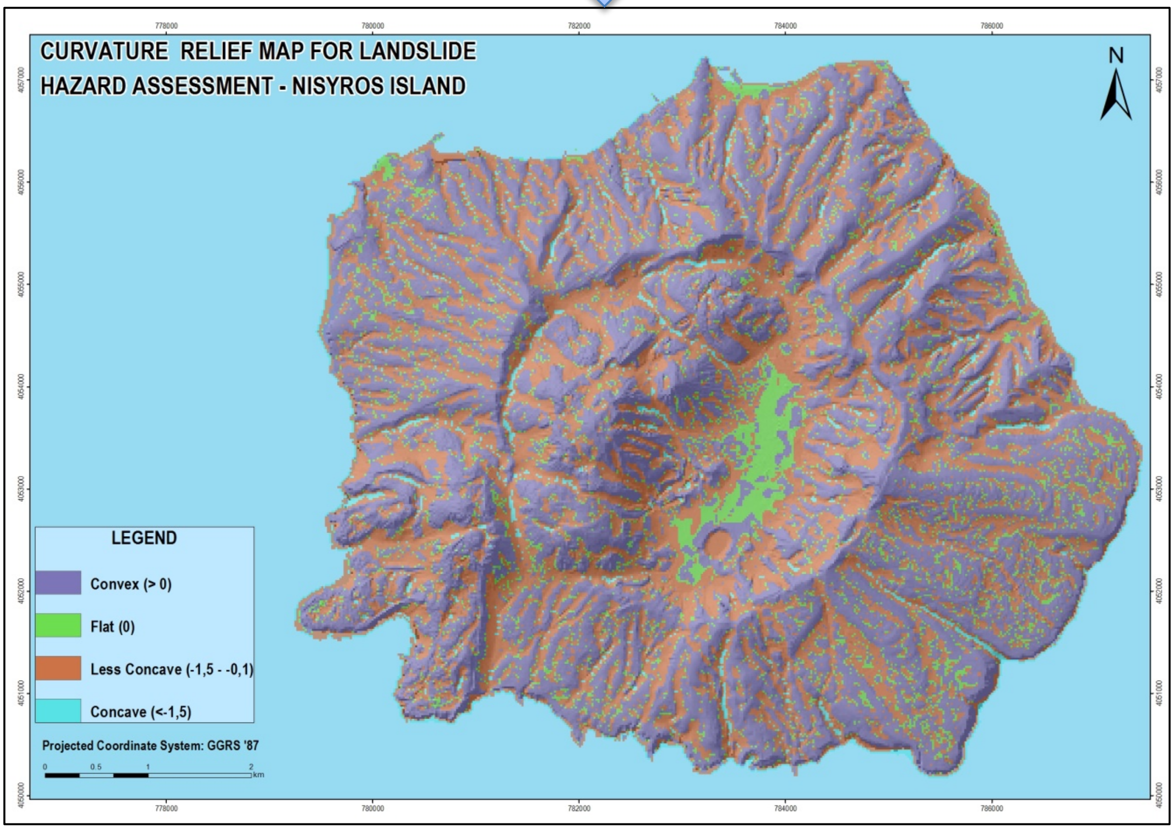


Figure 39: Curvature Relief Map for Landslide hazard assessment

3.8 LOCATION OF METEOROGICAL STATIONS OF HELLENIC NATIONAL METEOROGICAL SERVICE (HNMS) AND THE AVERAGE ANNUAL PRECIPITATION

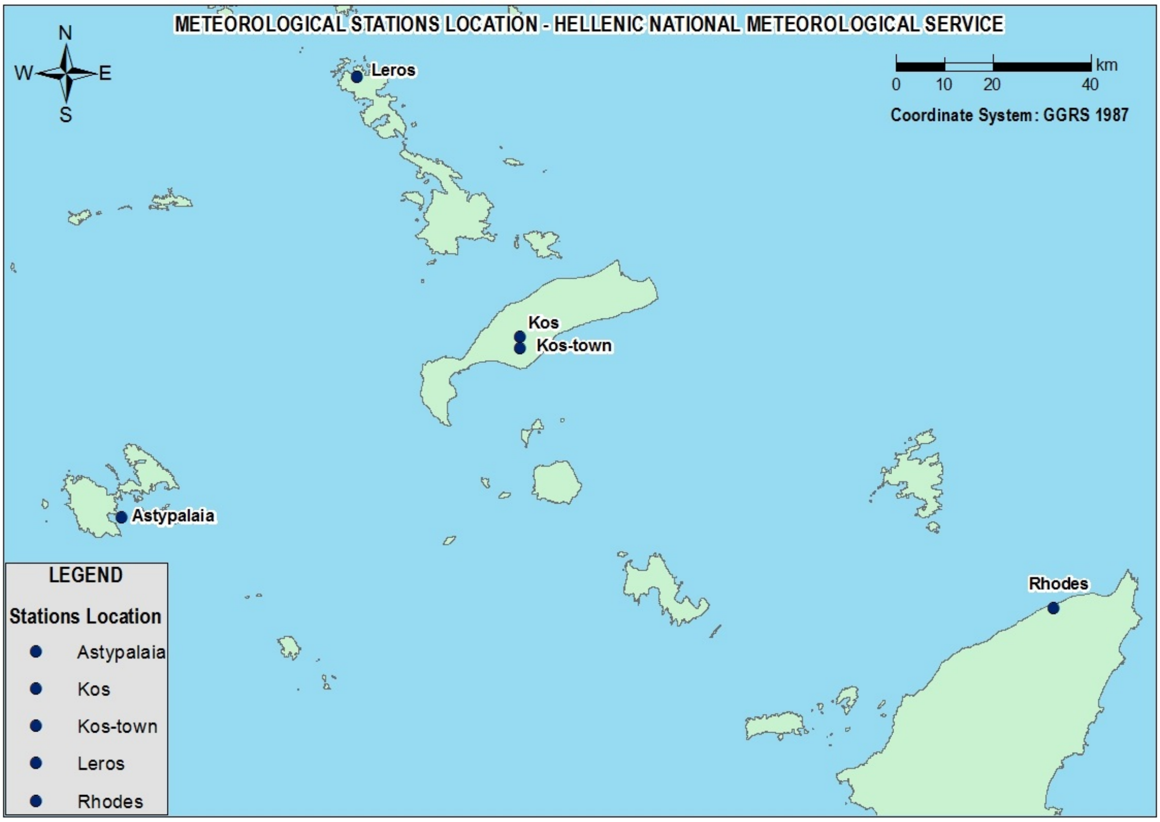


Figure 40: HNMS Meteorological Stations Location

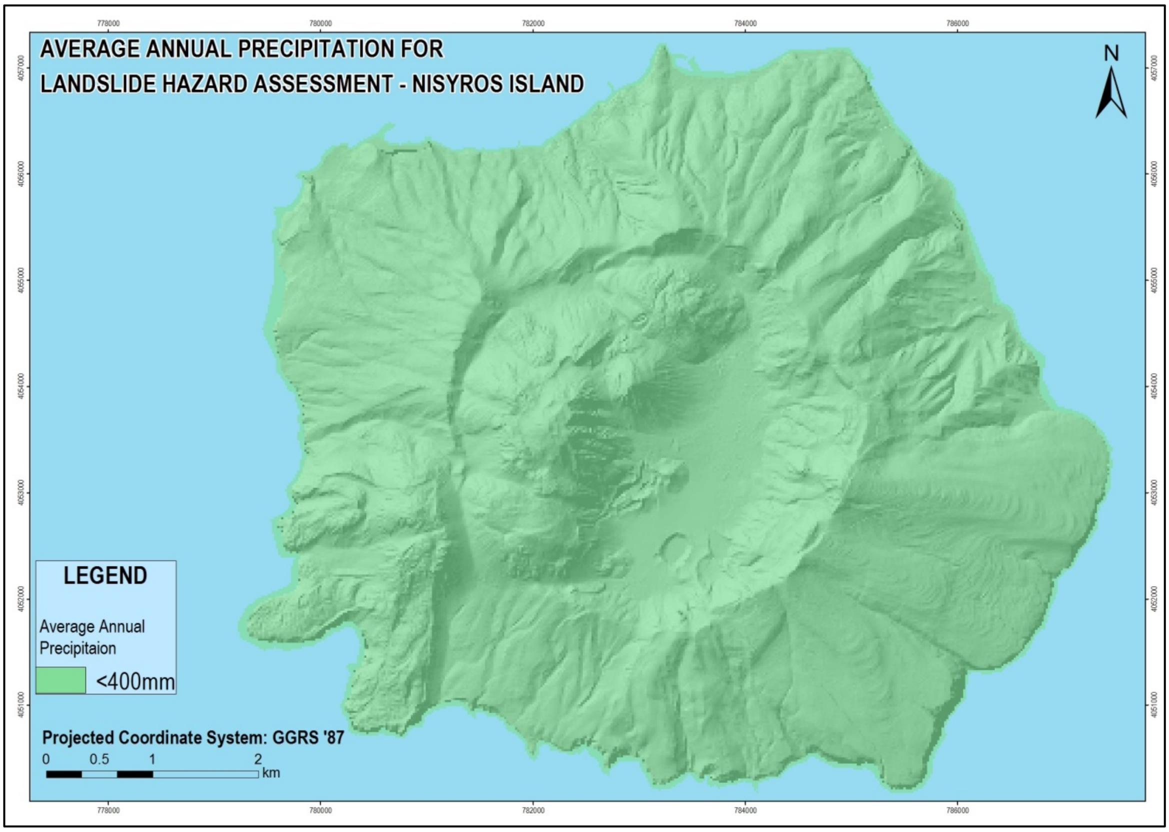


Figure 41: Annual Average Precipitation based on the HNMS Meteorological Stations data

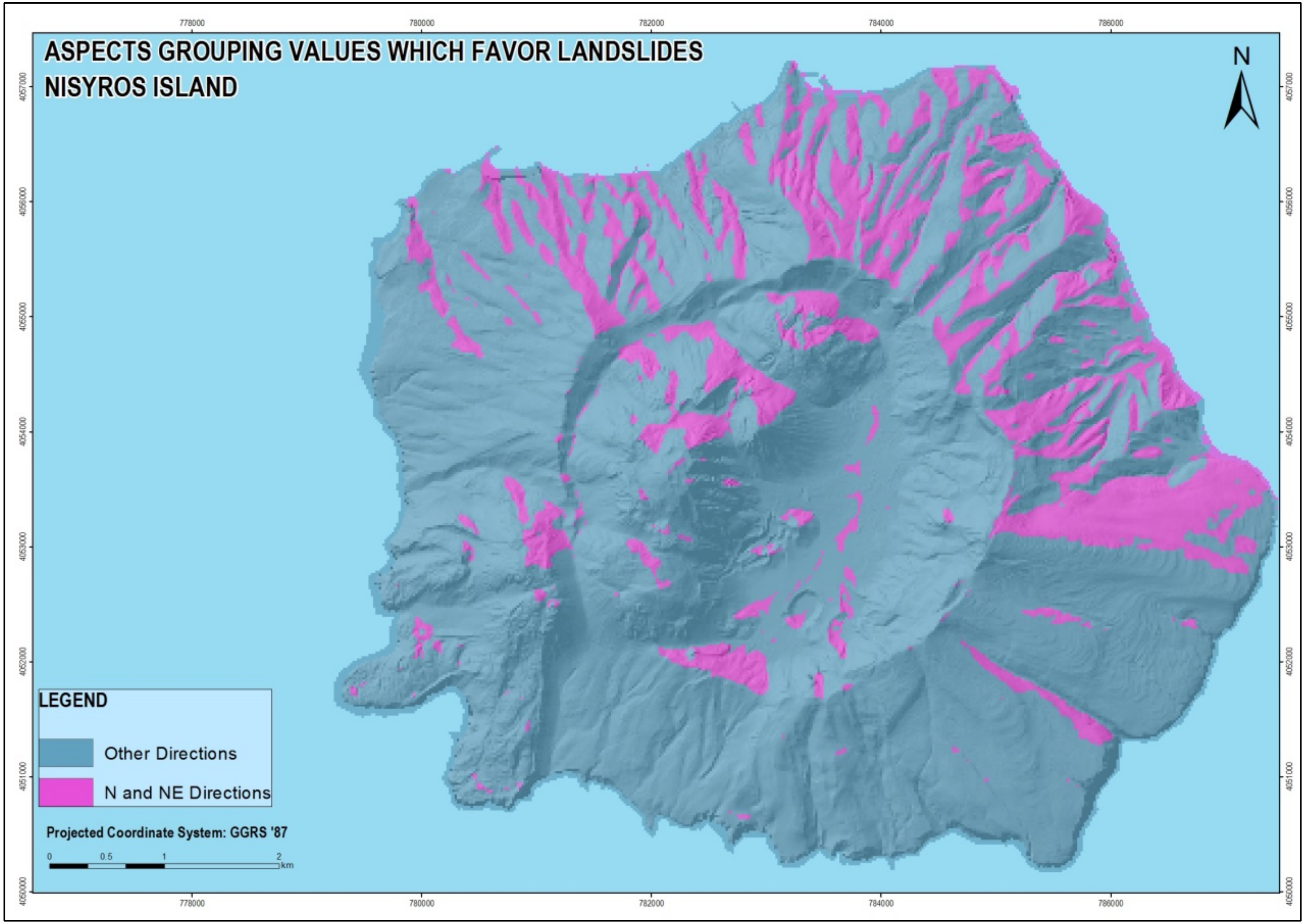


Figure 42: Aspects grouping values which favor landslides

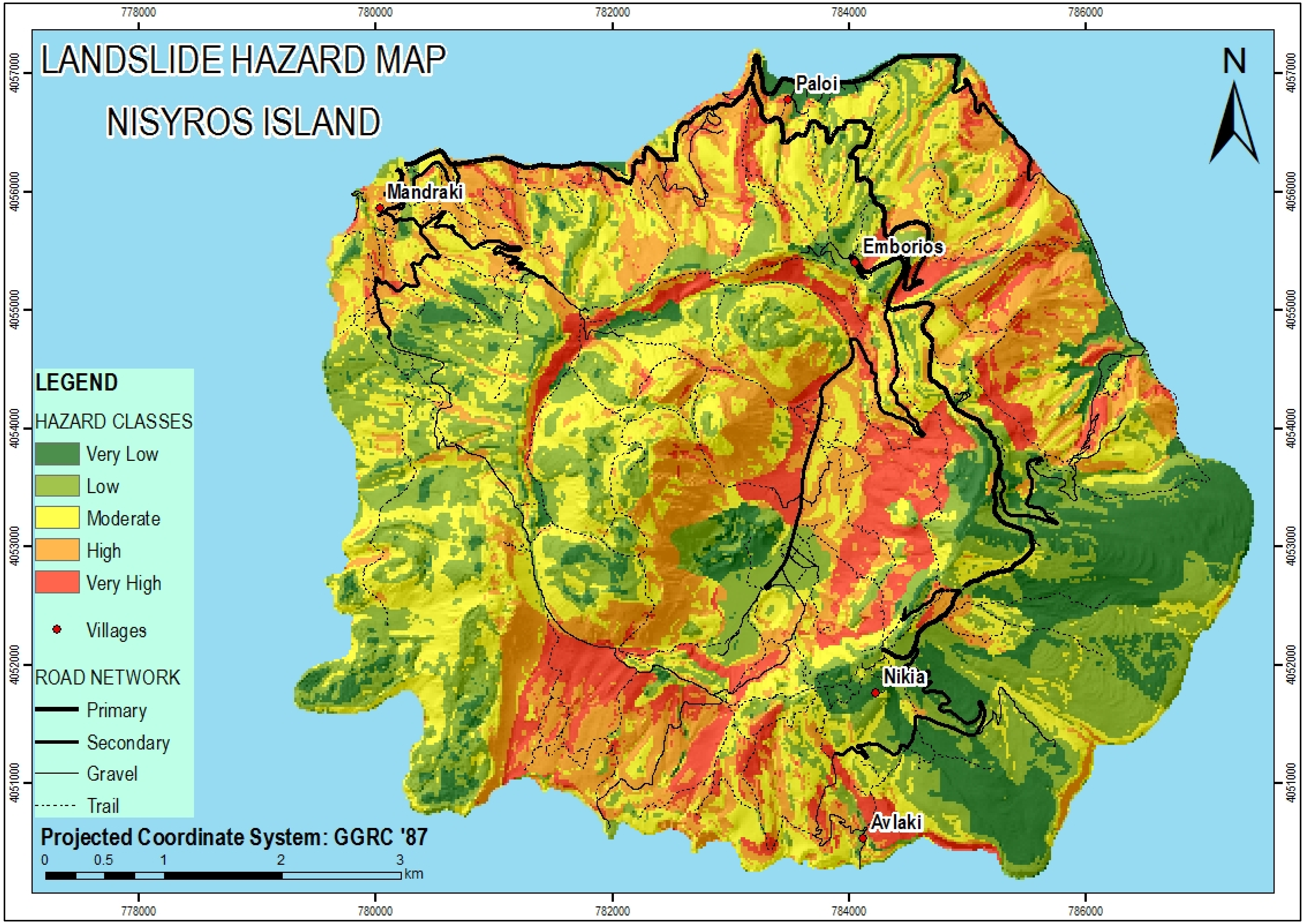


Figure 43: Landslide hazard map of Nisyros

3.9 LANDSLIDE REMEDIATION WORKS AT THE PANAGIA SPILIANI MONASTERY

3.10 CONCLUSIONS

Landslide hazard assessment is a critical task in landslide management process. Landslides are influenced by several triggering factors which vary significantly from region to region. It is therefore difficult to determine weights for given parameter. The assignment weights based on relative importance of landslide causative factors is determined by several methods differently. Multi-criteria decision approach provides tools to determine weights based on pair wise comparison. Application of Remote Sensing and Geographical Information System is of immense importance for effective landslide hazard assessment. High resolution satellite data combined with powerful GIS techniques have improved the level of accuracy of landslide hazard maps in recent times.

Large morphological gradients of the lithological-geotechnical context of Nisyros create a favorable landslide event field. Another factor that increases the seismo-volcanic hazard is the seismic response of the volcanic formations. Especially the appearance of pumice, ash and other pyroclastic rocks which are brittle rocks with small thicknesses overlaying compact lavas (which are rock formations), compose a negative field for building construction. The risk is particularly increased in case of an earthquake or volcano-seismic vibrations. The highest risk is located along the road connecting the village Emborios with the craters on the inner side of the caldera and along the faults of the island.

On the steep coasts usually observed coastal landforms like caves, arches and columns, while frequent are the debris falls and slips according to the inclinations of the rocks and the erosion and weathering rate. Volcanic rocks which appear in steep coasts are corrodible on the influence of marine processes (waves, coastal currents) and with a significant weathering rate.

Landslide events can occur either during an earthquake, or during heavy rain or storms. Therefore, the landslide hazard is considered to be High.

4. SEISMIC HAZARD

4.1 DEFINITION, CAUSES AND AREAS OF FORMATION
4.2 DIFFERENCE BETWEEN MAGNITUDE AND INTENSITY
4.3 THE BROAD AREA OF GREECE - ONE OF THE MOST ACTIVE PLATE TECTONIC REGIMES IN WESTERN EUROPE
4.4 EFFECTS OF EARTHQUAKES
4.5 HISTORICAL SEISMICITY
4.6 INTENSE SEISMIC ACTIVITY DURING 1995-1997
4.7 SEISMIC RISK ASSESSMENT CRITERIA
4.8 SEISMIC HAZARD METHODOLOGY STUDY
4.9 CONCLUSIONS

4.1 DEFINTION, CAUSES AND AREAS OF FORMATION

An earthquake is an earth tremor whose natural origins are below the surface of the earth. A distinction is made between tectonic, volcanic, and collapse earthquakes, depending on the cause. Collapse earthquakes, involving the collapse of subterranean cavities, are the least common and account for only 3% of all earthquake events. Volcanic earthquakes, i.e. tremors due to magma movements or subterranean explosions in volcanic areas, account for 7%. Tectonic factors are by far the commonest cause (90%) and produce the strongest earthquakes

Areas of formation

More than 90% of all earthquakes occur in regions where large tectonic plates meet. Many active volcanic areas are also to be found in the same regions. A distinction is made between three boundary types, depending on the relative movement of the plates:

- Convergent plate boundaries, where plates collide with each other. If an oceanic plate and a continental plate converge, the heavy oceanic crust pushes its way beneath the continental plate and descends into the mantle, where the rock melts. The area in which this happens is called a subduction zone (example: the Pacific coast of South America).
- Divergent plate boundaries, where plates move away from each other (example: the Mid-Atlantic Ridge).
- Transform plate boundaries, where plates move past each other horizontally (example: San Andreas Fault in California).

Owing to the different degrees of stress build-up, convergent zones produce the strongest earthquakes (Chile, 1960; Sumatra, 2004), followed by transform zones (San Francisco, 1906), and divergent zones. Since the hypocentre of quakes on convergent plate boundaries is often in the sea, these strong quakes account for less than 30% of overall global earthquake losses. There is a significant risk they will trigger a tsunami.

4.2 DIFFERENCE BETWEEN MAGNITUDE AND INTENSITY

There are two parameters that are used to describe the size of earthquakes: magnitude and intensity.

Magnitude on the Richter Scale is a fixed value of measurement based on recordings of ground movement called seismograms. It correlates with the size of the hypocentre and the energy radiated in the form of seismic waves. Many magnitude scales are used which differ in terms of which seismogram information seismologists use for calculation purposes. This is why different values of magnitude are often quoted for the same quake. The moment magnitude scale (Mw), which bears a direct relation to the dimensions of the quake's rupture surface, is becoming increasingly common. All scales of magnitude are logarithmic.

Intensity is an expression of the extent and distribution of damage caused by an earthquake. It is derived from a rough statistical analysis of local damaging effects on each type of building. The scale most commonly used worldwide is the Modified Mercalli Intensity Scale (MM) and its enhanced form, the European Macroseismic Scale (EMS-98). Another important – and again measurable – parameter is peak ground acceleration (PGA). This, together with its derivatives, velocity (PGV), and displacement (PGD), forms the basis for the earthquake-resistant design of buildings.

4.3 THE BROAD AREA OF GREECE - ONE OF THE MOST ACTIVE PLATE TECTONIC REGIMES IN WESTERN EUROPE

Greece is a tectonically active area, located at the convergence zone of tectonic plates of Eurasia and Africa, forming the Greek arc. Especially the Eastern Mediterranean is going through the final convergence stages (Total Compression Stage), before entering into the Conflict Stage.

Meanwhile, the conflict of the Arabian microplate with the Eurasia has created the Anatolia fault in a clockwise motion to the West. Thus, the present day, in the wider area of the Eastern Mediterranean, and considering the African plate as stable, have been formed the following kinematics:

- Arabia - Eurasia (to the North) 10 mm / year
- Anatolia (to the West) 20 mm / year
- South Aegean region (direction ENE-WSW) 40-50 mm / year
- North Aegean region and North mainland (to the South) 10mm / year

The Greek arc has acquired this special kinematics approximately five million years ago when:

- the Arabian plate clashed with the Eurasian one, creating the Anatolia fault in a clockwise motion to the West
- the subduction of Adria began beneath the Eurasia

(Adria is the continental crust which is currently sheltered beneath the shallow waters of the Adriatic Sea and its surrounding lands such as northern Italy.)

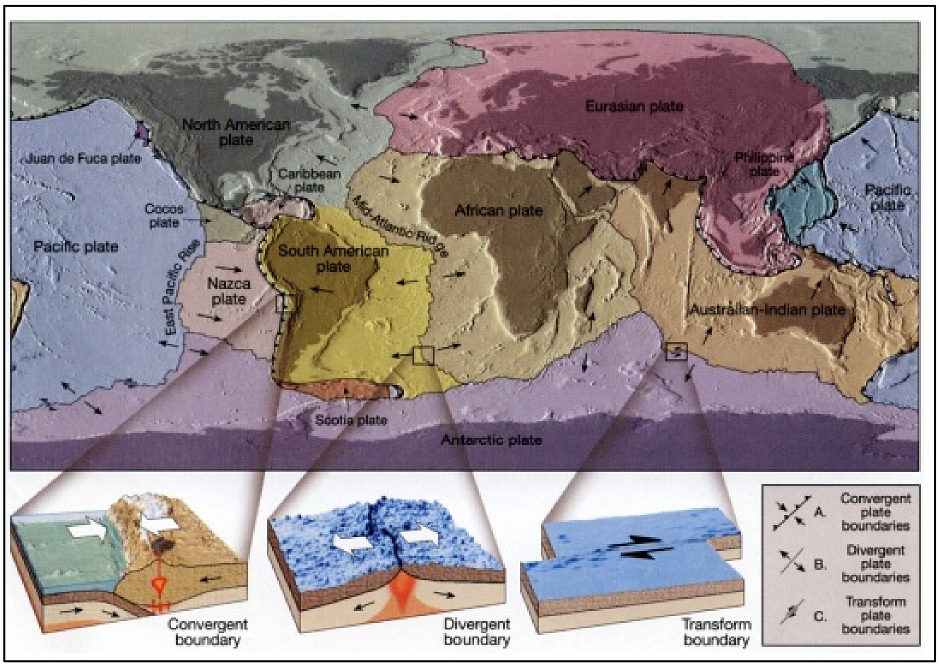


Figure 44: *The main lithospheric plates and types of their boundaries (source: Dynamic Geology Undergraduate courses, Faculty of Geology and Geoenvironment, National and Kapodistrian University of Athens)*

These movements result in the phenomenon of orogenesis, manifested as soil lift after any seismic activity. Because of these movements, when the tensions developed into one (or more) strata exceed the yield strength, then the rock is ruptured and starts moving between the two portions on either side. This fracturing, known as fault constitutes the source of the event and the expansion of seismic energy. Groups of visible faults with common direction and characteristics operate as a unitary structure (fault structures).

The Greek territory is distinguished by a multitude of faults and therefore faces seismic hazard.

As it is known, Greece has the highest seismic activity within the Mediterranean countries. Indicative is the fact that the seismic energy released each year in Greece is almost equal to the energy released in the rest of Europe.

The economic consequences of earthquakes are not only due to disasters and failures of technical works, but also to the fact that for long periods – during periods of intense seismic activity - there is social and economic disruption of the region.

