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Title: A Multi-Criteria Decision Analysis for Siting Refugee Camps in Greece

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Abstract

In this thesis, a GIS-based MCDA method will be applied to determine potential locations for refugee camps in Greece based on various criteria.

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1. Introduction

After the outbreak of the Syrian civil war in 2011, many Syrian refugees have migrated to Greece finding temporary protection both in and out of refugee camps. Some of them are lucky enough to be hosted in apartments provided through ESTIA, the Emergency Support to Integration and Accommodation programme, funded by the European Union Civil Protection and Humanitarian Aid (UNHCR n.d.), while most of them have to stay in one of the reception facilities. Despite the fact that the numbers are changing daily, there are 49,200 people stranded in refugee camps according to the International Organisation for Migration (International Organization for Migration n.d.).

One of the biggest issues for many of these facilities is that they are overcrowded and some of them are also in unsuitable sites or have unsuitable settlements.

There seems to be a need for additional camps and re-evaluation of the existing ones. Multi-Criteria Decision Analysis (MCDA) provides a rich collection of techniques and procedures for evaluating and prioritizing multiple conflicting criteria in decision making. Geographic Information System-based Multi-Criteria Decision Analysis techniques can be applied to transform and combine geographical data to obtain information for different spatial decision problems such as landslide susceptibility mapping or site selection.

In this thesis, a GIS-based MCDA method will be applied to determine the best locations for temporary settlements in Greece based on various criteria. The following research question are to be examined:

1. What kind of criteria are relevant for a multi-criteria decision analysis that determines new potential locations for temporary settlements?
2. Which is the optimal multi-criteria decision analysis method for temporary settlement location site selection?
3. Which are the optimal locations for temporary settlements and how do they compare to the existing sites?

In the next chapter, *Multi-Criteria Decision Analysis*, the main MCDA methods and the respective weighting methods are presented.Next, in *Software*, the different software used for this project is described and in *Data* the focus is on the type of data needed for the suitability model. *Methodology* is where the criteria selection methodology is explained. The next chapter, *Model*, describes in detail the creation of every criterion layer necessary for the suitability model that will give the optimal site locations. In *Results* the outputs of the model are explained and in the *Discussion* it is examined if the goals of this project are met.

2. Multi Criteria Decision Analysis

Multi-criteria decision analysis is a multidisciplinary tool which helps the decision-makers or stakeholders evaluate multiple and often conflicting criteria in order to choose the preferable alternative (Malczewski & Rinner n.d.). It has been used in a wide range of real-world planning and management situations such as landslide susceptibility mapping, flood risk assessment, site selection or environmental vulnerability assessment (Afshari & Yusuff 2012).

The Multi Criteria Decision Analysis methods can be divided in two categories, the Multi Attribute Decision Analysis (MADA) and the Multi Objective Decision Analysis (MODA). The first is used in cases where there is one objective with multiple attributes, while the second in cases where the objectives are more than one. Two examples that make the difference between the two categories clear are the difference between searching which sites are suitable for a specific land use, lets say temporary settlements, and when trying to locate sites suitable for various land uses, for example in urban planning.

2.1. Multiattribute Decision Analysis Methods

There are various multiattribute decision analysis methods available, but four of them are the ones most commonly used in combination with GIS:

- Analytical Hierarchy Process

The analytic hierarchy process (AHP) is one of the most widely used methods of multicriteria decision analysis. The method is based on the decomposition of the problem into its main characteristics. Then each one of these elements is compared with each one of the rest of the criteria using pairwise comparisons. After all the comparisons are finished the final weighting is being calculated constructing an overall priority rating.

- Ideal Point Models

The ideal point approach rates the decision alternatives under consideration according to their multidimensional distance to the ideal point using the distance metric. Two versions of the ideal point model can be defined: the positive and negative ideal models (Malczewski & Rinner n.d.).

- Outranking Methods

The outranking methods are based on a pairwise comparison of alternatives for each evaluation criterion (Malczewski & Rinner n.d.).

- Weighted Linear Combination (WLC)

The weighted linear combination (WLC) is the most often used GIS-MADA methods. The evaluation model consists of the value of the criterion and its weight which are multiplied to give the weighted value.

2.2. Criteria weighting methods

Ranking Method

This is the easiest and simplest method for estimating the criterion weights. After the decision-maker ranks the criteria according to their importance (the most important = 1, second important = 2, etc.), the weights can be calculated using a formula which depends solely on the rank position of the criterion. It is evident that, even though this method is an attractive option due to its simplicity, it can not provide trustworthy results. I

Pairwise Comparison

The pairwise comparison method was developed in the context of the analytic hierarchy process (AHP). It employs an underlying scale with values from 1 to 9 to rate the preferences between a pair of criteria (Malczewski & Rinner n.d.). It is being contacted from experts on the field of study of the research and it is considered to be the method with the most accurate results

Entropy-Based Criterion Weights

Unlike the other methods, the *entropy-based criterion weighting* approach does not require the decision-makers or the experts to specify the weights of the criteria. The criteria weights can be estimated based on the amount of information contained in each criterion. These weights can be used alone or even combined with the weights obtained using one of the other methods. The more diverse information is contained in a criterion, the higher the value of that criterion. This implies that the more information a criterion provides, the more important that criterion is in the decision making procedure. That also goes the other way, meaning that the more homogeneous a criterion is, the closer to zero its weight is. In case of total homogeneity this criterion can be removed because it provides no information about the decision making situation.

Rating Method

The rating methods require the decision maker to estimate weights on the basis of a predetermined scale where the highest score is assigned to the most important criterion. Proportionately smaller weights are then given to criteria lower in the order. The procedure is continued until a score is assigned to the least important criterion. Finally, the weights are normalized by dividing each of the weights by the sum total which give a percentage.

In this project the rating weighting method is used. This was considered to be the best choice for this project as it was not possible to interview field experts. The criteria weights were calculated based on literature survey. For the suitability model, the Weighted Linear Combination was used because of experience.

3. Software and Programming Languages

3.1. ArcGIS

ArcGIS is a GIS software developed by ESRI (Esri n.d.). It was used for most of the data manipulation and spatial analysis in this project. Italics will be used to describe the different functions used in ArcGIS. The choice of the software for this project was made based on experience and availability.

3.2. QGIS

QGIS is an open-source GIS system that runs on various operating systems and supports numerous formats and functionalities (QGIS n.d.). Italics will be used to describe the different functions used in QGIS. QGIS was used for its geolocation function which worked better that the geolocation function available in ArcGIS.

3.3. Google Sheets

Google Sheets is an online spreadsheet application that is used to create and format spreadsheets (Google n.d.). Google Sheets was the main tool for all the criteria weight calculations.

3.4. Python

Python is an widely used open-source programming language (Python n.d.). It was used to write a script that scrapes climatic data from a website.

4. Criteria Selection Methodology and Weighting

In this study, the criteria were determined by considering literature search.The literature search for scholarly articles was conducted in February 2018 and covered the articles that were published by the end of January 2018 without any limitation on publication year. We searched Science Direct, ResearchGate, Academia and Google Scholar as our databases without any limitation on publication year.

A Boolean search was used containing the following terms: 1) keywords about sheltering such as “shelter”, “settlement”, and “housing”, 2) keywords about site selection which were site, site selection, site selecting, locate, location, locating and site mapping, 3) “GIS”, 4) “disaster management” and “multi criteria”. Our search strategy was formulated as follows: GIS AND (disaster management OR multi criteria) AND (shelter* OR settlement OR hous*) AND (site OR locat*).

Articles in the field of disaster management or humanitarian relief about temporary sheltering of affected people were included whereas non-English articles, articles about permanent housing and articles irrelevant to the subjects of site selection were excluded.
First of all the identified papers were scanned for inclusion criteria by examining the titles. The studies that met both of the inclusion criteria selected to review the abstracts.
The search resulted in 740 potentially relevant articles. After reviewing abstracts and removing the duplicates, 32 articles met the inclusion and exclusion criteria and found potentially relevant to the aim of study. Full text review of these articles led to seven articles and 3 handbooks (Table 1).

Determination of Temporary Shelter Areas in Natural Disasters by GIS: A Case Study for Gölcük/Turkey.	(Şentürk & Erener 2017)
GIS-based fuzzy MCDA approach for siting refugee camp: A case study for southeastern Turkey.	(Çetinkaya et al. 2016)
Application of fuzzy logic and GIS to provide geospatial solutions for displaced people in Al-Anbar province , Iraq (Aziz n.d.)	(Aziz n.d.)
Temporary site selection and decision making methods: a case study of Tehran, Iran.	(Omidvar et al. 2013)
Site Selection Criteria for Sheltering after Earthquake: A Systematic Review	(Soltani et al. 2014)
A hybrid multi-objective decision model for emergency shelter location-relocation projects using fuzzy analytic hierarchy process and goal programming approach.	(Trivedi & Singh 2017)
Engineering in Emergencies.	(Davis et al. 2002)
Sphere Project Handbook	(The Sphere Project n.d.)
UN emergency handbook	(UNHCR n.d.)