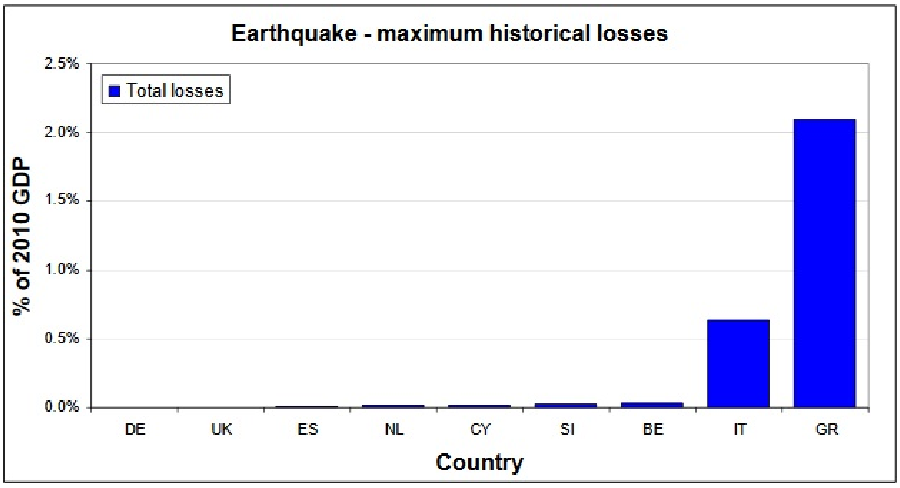


Figure 45: Maximum historical losses from earthquakes (source: Maccaferri, S. Cariboni F., Campolongo F. Natural Catastrophes: Risk relevance and Insurance Coverage in the EU. Institute for the Protection and Security of the Citizens, Scientific Support to Financial Analysis Unit, Joint Research Centre, European Commission, 2012)

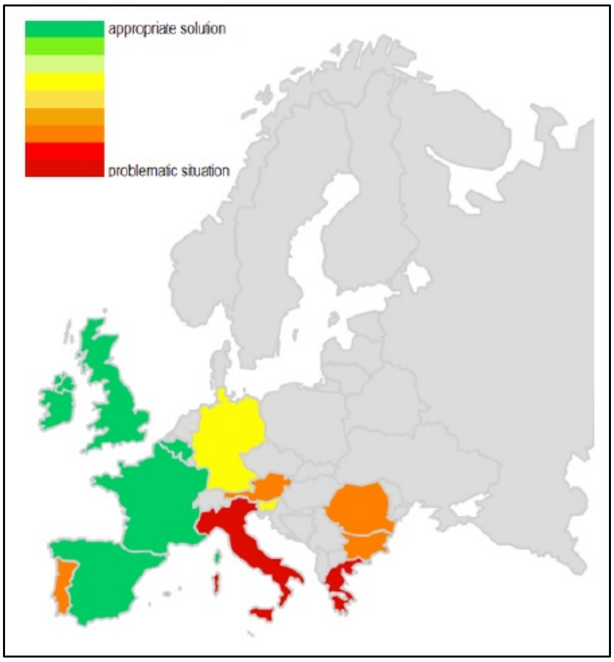


Figure 46: Earthquake - Map of the clusters based on available information (source: Maccaferri, S. Cariboni F., Campolongo F. Natural Catastrophes: Risk relevance and Insurance Coverage in the EU. Institute for the Protection and Security of the Citizens, Scientific Support to Financial Analysis Unit, Joint Research Centre, European Commission, 2012)

According to the Figures 45 and 46 of the European Union, Greece is the country with most deaths due to earthquake. Situation in Greece is rather crucial because earthquakes had relevant impacts in the past but the penetration rate is very low (<10%) and earthquake insurance is offered as an extension of fire insurance.

4.4 EFFECTS OF EARTHQUAKES

The primary effect of an earthquake is the ground motion caused by seismic waves. The loss generated by an earthquake is determined not only by the earthquake parameters themselves (magnitude, distance, duration) and the local subsoil conditions (intensity) but also by the characteristics of the affected buildings: type of design, type of building, occupancy, year of construction, height, asymmetries in the floor and elevation plan, resonant frequency, etc.

Strong earthquakes in particular often trigger secondary effects which also have a high loss potential and are usually the prime factor for determining whether an earthquake is categorized as a catastrophe. The main secondary effects are: i) amplification ii) seismic sea waves (tsunamis), iii) liquefaction, iv) landslides, v) surface rupture, vi) subsidence, vii) fire following earthquake.

4.5 HISTORICAL SEISMICITY

Until the 19th century there is no much information about earthquakes that struck the island of Nisyros, although neighboring islands like Kos and Tilos have repeatedly hit by strong earthquakes. The information is very limited and those more related to hydrothermal activity of the volcano, despite the seismicity.

In the period from 1500 to 1900, most powerful earthquakes that struck the wider region of Nisyros gather northwest and north of the island of Rhodes, between the islands of Tilos, Symi and Rhodes. It is noteworthy that there are no strong earthquakes for the period up to the mid-19th century, when it starts a strong seismic activity in the area mentioned. Two are the earthquakes that hit Nisyros. The first took place in 1862, magnitude M = 6.4 and apart from Nisyros caused damage in the city of Rhodes. The second takes place a year later, on April 22, 1863 and destroyed 13 villages in Rhodes and slight damage in Kos.

On July 26, 1926 took place and the strongest earthquake in the Dodecanese. Its size and epicenter are still under discussion. In most earthquake catalogues it is mentioned as the strongest earthquake in the Eastern Mediterranean with a depth of ~ 100 km and magnitude M = 8.3 or other M = 8.0. Newer investigations degrade size Ms = 7.4 ± 0.3 (Ambraseys & Adams, 1998) and shift the epicenter of the earthquake at sea between Astypalea and Nisyros in 115km depth. The earthquake destroyed thousands of homes in Rhodes, Karpathos, Kastelorizo and Kos. Damage caused in areas hundreds of kilometers away from the epicenter, as in Crete and Egypt and in the Nile delta.

The seismic data were obtained from the earthquake catalogs of the University of Athens and the Geodynamic Institute. A catalogue of earthquakes compiled by Papazachos (1997) records the effects from major earthquakes affecting Greece and the surrounding areas since ancient times (550 B.C. until present).

YEAR	EPICENTRE	MAGNITUDE	INTESITY	DAMAGE & CASUALTIES
227 B.C.	East of Rhodes	7.2	X	The earthquake knocked the Colossus of Rhodes, devastating the city. Inflict damage on Tilos and other islands of the Dodecanese.
142 A.D.	East of Symi	7.0	X	Destroyed cities in Rhodes, Kos, Serifos, Kimi as Lycia and Caria in Asia Minor. The city of Rhodes was destroyed mainly by the gravitational wave that followed the earthquake.
554	Northeast of Kos	7.0	X	All Kos destroyed along and Asklepion. After the earthquake occurred tsunami which hit all coastal buildings and wiped out the town of Kos.
1493	Antimachia (Kos)	6.8	IX	5,000 people killed in Kos. Towers demolished in western Kos and houses collpased in Kefalos, Antimachia, Kardamena and Pyrgi.
1862	Southwest of Rhodes	6.4	VII	Rhodes old walls collapsed and the quake was felt in Halki, Nisyros and the opposite coast of Turkey. The earthquake occurred on March 24.
1863	West-Southwest of Rhodes	7.8	X	The earthquake took place on April 22 and destroyed 13 villages in Rhodes, where 2050 buildings collapsed. Damages suffered homes in Kos and Halki. No damage to Symi, unlike Makri and Marmaris in SE Turkey.
1926	West of Tilos	7.4 ±0.3	XI	It occurred on June 26 and destroyed Archangelos and Pilonas in Rhodes killing four people. 3,000 houses collapsed in the eastern coast of Rhodes. Many houses demolished in Karpathos, Kastelorizo, Kos and in Heraklion (Crete) as well. The coastline lifted about 20-30 cm. Damage were reported in Egypt too.
1933	South of Kos	6.6	IX	The earthquake that took place on April 23, hit Kos and Nisyros. Almost, completely were destroyed the city of Kos, Antimachia, Kardamena and Pili. 200 people were killed.
1958	West of Tilos	6.0	V	The earthquake that occurred on June 30, was strongly felt in the Dodecanese.
1959	Southwestern Turkey	6.2	VIII	The earthquake that occurred on April 25, was strongly felt in Rhodes, Kalymnos, Kos and Samos
1961	Northeast of Rhodes	6.4	VII	The earthquake took place on May 23 and caused severe damage to the coasts of southwest Turkey. In Rhodes 5 houses destroyed and 250 suffered lighter damage. In Antimachia (Kos) two houses collapsed and in Leros other 16 suffered damage.
1965	West of Southern Rhodes	6.0	VI	It was particularly felt in Tilos, Rhodes, Symi, Kos, Karpathos, Kassos and Crete. Occurred on November 28.
1968	West of Nisyros	6.0	V+	The earthquake that occurred on December 5, was felt in Nisyros, Kos and Naxos.

Table 7: Historical earthquakes in the wider region of Nisyros Island

Recent research showed high microseismic activity in various areas adjacent to Nisyros (Brüstle et al. 2008). These areas are the Gulf of Goekova east of Kos, the submarine area northeast of Nisyros, the wider region of Kasos and Karpathos islands, mainly south of them and finally the submarine area southwest of Nisyros. Microseismic intermediate depth activity detected southeast of Astypalaia *(Fig. 22)*.

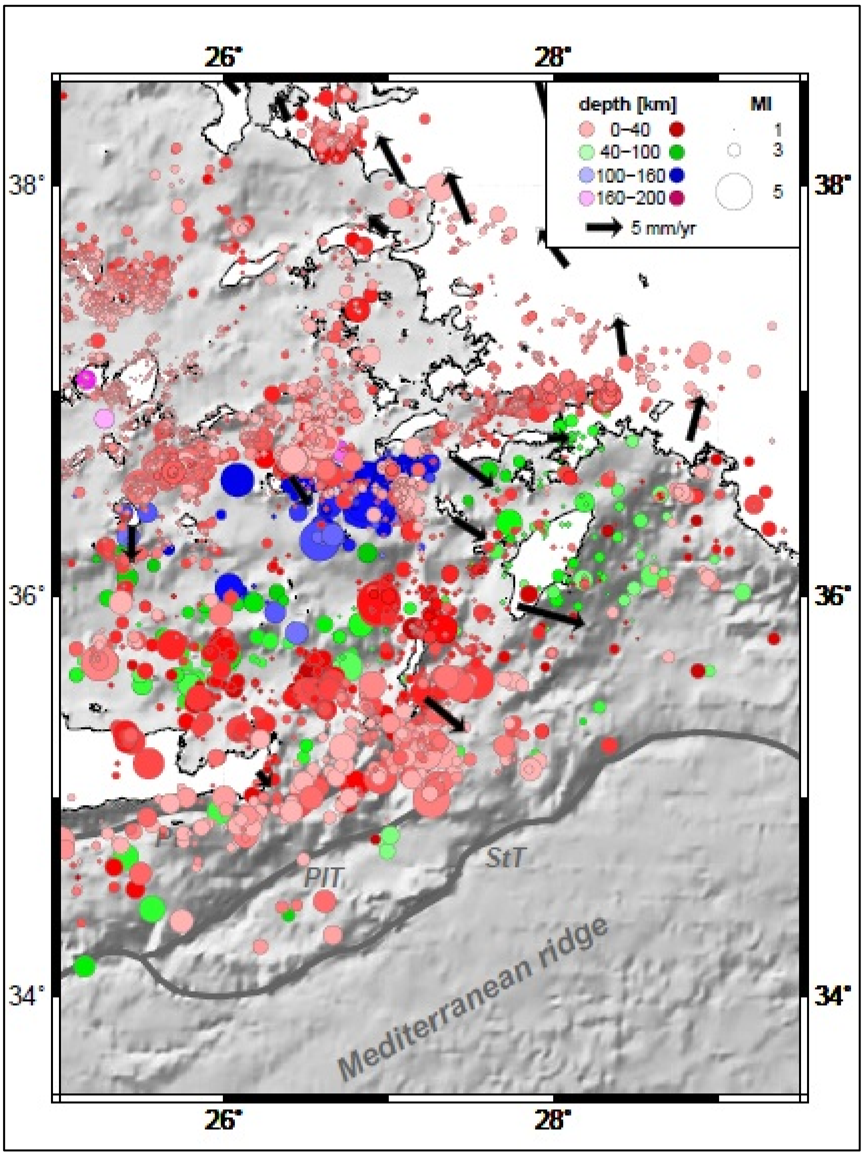


Figure 47: Seismicity of the eastern HSZ observed by the temporary CYCNET and EGELADOS networks from September 2002 to March 2007. In total, 6969 hypocenters were located with a location uncertainty of less than 20 km (location class 1-3) and an average location uncertainty of 10 km. Black arrows indicate GPS-velocities relative to the central Aegean (Reilinger et al., 2010). Background topography was generated from the ETOPO1 global relief model of Amante & Eakins (2009).

4.6 THE INTENSE SEISMIC ACTIVITY DURING 1995-1997

An intense seismic activity started at the end of 1995 and lasted up to 1998. In 1995 significant seismic activity began in the area of Nisyros. In particular, on August 22, an intermediate depth earthquake occurred, magnitude Ms=5.3, approximately 40 km west of the island and at a focal depth of 165 km. Three months later, on November 30, a second same magnitude earthquake occurred near the volcano at a focal depth of 136 km. On April 12, 1996 a powerful earthquake Ms=5.5 was felt in the same epicentral area, between the islands of Nisyros and Yali and focal depth of 156 km. After this event, the seismic activity migrated southeast of Nisyros, where a powerful earthquake Ms=6.6 occurred west of Rhodes.

In March 1997 the epicenters records show an epicenters density between the northern coast of Nisyros and Yali, a non-seimic area clearly reflected southeast of Yali. The whole scene changes four months later with new active seismic zones along the central and southern part of the island, as on the submarine part of this. In both periods, the records show the existence of a non-seismic area south of Yali. The absence of microseismicity in the region may be due to the existence of low strength and consistency of material, which may correspond to magma. The results of the seismic analysis the period after 1998, show that the seismic activity in the area of volcanic field Nisyros - Kos - Yali - Tilos, decreased significantly compared to that of the period 1996-1998.

Damages were reported along the western edge of the Mandraki town related to the Mandraki fault (in July 1996 damaged about 30 houses in Mandraki). The onshore geological, tectonic and morphological data show that the Mandraki fault throw is 80-100m and its length about 2km. Nomikou & Papanikolaou (2010) have shown that the fault continues northward into the Yali-Nisyros strait where it has created a 100m high submarine escarpment.

According to the local authorities and the civil engineers, there was not any house collapse, just fissures. Damage was recorded at renovated houses, while the old traditional ones remained intact. That happened because the renovated houses had concrete-made roof with lightweight concrete. On the contrary, the old traditional houses are made of stone.

Significant interpretations could be made on the basis of the spatial distribution of the microseismicity epicenters:

i) Very weak shallow earthquakes are gathered in the area around Nisyros with a small movement to the north and to the east.

ii) No activity was observed along the fault direction NW-SE and EW

iii) Three areas of microseismic activity were observed: Northeast of Nisyros to the Strongyli island, north of Yali island and east of Strongyli island. The focal depth for these areas reaches the deeper crust and extends to the lithosphere at depths of 70 km.

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The area is still highly active with five major fault systems having been identified in the Kos-Yali-Nisyros volcanic field from geological and structural investigations (Papanikolaou et al., 1991; Vougioukalakis., 1993; Papanikolaou and Nomikou., 2001).

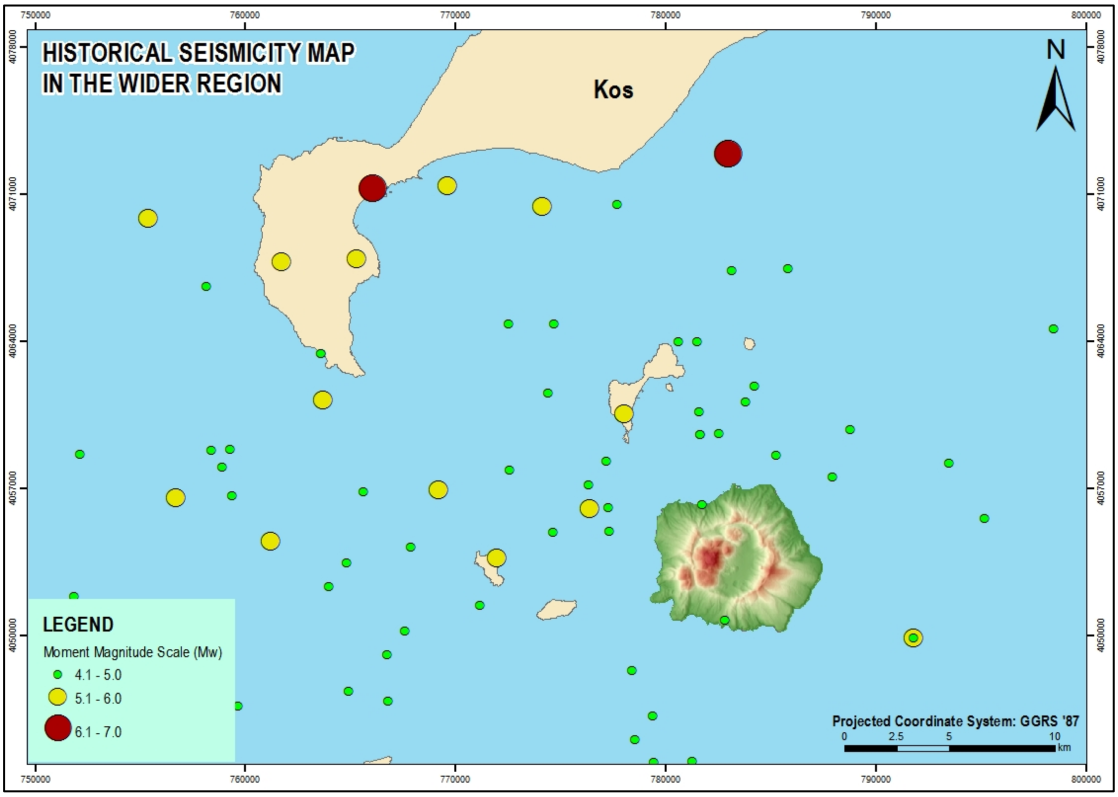


Figure 48: Historical seismicity in the wider region of Nisyros.(source: updated earthquake catalog, Laboratory of Seismology, University of Athens)

Figure 49: Historical seismicity imagey in wider the region of Nisyros (source: Google Earth)

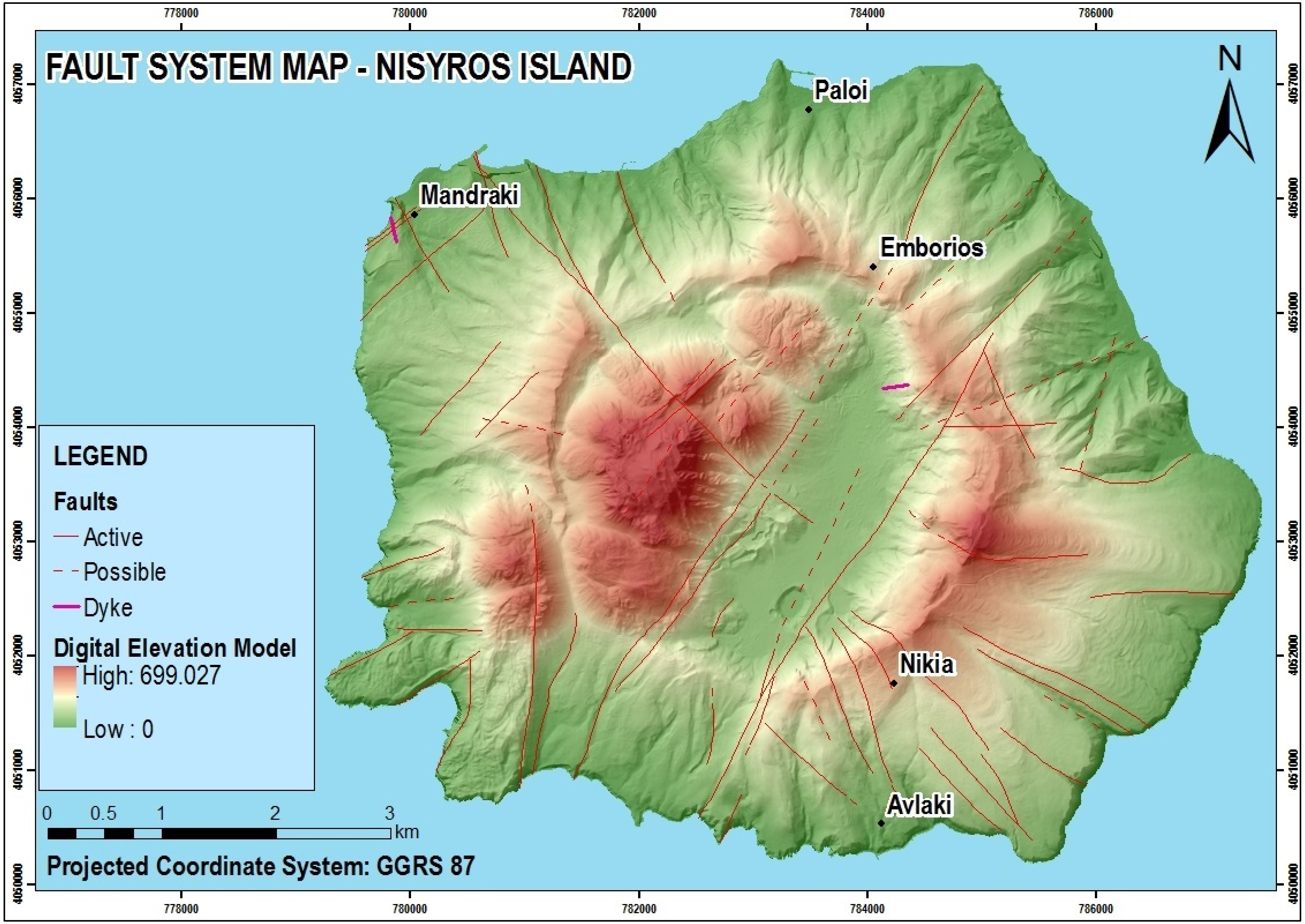


Figure 50: Fault System Map of Nisyros Island

Figure 51: Fault System Map satellite image (Google Earth Pro)

Figure 52: The F1 fault zone on the Profitis Elias caldera (source: Nomikou E., 2004)

Figure 53: The southern part of the F2 Fault Zone, situated on the caldera's eastern slope. (source: Nomikou E., 2004)

Figure 54: The F3 fault ends to the harbour, while the Panagia Spiliani fault (parallel to the F3) activated during the 1996-1998 period (source: Nomikou E., 2004).

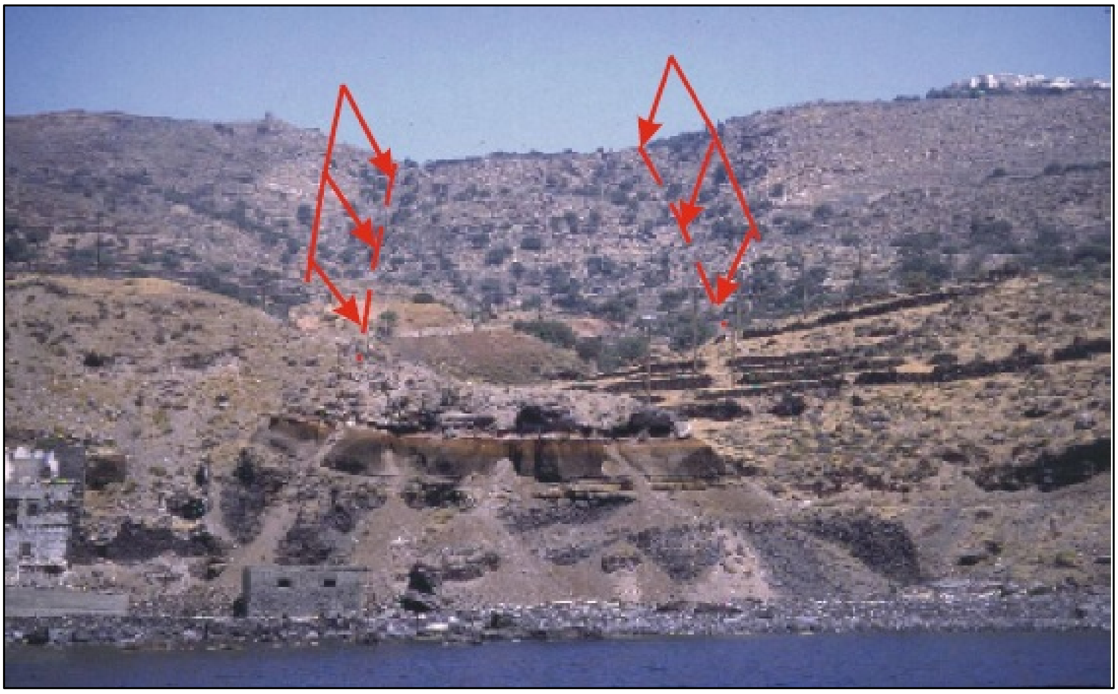


Figure 55: The F4 fault zone at the SW of Nikia village (source: Nomikou E., 2004)

4.7 SEISMIC RISK ASSESSMENT CRITERIA

The seismic activity is inextricably linked to the existence of fault structures.

The time factor is determined by the history of seismic activity in each area, given the periodicity of the phenomena. However, the non-instrumental, subjective and occasionally incomplete recording of seismic events in historical times often make the determination of the seismic events for each fault structure an extremely difficult process with results that contain high degrees of uncertainty.

The effect of seismic activity in human culture is related to:

- the spatial dispersion (settlements, infrastructure) of human presence
- the seismic behavior of bedrock
- the infrastructure position compared to the slope of each structure.

(Note that the effect of seismic activity is very intense to the footwall comparing to the hanging wall).

Finally, the bedrock's seismic behavior during the shake differs from one formation to another, sometimes increased, others decreased and some other times not affected by the intensity of the event (Figure 55).

Thus, the criteria for determining the seismic risk are taking into consideration:

- fault structures
- historical seismicity
- seismic behavior of the geological bedrock
- settlements

4.8 SEISMIC HAZARD METHODOLOGY STUDY

a) Identification and formulation of Nisyros faults which characterized by an over 6 km length (the F3 fault in this case study).
b) Calculation of the maximum earthquake magnitude (Richter scale) for each fault (just for the F3 fault in this case study).
c) Regional historical seismicity research.
d) Analysis of the geological conditions of the island and determination of seismic behavior for each geological formation.
e) Hypothetical epicenters placement on the footwall for each normal fault, about 10 km beyond this and more epicenters density in the middle and less in the edge.
f) For each fault calculated, based on the hypothetical epicenters, an affection zone just for VIII-XI and VIII intensities of a possible earthquake.
g) Overlay of geological information (seismic behavior of the geological bedrock) with the aforementioned zones of influence.
h) Number of faults calculation which affect each settlement, as well as the limits of the maximum magnitudes that can arise from them.

Based on the fault data and using the equation proposed by Wells and Coppersmith (1994) and Pavlides and Caputo (2004) the expected seismic magnitude of the F3 fault is between 6.1 and 6.4

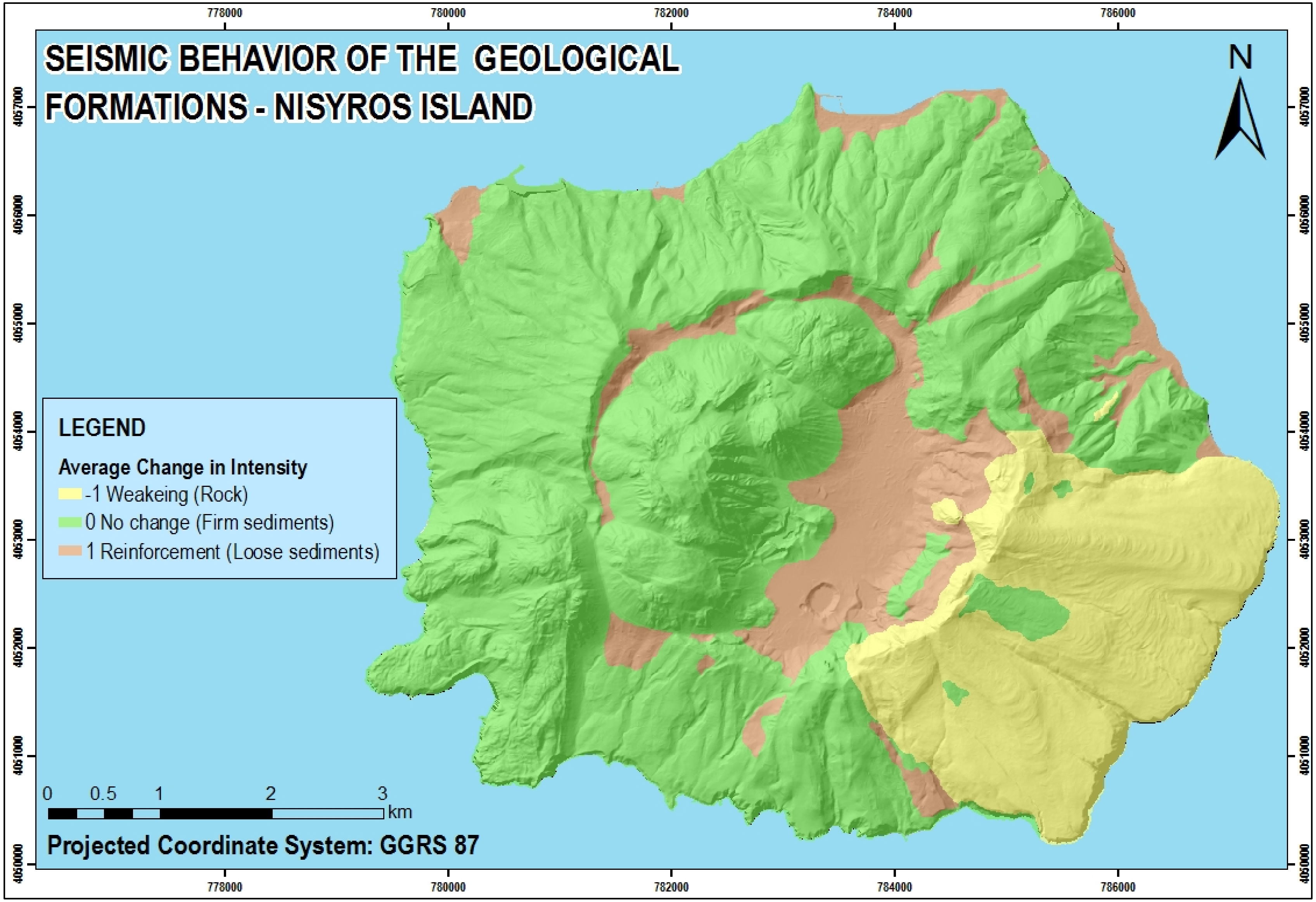


Figure 56: Seismic behavior of the geological formations

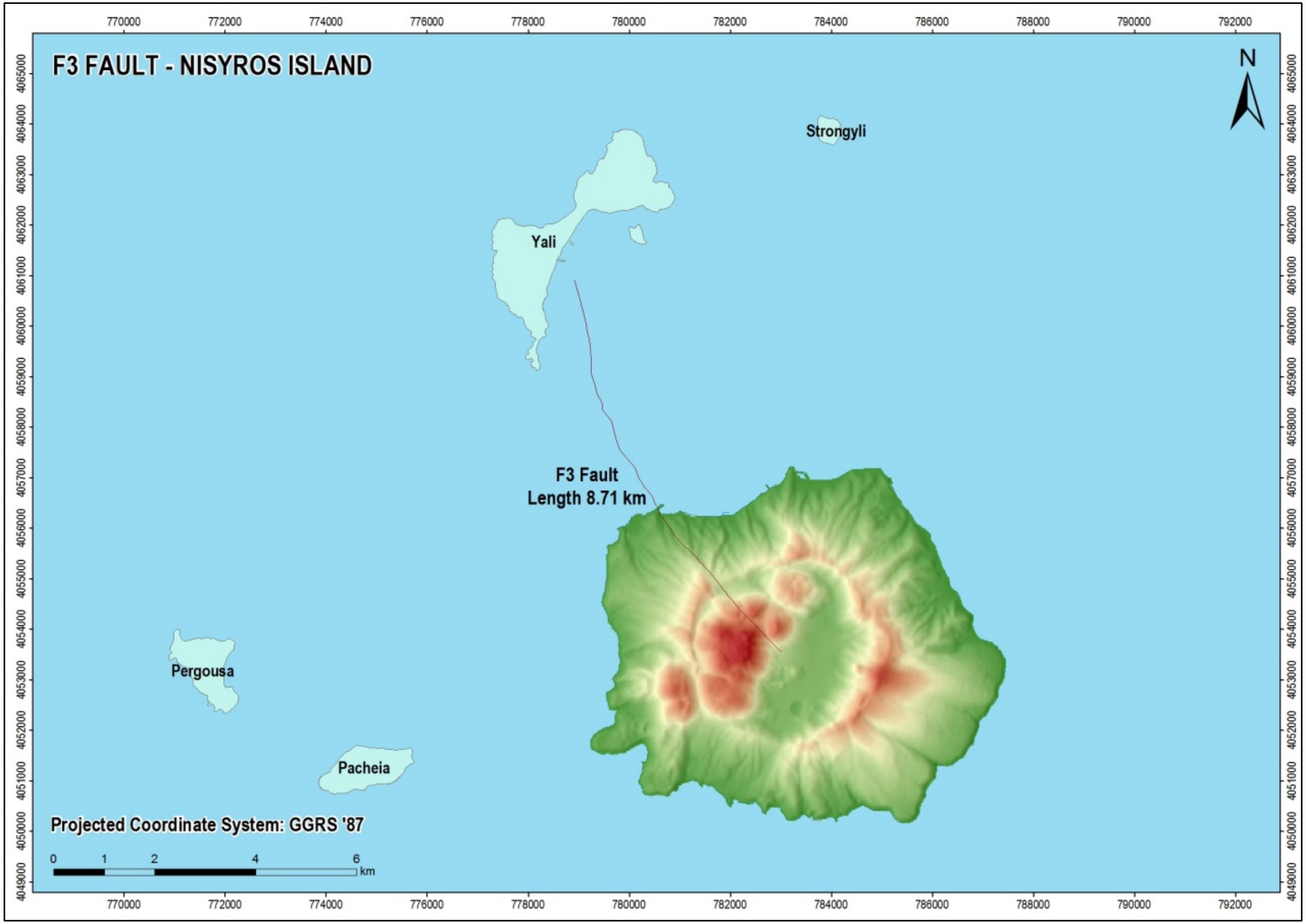


Figure 57: The F3 Fault

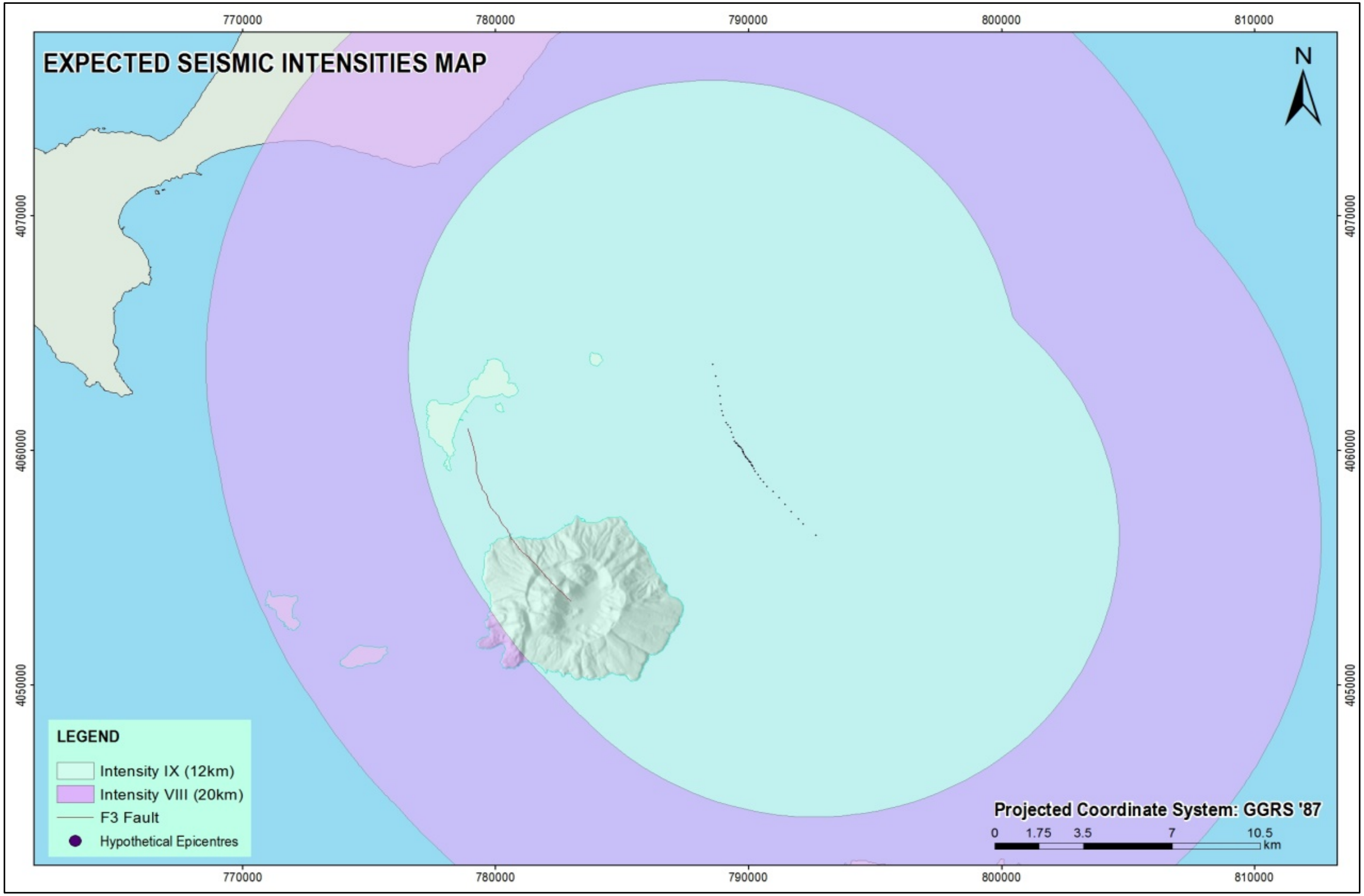


Figure 58: Hypothetical epicentres and expected intensities map for the F3 fault

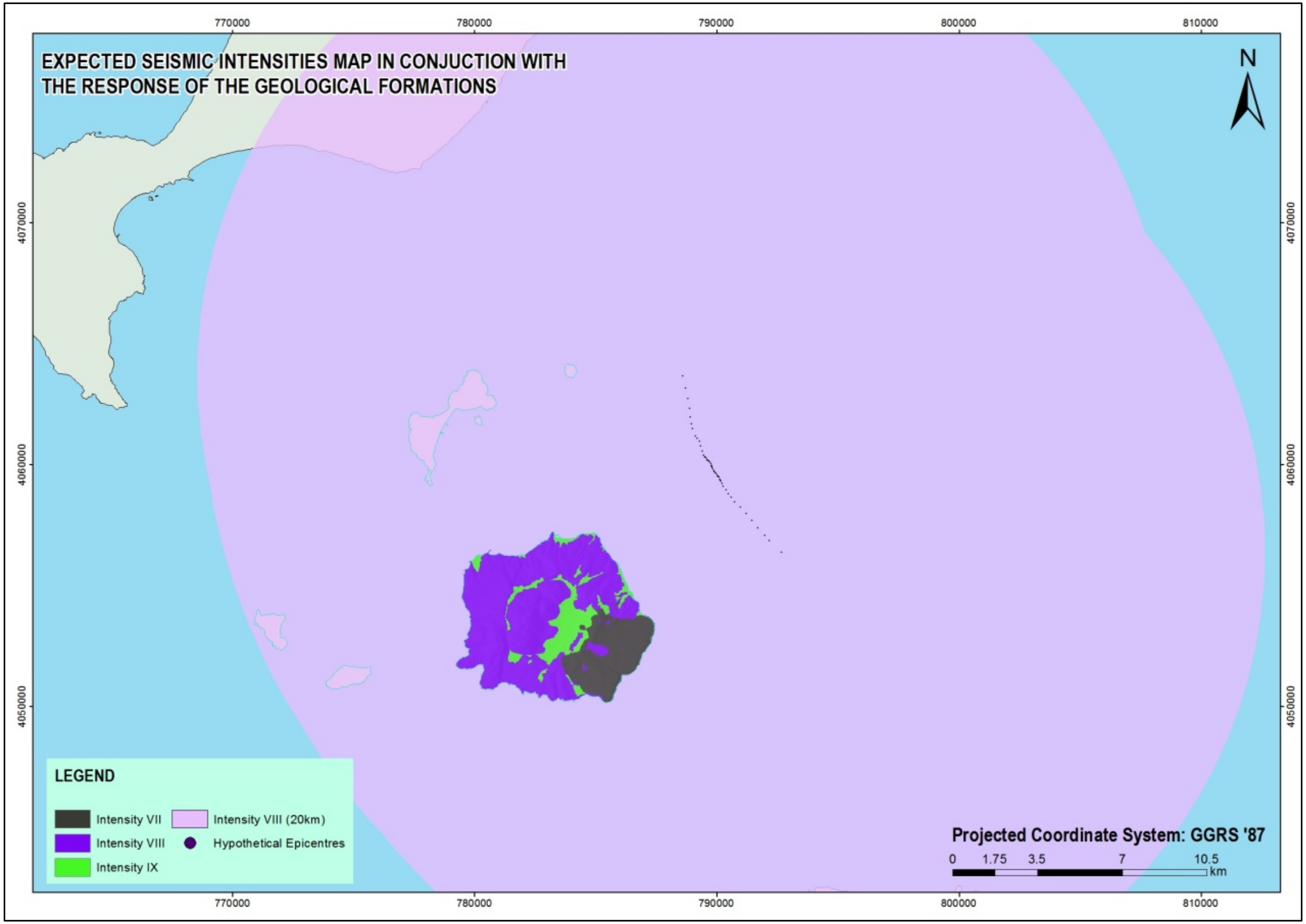


Figure 59: Seismic response of the geological formations for intensity VIII for the F3 fault

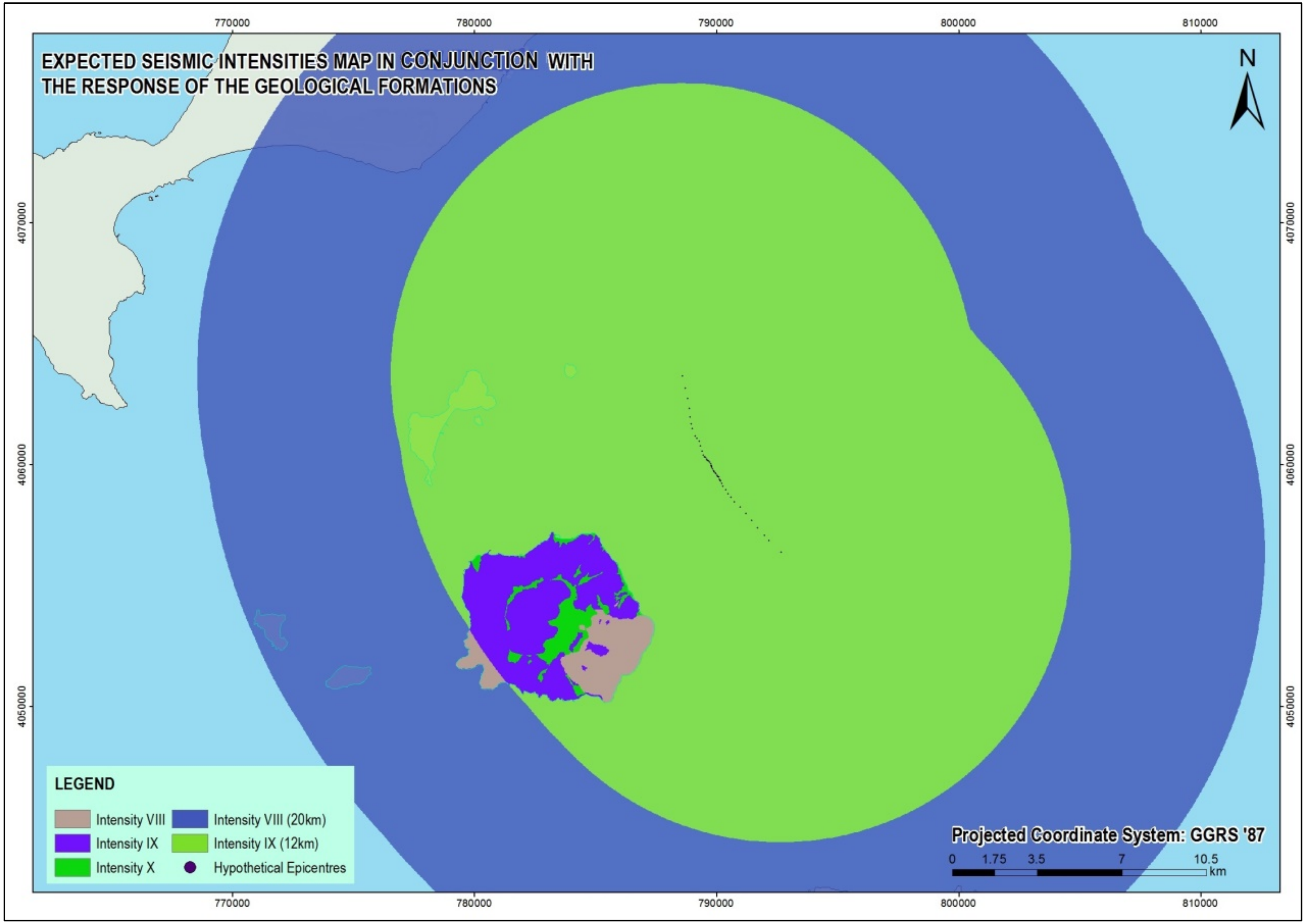


Figure 60: Seismic response of the geological formations for intensities VIII and IX for the F3 fault

4.9 CONCLUSIONS

The risk of an "earthquake-volcanic activity is greatly increased (even though a possible volcanic activity along the volcanic arc appears to be limited), which may have no apparent effect on the surface, but to be accompanied by a flare microseismic activity from the upheavals of magma in the volcanic field Kos- Nisyros - Yali - Tilos..

Any earthquake - volcanic risk is mainly controlled by the fault zones of the island and the geological formations with seismic response. The seismic crisis of 1995-1997 showed that the fault zones are high-risk areas. Thus, the major fault zones F1, F2 F3 and F4 can have a key role in the deformation and the evolution of the volcano.

The most prominent example is the seismic fault in Mandraki. This fault had been reactivated in the past during similar seismic crisis in 1873 and 1970. It is interesting to notice that the northwestern part of Nisyros is a tectonic block which during the last seismic crisis, showed the highest elevation in the recent geological evolution of the island.

The Nisyros caldera floor is affected by faults striking NE-SW.

Such seismic crisis involves many earthquakes M≤5.5. Although such earthquakes magnitudes do not impact on the surface, however, due to the potential small focal depth, although can be particularly dangerous for the settlements of the island.

Based on the geometric and kinematic characteristics of the main faults of Nisyros can be documented that the seismic potential of the faults of the island cannot go beyond a magnitude size M = 5.5.

The National Centre for Marine Research (Papanikolaou et al, 1998) studied the seabed around Nisyros and documented that the main active fault that was identified is the few kilometers extension of the Mandraki fault to the north.

Maximum magnitude calculation of the F3 fault according to the following equations for normal faults:

- Mw=4.86+1.32*log(SRL), Wells & Coppersmith (1994) and
- Ms = 0.98log(SRL) + 5.48, Pavlides & Caputo (2004).
  (SRL: Surface Rupture Length)

Fault	Length (km)	Magnitude (R)
F3	8,71	6,1-6,4

The risk of major earthquakes, similar to those which created widespread destruction in Kos and Nisyros in the past exists. That is due to:

- The major faults bounding the southern coast of Kos Island
- The NE-SW direction faults bounding toward the northwest tectonic horst of Tilos, which have given strong intermediate depth earthquakes that caused major disasters in Kos,
- The submarine NE-SW direction fault bounding the Kondeliousa tectonic horst southeast of Nisyros,
- A zone southwest of Tilos, with strong earthquakes both intermediate depth, and surface, which were felt in Kos
- The seismogenic zone around Nisyros (mainly west and southwest) and especially the possible fault zone passing through the northern part of Nisyros, which is related to the seismic events throughout the period 1901-1997.
- Similar direction faults detected in the submarine space of Goekova Gulf, east of Kos (Figure 17).

So, based on what has been mentioned above, the seismic hazard of Nisyros island is considered Very High.

5. WILDLAND FIRE HAZARD

5.1 FOREST FIRES, AN UNDOUBTEDLY MAJOR AND PERMANENT THREAT

Forest fires are currently the best known common problem facing our forests and the natural environment, destroying important ecosystems every year and high social importance areas. Over 10% of the country's area is covered by arid and rocky areas, as a result of successive fires. The fire is not only a factor of rapid degradation of forests, but frequently, at least in the case of Mediterranean forests, and renewal factor that fits into the natural ecological cycle.

Over the last two decades in southern Europe, more than 10 million hectares of forest have been damaged by fire. Each annual fire-fighting season incurs significant costs, measurable principally in terms of loss of human life, investment in fire-fighting resources, damage to the environment and the cost of recuperating the affected areas.

But modern conditions of rural use, development of summer houses and expansion of access roads increase the frequency of fire so much that is overcome by its natural role and can prove disastrous. The destructiveness of fires is primarily due to an increase in the frequency and the intensity and secondly the inadequate protection of natural regeneration processes and use of space.

Wildland fires present a challenge for forest management because they have the potential to be at once harmful and beneficial.

- On the one hand, wildland fires can threaten communities and destroy vast amounts of timber resources, resulting in costly losses.
- On the other hand, wildland fires are a natural part of the forest ecosystem and important in many parts of Canada for maintaining the health and diversity of the forest. In this way, prescribed fires offer a valuable resource management tool for enhancing ecological conditions and eliminating excessive fuel build-up.

Not all wildland fires should (or can) be controlled. Forest agencies work to harness the force of natural fire to take advantage of its ecological benefits while at the same time limiting its potential damage and costs.

This makes fire control strategies a vital component of forest management and emergency management.

The climatic conditions are a key factor in both the initiation and progression of a fire, and to restore vegetation in burned areas (Sharma and Rikhari, 1997). In recent years, the variation in the climate system, coupled with the increase in biomass, due to the decline of agricultural activities in rural areas and the abandonment of forest management, have aggravated the problem, resulting in the emergence of large and uncontrolled wildfires.

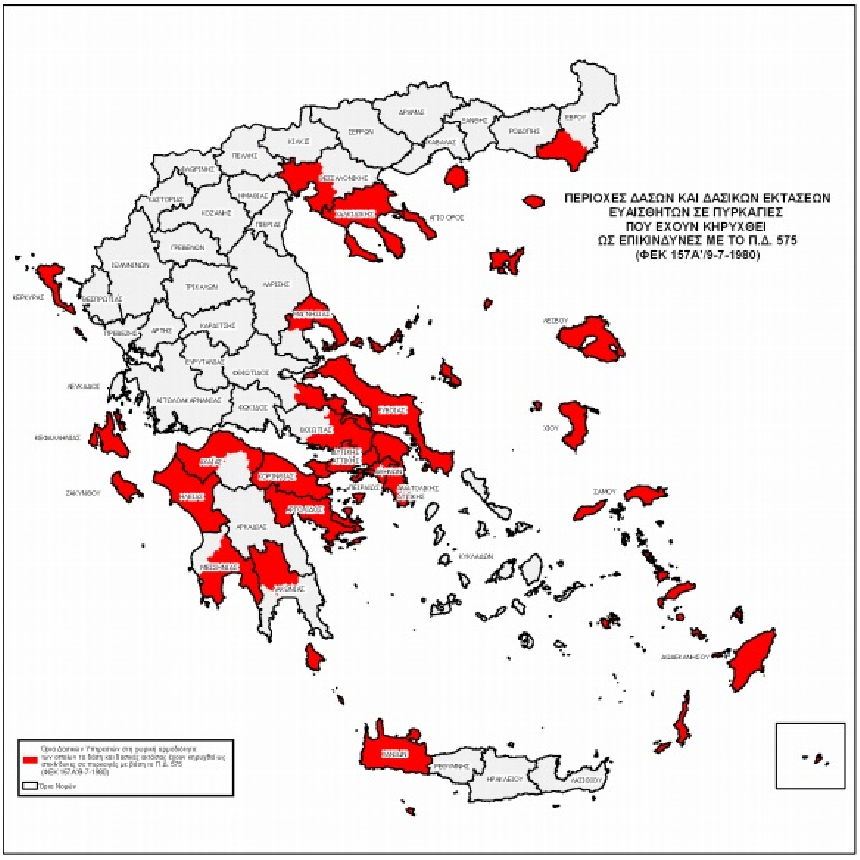


Figure 61: Forest areas and forests susceptible to fires that have been declared "High Risk" under the Presidential Decree No. 575.

5.2 FOREST FIRES AND CLIMATE CHANGE

The climate change currently affecting our globe will most likely exacerbate the current risks of forest fires. In particular, the climate of Southern Europe and the Mediterranean basin is projected to warm at a rate exceeding the global average. Precipitations are projected to decrease, while temperature variability, the number of dry spells and droughts and the intensity of heat waves are all projected to increase. Consequently, the length and severity of the fire season, the extreme conditions in many areas, the extension of areas of risk and the probability of large fires will increase. As a result, climate change will have an added impact upon the growth conditions and evolution of European forests and may, as a consequence, enhance desertification.

5.3 FOREST FIRE OCCURRENCE SPOTS

It is necessary to know the spots where forest fires usually occur, since this information is considered important for the organization of protection and the enforcement mechanisms. The classification according to the records is:

- residential area
- national or provincial road
- forest
- forest road

- forest soil
- woodland
- farming installation
- agricultural cultivation
- regeneration-reforestation
- unknown

5.4 FOREST FIRE CAUSES

According to forest fire statistics, 9 out of 10 forest fires are of human-caused origin. The main causes of forest fires are:

- Agricultural activities like burning grass-gorse or stubble.
- Throwing of burning cigarettes end or matches.
- Lighting of fires in restricted areas.
- Burning of wastes and garbage at non-authorized landfill sites.
- Military exercises.
- Hunting activities
- Residential activities like the use of electrical tools that cause sparks and burn of wastes.
- Arson.
- Short-circuit of power lines.
- Lightnings.