Table 1: Criteria selection literature

After examining the articles and the handbooks there were 16 criteria that appeared at, at least, 50% of the literature (Table 2). From these 16, only 11 were finally chosen to be used on the suitability model due the lack of data. The final criteria are:

1. elevation
2. slope
3. proximity to water
4. proximity to road network
5. proximity to towns
6. proximity to health facilities
7. windy areas
8. landslide danger
9. flood danger
10. earthquake danger
11. Size

Only the first 10 will be used as layer in the suitability model. The size will be used to examine if the output from the suitability model is large enough to host 49.200 people since for every person 45sqm must be calculated. So a total of 2,214,000sqm is needed.

The weights of the criteria the suitability model are calculated by the Ranking method (Table 3). First the 3 sets of weights from the literature research are normalized so that all of them are converted into percentages. Then the average of these weights is calculated and the final average weight is normalized again in order to get a sum of 100 at the end.

criteria	**1**	**2**	**3**	**4**	5	6	7	**8**	**9**	**10**	**#**
elevation	x	x	x	x	x		x			x	7
slope	x	x	x	x	x	x	x	x	x	x	10
soil	x	x	x	x		x			x	x	8
size	x	x	x				x			x	5
proximity to water	x	x	x		x	x	x	x	x	x	9
land use	x	x	x				x		x	x	6
proximity to road network	x	x	x	x	x	x	x	x	x	x	10
proximity to towns	x	x			x		x	x			5
proximity to health facilities	x	x			x	x			x	x	6
sufficient distance from international borders	x	x					x				3
sufficient distance from conflict zones	x	x					x				3
sufficient distance from military installations	x				x	x			x	x	5
extreme temperature	x								x		2
high winds	x	x		x			x		x		5
landslides	x	x		x	x	x	x		x	x	8
flooding	x	x		x		x	x	x	x	x	8
earthquakes	x	x			x	x	x		x	x	7
vegetation and ground cover	x		x						x	x	4
dust clouds	x										1
environmentally protected areas	x					x			x	x	4
forest	x						x				2
proximity to agriculture		x								x	2
proximity to train station, port, airport		x			x		x				3
proximity to potential hazardous materials		x		x	x	x			x	x	6
proximity to power lines, gas transfer lines				x	x	x		x		x	5
proximity to poverty density							x				1
proximity to tourism attractiveness							x				1
proximity to bus stations					x						1

Table 2: The criteria found in literature. The criteria that are used are highlighted with green colour while the criteria that were not used afterall due to lack of data are highlighted in pink colour.

Criteria	Weight A	Normalized Weight A	Weight B	Normalized Weight B	Weight C	Normalized Weight C	Average Weight	Normalized Av. Weight
proximity to health facilities	10.3	22.079	11	20	**-**	-	22	**18**
Access to water	3.65	7.824	7	12.727	15.1	27.207	16	**13**
proximity to towns	2.3	4.93	-	-	14.8	26.667	16	**13**
proximity to road network	12.4	26.581	5	9.091	3.4	6.126	14	**11**
landslides	7.1	15.22	13	23.636	0.9	1.622	14	**11**
high winds	-	-	-	-	4.7	8.468	8	**7**
earthquakes	7.1	15.22	4	7.273	1.6	2.883	9	**7**
flooding	-	-	6	10.909	3	5.405	9	**7**
elevation	2.7	5.788	-	-	5.4	9.73	8	**7**
slope	1.1	2.358	4	7.273	6.6	11.892	7	**6**
Sum	**46.65**	**100**	**55**	**100**	**55.5**	**100**	**123**	**100**

Table 3: The weights A, B and C from the literature and the final Normalized Average Weight calculated with the rating method

5. Data

The data were obtained from different sources.

The main **cities** of Greece were downloaded from Geodata as shapefiles. Geodata.gov.gr is an open data catalogue providing open geospatial data and services for Greece, according to the INSPIRE data specifications (GEODATA n.d.).
Country outlines, **water bodies** and **road network** were downloaded from DIVA-GIS as a geodatabase. DIVA-GIS provides free spatial data for the whole world that can be used in the DIVA-GIS mapping program or any other mapping software.
Elevation data were obtained from from HydroSHEDS as a SRTM dataset with a cell size of 85.51467216 meters. HydroSHEDS is a mapping product that provides geo-referenced data sets. It is based on high-resolution elevation data obtained during a Space Shuttle flight for NASA's Shuttle Radar Topography Mission (SRTM) (Shea n.d.).
The **fault lines** are in a shapefile format from the web site of the Research Group on Earthquake Geology in Greece (Research Group on Earthquake Geology in Greece n.d.).
The **landslide** susceptibility map was downloaded from NASA Earth Observatory (Observatory 1999). NASA Earth Observatory is a web page used by NASA to publish climatic and environmental information and satellite imagery.
Flood danger zones were downloaded from the map server of the Ministry of Environment and Energy (Esri n.d.).

Information about the public and university **hospitals** were obtained from the Health Atlas web platform (Ministry of Health n.d.). All the data on the website are collected by ‘supervised authorities of the Ministry of Health of Greece, the wider public and private sector, the Greek Statistical Authority (ELSTAT), IDIKA S.A., as well as recognized non-governmental organizations that have been granted the competence or the right to collect relevant data’ (Ministry of Health n.d.). The name of each hospital along with its address were entered manually on a Google Sheets spreadsheet.

The **wind speed** records were obtained from METEO (National Observatory of Athens n.d.), a data search application which aims to provide data to the public about pressure, temperature, humidity, rainfall, wind direction and intensity. The meteorological data are extracted from the 381 automatic weather stations of the National Observatory of Athens that are located throughout Greece. The website allows the user to find monthly climatic data for each one of the weather stations which can be downloaded in text format. The user can also download a spreadsheet with all the records from the weather stations, from year 2006 until 2015.
For this thesis it was important that the most recent climatological data were made available since there are drastic environmental changes during the recent years which affect temperature, rainfall and wind. Since it was very time consuming to read every monthly report for every weather station and then manually write the information, a python script was written to create a csv file with all the relevant data (Appendix 1).
The url that gives the monthly climatological summary for each station has the following format:

http://meteosearch.meteo.gr/data/”station name”/”year”-”month”.txt

Each time the user accesses a monthly climatological summary for a station (Figure 1), the url changes accordingly. So the script has to recreate this url for each station, for each month of the years 2016 and 2017, access it and retrieve information about the average wind speed.

MONTHLY CLIMATOLOGICAL SUMMARY for DEC. 2017

NAME: Agia Kiriaki   CITY: Dodoni   STATE: Ioannina
ELEV: 515 m   LAT: 39° 31' 27" N   LONG: 20° 52' 55" E

TEMPERATURE (°C), RAIN (mm), WIND SPEED (km/hr)

DAY	MEAN TEMP	HIGH	TIME	LOW	TIME	HEAT DEG DAYS	COOL DEG DAYS	RAIN	AVG WIND SPEED	HIGH	TIME	DOM DIR
1	13.6	14.5	20:40	10.7	23:20	4.7	0.0	151.6	20.9	66.0	7:50	ESE
2	12.3	13.4	14:30	11.1	0:10	6.0	0.0	11.6	8.2	33.8	16:00	ESE
3	10.7	12.8	14:10	7.2	22:50	7.6	0.0	9.6	10.6	45.1	4:40	ESE
4	6.9	10.4	13:50	2.4	23:50	11.4	0.0	8.0	2.6	29.0	16:40	W
5	3.3	9.3	13:40	-0.8	7:50	15.0	0.0	0.2	4.3	37.0	16:10	E
6	2.4	9.7	15:10	-2.9	3:50	15.8	0.0	0.0	3.1	19.3	4:50	SE
7	1.3	10.2	15:10	-4.2	7:50	17.0	0.0	0.2	1.3	11.3	12:40	S
8	2.4	9.5	14:50	-4.2	8:10	15.9	0.0	0.2	1.8	12.9	18:50	S
9	8.3	10.3	16:40	3.1	0:10	10.0	0.0	31.2	10.3	66.0	16:40	ESE
10	4.3	9.2	0:10	-1.4	00:00	14.0	0.0	5.0	5.1	48.3	2:10	W
11	3.6	8.8	20:10	-2.7	4:20	14.7	0.0	0.2	2.3	22.5	19:40	SSE
12	10.1	12.0	15:10	7.6	23:20	8.2	0.0	3.6	4.7	25.7	4:50	SE
13	9.9	14.3	13:00	6.1	8:30	8.4	0.0	1.2	3.9	24.1	18:50	SE
14	9.4	12.3	13:10	4.6	00:00	8.9	0.0	11.6	2.7	29.0	0:40	E
15	7.9	11.8	23:50	2.2	4:50	10.4	0.0	8.2	6.0	38.6	22:20	ESE
16	11.2	13.2	12:20	9.0	00:00	7.1	0.0	14.2	12.6	41.8	14:10	ESE
17	7.8	10.2	14:40	3.1	21:20	10.4	0.0	12.2	3.5	24.1	1:40	SE
18	3.8	6.3	15:00	0.2	00:00	14.5	0.0	0.8	2.7	24.1	16:30	WNW
19	0.2	5.6	13:20	-3.6	00:00	18.1	0.0	0.2	1.8	16.1	13:00	E
20	-1.3	4.6	15:10	-6.2	8:30	19.6	0.0	0.2	1.9	17.7	12:40	SSE
21	0.7	3.3	00:00	-1.3	0:30	17.6	0.0	0.6	1.6	14.5	11:30	WNW
22	3.8	6.4	12:00	0.2	5:00	14.4	0.0	0.2	12.2	43.5	22:00	WNW
23	4.4	8.1	13:10	-1.5	22:30	13.9	0.0	0.0	13.0	51.5	4:10	WNW
24	2.0	11.8	15:10	-4.2	5:00	16.3	0.0	0.0	2.4	22.5	14:50	E
25	3.2	12.1	15:10	-3.6	8:00	15.1	0.0	0.2	1.9	16.1	19:50	SE
26	3.9	10.9	14:40	-3.2	6:40	14.4	0.0	1.2	1.6	16.1	12:30	E
27	8.3	9.2	13:00	7.1	0:10	10.0	0.0	12.6	9.2	33.8	19:50	ESE
28	7.9	9.2	5:00	5.7	00:00	10.4	0.0	77.8	11.9	57.9	5:00	ESE
29	5.2	7.4	14:00	2.2	00:00	13.1	0.0	11.4	3.2	27.4	3:20	SE
30	2.9	7.7	15:10	-1.7	00:00	15.4	0.0	0.2	2.9	22.5	13:30	WNW
31	0.2	7.6	15:00	-4.9	8:10	18.1	0.0	0.2	1.3	11.3	12:50	E
	5.5	14.5	1	-6.2	20	396.5	0.0	374.4	5.5	66.0	1	ESE