According to WWF Hellas, the Prefecture of South Aegean (where the island of Nisyros administratively belongs to), the annual number of forest fires is between 31-40 and the places where forest fires start, mainly, are the forests, woodlands and agricultural cultivations.

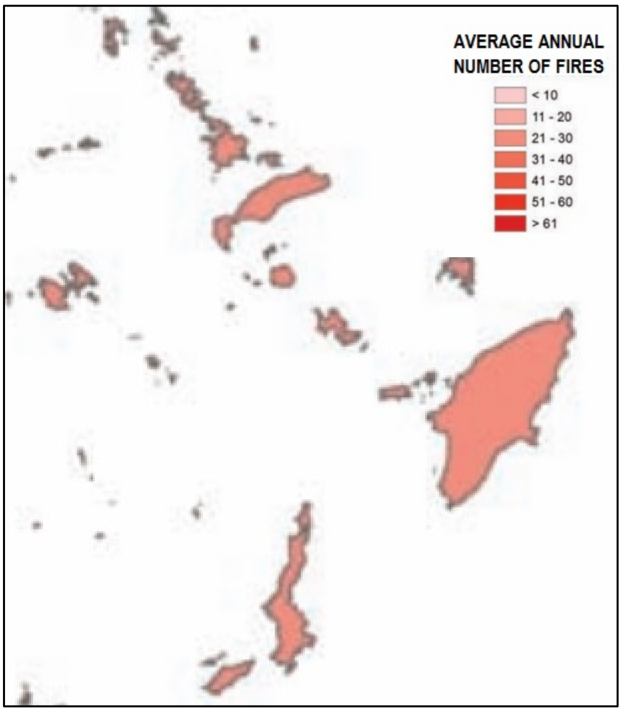


Figure 62: Average annual number of fires (source: WWF Hellas)

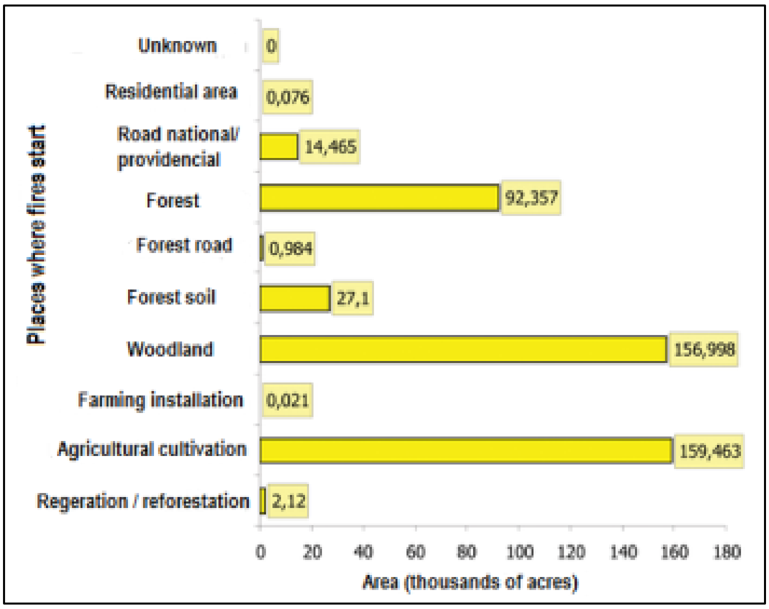


Figure 63: Total number of fire occurrences per event in the Prefecture of South Aegean (source: WWF Hellas)

5.5 RECORDED FOREST FIRES IN NISYROS ISLAND

PLACE	FIRE EVENT DATE	FIRE EVENT TIME	FIRE EXTINCTION DATE	FIRE EXTINCTION TIME	BURNT FOREST AREAS (ESTIMATE IN ACRES)	BURNT GRASSLAND AREAS (ESTIMATE IN ACRES)	BURNT AREAS – OTHER CULTIVATION (ESTIMATE IN ACRES)
EMBORIOS	1/7/1977 2/7/1977				6600		
MANDRAKI	29/7/1977 30/7/1977 31/71977 1/8/1977				5000		
NIKIA	17/6/1989				100		
NIKIA	17/8/1999	14:20:00	8/17/1999	16:40:00			10
NIKIA	14/7/2000	22:30:00	7/16/2000	7:00:00	150		
HAROUPIA	9/11/2000	11:30:00	11/9/2000	13:30:00		3	
NIKIA	18/9/2004	10:20:00	9/19/2004	4:00:00	10	30	
AGIOS IOANNIS THEOLOGOS	3/7/2005	10:20:00	7/3/2005	19:00:00		0,3	

Table 8: Recorded forest fires (source: Fire Service, Rhodes Forestry Service)

Causes that can cause fire through negligence:

- throwing lit cigarettes,
- burning dry grass and branches or cleaning residues,
- the use of machines that cause sparks as circular saws, welding machines,
- the use of outdoor grill

It is important to notice that in Nisyros island there is no Fire Service. During the fire period from May 1st to October 31st, trained volunteers and seasonal firefighters are responsible to act in case of a fire event.

Specifically, there are 2 spouts, one at Emborios village square and the other one at Ilikiomeni square in Mandraki village. There are municipal tanks in every village and a desalination tank at Loutra. The municipal tank at Nikia fills all fire vehicles (Figure 66).

5.6 NISYROS ISLAND ELECTRICITY

Most islands in Greece (mainly in the Aegean Sea) are electrified by autonomous electrical systems to generate electricity primarily from local thermal power plants, which operate with fuel oil, heavy (mazut) or light (diesel), and stations RES (wind and photovoltaic). These islands are not interconnected to date with the mainland power system, mainly due to technical and technological difficulties, which existed previously, but due to financial difficulties as the interfaces are capital-intensive projects.

According to HEDNO S.A. (Hellenic Electricity Distribution Network Operator S.A.), in Nisyros island there is no high voltage network (so no pillars). There is a 20KW voltage network and a transformer reduces the voltage to 220V for home use. Consequently, there is no power station in Nisyros. Therefore, the island is powered by a power station in the neighboring Kos island via submarine cable. (Figure 63).

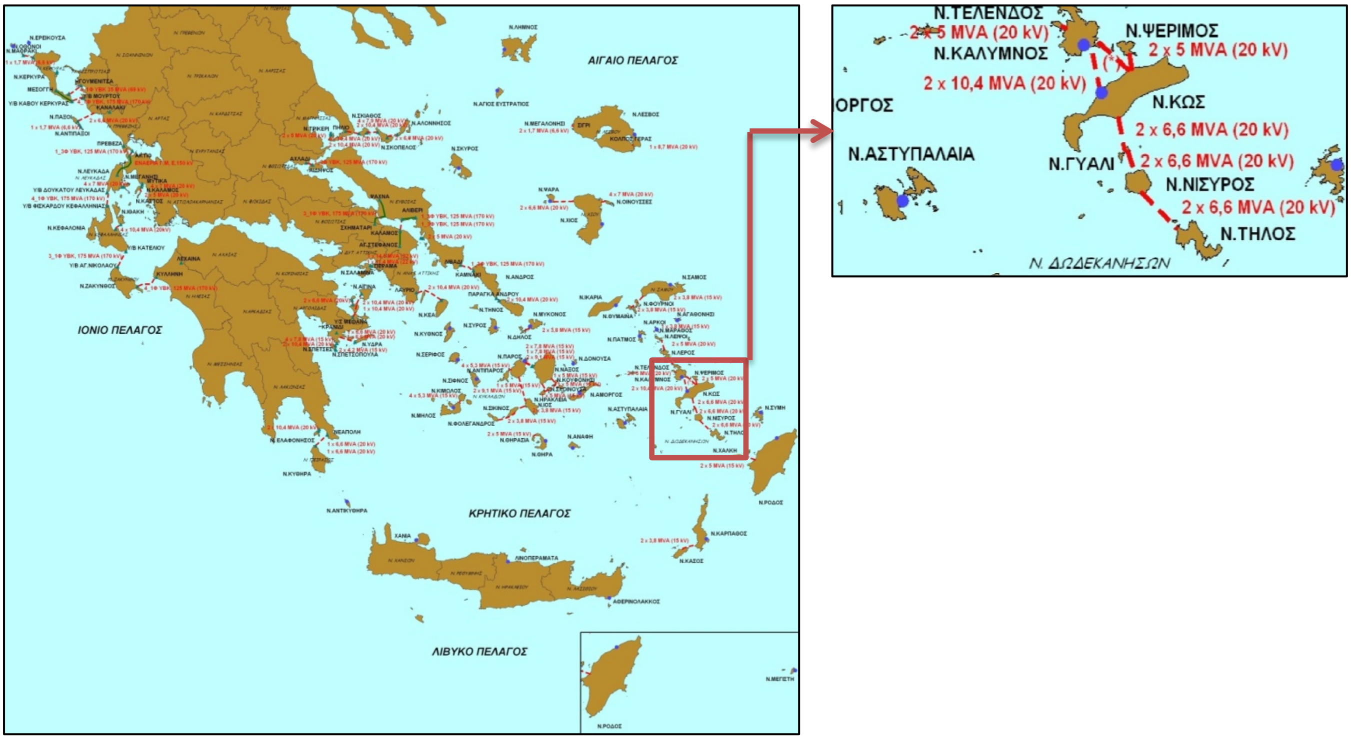


Figure 64: Public Power Corporation S.A. Interconnected Transmission System Map of Greece

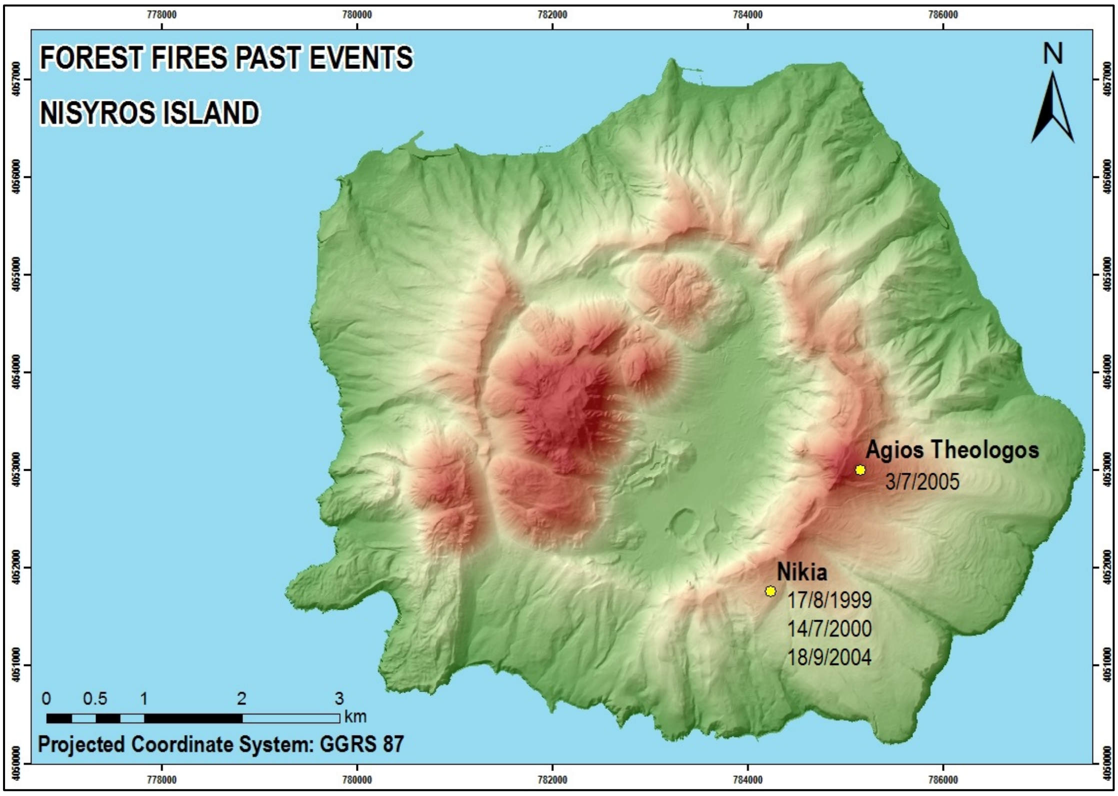


Figure 65: Forest fire historical events

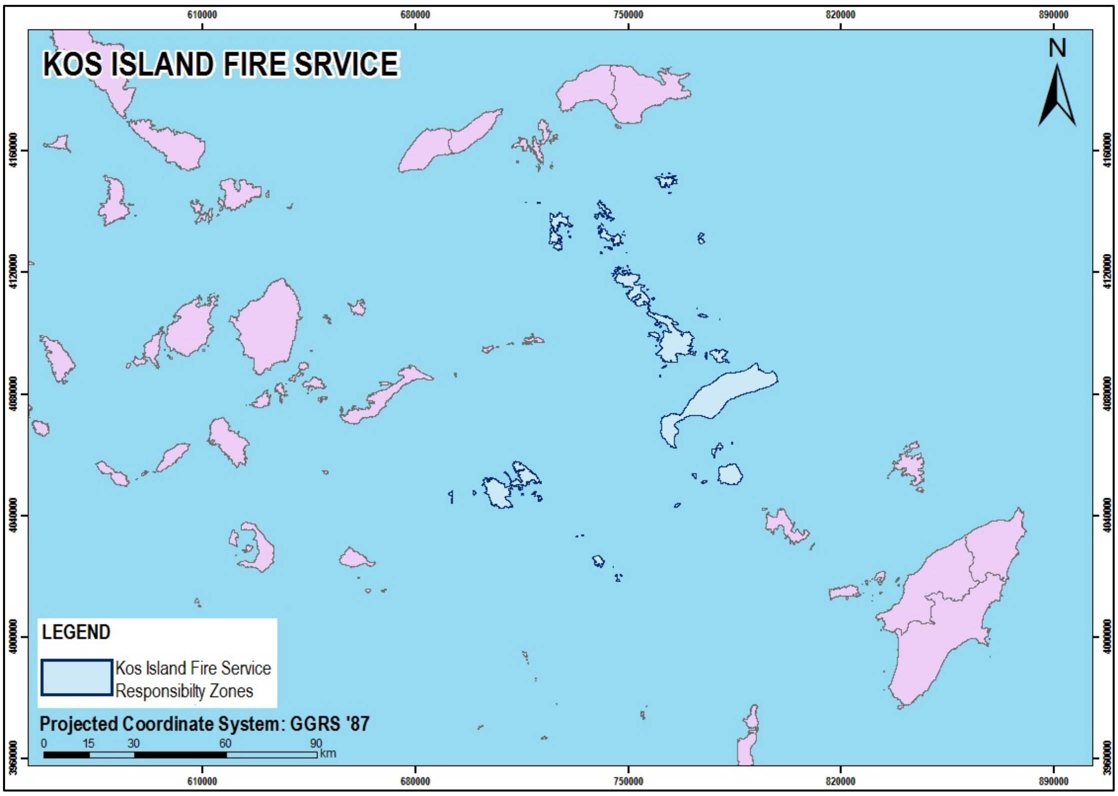


Figure 66: Kos island Fire Service responsibility zone

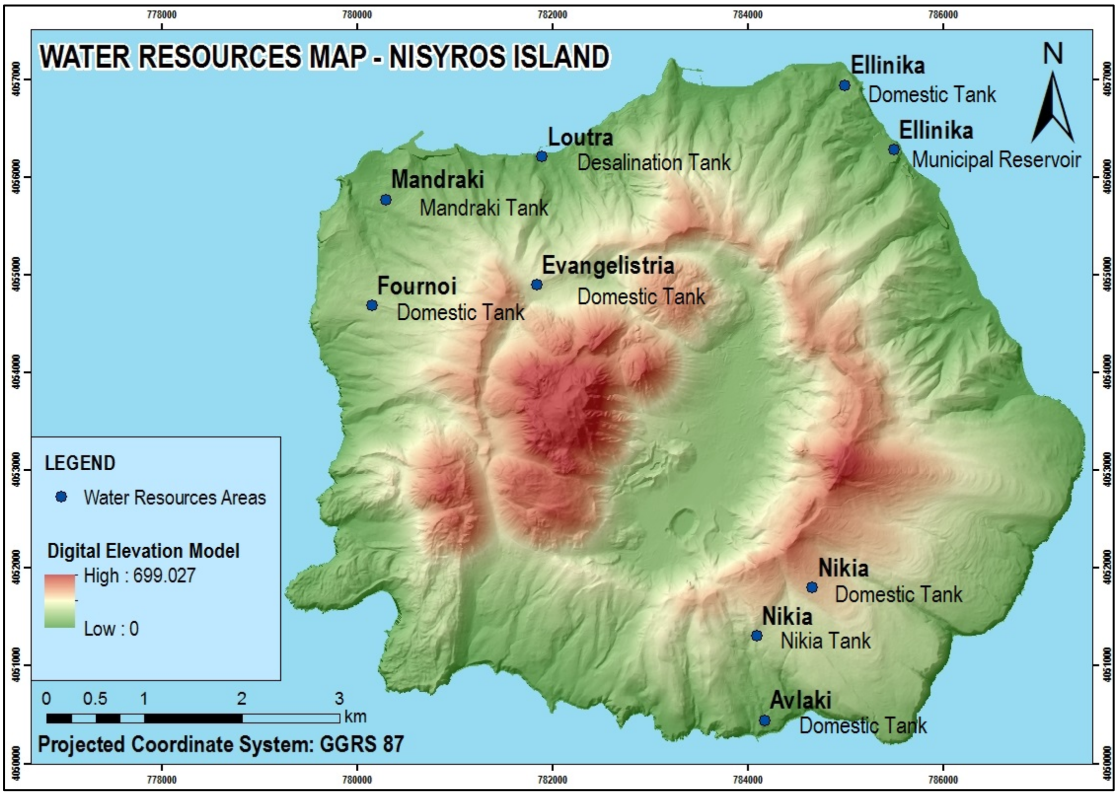


Figure 67: Water resources spots

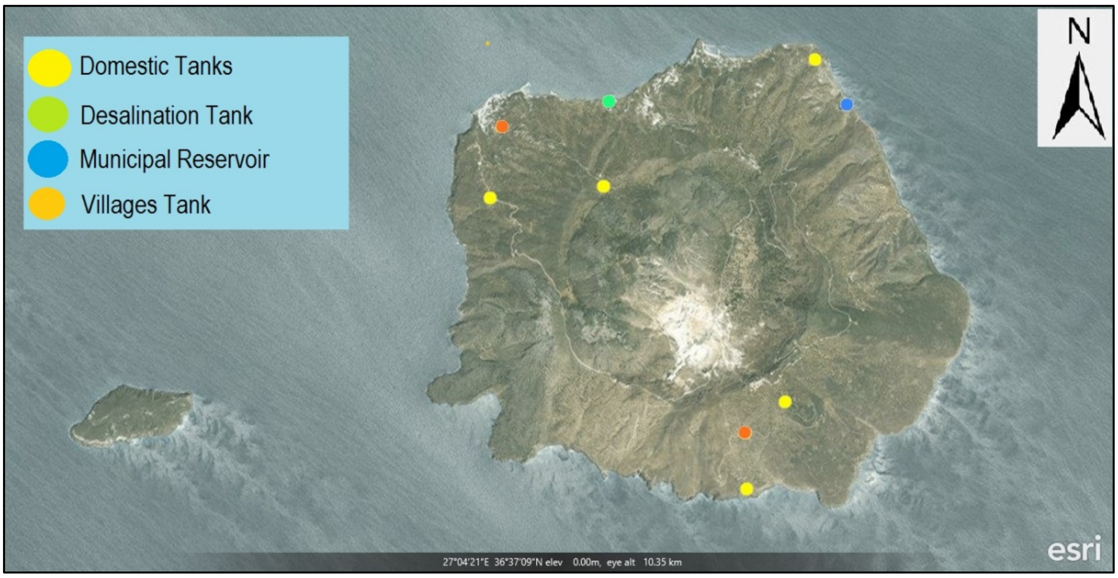


Figure 68: Water Resources spots satellite image (ESRI ArcGIS Earth)

5.7 FOREST FIRE RISK ASSESSMENT

For the forest fire risk assessment, it will be used the "Action Plan Drafting Guide for the Prevention of Forest Fires", which was written under the European Project LIFE-Environment entitled "Local Authorities for Forest Fire Prevention Program".

A cause forest fire could be both natural and anthropogenic factor. According to this guide, the key factors used to construct a quantitative fire risk map is the vegetation, topographical slope, the aspect slopes, as well as the affection of settlements and landfills in the region, roads and high voltage grid of Public Power Corporation.

VARIABLES	CLASSES	RATINGS	WEIGHTING FACTOR
Land Use/ Vegetation type	Forests Grassland Olive Groves-Pastures Agricultural areas Artificial surfaces	5 4 3 2 1	47%
Habitation/ Landfill Sites	Landfill Site (100m) Settlements (400m)	5 4	15%
Topographical Slopes (%)	40,1%-53% 13,1%-40% 0%-13%	5 3 1	17%
Aspect Slopes (degrees)	135°-270° 46°-135° & 271°-315° 0°-45° & 316°-360°	5 3 1	7%
Road Network (fire influence zone with a radius of 50m)	< 50m > 50m	5 4	14%
Electricity Distribution Network of Public Power Corporation (fire influence zone with a radius of 30m)	No data	-	-

Table 9: Parameters affecting fire occurrence and their weighting factors (Source: Action Plan Drafting Guide for the Prevention of Forest Fires, Project "Life")

Therefore, the following fire initiation risk factors should be considered:

- aspect slopes (S-SW)
- slopes (fire travels most rapidly up slopes and least rapidly down slopes)
- forest fuel and vegetation
- land use
- recorded previous forest fires
- anthropogenic Interventions (deliberately or accidentally) - high risk areas (settlements, roads, railways, dumps)
- hydrographic Network
- climatic data (rainfall - temperature)

In the study area, the vegetation map was constructed based on data collected by the Ministry of the Environment and Climate change Maps Service. Most of the island is covered by shrubs, pastures and crops with small to medium risk of flammability. Additionally, it is one of the three islands of the Dodecanese whose forests consist of oaks. Oaks' risk of flammability is very high (Figure 68).

Then, dangerous slopes were grouped conducive to the spread of fire, with the riskier ones over 40% and the proportional Map (Figure 69) was constructed. Subsequently, were grouped the dangerous aspects that favor the fire start, which are the South and Southwest, considering that they are warm and dry winds, while in the same time affect the vegetation as well (Figure 70).

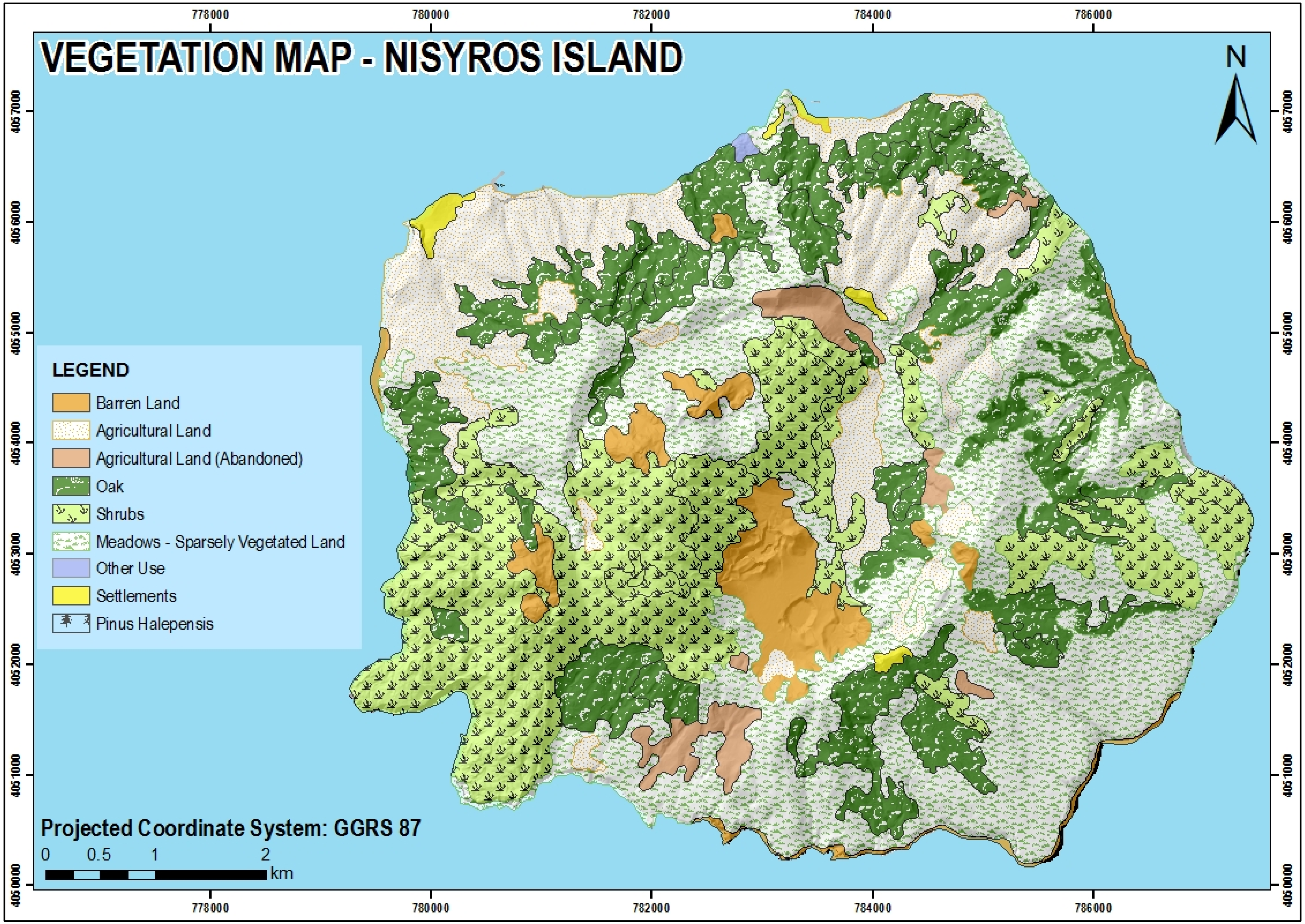


Figure 69: Vegetation Map of Nisyros Island

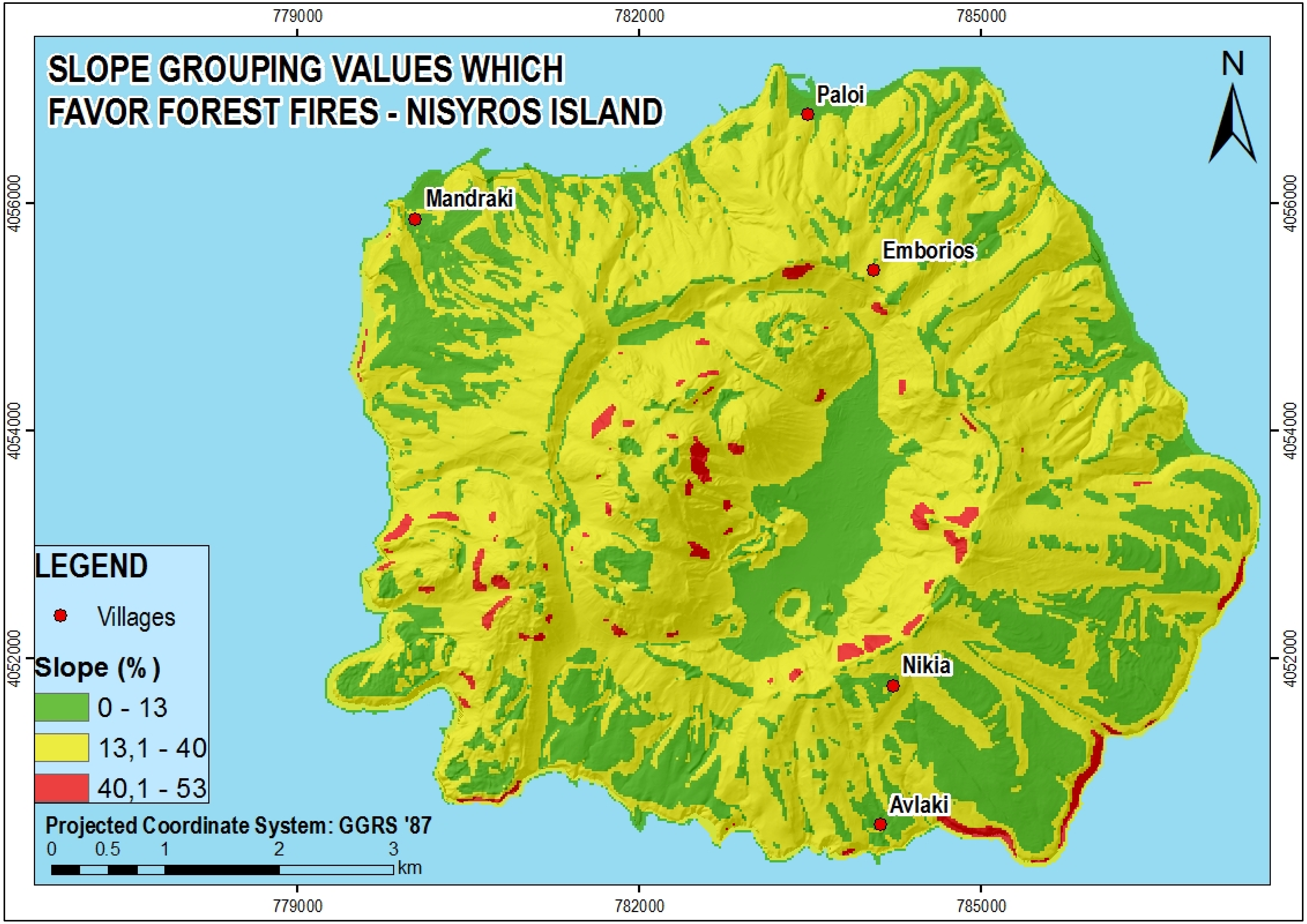


Figure 70: Slope grouping values which favor forest fires

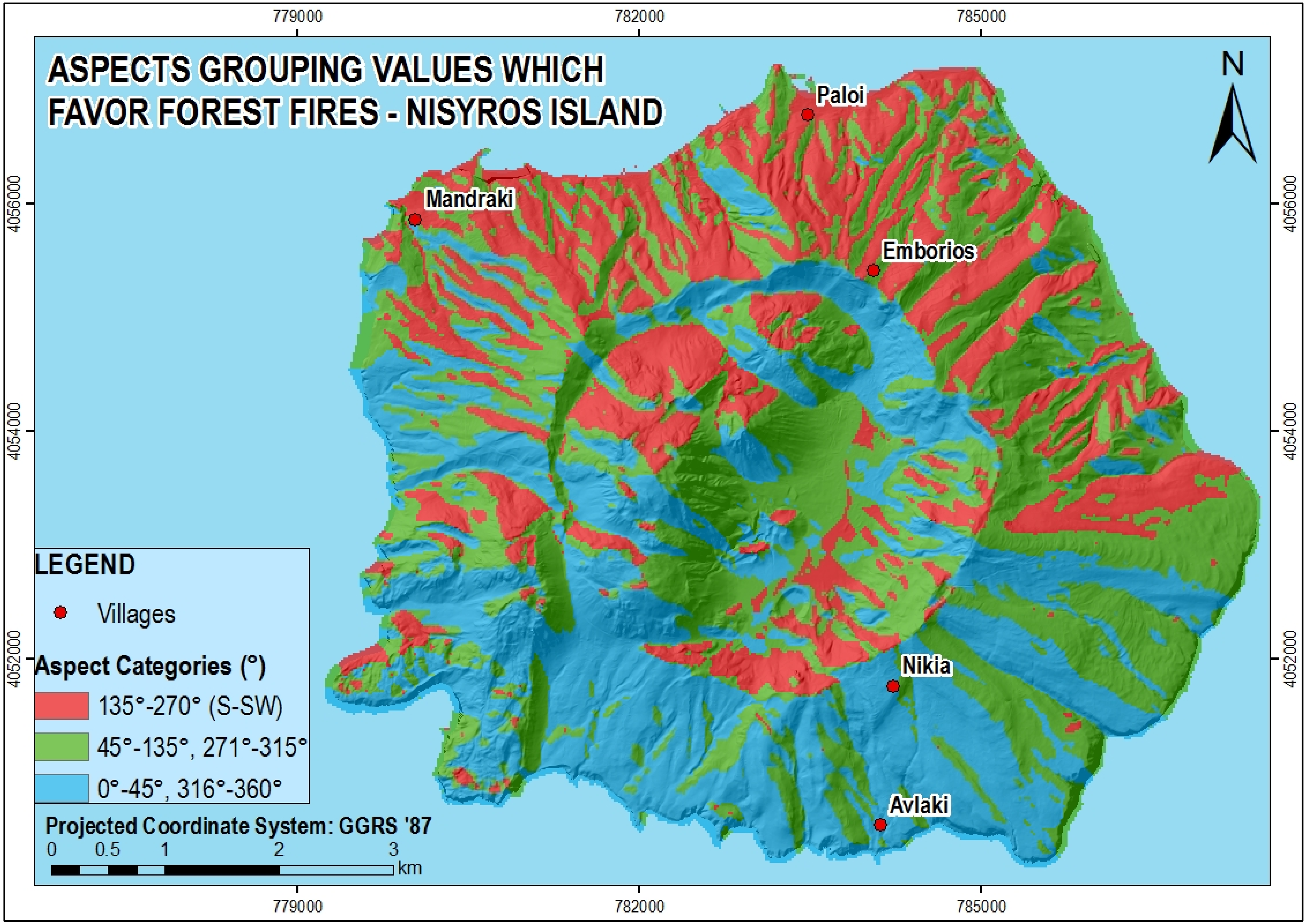


Figure 71: Aspects grouping values which favor forest fires

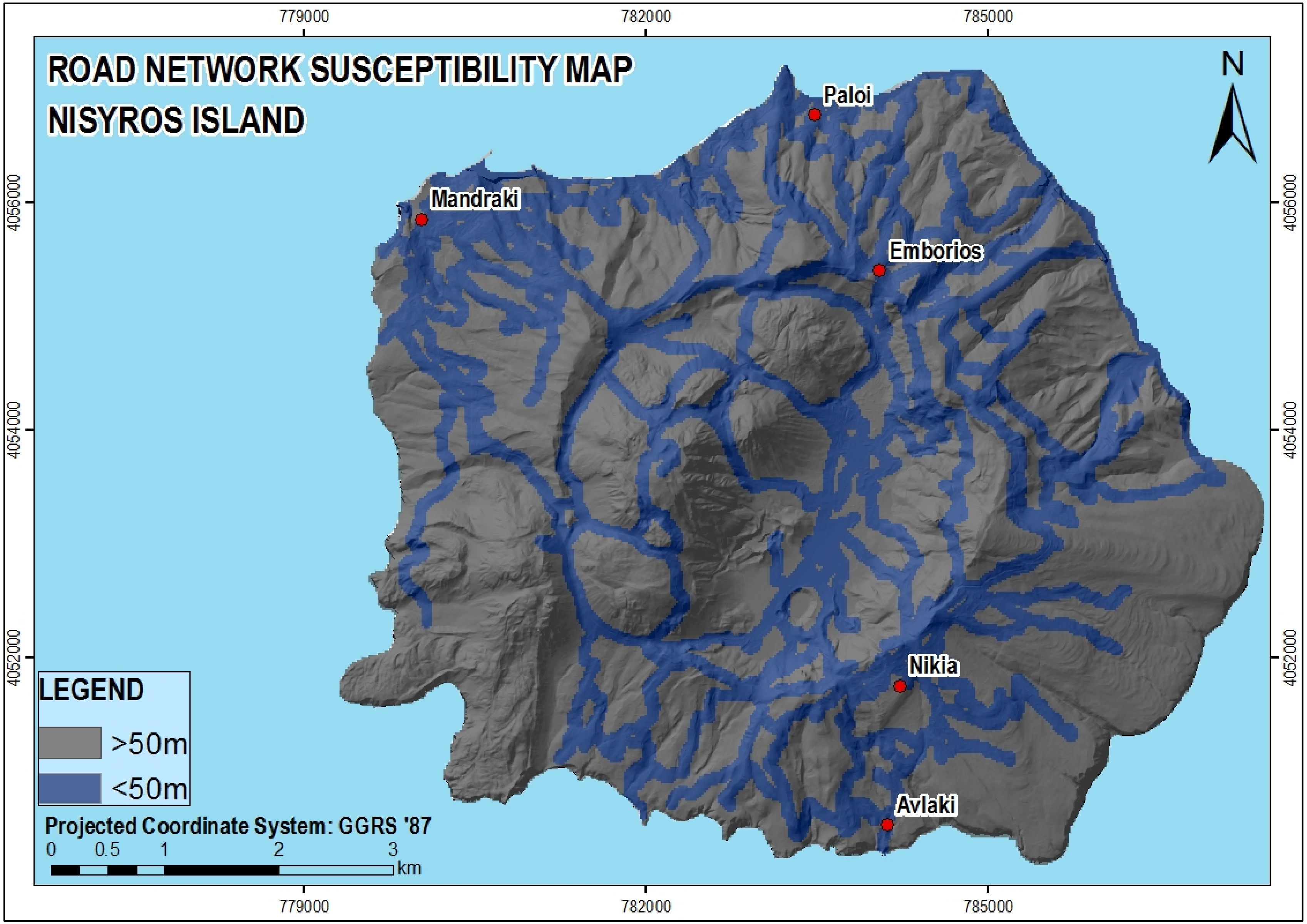


Figure 72: Road network susceptibility map

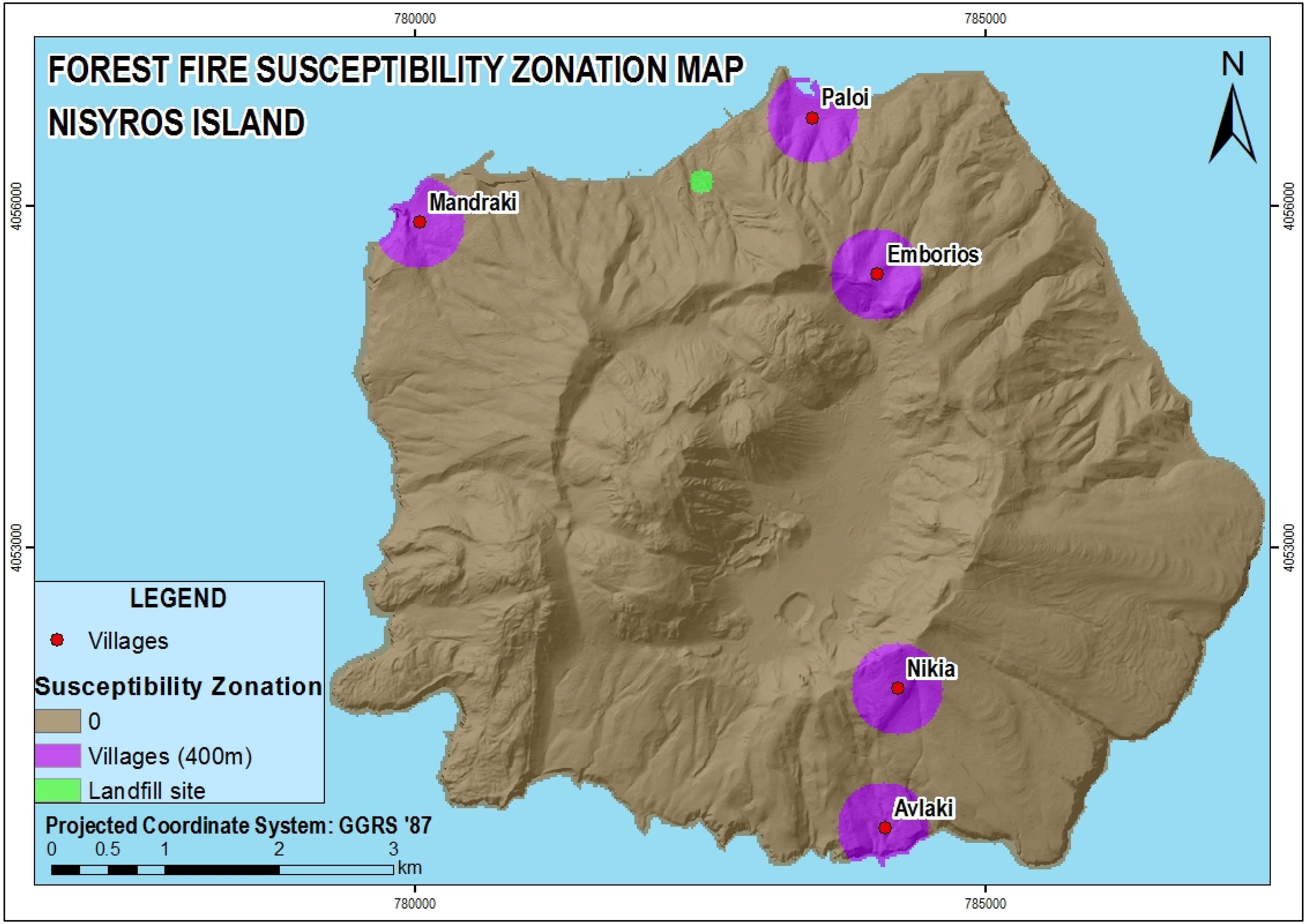


Figure 73: Forest fire susceptibility zonation map

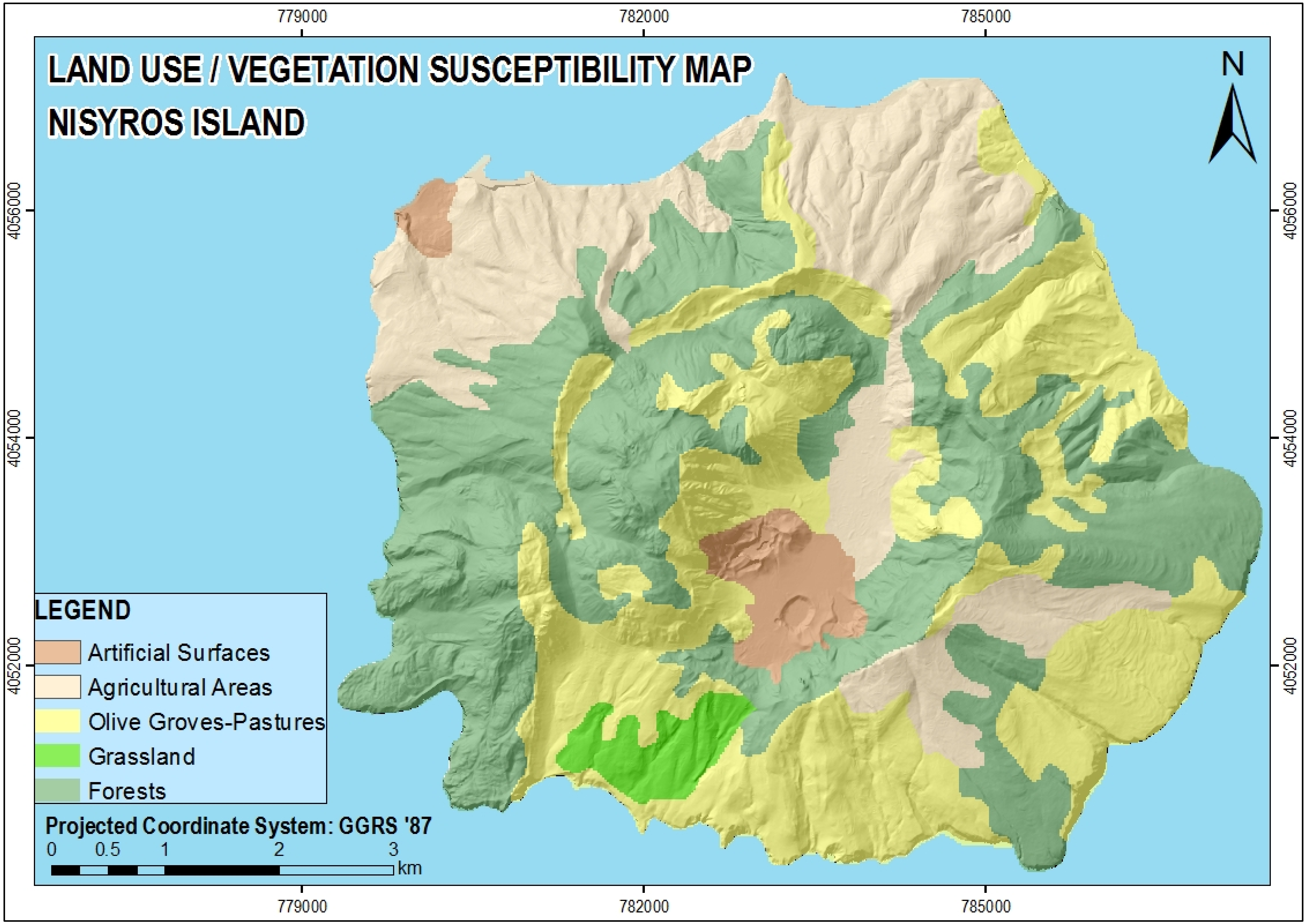


Figure 74: Land Use/Vegetation susceptibility map (the risk increases from the Artificial surfaces to the Forests)

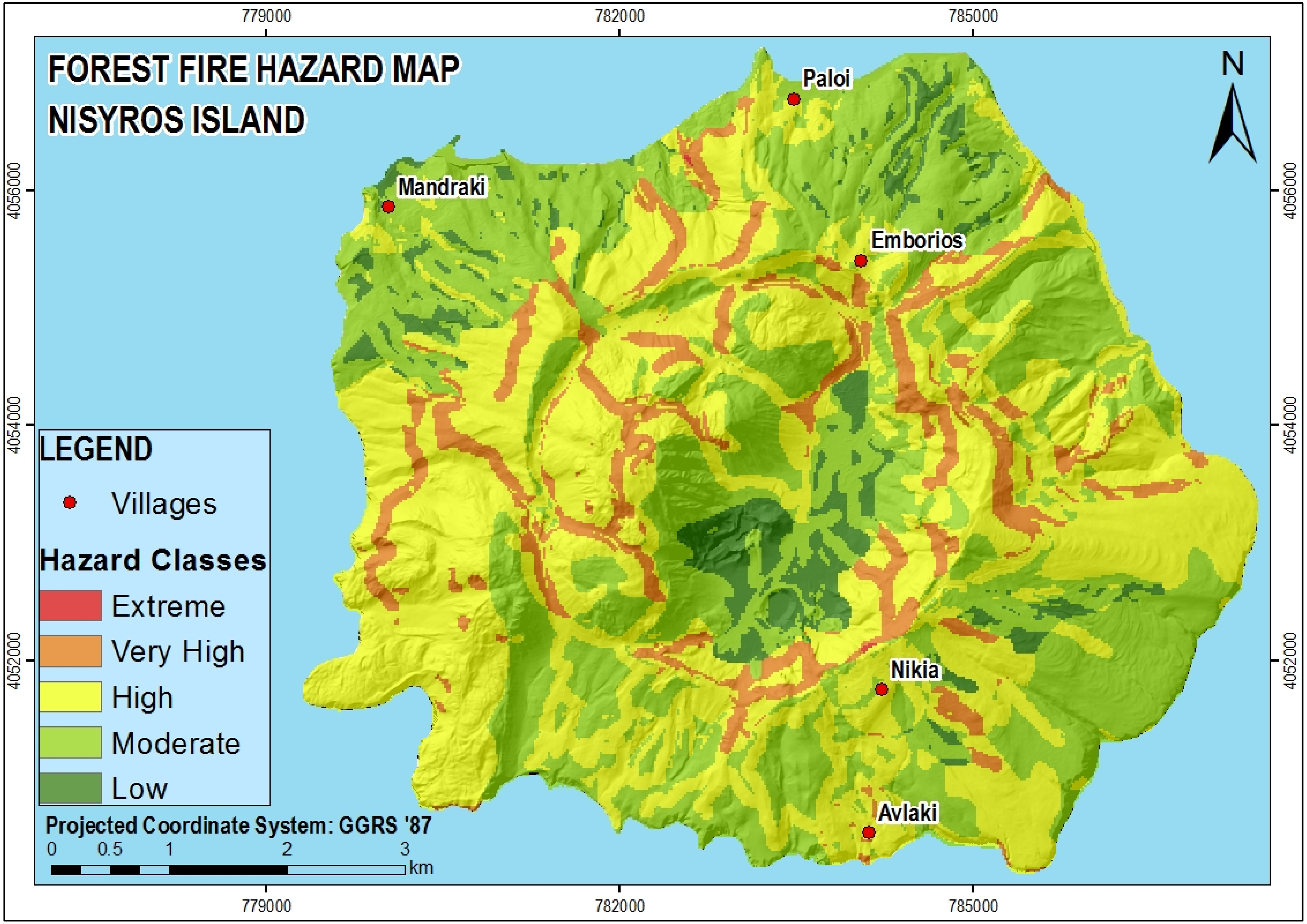


Figure 75: Forest fire hazard map for Nisyros Island

5.8 CONCLUSIONS AND RECOMMENDATIONS

Forest fires are the most serious risk that threatens the existence of forests on the island of Nisyros. These forests consist mainly of oak, where Nisyros is one of the three islands of the Dodecanese having such forest. Besides arboreal vegetation, thick bushy vegetation occupies large areas.

There is a wide range of factors that contribute to an increased forest fire risk, such as the prolonged dry and hot summers, strong winds, large gradients of forest soils and flammable vegetation.

The negative consequences that follow the fire are numerous. Degradation of the environment, disturbance of the ecosystem balance, soil erosion, torrents and floods are created, affection of the microclimate, flora and fauna are destroyed damaging the economy and replacing the beauty by the desertification.

The main causes of forest fires on the island of Nisyros are:

- hydrothermal eruptions and gases escape into the volcano crater
- temperature increase due to volcanic activity
- discarding lit cigarettes and matches or fires in the unauthorized areas
- burning garbage
- various activities in cottages
- arsons
- lightnings

Therefore, the risk is considered very high.

Forest Fire Prevention & Safety Tips

- Fire observatories installation in order to help the fire staff having visibility among the dangerous sites.
- Awareness and informing of citizens and students about fire risk issues and protection.
- A common understanding of forest fire prevention (definition, activities) is needed.
- Utilization of more trained volunteers.
- Increased importance must be given to forest prevention measures, also on specific budget allocations, with the aim to reduce the probability of fire occurrence and to limit the effects of forest fires.

In qualitative map below (Figure 75), was overlaid the vegetation cover and the visible areas, as well as water points in order to identify "hazardous" areas, which are marked with the oval shapes. Potential fire observatories were placed as a visibility example.

The importance of forest fires, and in particular, fire prevention should be integrated in adaptation strategies. Especially for the Mediterranean region the need for measures that make it possible to live in harmony with forest fires should be in top priority. Contrary to other natural hazards (earthquakes, storms etc.), forest fires are predictable. This, in principle, should leave modern societies with a degree of freedom, and an advantage for implementing efficient preventive strategies and measures.

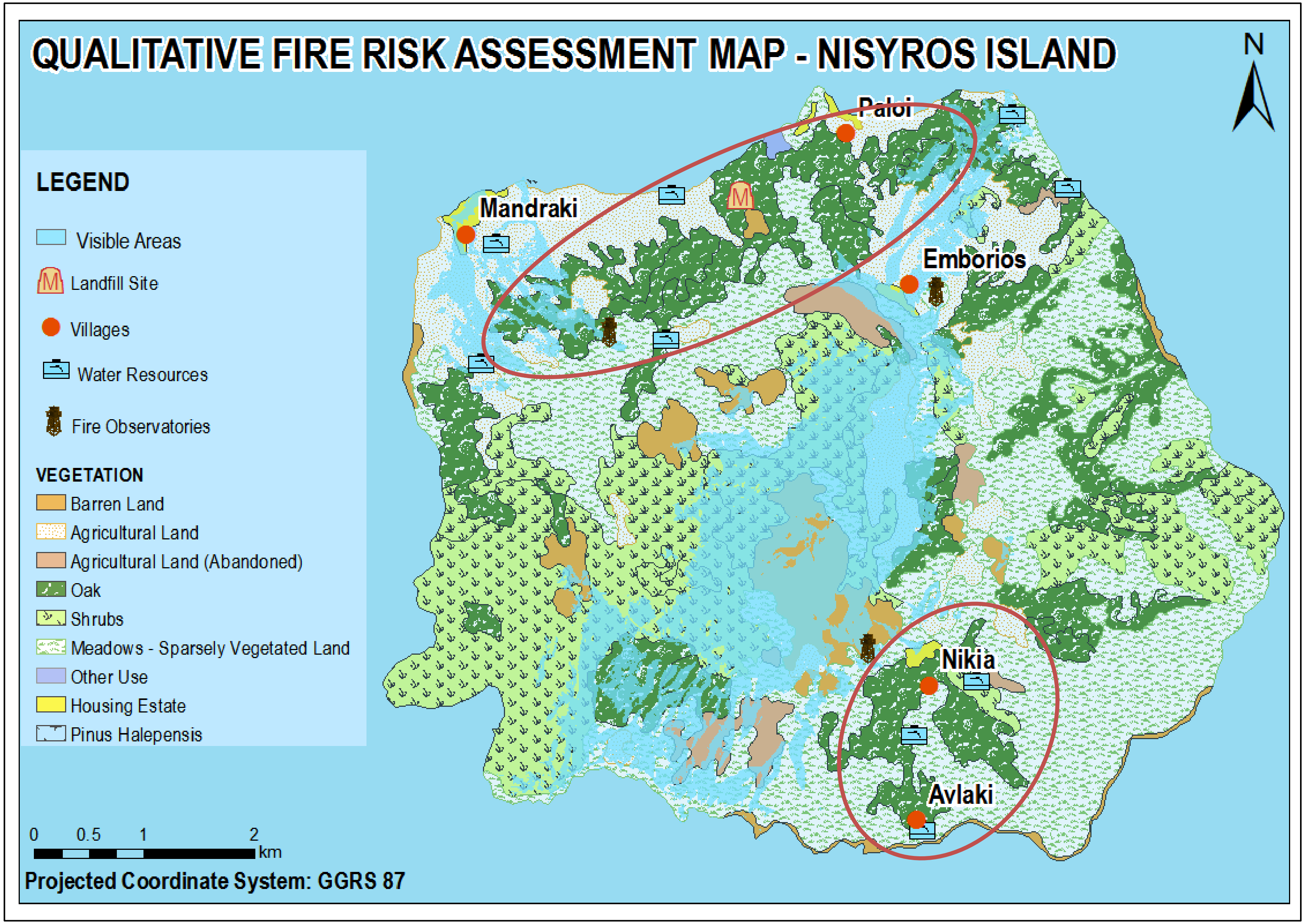


Figure 76: Qualitative Risk Assessment Map. Hazardous areas identified within the oval shapes

6. FLOOD HAZARD

6.1 FLOODS - A SIGNIFICANT THREAT TO HUMAN LIFE

Floods are considered among the most frequent and destructive types of natural disasters worldwide. The report of human life and property at risk, destruction of infrastructure, agricultural and livestock buildings, the intense soil erosion and pollution of water masses are some of their most significant impacts. They are one of the most important natural disasters in Europe (together with storms) and have caused about 100 billion euros of damage over the period 1986– 2006 (CEA, 2007).