Max >= 32.0: 0
Max <= 0.0: 0
Min <= 0.0: 15
Min <= -18.0: 0
Max Rain: 151.61 ON 01/12/17
Days of Rain: 28 (> .2 mm) 14 (> 2 mm) 3 (> 20 mm)
Heat Base: 18.3 Cool Base: 18.3 Method: Integration

Figure 1: Monthly climatological summary from the National Observatory of Athens

6. Suitability Model

Criteria	Study A	Study B	Study C	
Proximity to health facilities	The most favorable distance is 1000	The closer the better	-	The closer the better
Access to water	Considering the boundary is 100m	The closer the better	The closer the better	Considering the boundary is 100m and after that the closer the better
Proximity to towns	The closer the better	-	The closer the better	The closer the better
Proximity to road network	The most desirable distance is 200 meters	The closer the better	The closer the better	The closer the better
Landslides	Considering the boundary is 200m	Low-Risk Area 3 Risk Area 2 High-Risk Area 1 No Risk 5	Away from landslide hazard zones	High-Risk Area 5 Risk Area 4 Moderate-Risk Area 3 Low-Risk Area 2 No Risk 1
Winds	-	-	Far from windy areas	Far from windy areas
Earthquakes	Considering the boundary is 200m	The further the better	Away from earthquake hazard zones	0-200 m not desirable. After that the further the better
Flood	-	Flood, no flood	Away from flood hazard zones	Flood, no flood
Elevation	Height above 30 meters is more desirable	-	Plane area	Height above 30 meters is more desirable
Slope	2%-7%	0% - 8%	No more than 7%	2%-7% the best No more than 10%

Table 4

In order to determine how each criterion layer should be reclassified, we need to examine the classification of the criteria layers of the study cases that are used as reference. Table 4 demonstrates how the three study cases from the literature affected the final classifications. The new classes will take values from 1 to 10, with 10 being the most suitable. This will help at the next step of the suitability analysis where the reclassified layers will be used as inputs to the *Weighted Overlay* tool. This tool will apply the weights to the criteria and the output will be the suitability map.

6.1.1. Elevation

The elevation dataset was not one raster for the whole country, but seven separate consequent rasters.
With the tool *Mosaic To New Raster* from the *Data Management* toolbox these rasters were merged into one.
Using *Project Raster* from the *Data Management* toolbox, the projected coordinate system changed to WGS_1984_UTM_Zone_35N which is in meters and also corresponds to the specific location.
Next, the *Clip* tool from the same toolbox is used to clip the DEM raster to the extent and the geometry of the country's outline.
According to the previous analysis (Table 4), the elevation raster has to be reclassified to two classes. The first class will be from the lowest value of the elevation raster until 30 meters, and the second class from 30 meters up to the highest value of the raster (Figure 2)

6.1.2. Slope

In order to get the slope, the *Slope* tool from the *Spatial Analyst* toolbox has to used. The input is the elevation raster after it has been merged, projected and clipped to the shape of the country.
The slope needs to be reclassified into four classes. The first will be from 0% to 2% with moderate suitability, the second from 2% to 7% with maximum suitability, the third from 7% to 10% with moderate suitability and the last over 10% with least suitability (Figure 3).

6.1.3. Proximity to water

The site has to be as close to water bodies as possible but not too close in order to avoid contamination.
First a buffer is created with the *Buffer* tool with a value of 100 meters. The output of this tool is used as an input to the *Euclidean distance* tool which creates a raster where each cell value represents the distance from the closest buffer.
The final raster is been classified to ten classes using the *Natural Breaks* option on the classification method. The break values where slightly adjusted in order to make it more comfortable for the reader to examine the map legend (Figure 4).

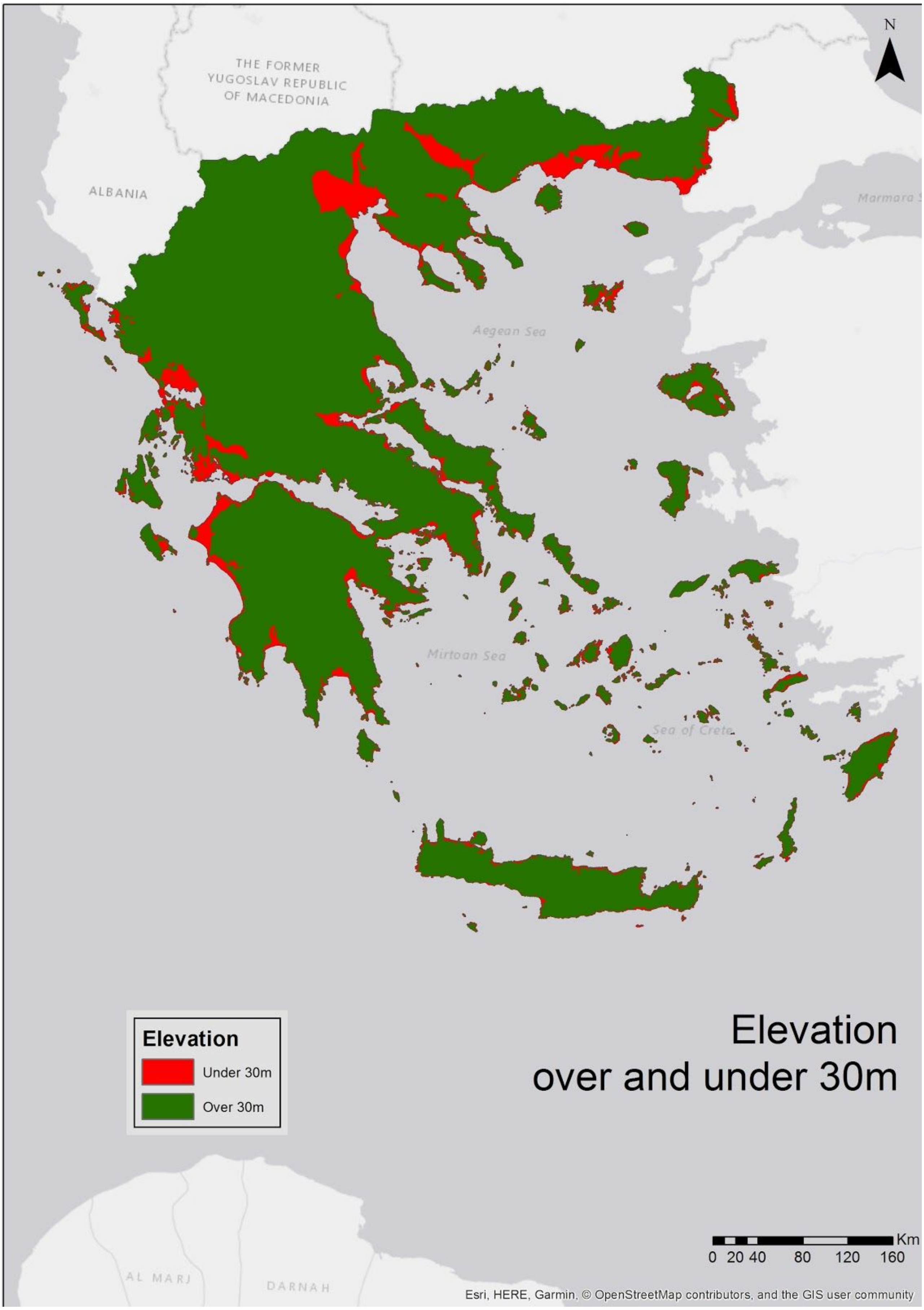

Figure 2: The elevation raster, reclassified.