According to Downton and Pielke (2001) and Golian et al (2010), floods affect the largest number of people and cause the most damage of all natural disasters annually. Pilon (2004) mentions that floods cause one third of the estimated damage caused by natural disasters worldwide.

World's leading reinsurance companies such as Munich Re, declare that floods record significant rates among other types of disasters both in absolute number of events, and in terms of financial losses. Specifically floods account for 26% of the number of large-scale catastrophic events between 1950 to 2002, 8% of deaths and 27% of the economic cost caused by natural disasters in the same period (Munich Re 2002).

Floods are encountered in various forms, and their causes and effects vary greatly: they may develop over a period of several rainy weeks, due to the rising waters of a lake or groundwater table, or in a matter of minutes, when streams are transformed into raging torrents during a thunderstorm. Almost any location may be inundated. Floods are a recurring threat to buildings and facilities built close to bodies of water, but even areas situated far away from watercourses and lakes are not immune to flooding.

In the Greek territory, floods are one of the most important classes of natural disasters, both economically and in terms of cost in human lives.

The victims in Greece between 1887-1994 amounted to 216 (Nikolaidou, Chatzichristou, 1995). Besides human lives floods have substantial effects on properties (houses, shops, factories), in agriculture, livestock, infrastructure (engineering structures, roads) and utility lines. Also, important are the consequences on the environment, although the extent of the impact has not been sufficiently investigated. One of the technical features in Greece is the significant lack of instrumental data mainly regarding the systematic recording of runoff water courses.

According to the Directive 2007/60/EC of the European Parliament and of the Council on the assessment and management of flood risks: Floods have the potential to cause fatalities, displacement of people and damage to the environment, to severely compromise economic development and to undermine the economic activities of the Community. Definitions of "flood" and "flood risk" are given below.

- "Flood" means the temporary covering by water of land not normally covered by water. This shall include floods from rivers, mountain torrents, Mediterranean ephemeral water courses, and floods from the sea in coastal areas, and may exclude floods from sewerage systems.

➢ "Flood risk" means the combination of the probability of a flood event and of the potential adverse consequences for human health, the environment, cultural heritage and economic activity associated with a flood event.

The island of Nisyros is characterized by the typical volcanic stratigraphy of a stratovolcano.

6.2 FLOOD RISK ASSESSMENT CRITERIA:

- very low slope gradients
- alluvial deposits
- permeability
- stream convergence
- land use
- man interventions (settlements, bridges, roads)
- disaster History

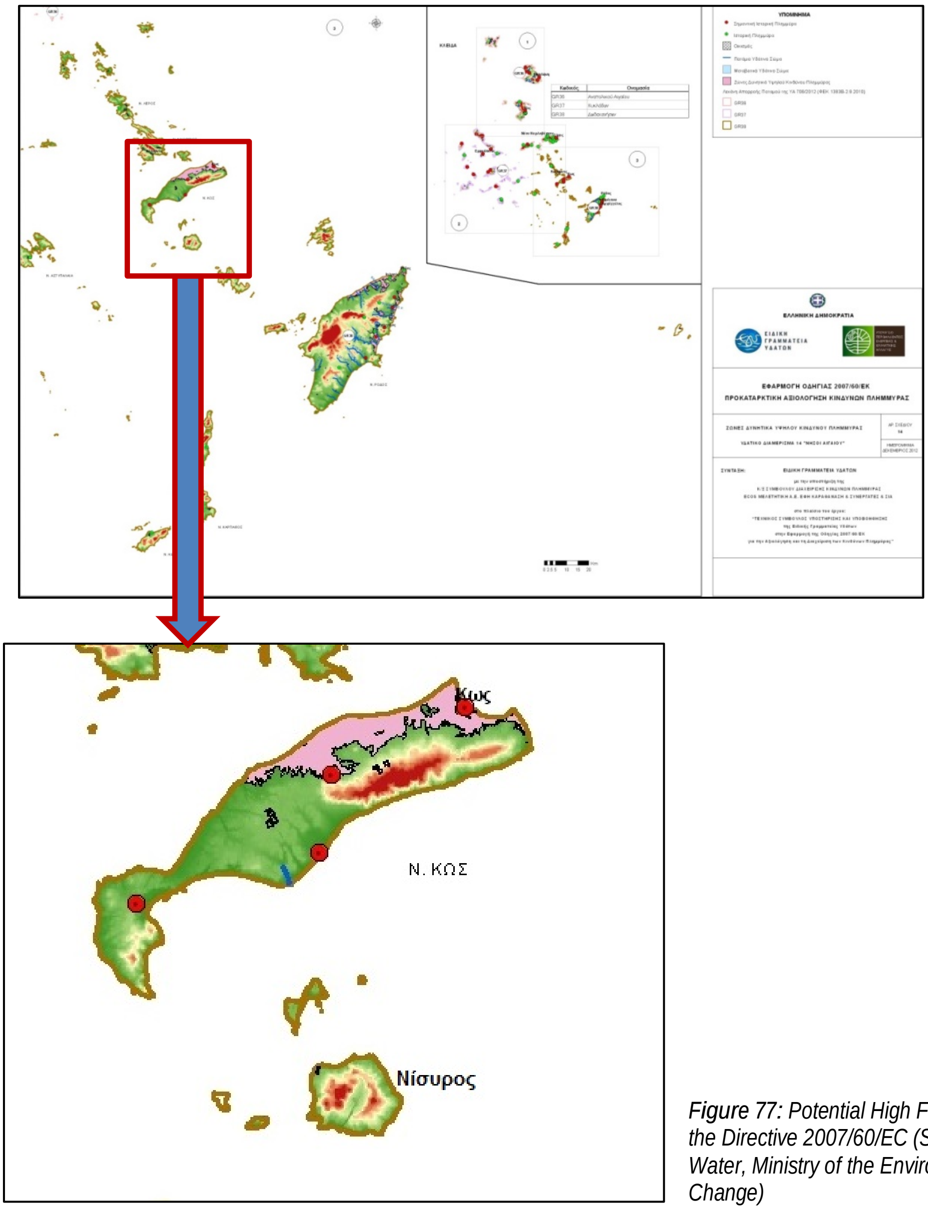


Figure 77: Potential High Flood Risk Zones based on the Directive 2007/60/EC (Special Secretariat For Water, Ministry of the Environment, Energy and Climate Change)

6.3 PERMEABILITY

- Coastal deposits and conglomerates - Permeable

Located in the northern and northeastern part of the volcano, at the exit of the main currents of the river drainage network and are mainly due to limited deposits. Characterized 'permeable' deposits as soft coastal deposits and conglomerate deposits are characterized by double porosity due to faults and joints.

- Intracalderic deposits - Impermeable

These are products of hydrothermal explosions and lake sediments. These cover the remaining uncovered part of the caldera floor and constructed mainly of clay minerals. These deposits are characterized as "impermeable" due to the high clay minerals stake.

- Scree and tectonic breccia - Permeable

Limited deposits, poorly classified clastic sediments derived from rock falls and / or gravity slips. These deposits are characterized as "permeable" but significant enrichment does not occur due to the low amount of rainfall observed on the island.

- Pumice deposits - Semi-permeable to impermeable

The pumice deposits while exhibiting a high porosity (up to 90%) characterized as a "semi-permeable" to "impermeable" because of their low conductivity as there is no communication between most of the holes.

- Pyroclastic deposits - Semi-permeable to impermeable

Pyroclastic deposits basic pyroclastic flows and ash located in the northeastern and eastern parts of the volcano and also characterized as "semi-permeable" to "impermeable" because of the large proportion of fine material in bulk.

- Lava flows - Semi-permeable to impermeable

Also, lava flows detected island designated as "semi-permeable" to "impermeable." These formations (lava domes and lava flows) have double porosity and allow infiltration of rainwater through the handles cooling cracks. However, the permeability decreases due to the development of clay minerals that fill these cooling cracks.

Based on the above, the permeability map was created (Figure 77). As a result, it is concluded that on the Nisyros volcano extensive aquifers cannot be developed.

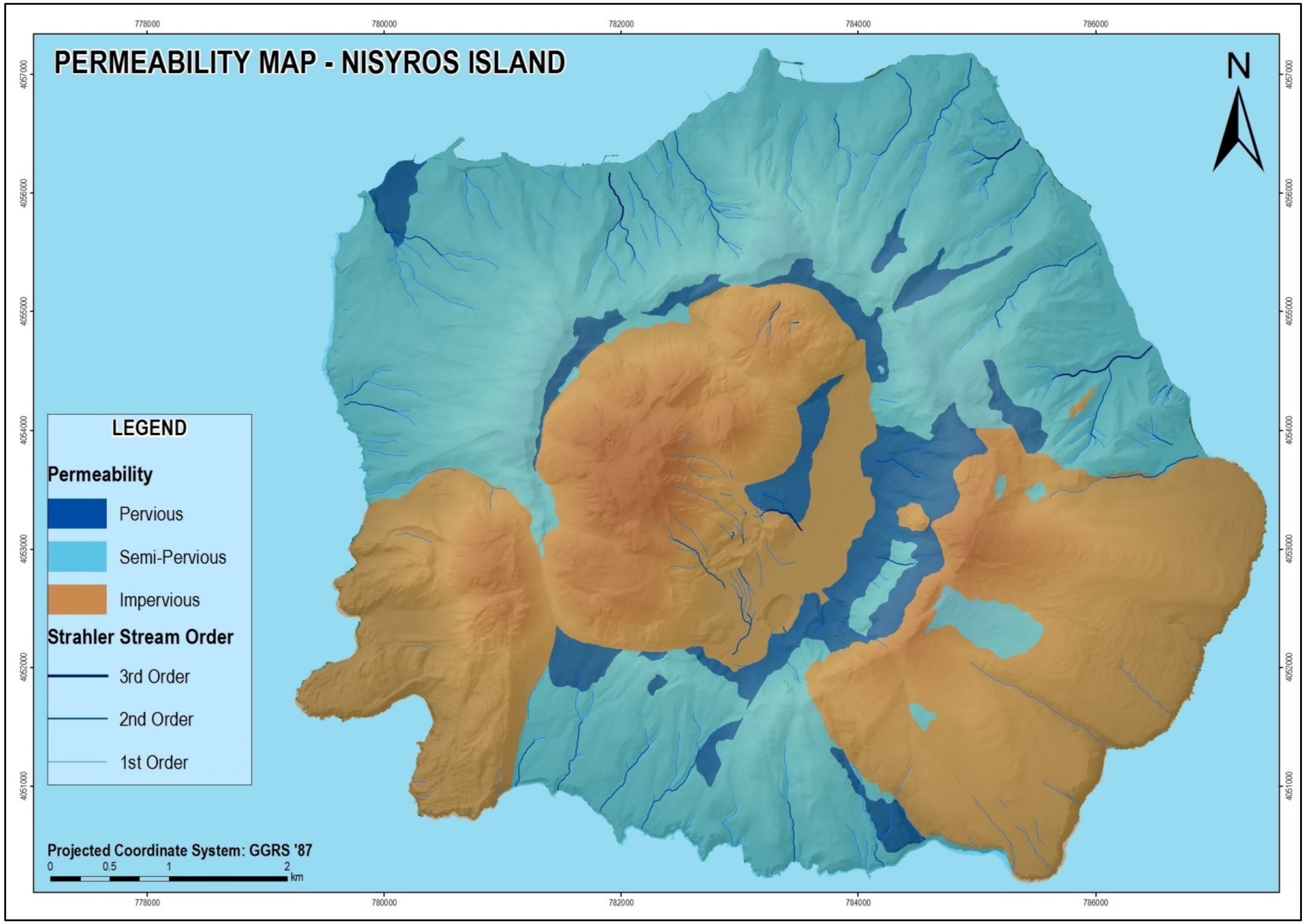


Figure 78: Permeability map of Nisyros

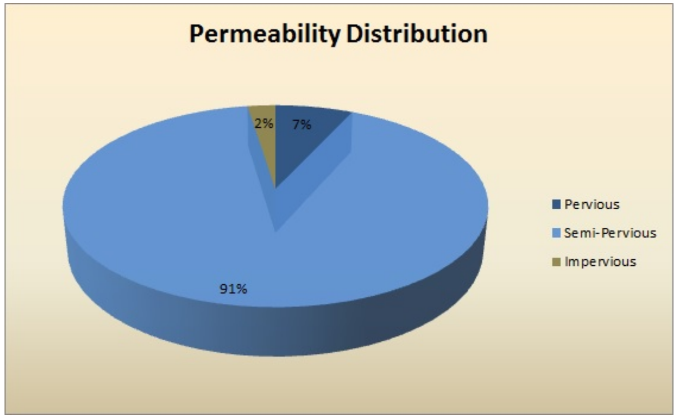


Figure 79: Permeability distribution

Figure 80: Permeability Map Satellite image (Google Earth Pro)

6.4 HYDROGRAPHIC NETWORK

Nisyros presents a typical radial drainage pattern in the youth stage. Due to the steep relief of the volcano, watershed is not able to grow. This leads to the fact that the stream flows of the radial drainage pattern have a minimum number of branches and short length (maximum length of river power ~ 2.2 km). The hydrographic network was digitized based on the Hellenic Military Geographical Service topographic maps, scale 1:5,000, placed on the European Research Project "GEOWARN" (Figure 80).

For the assessment of the final flood hazard map were created:

- A low slope map (as low slope areas are considered high risk. (Figure 81)
- An alluvial deposits map (Figure 82)

It can easily be seen, from the above maps, that the flat areas are located mainly in the coastal areas, while the alluvial deposits gathered mainly at the eastern and northeastern part where we could say that coexist with low slope areas.

6.5 RAINFALL DATA

Meteorological data was taken from stations of the Hellenic National Meteorological Service

Name - Location	Code	Longitude	Latitude	Height (m)
Kos	16742	36°48'0.00"	27°06'0.00"	-
Kos-town	16740	36°47'0.00"	27°06'0.00"	127
Leros	16768	37°11'0.00"	26°48'0.00"	11
Rhodes	16739	36°24'0.00"	28°05'0.00"	11

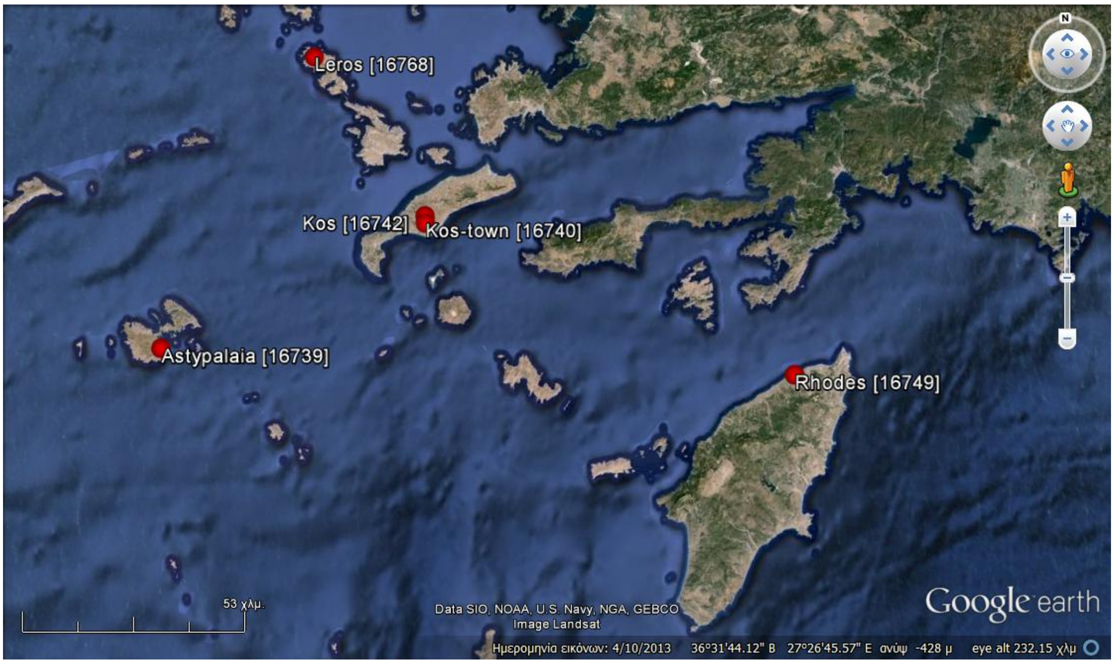


Figure 81: HNMS Meteorological Stations satellite image (Google Erath)

After digitization and classification based on Strahler Stream Classification System, were counted:

STRAHLER STREAM ORDER CLASSIFICATION	COUNT
1st order	216
2nd order	77
3rd order	8

Table 10: Strahler Stream Order Classification

6.6 RECURRENCE INTERVALS

Flood recurrence intervals are a simple calculation based on past flooding events. The intervals look at how long an accurate record is available for a particular river and the number of times floodwater has reached a specific level. Recurrence intervals, therefore, deal with past events, and are completely different from the forecasting of future floods, which is based on an estimate of probability. This gives the opportunity to answer to the following questions.

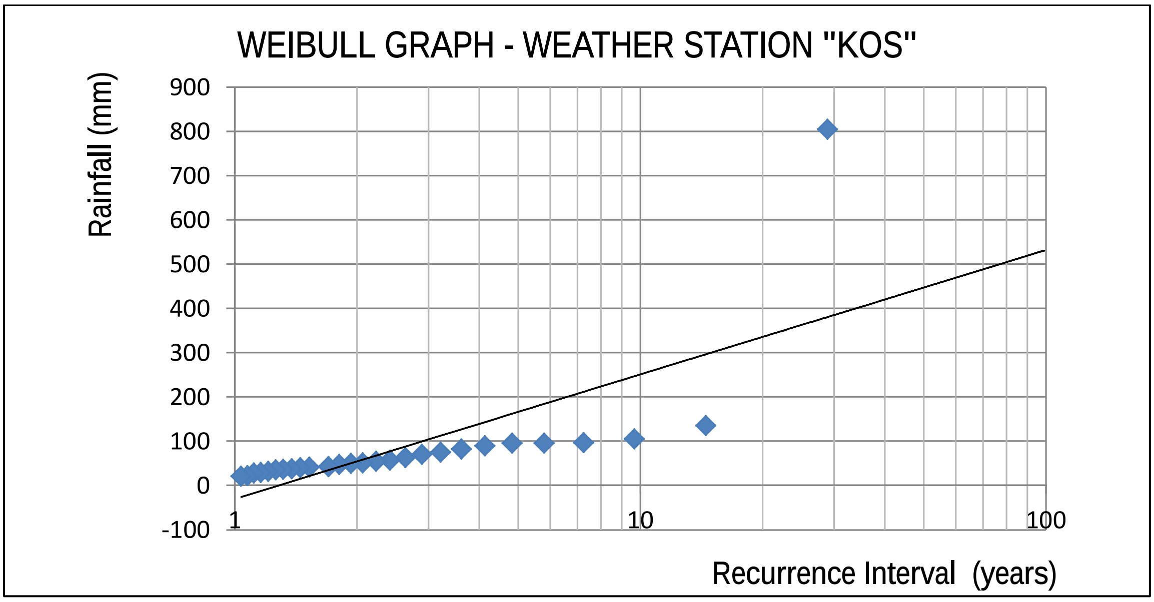
- How frequently do floods happen?
- How long between huge floods?

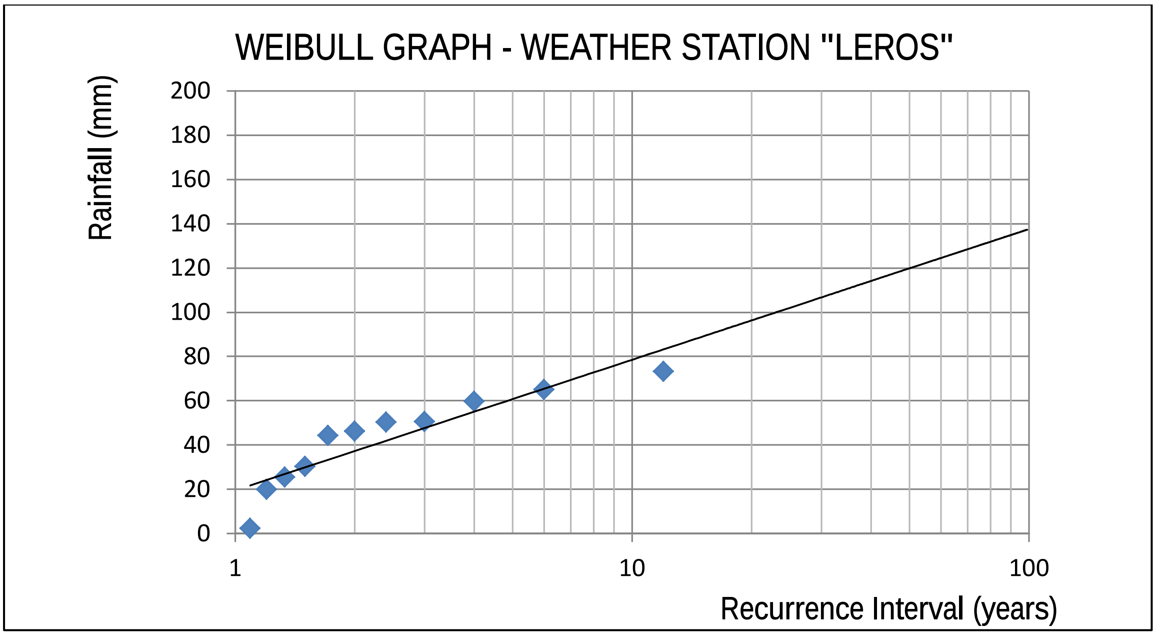
In this case study, the rainfall data that used, include the daily amount of rain in mm for all months of the year. The data was taken from the Hellenic National Meteorological Service (HNMS) meteorological stations Kos, Kos-Poli, Astypalaia (no data), Leros and Rodos (Figure 79).

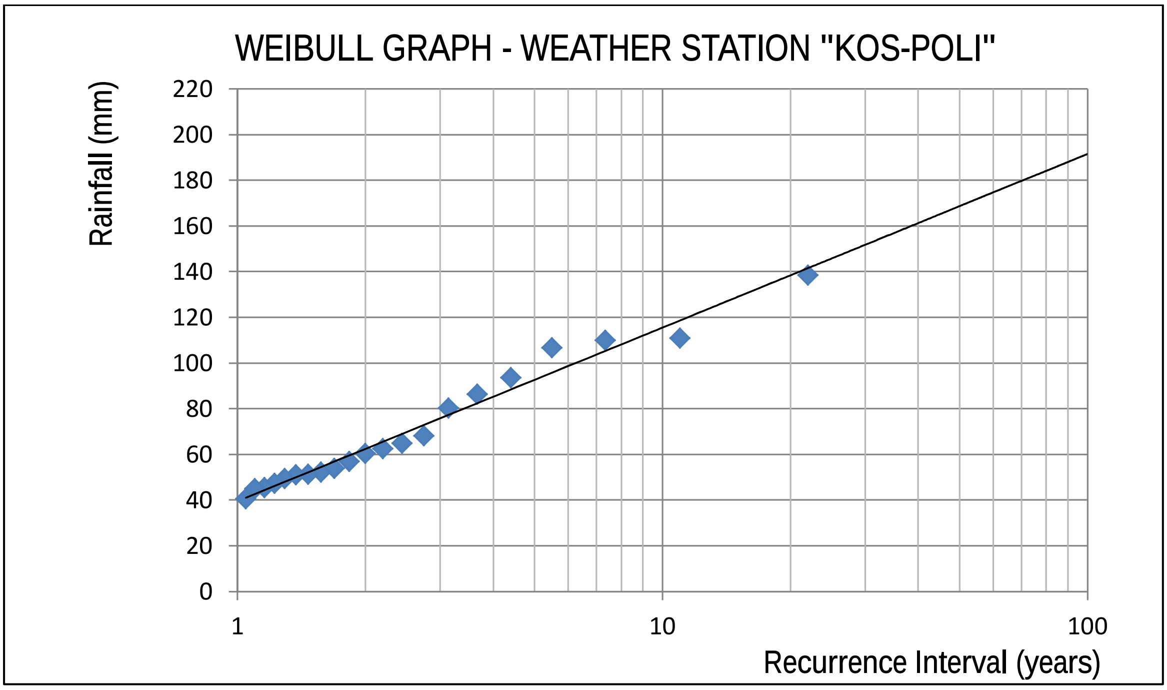
The number of days of measurements (n) and calibration for each peak are used to calculate the recurrence interval, R, using the following equation called Weibull equation:

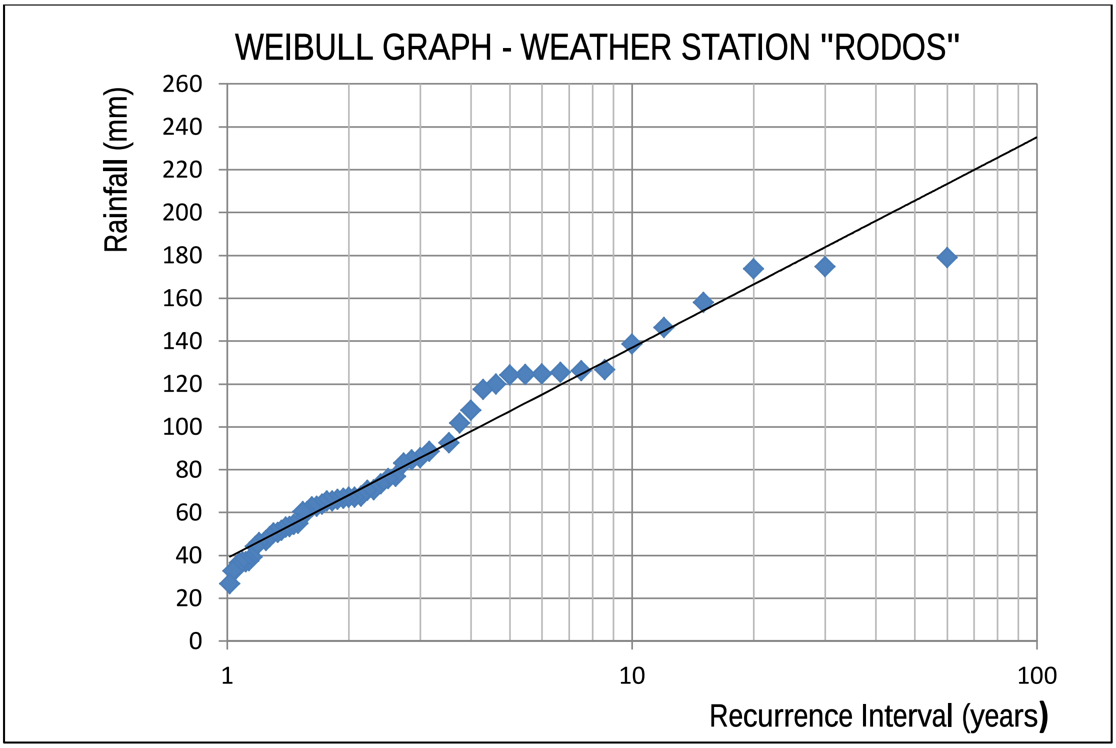
R = (n + 1) / m

From the processed data, the following graphs were created.




WEIBULL GRAPH - WEATHER STATION "LEROS"
Rainfall (mm)
200
180
160
140
120
100
80
60
40
20
0
1
10
100
Recurrence Interval (years)


WEIBULL GRAPH - WEATHER STATION "KOS-POLI"
Rainfall (mm)
220
200
180
160
140
120
100
80
60
40
20
0
1
10
100
Recurrence Interval (years)



Using the Weibull distribution was calculated the annual maximum one-day rainfall. The results are shown below.

Name - Location	Recurrence Interval 50 years	Recurrence Interval 100 years
Kos	450mm	530mm
Kos-poli	168mm	191mm
Leros	120mm	138mm
Rodos	206mm	234mm

Table 11: Annual Maximum One-Day Rainfall calculation base on the Weibull distribution

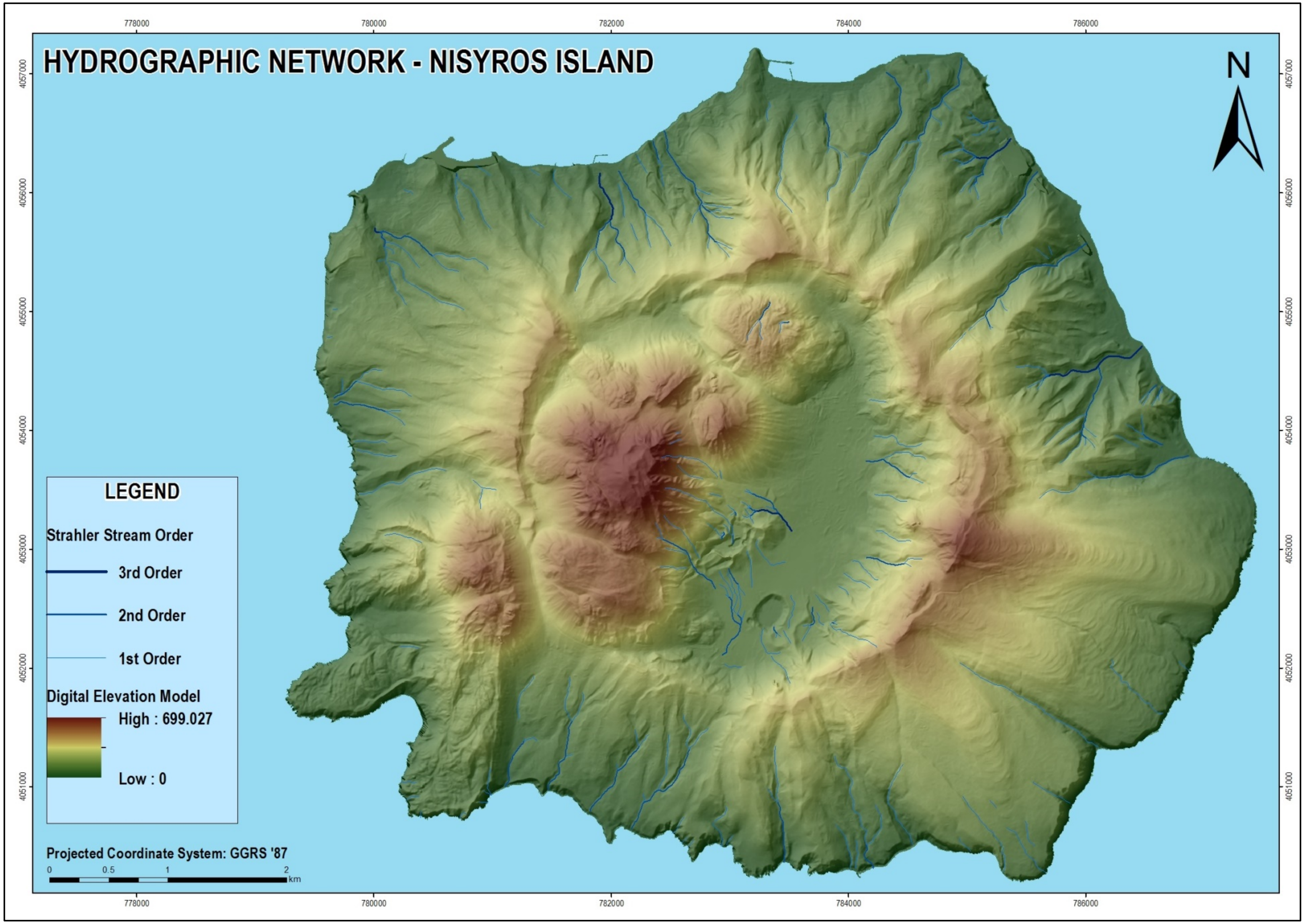


Figure 82: Hydrographic network of Nisyros

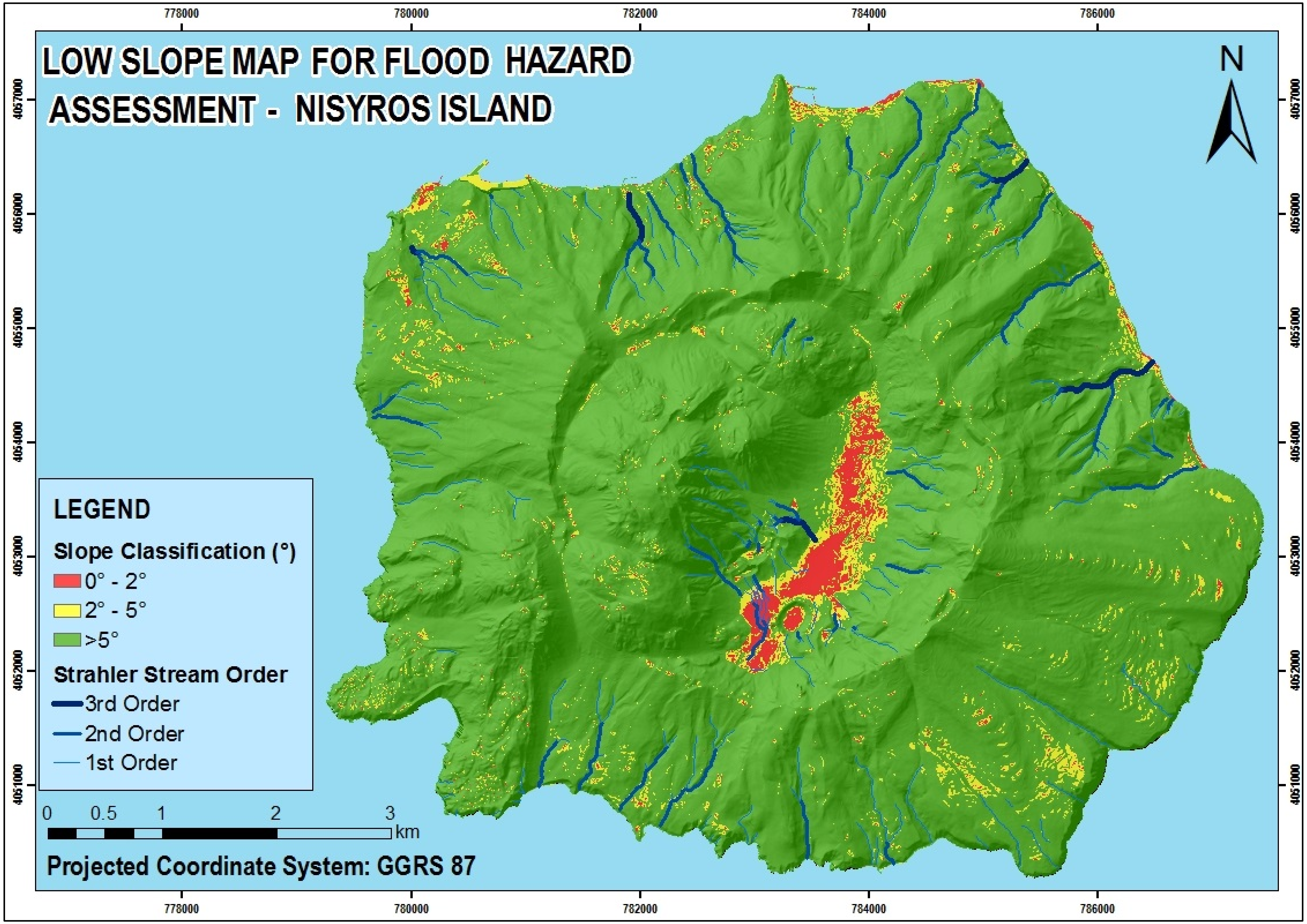


Figure 83: Low slope map area for flood hazard assessment

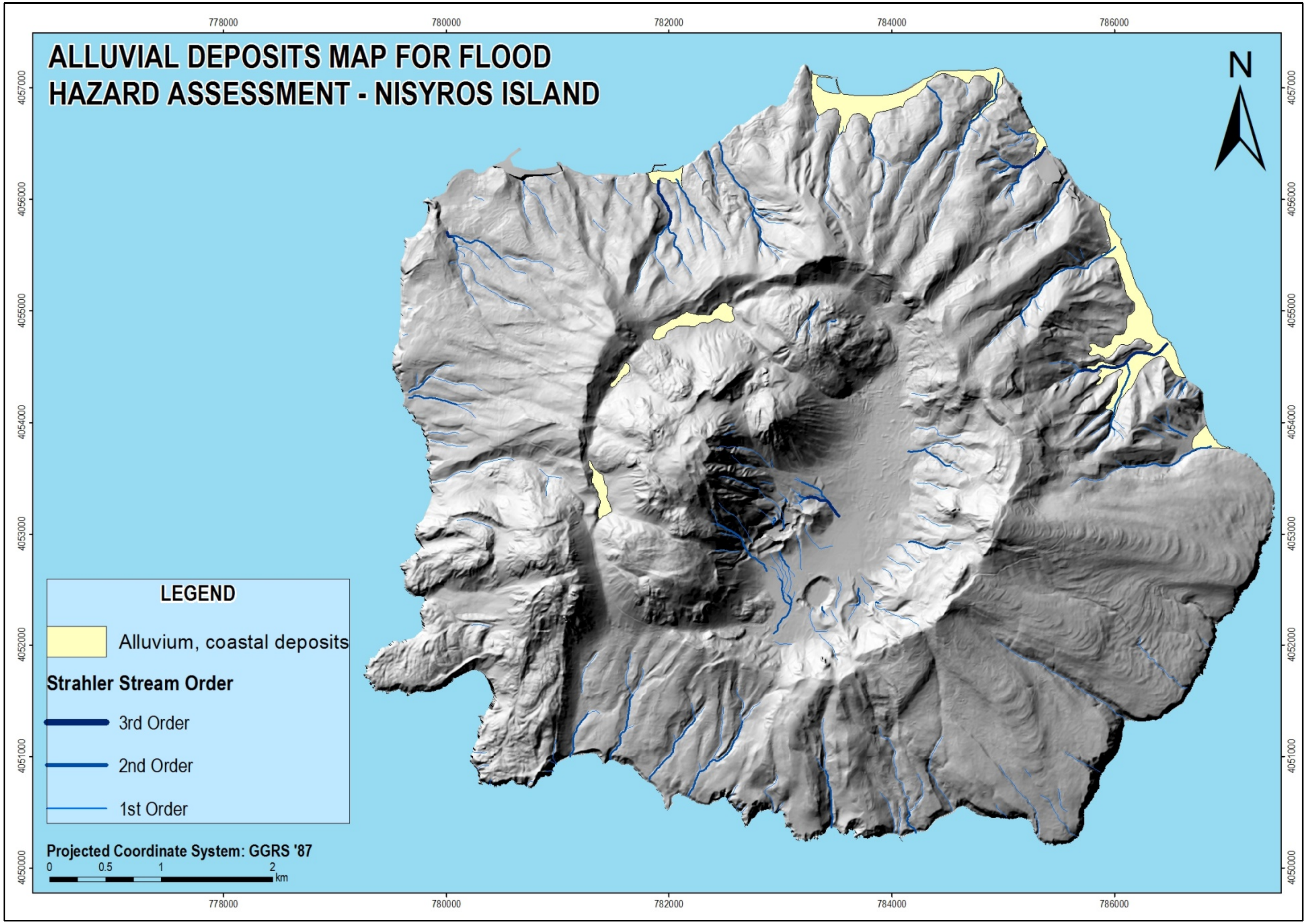


Figure 84: Alluvial deposits map for flood hazard assessment

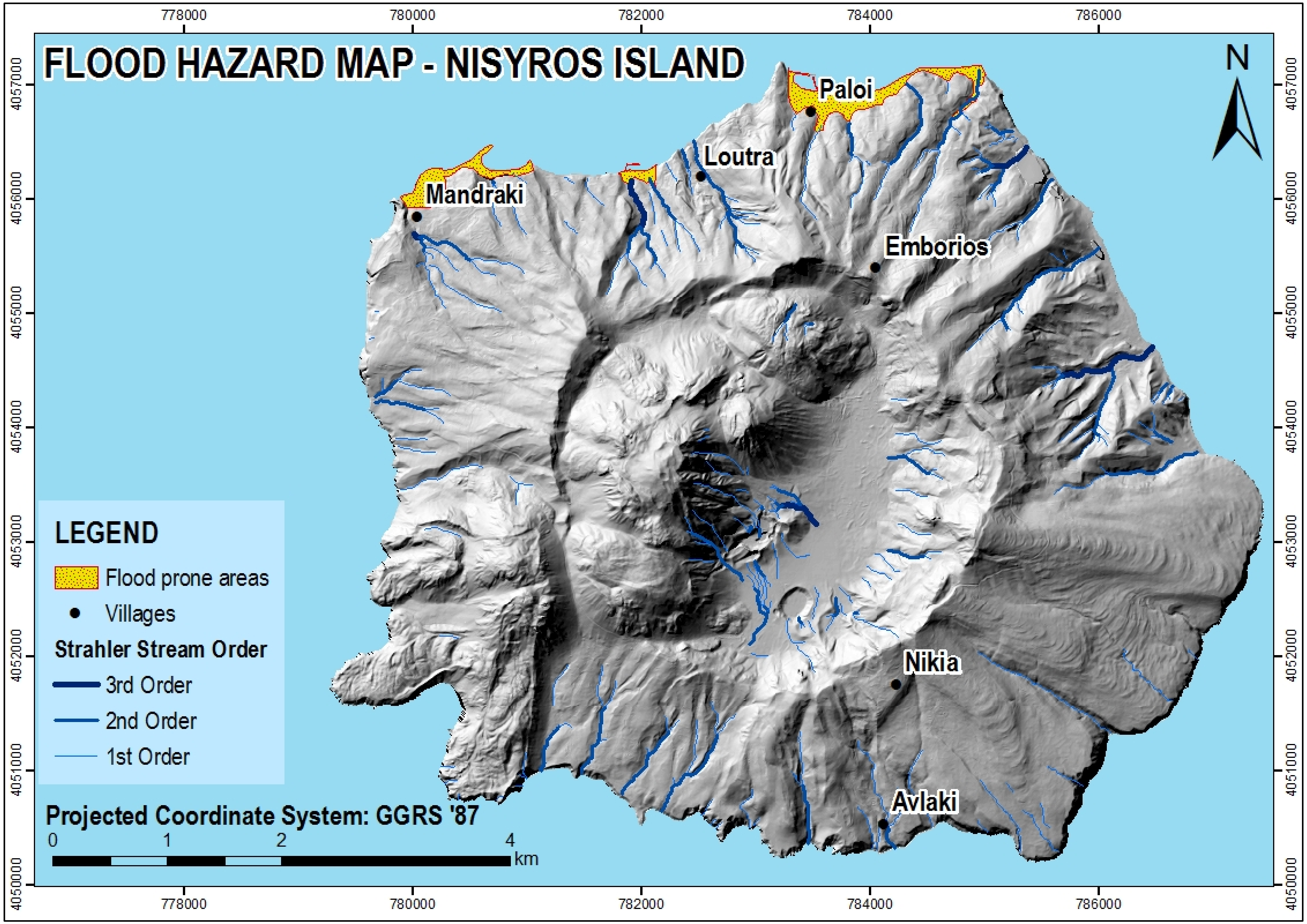


Figure 85: Flood Hazard Map of Nisyros

6.7 THE COASTAL VULNERABILITY

The anticipated accelerated rise in sea level has created the need to identify the change in the coastline as a natural reaction. The understanding of how the shoreline configuration to possible changes in sea levels is useful for the preservation and protection of vulnerable coastal systems. There is no, however, accurate and quantitative changes in coastal forecasting methodology, and even the required data are scientific disputes (Hammar-Klose, Thieler, 2001).

Various approaches and methods are internationally used about the provision of natural "reaction" of shorelines to individual stress factors such as a possible rise in sea level. Each of these approaches has its weaknesses or is suitable for only certain applications.

One feature of Greek geographical territory is the existence of very extensive coastline with the main elements of the diversity of types and landforms and intensive anthropogenic coastal activity. The particular environmental, ecological and economic value of the Greek coast, as a valuable resource for sustainable management requires the creation of a tool or mathematical model that identifies the local coastal hazards.

6.8 THE COASTLINE CHANGE

The accelerated rise in sea level in conjunction with major climatic changes that occur will create a host of problems in many coastal areas of our country, especially in those where human activities have reduced the natural adaptability. So the temperature increase and rising sea levels will increase the risk of potential disasters to coastal populations, urban structures and for future investments (IPCC, 2001).

Because of the great contradictions of natural coastal and the socio-economic systems as well as their dynamic response to expected changes is difficult to predict future impacts. The adjustment of each system will vary depending on the physical-economic conditions, and the complexity of the event location each time.

The expected rise in sea levels in the Mediterranean will not of course affect only the coastal cities and areas with residential development of our country. The greek coastal habitats will significantly be affected and, most river deltas and areas with gentle slope. The risk of erosion and flooding events will increase in these areas, while rivers and coastal freshwater reservoirs will be reduced by the penetration of brackish water.

Our country's existing problems of coastal areas, such as environmental pollution, urban degradation, destruction of ecosystems and landscapes, etc. (Rokos, 1982), will yet swell more than changes in climate and the occurrence of extreme weather events. This will directly threaten the natural balance of all our coastal country systems, which will have to adapt to new conditions.

6.9 CONCLUSIONS

Because of the small size of the islands, not remarkable hydrological basins can be developed in them. The drainage of rainwater is via small coastal streams in radial arrangement.

According to the Ministry for the Environment, Energy and Climate Change all flood cases affect only adjacent to the sea areas. These areas are:

- Mandraki (territory from the village Mandraki to Panagia Spiliani)
- Loutra
- Pali (territory from the village Pali to Lhies)

The cause of the flooding is severe due to strong west and northwest winds that blow almost throughout the year.

Floods in Nisyros could be a result of:

i. rapid precipitation and storms with very heavy rainfall over a short period
ii. rogue waves due to strong winds.

Consequently, the risk is characterized moderate.

7. NISYROS WEB APPLICATION

7.1 WEB GIS: A MISSION-CRITICAL TECHNOLOGY FOR EMERGENCY MANAGEMENT
7.2 WHAT IS WEB GIS
7.3 WHY WEB GIS?
7.4 WEB-MAPPING APPLICATION STRUCTURE
7.5 A FRAMEWORK FOR DEPLOYING WEB GIS APPLICATIONS
7.6 ONE HUB FOR INTEGRATING INFORMATION
7.7 SHARING IS THE KEY
7.8 THE NISYROS WEB-APPLICATION

7.1 WEB GIS: A MISSION-CRITICAL TECHNOLOGY FOR EMERGENCY MANAGEMENT

The largest difficulty in disseminating natural hazard risk information is discovering a way to awaken public interest before a disaster occurs. The best way to survive a natural disaster is to be prepared for one.

For example, being prepared for a landslide requires foreknowledge of a geographic risk and susceptibility to major landslide triggering events, such as rainfall and earthquakes. Even if the risk information is not certain, the value of knowing where disasters are likely to occur could be enough to save lives. A validated model can mean the difference between ignorance and informed awareness.

GIS has been an important tool for improving situational awareness, especially in emergency preparedness and response. During a crisis, having a clear, real-time understanding of the situation as it unfolds is critical for making decisions that help save lives. The challenge for decision makers has always been to acquire and analyze meaningful information so they can make timely and informed decisions. GIS—with its capacity to mash up and visualize multiple datasets in a single platform—makes it easier to identify the data you need to make those decisions.

Emergency preparedness and response missions have found in GIS a foundational and mission-critical technology. The creation of the web map format, coupled with the deployment of web GIS, was a game changer. Now, emergency management professionals have unprecedented capabilities to obtain, share, make sense of, and use information in increasingly more effective ways.

7.2 WHAT IS WEB GIS?

Based on Environmental Systems Research Institute (ESRI), Web GIS is a type of distributed information system, comprising at least a server and a client, where the server is a GIS server and the client is a web browser, desktop application, or mobile application. In its simplest form, web GIS can be defined as any GIS that uses web technology to communicate between a server and a client.

Here are a few key elements essential to web GIS:

- The server has a URL so that clients can find it on the web.
- The client relies on HTTP specifications to send requests to the server.
- The server performs the requested GIS operations and sends responses to the client via HTTP.

The format of the response sent to the client can be in many formats, such as HTML, binary image, XML (Extensible Markup Language), or JSON (JavaScript Object Notation).

Web GIS is the outcome of the combination of Web technology and GIS technology, as well as a distributed GIS based on the Client/server architecture. The simplest architecture of a Web GIS must have at least one client and one server that client is a desktop application or web browser application that allows users to communicate with server, and the server is a web server application.

Figure 86: A simple design of the architecture of a Web GIS

Beginning in the 2000s, Web GIS used the web itself as a platform, leveraging GIS services that reference centralized geodatabases. Once authors publish services, those services can be referenced with Uniform Resource Locators (URLs) over Hypertext Transfer Protocol (HTTP). The same GIS service can be assessed by GIS, mobile, and web users.

7.3 WHY WEB GIS?

- Aimed at the general public (not required to have GIS knowledge).
- Saves resources (not required expensive hardware & software to users).
- Allows centralized management, immediate information and distribute geographic information. That means faster distribution of information to decision makers.
- Reduce the need to create new applications from scratch (by exploiting existing APIs).
- Can be combined data-service resources (avoiding data copies between organizations).

Using Web GIS, users are able to:

- Map geographic coordinates, or to input a street address or cross-roads and map the approximate location using a geocoding service. The results would need to be immediately visible on the map, but then could be discarded (adding a point to represent a project review site could happen as a separate manual editing action).
- Control data visibility, turning layers on and off at will. These should be organized in a map legend and layer list in a clear and logical way.
- Measure the length and/or area of a feature by successively clicking on two or more locations in the map. This should use a straightforward interface, and users should be able to change the units of measurement.
- Identify features via a simple mouse click in the map and have select attributes made visible in a pop-up window.

- Toggle between a satellite image and topographic base map. These base maps should be as up-to-date as possible.
- Filter or query layer attributes using a simple interface.
- Export and print the current map view, including a map legend, and scale information.

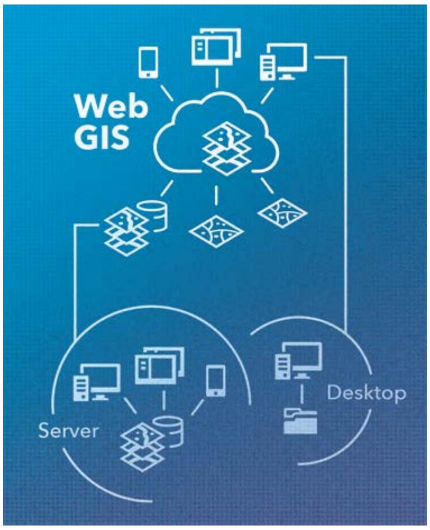


Figure 87: Web GIS is a transformational architecture that opens, integrates and simplifies everything. It brings together our systems of record into a GIS-based system of engagement. (source: ArcNews, ESRI, Fall 2015)

Synthesizing these functionality requirements along, ArcGIS Online was decided as the preferred platform. As it is explained further below, this allowed the creation of custom web-maps of the desired data and afterwards the development of a web-application from these maps.

ArcGIS Online is a "Software as a Service" (SaaS) platform that provides users with tools to create web maps, manage and host services, develop applications, and more. This presents several advantages for personnel who will maintain the system. First, it is a viable low cost solution since it is considered "approved software". Second, since ArcGIS Online is a cloud-based platform, personnel will largely avoid the burden of maintaining the application or data on a public server or server instance. Finally, ArcGIS Online is designed to be easy to use, meaning that web maps and applications can be developed with zero to minimal coding, an important feature for long-term maintenance of the system.

The main result of this project is a web-mapping application designed to facilitate the project review process. As explained above, development of this application is still ongoing, however, a working prototype has been designed to address the needs identified thus far. This prototype will serve as a solid foundation on which to complete the final system.

After identifying and assembling the data, it was necessary, then, to arrange the layers in a custom web-map. This is the key precursor step to application development in ArcGIS Online. As explained by ESRI, "a web map is a configuration file that stores map definition (e.g., layers, visibility, and extent) and behaviors (e.g., pop-up windows)" and is considered an integral component of the ArcGIS platform. Users with an ArcGIS Online organizational account can create web-maps directly in their web browser, and control their sharing (i.e. keep private, make available to other organization users, or release to the public).

A web-map was created to serve as the base for a web-mapping application. The look and feel of the web-map was tailored to the needs identified throughout the evolution of the MSc Thesis. For example, some of the key considerations included:

- Organizing layers hierarchically so that they draw in a logical order and so that users will have ready access to visibility controls for layers that are expected to be used frequently.
- Using feature symbologies that are consistent, easy to understand.
- Labeling features judiciously and unambiguously to prevent information overload.
- Configuring pop-up windows so that pertinent attributes are easy to access and understand.
- Choosing a default basemap that will meet user needs in the majority of cases.

7.4 WEB-MAPPING APPLICATION STRUCTURE

A web-mapping application consists of basemap layers and operational layers.

Basemap service layers are often used repeatedly for multiple web-mapping applications . They provide a background context for the operational layers. *Operational service layers* are focused and interactive. They provide functions that fulfill a business need.