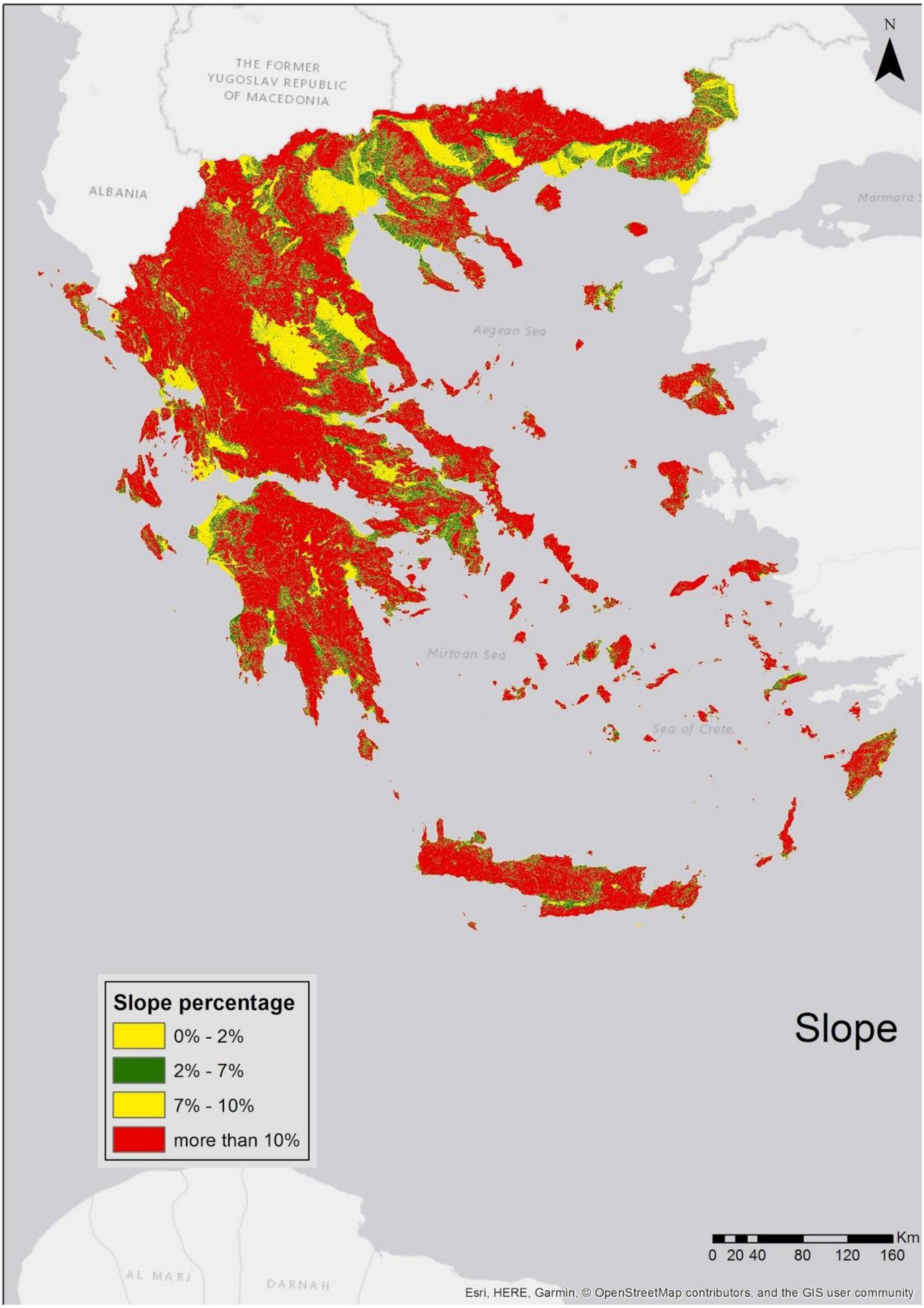

Figure 3: The slope raster, reclassified.

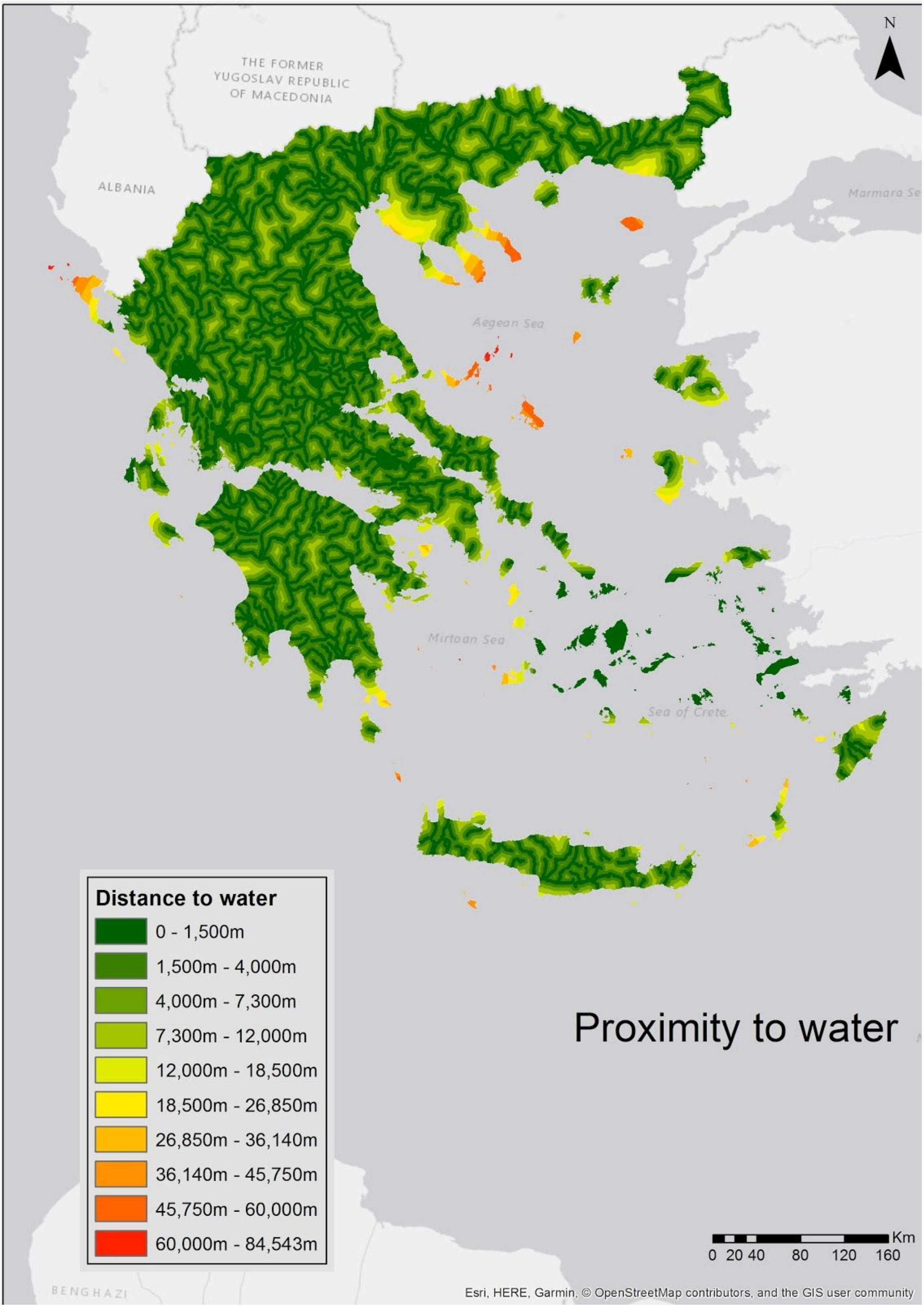

Figure 4: Proximity to water bodies

6.1.4. Proximity to road network,towns and hospitals

The site has to be as close to roads, towns and hospitals as possible. Using the *Euclidean Distance* and then the *Reclassify* tools again we get the final raster (Figure 5,6 & 7).

6.1.5. WIndy areas

The site has to be away from windy areas. The csv with the wind speed data was imported into the map. It was possible to create points from the latitude and longitude of the meteorological stations. After an interpolation analysis on the sample data we get an approximation of the most and least windy areas (Figure 8). We also *Reclassifyi* and *Clip* to the shape of the country.

6.1.6. Landslides and floods

The rasters were clipped and reclassified. The landslides raster already had values from 0 to 5 indicating the degree of danger. It was changed to 1-5 (Figure 9). The flood raster was also classified to flood/no flood (Figure 10).

6.1.7. Earthquakes

The site has to be away from areas where the possibility of an earthquake is big. The *Euclidean Distance* tool is used having as input the fault lines. It is also being reclassified into ten classes (Figure 11).

When all the layers are ready they can be used as inputs to the Weighted Overlay tool which will give as an output the suitability map.