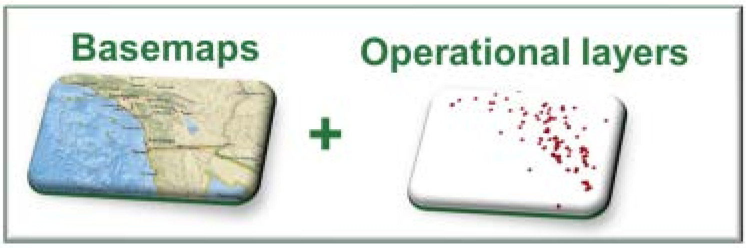


Figure 88: Web-mapping applications are made up of basemap and operational service layers

	Basemap service layers	Operational sevice layers
Purpose	Reusable background sevice for context	Interactive service
Examples	• Transportation • Topography • Terrain • Imagery • Hybrid	• Thematic layers • Query results • Real-time observations • Geoprocessing result • Editable features

Basemaps Layers

In web GIS applications, the basemap provides the geographic context for each application. The type of application (for example, hydrology, parcels, electrical utilities, and conservation) often defines the type of basemap that will be needed to use.

The following are some examples of common basemaps:

- Transportation basemaps often contain roads, street names, points of interest, generalized land use, water bodies, and place-names.
- Topographic basemaps often contain administrative boundaries, cities, water features, physiographic features, parks, landmarks, transportation, and buildings.
- Terrain basemaps often contain shaded relief imagery, bathymetry, and coastal water features designed to provide a neutral background for other data layers.
- Imagery basemaps often contain low-resolution satellite imagery for the world and high-resolution satellite imagery for select geographies around the world.
- Hybrid basemaps often contain optional layers that you can toggle on and off as map overlays—for example, map layers such as transportation, topography, terrain, and imagery are often included as optional basemap overlays that can be turned on or off for different viewing purposes.

Operational layers

Operational layers are the small set of layers that you work with directly or derive as the result of an operation (such as a query) in a web GIS application. These layers are often tailored to a particular group of users by a GIS professional. For example, an urban planner uses a Windows smartphone running a GIS application to update the location of manhole covers in a sanitary sewer/storm water system layer.

In most GIS applications, users work with operational information (sometimes multiple operational layers) on top of their basemap, which provides the geographic context. At other times, the operational layer is displayed underneath other layers that help provide locational context.

Operational layers are often dynamic; they are retrieved from the GIS database and displayed during runtime, for example, each time you pan, zoom, or refresh your map. It is common that operational layers work within a focused range of map scales and resolutions.

There are five essential elements in every Web GIS application:

1. A web application
2. Digital basemaps
3. Operational layers
4. Tasks and tools in the Web GIS application
5. One or more geodatabases

7.5 BUILDING A WEB APPLICATION

A web-mapping application is created using the ESRI’s software "Web AppBuilder for ArcGIS". This software allows ArcGIS Online users to create custom web-mapping applications using preexisting themes and widgets. Themes are ready made but adjustable templates that define the overall appearance of the application. ESRI (2015) explains that “contents in a theme include a collection of panels, styles, and layouts, and a set of preconfigured theme widgets.”

Widgets are small “out-of-the-box” tools that “provide fundamental functions to easily create web apps” (ESRI 2015). Mixing and matching existing widgets in a web-mapping application is a relatively easy and straightforward way to build in desired functionality.

According to Shannon L. Thol *(Developing a Geographic Information System for the Upper Delaware Scenic and Recreational River The Pennsylvania State University, 2016),* the framework outline of an application is organized into six actionable phases:

1. Plan
   First, resource managers research information needed from the system (i.e. investigate land and water use regulations that have a spatial component, identify management goals for the river and how these might integrate into the system). They then brainstorm and develop an overall vision for the system.
2. Formulate
   Based on the outcomes of the planning step, resource managers then identify the intended users, information projects, and required functionalities of the system, and they outline accessibility, security, cost capacity, and timetable considerations. They also take stock of the current GIS capabilities of their organization and identify internal or external budget and personnel resources that may be available.
3. Prepare
   After Formulate, resource managers then start preparing to build the system. They collect, process, and analyze data relevant to their management activities, and identify the target platform (software/hardware) that will meet the needs identified in the preceding steps. They also pinpoint additional system components (i.e. widgets, applications) that may be required.
4. Build
   Next, resource managers carry out an iterative Develop and Review process to create the system. This entails putting pieces together into a working prototype, testing the prototype and evaluating its design, and then ultimately going back to adjust or fine-tune the system. Users should be involved in the process and provide feedback that can help refine the design.
5. Implement
   After the system has been built, resource managers then put it into use. This may involve promoting the system to different user groups, creating user guides, and/or demonstrating the advantages of the system to encourage its adoption.
6. Maintain
   Finally, the resource managers need to maintain the system so that it stays up to date and relevant. This could require developing a maintenance plan, assigning upkeep responsibilities to different stakeholders, and/or scheduling periodic check-ins with users.

There are also several steps that need to be carried out before the prototype system can move to a final state. These include teaching resource management partners how to use the system to their advantage, strengthening relationships among partners to promote data sharing, and planning for long-term maintenance of the system.

The uploaded data can be viewed to tablets, smartphones, laptops, desktop workstations, and any other devices that can connect to web services.

7.6 ONE HUB FOR INTEGRATING INFORMATION

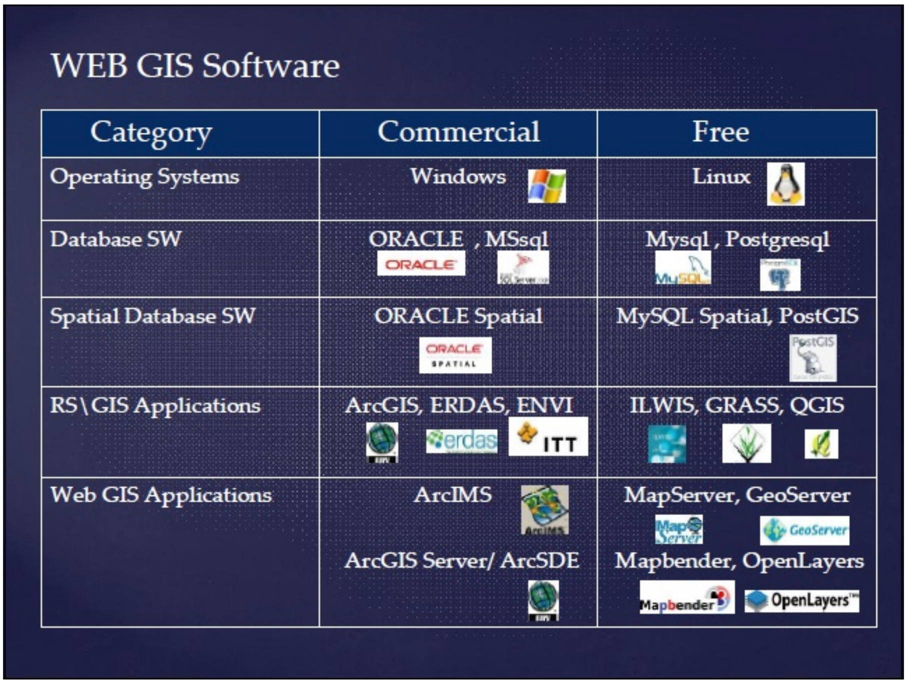
ArcGIS Online serves as the interoperability platform, or hub, that allows users to integrate information housed in so many different systems of record. The web map was the building block of that effort because it made it possible to turn each dataset into a web service and then share that with all users. Thus, once enabled, the tools provided on ESRI's Web GIS platform let users use data in numerous ways, resulting in a dramatic improvement in coordination, force multiplication, and decision making.

7.7 SHARING IS THE KEY

The importance of information sharing cannot be overstated. The proven role of GIS as a conduit of information sharing makes it a mission-critical technology for preparing for, responding to, recovering from, and mitigating any incident—whether it is in an emergency situation or has to do with business planning, monitoring public health, analyzing crime, or any number of other, distinct situations.

GIS has always been good to have, but now it is a must-have. While there is still much hard work to do to realize GIS as a truly ubiquitous interoperability platform, the pathway to achieve it has never been clearer.

The opening line of US president Barack Obama's "National Strategy for Information Sharing and Safeguarding" says, "Our national security depends on our ability to share the right information, with the right people, at the right time." As we have seen in nearly every major incident—from the terrorist attacks on September 11, 2001, to natural disasters such as hurricanes Katrina and Sandy—lack of authoritative, actionable, and timely information leads to unnecessary suffering, excessive property damage, and the tragic loss of lives.



WEB GIS Software

Category	Commercial	Free
Operating Systems	Windows	Linux
Database SW	ORACLE , MSsql	Mysql , Postgresql
Spatial Database SW	ORACLE Spatial	MySQL Spatial, PostGIS
RS\GIS Applications	ArcGIS, ERDAS, ENVI	ILWIS, GRASS, QGIS
Web GIS Applications	ArcIMS ArcGIS Server/ ArcSDE	MapServer, GeoServer Mapbender, OpenLayers

Figure 89: The Web GIS software in commercial and free use

7.8 THE NISYROS WEB-APPLICATION

This case study deals with two major issues impacting current Web GIS development: interoperability of heterogeneous data and visualization of vector and rater data on the Web.

By integrating basemap and operational layers through Web GIS, processing, analyzing and releasing the data by means of adopting geological disaster warning model to build a sound early warning and predicting system platform, the early warning and predicting of geological disaster can be realized. This can not only provide general information analysis and management support for the governments, but also convenience for the public to know the disaster on time to reduce the loss of the lives and property of the people.

The previously mentioned process was implemented for the web application about the natural hazards assessment on Nisyros island.

Initially, using the software of ESRI "Web AppBuilder for ArcGIS (Developer Edition)", vector and raster data of the thematic maps that were made for the risk assessment, were uploaded using the ESRI basemap templates.

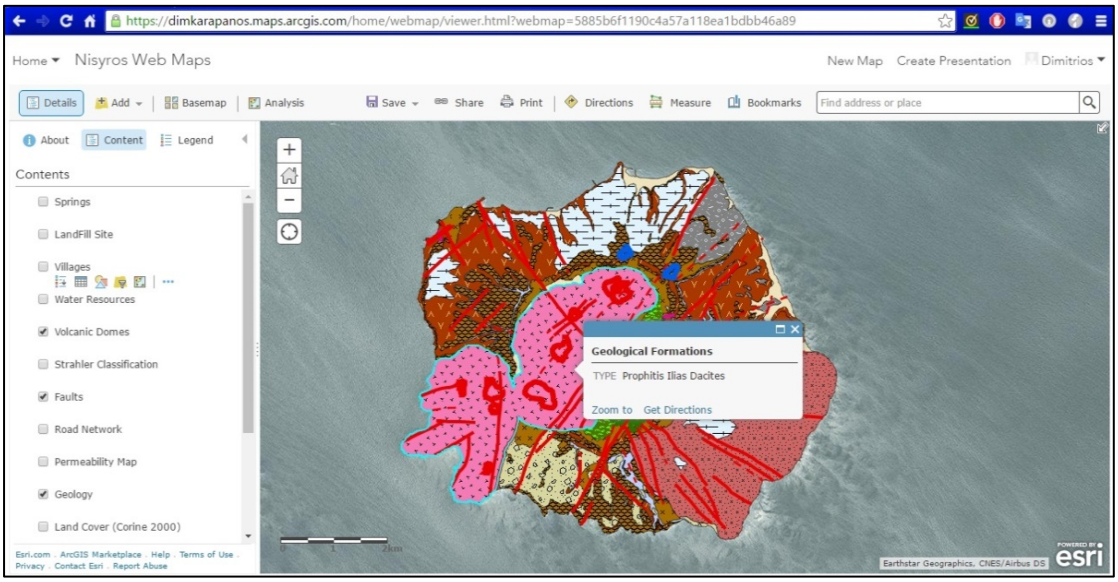


Figure 90: Geological map of Nisyros displayed on the main screen. The rest of the vector and raster data displayed on the left side of the screen A click on the map shows the type of formation

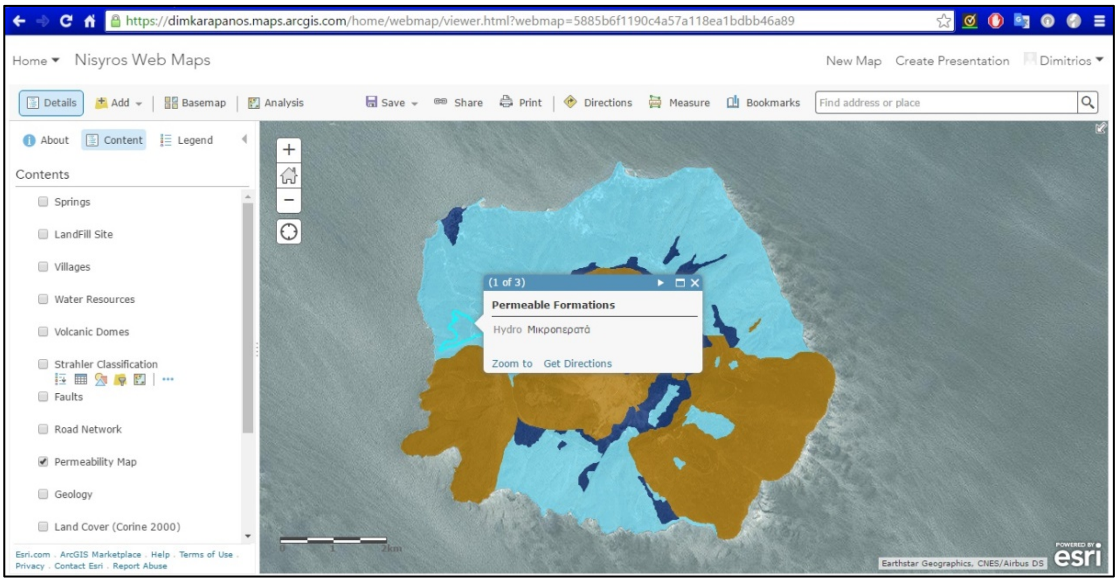


Figure 91: Just like Figure 5, permeability map displayed on the main screen

Subsequently, after the vector and raster data were uploaded on the web, the next part is building the web application. Basemap and operational layers were integrated and the following figures show the result of result of that.

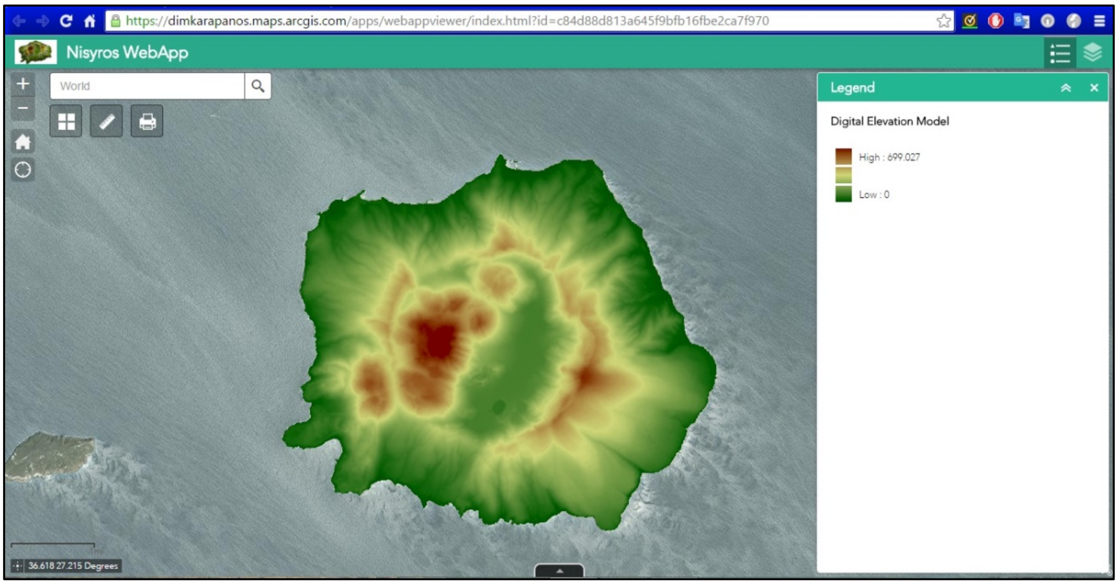


Figure 92: Nisyros Digital Elevation Model displayed on the Web-Application

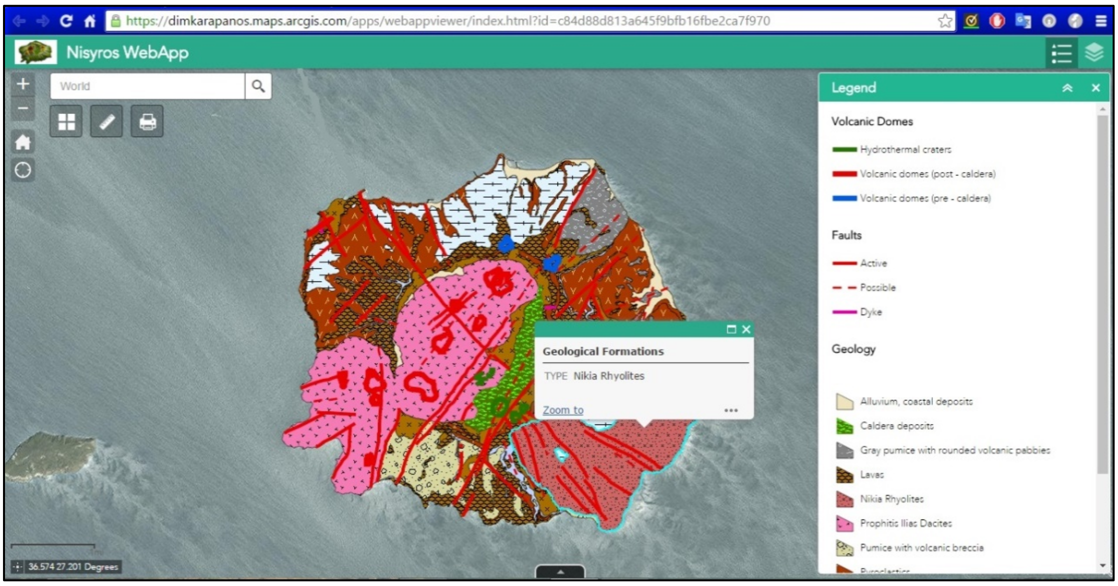


Figure 93: *Nisyros Geological Map displayed on the Web-Application*

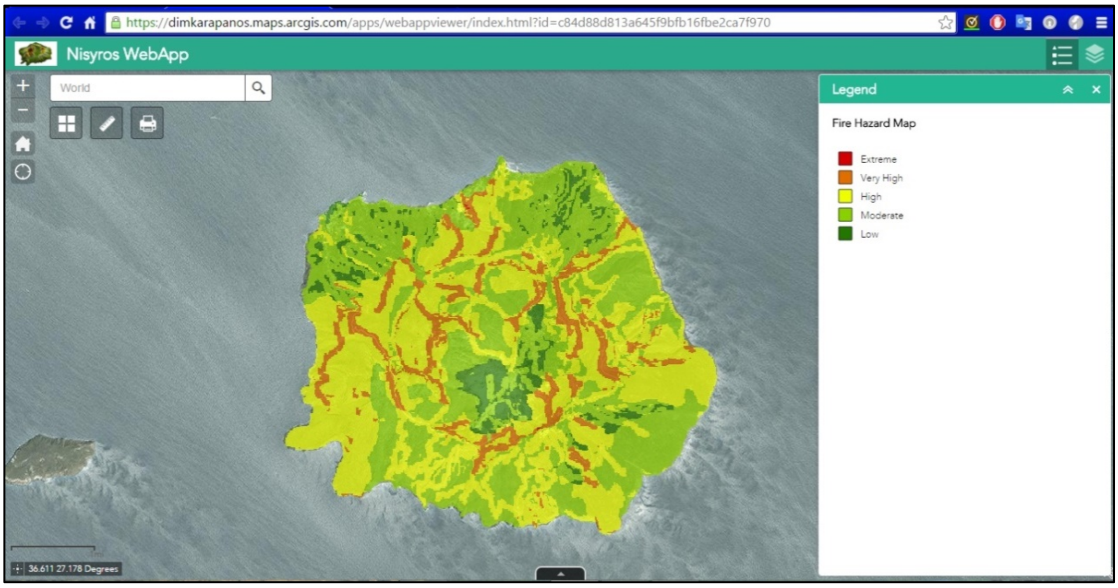


Figure 94: *Nisyros Forest Fire Hazard Map displayed on the Web-Application*

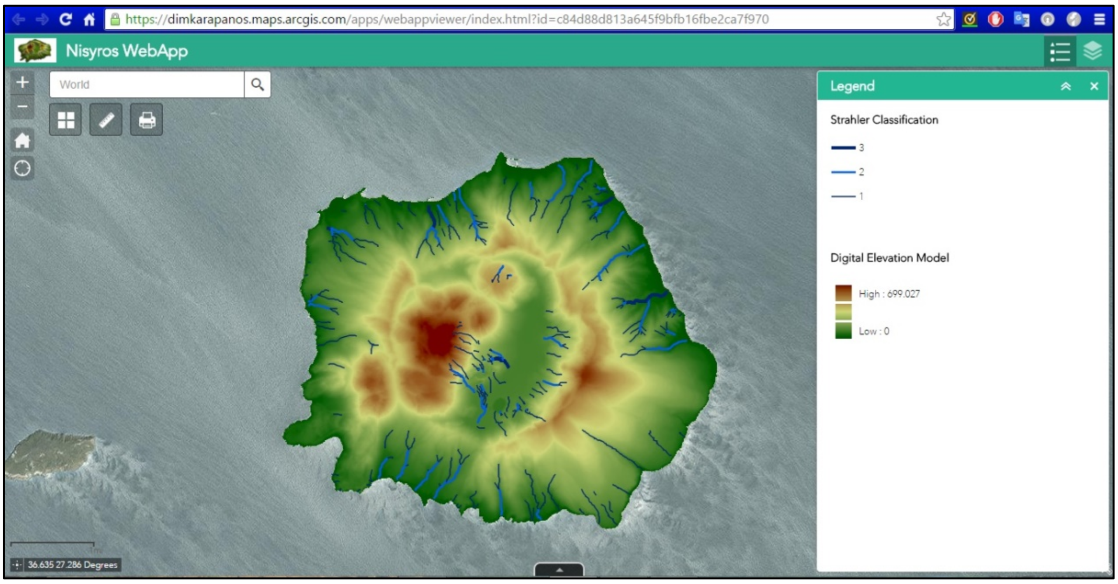


Figure 95: Nisyros hydrographic network displayed on the Web-Application

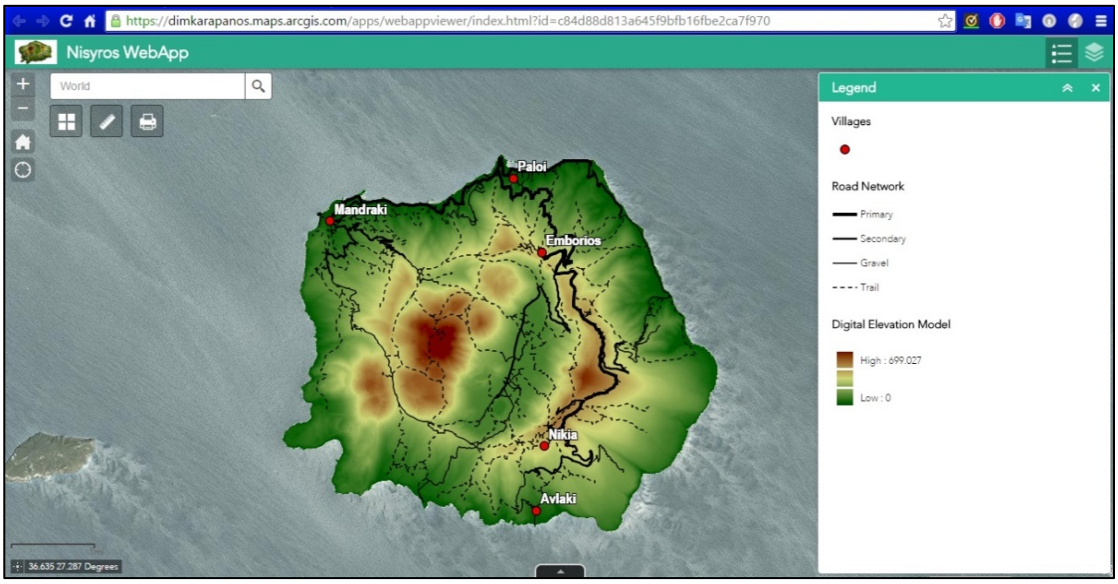


Figure 96: Nisyros Road Network displayed on the Web-Application

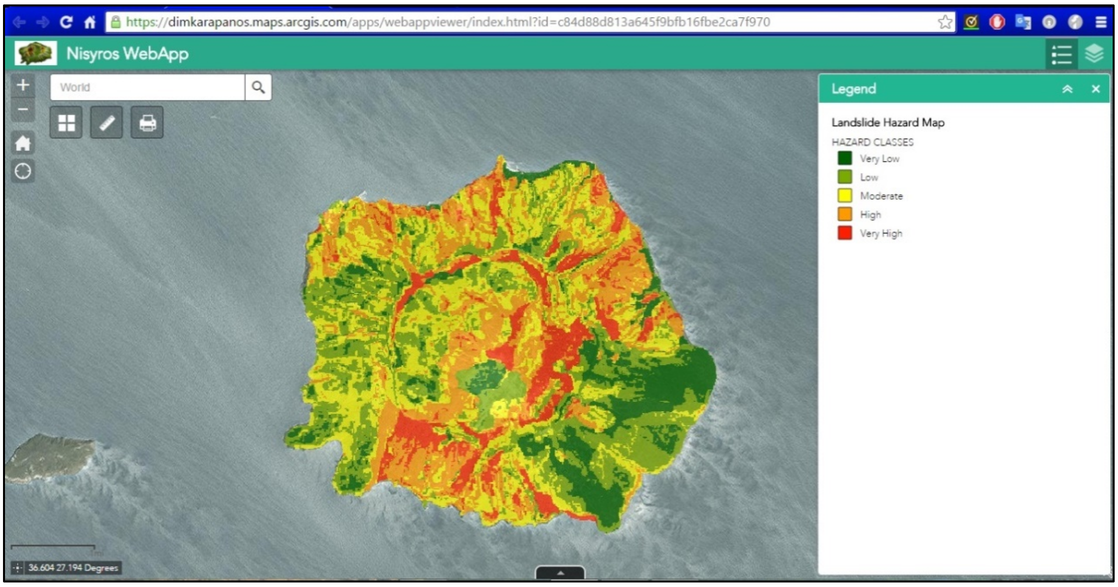


Figure 97: Nisyros Landslide Hazard Map displayed on the Web-Application

Figure 98: A user can can view the Web-Application either on a smartphone or a tablet just by taking a photo of the QR code and scan it, without having to type the URL.

The link for the Web application is:

https://dimkarapanos.maps.arcgis.com/apps/webappviewer/index.html?id=c84d88d813a645f9bfb16fbe2ca7f970

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