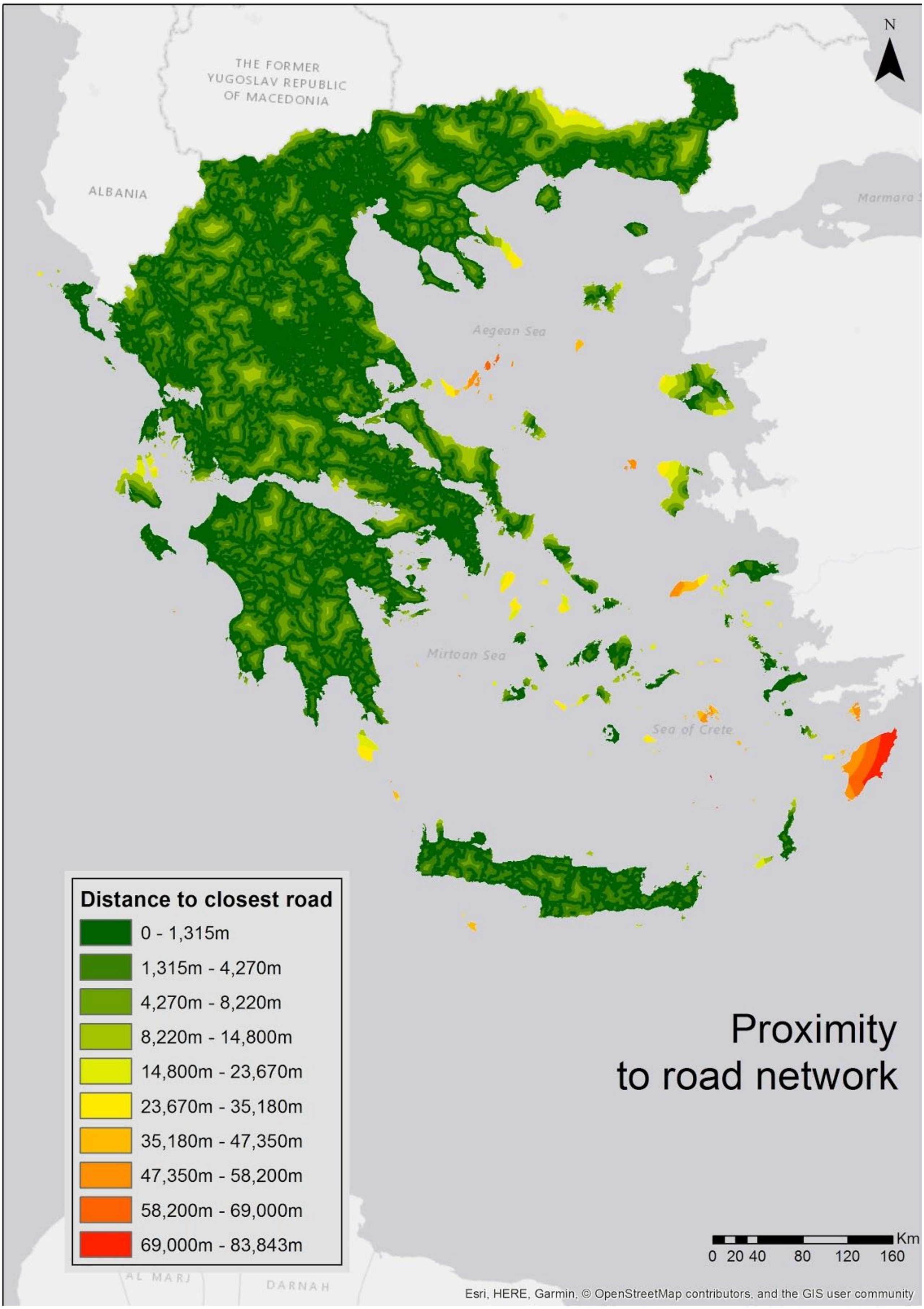

Figure 5: Proximity to road network

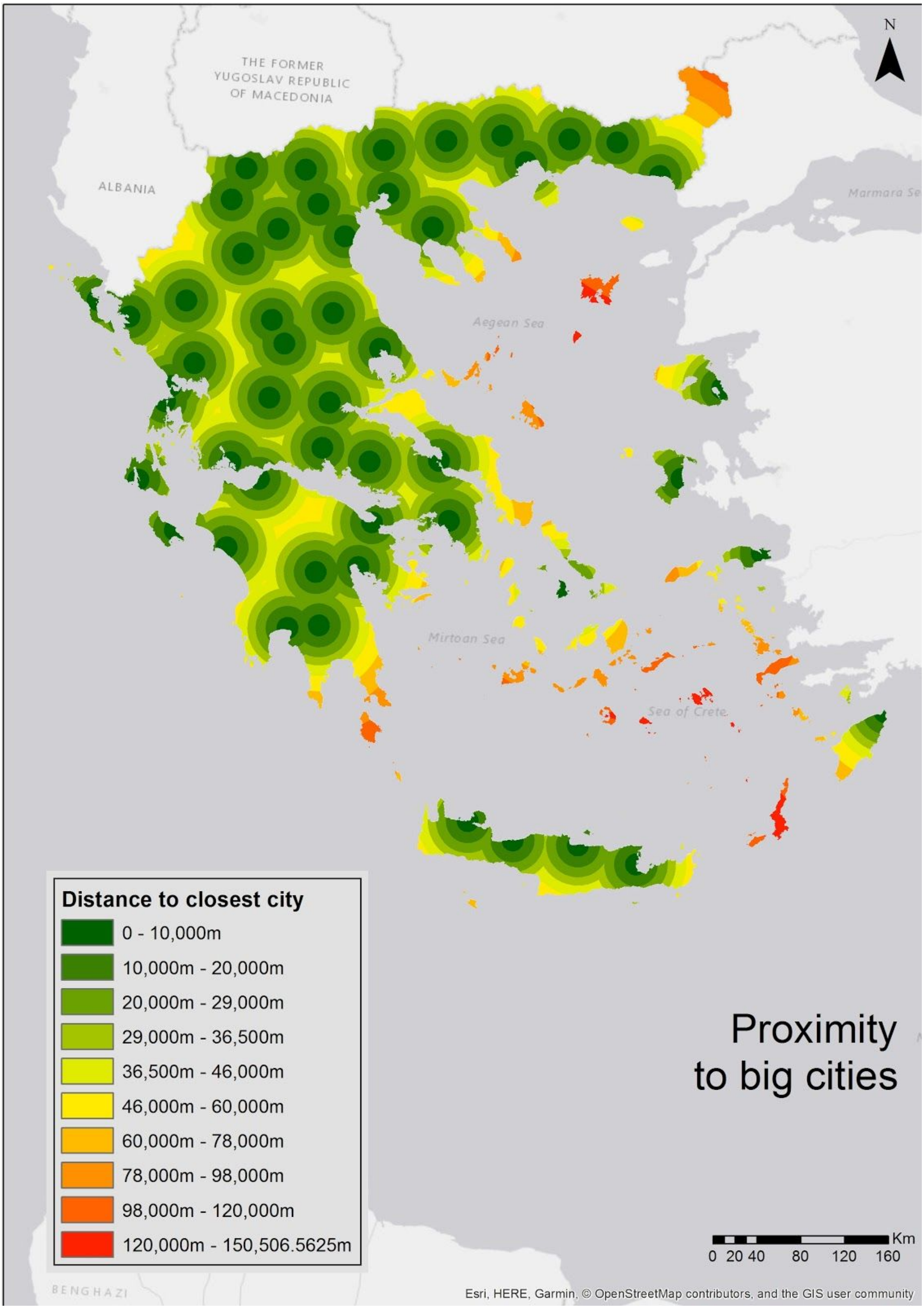

Figure 6: Proximity to cities

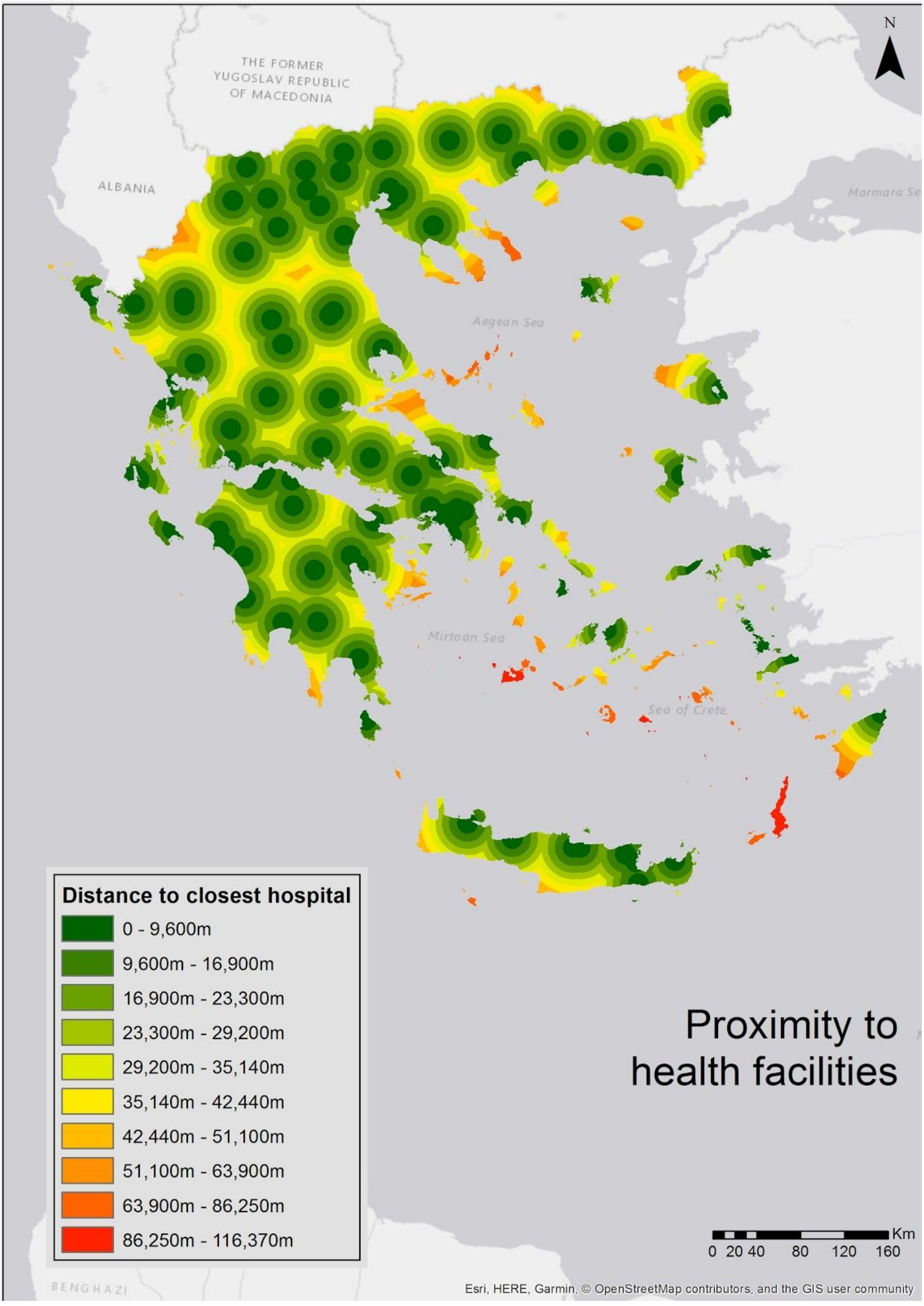

Figure 7: Proximity to health facilities

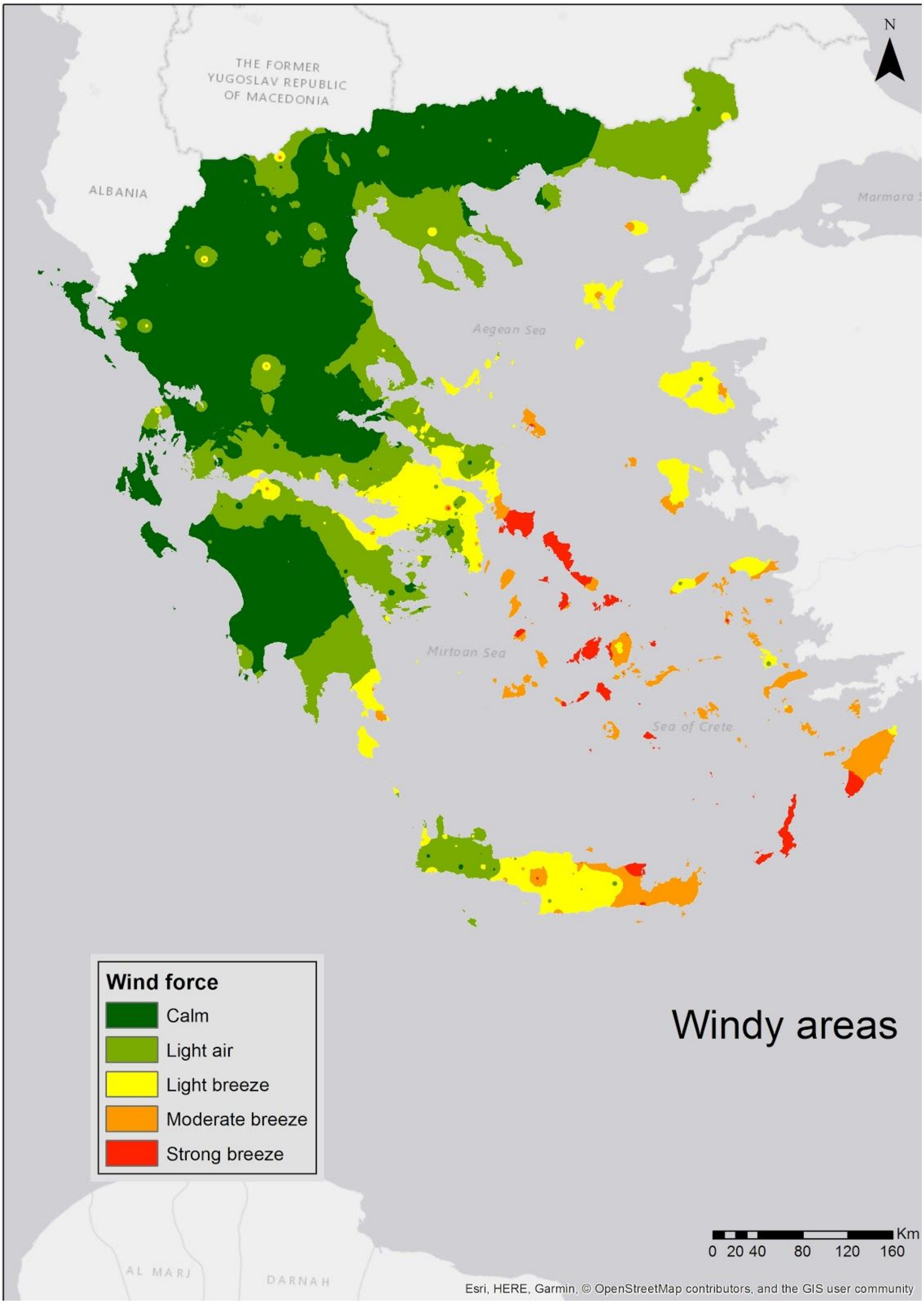

Figure 8: Windy areas

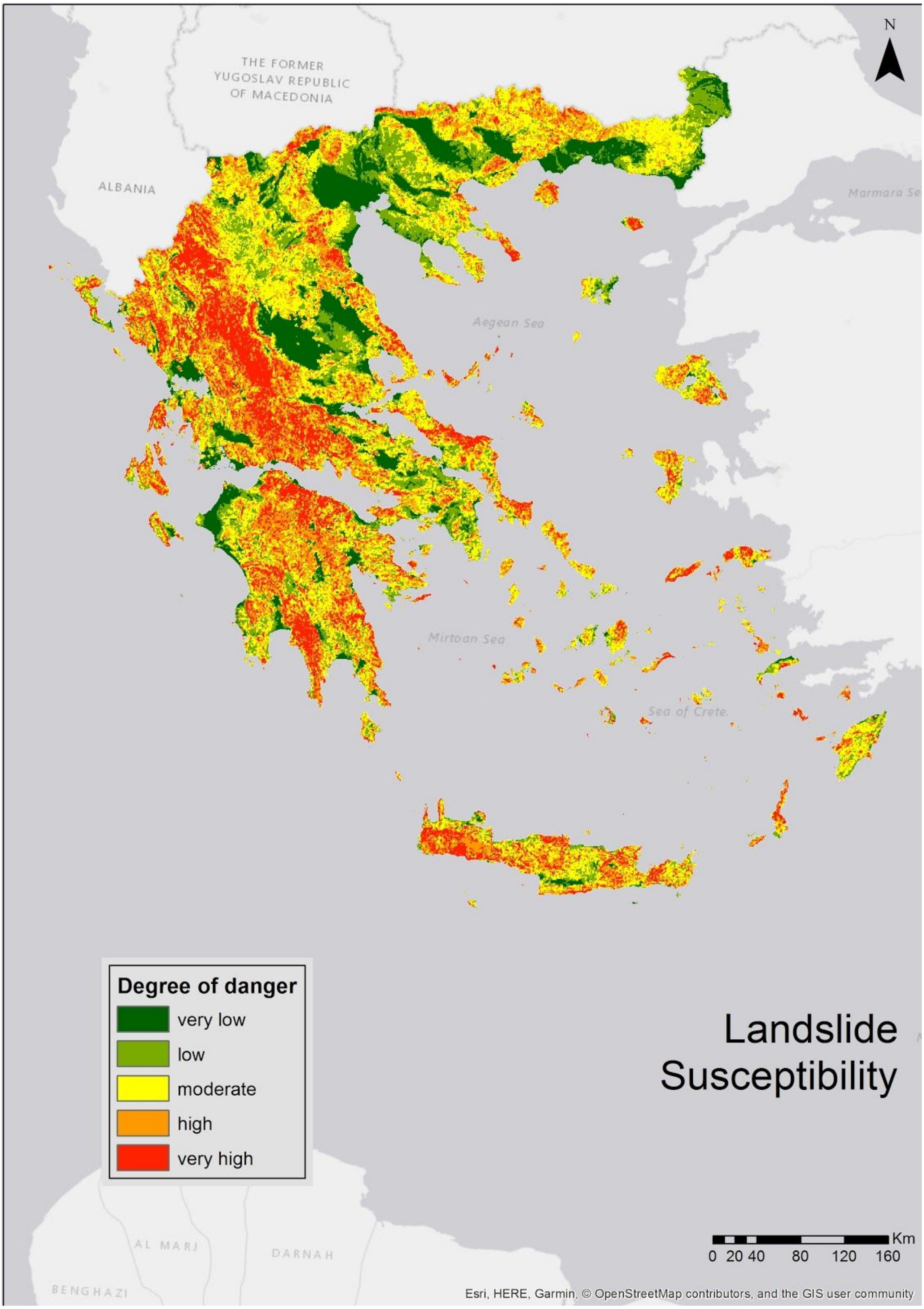

Figure 9: Landslide susceptibility

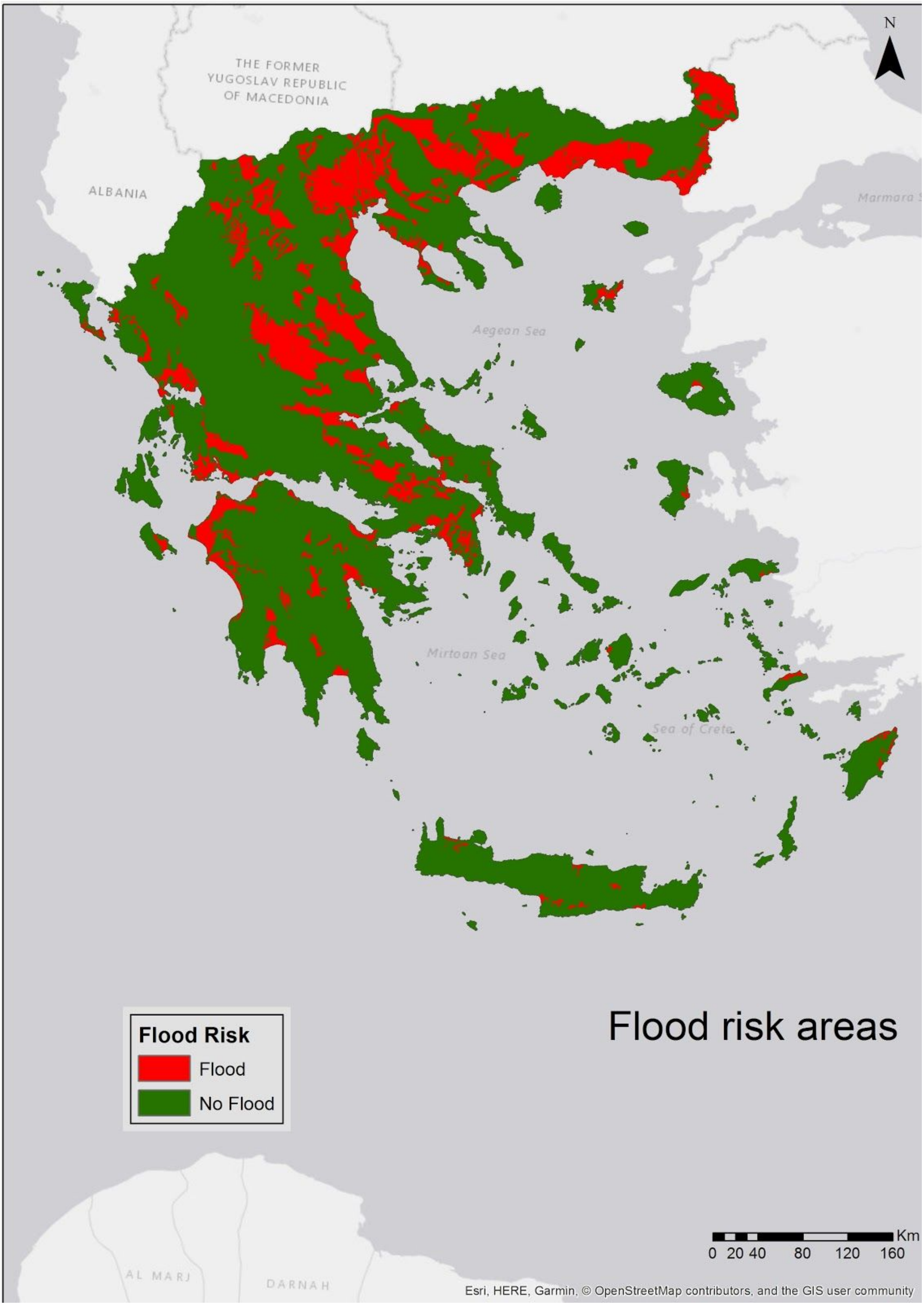

Figure 10: Flood risk map

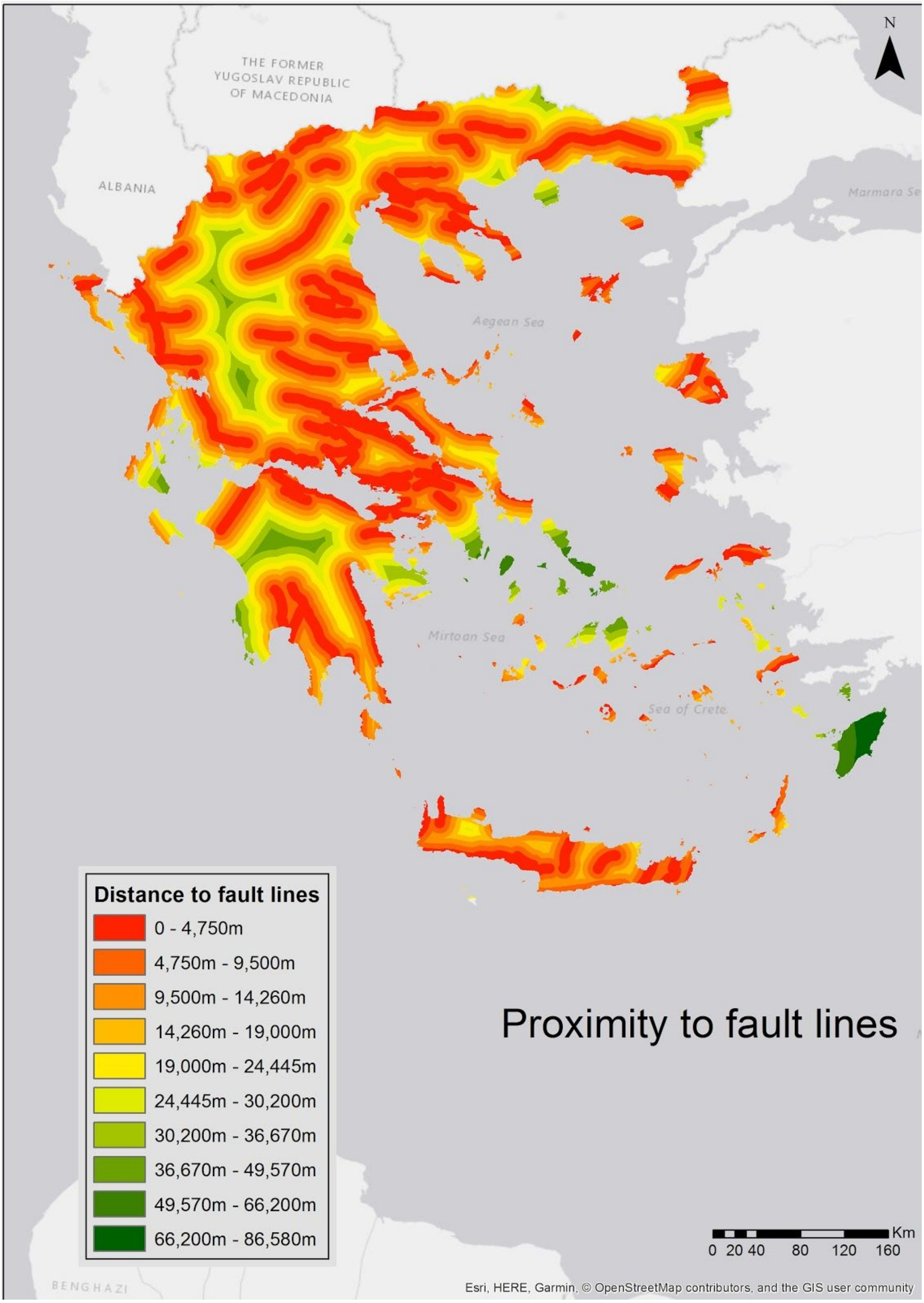

Figure 11: Proximity to fault lines

7. Results

Examining the output of the suitability analysis we can see that a large percentage of the country is very suitable for temporary settlement (Figure 14).
In Figure 12 we can see that the cells with the highest record (the most suitable) are enough to facilitate the needs of 49,200 people.
And even if these areas are not available for some reason then the cells with the lower value, that are still very suitable, can accommodate 107,049,060 people.

WLC90

OBJECTID *	Value	Count	area	No_of_People
1	2	3	24300	540
2	3	665	5386500	119700
3	4	34743	281418300	6253740
4	5	265762	2152672200	47837160
5	6	1294822	10488058200	233067960
6	7	5879483	47623812300	1058306940
7	8	8031234	65052995400	1445622120
8	9	594717	4817207700	107049060
9	10	324	2624400	58320

Figure 12: The attribute table of the suitability map

Regarding the existing campsites, it seems from the statistics on their suitability score, that they are already in sites with high suitability value (Figure 13).

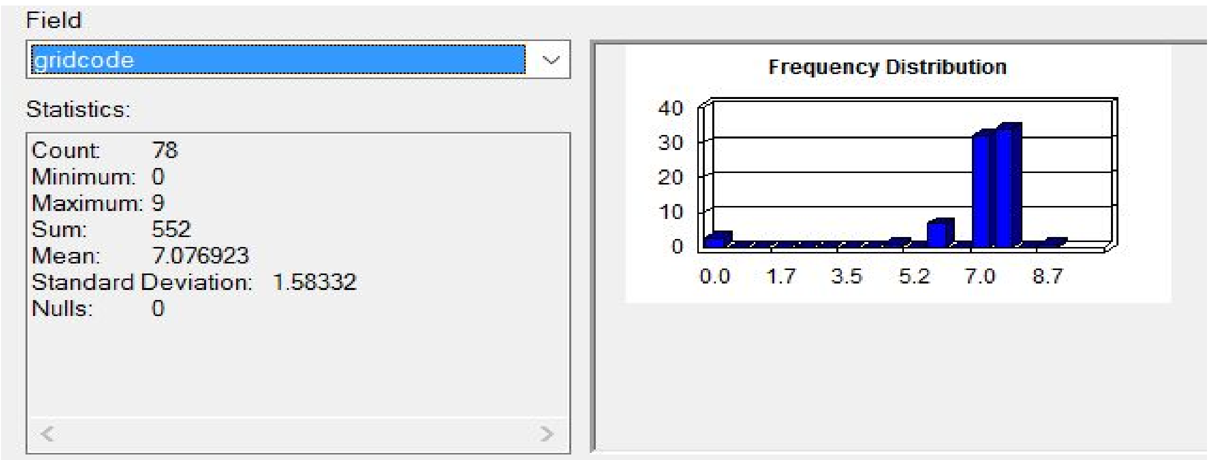

Figure 13: The statistics of the suitability value of the existing camps

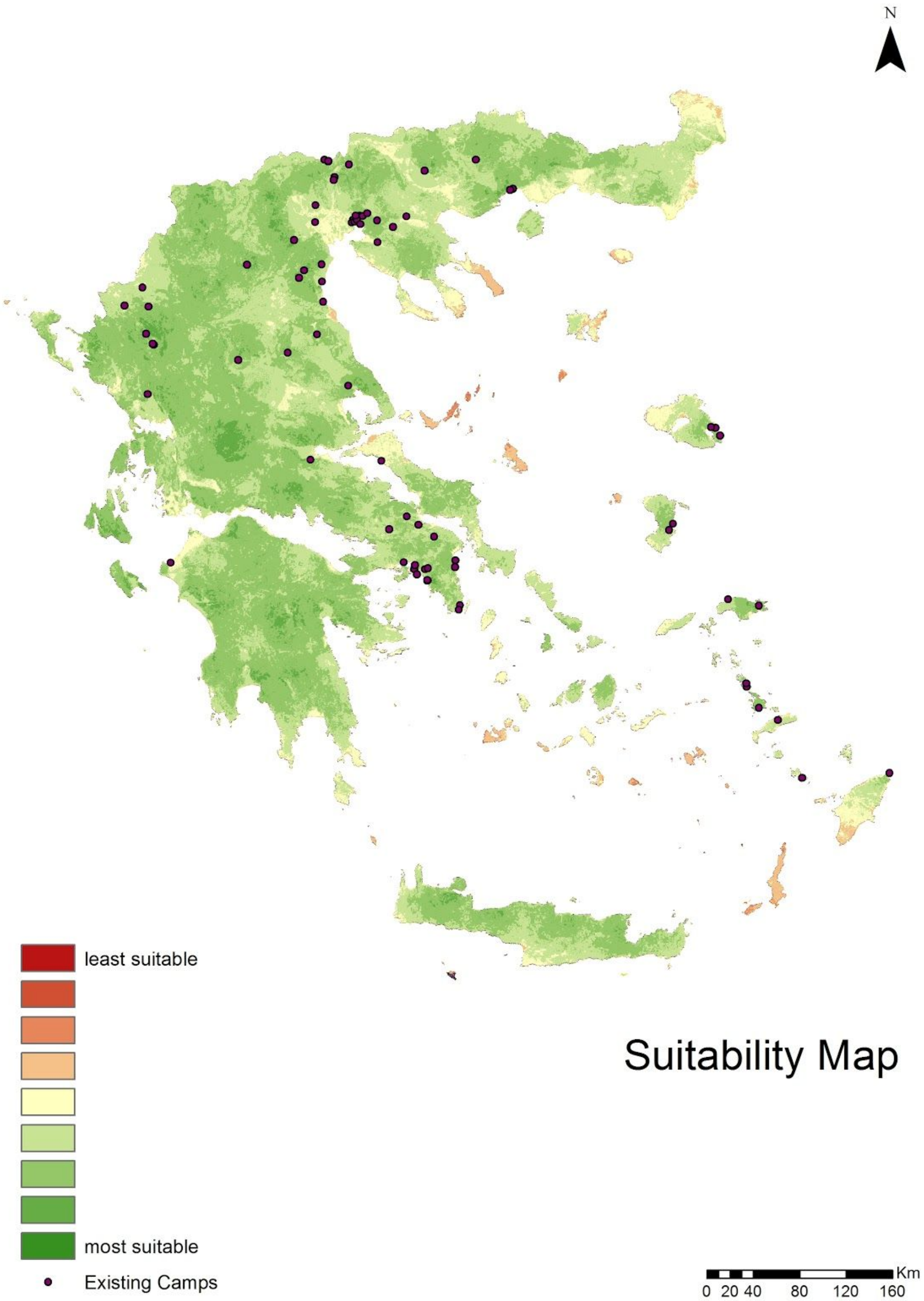

Figure 14: Suitability map

8. Discussion

What kind of criteria are relevant for a multi-criteria decision analysis that determines new potential locations for temporary settlements?
It became clear that there is not a list of specific criteria that we can use every time we want to have a similar analysis. The choice of criteria depends on the place and sometimes even the experts have different opinions. Even in cases of two analyses
The best way to make sure that the criteria are

Which is the optimal multi-criteria decision analysis method for temporary settlement location site selection?
The choice of method depends on how many data there are available and who is deciding the weights. If you have the opinion of expert then Analytical Hierarchy Process is the most favourable. If you are only based on the amount of data available , then the Entropy-Based Criterion Weighting is a good start. There is always the option to rely on literature which can be perceived as an expert's opinion especially if there are multiple sources of information.

Which are the optimal locations for temporary settlements and how do they compare to the existing sites?
Comparing the existing sites with the output of this analysis, one can she that they are already suitable for temporary accommodation. Then maybe the problem is not the site location but how the sites are been managed or the types of shelters used. It might also be the case that the choice of criteria and weights was incorrect. More research needs to be done before deciding if these are the optimal locations.
For now, and based on the methods, the criteria and the weights that were used for this project the existing sites are suitable.

Drawbacks
Some major drawback were the lack of data and the fact that the study area was very big leading to slow processing times. Based on this, if I were to do this again, I would choose a much smaller area to begin with.

Further development
There are some possibilities to develop this project further. A comparison of different MCDA methods would offer a better result and a better understanding on the similarities and the differences between the methods. A sensitivity analysis would offer a better review of the effect of the different criteria on the final result. A collaboration with researchers from different disciplines like hydrology or soil engineering would give the possibility for the study to go further.

9. Conclusion

This thesis was an effort to apply a GIS-based MCDA method in order to find the best locations for refugee camps in Greece, but also an effort to find the optimal set of criteria and the most suitable MCDA method to apply in cases of temporary settlement site selection.
What was clear was the fact that there is not a predetermined set of tools and criteria. It appears that the best way to get closer to the optimal solution is by trying and comparing or ever combining the different methods.
At the end, it might not be certain that this specific set of criteria, with these specific weights, is the best solution, but it is a good start, where further investigation and experimentation on the different combination of criteria can start from.
This project was a great opportunity to use various gis tools, to handle data of various formats and sources and figure out ways to make them work together.

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Appendices

Appendix 1

```
import urllib2  # the lib that handles the url stuff
import re       # regular expressions


stations=[]
longitude=[]
latitude=[]
months   = ["01", "02", "03", "04", "05", "06", "07", "08", "09", "10", "11", "12"] # ... and so on
years    = ["2016", "2017"] # add more years if you see that just 2017 doesn't give you enough
data

# let's write the header to a new CSV file
# this will overwrite the file if it already exists!
outF = open("stations.csv", "w")
firstline = "station" + ", " + "lat" + ", " + "lon"
for year in years:
    for month in months:
        firstline = firstline + "," + "wind_" + month + "/" + year
outF.write(firstline + "\n") # add more as required
outF.close()


with open ('stations_list.txt', 'rt') as infile:
    for i, line in enumerate(infile):
        if i > 1:
            station=line[14:42]
            station=re.sub( '\s+', '', station ).strip()
            stations.append(station)
            lon=line[42:53]
            longitude.append(lon)
            lat=line[56:67]
            latitude.append(lat)
print stations
outF = open("stations.csv", "a")
for station in stations:
    j= stations.index(station)
    lat= latitude[j]
    lon= longitude[j]
    wind=[]
    csvline = station + ", " + lat + ", " + lon
```

```
    i=0
    for y in range(0,len(years)):
        for z in range(0,len(months)):
            q= z +(12*y)
            url = "http://meteosearch.meteo.gr/data/"+station+"/"+years[y]+"-"+months[z]+".txt"
            # we'll use try/except to make sure the script doesn't crash
            # if one of the files cannot be found
            print station, years[y], months[z], q

            try:
                data = urllib2.urlopen(url) # open the file at the URL

                # keep count of the separator lines with dashes,

                # we need to fetch the line with the summary data after
                # the second line of dashes
                dashedlines = 0

                for line in data:# go through that file line by line
                    if (dashedlines == 2):

                        parts = str.split(line) # split at white spaces
                        wind.append(parts[8])

                        # to make sure this block won't be executed again
                        dashedlines = dashedlines + 1
                    if "------------" in line:
                        dashedlines = dashedlines + 1
                csvline = csvline + ", " + wind[q]


            except Exception as e:
                print e
                print url
                wind.append("")   #add blank if there is no record
                csvline = csvline + ", " + mT[q] + ", " + hT[q] + ", " + lT[q] + ", " + rain[q] + ", " + wind[q]



    print csvline
    outF.write(csvline+"\n")

outF.close()
```