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MOONRISES
INTEGRATED MONITORING SYSTEM FOR DESERTIFICATION RISK ASSESSMENT

COFINANCED BY THE EUROPEAN REGIONAL DEVELOPMENT FUND

INTEGRATED MONITORING SYSTEM FOR DESERTIFICATION RISK ASSESSMENT

MOONRISES

ΟΛΟΚΛΗΡΩΜΕΝΟ ΣΥΣΤΗΜΑ ΠΑΡΑΚΟΛΟΥΘΗΣΗΣ ΓΙΑ ΤΗΝ ΕΚΤΙΜΗΣΗ ΤΟΥ ΚΙΝΔΥΝΟΥ ΕΡΗΜΟΠΟΙΗΣΗΣ

Guide for Management and Strategic Action Development (SAD)

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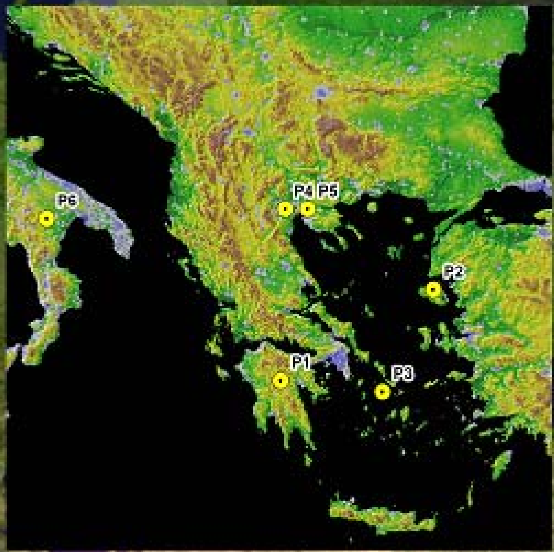

INTERREG III

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MOONRISES

INTEGRATED MONITORING SYSTEM FOR DESERTIFICATION RISK ASSESSMENT

Guide for Management and Strategic Action Development (SAD)

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CHAPTER 1: IDENTIFICATION SHEET

Identification Sheet

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Abstract

The Guide will include the parameters under consideration and in the same way will be accompanied from manual containing the principles and the targets of monitoring procedures (monitoring rules), the description of the common methodology of the investigated parameters (sampling strategy, sampling methods, time repeatability, etc.), the necessary hardware and software.

Keywords:

Management, strategic, administration, mitigation measures

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1 Introduction

Desertification is a dynamic process active in arid, semi-arid and sub-humid zones. It induces severe degradations to natural resources such as the impoverishment of soils, the deterioration of the biomass or even the reduction of the biodiversity. The degradations can have various levels of severity and can, in the extreme cases, reach a point where the damage on soil and vegetation are irreversible.

Various regions in the world are affected by Desertification. For instance, the countries of the Mediterranean basin are particularly threatened by the spread of the desertification process. During the last decades, the process has been activated in North-Mediterranean countries by the intensification of cultivation, the increase in water demand and the urbanization in rural areas. The Mediterranean ecosystems are extremely rich but also can be considered as highly vulnerable. Therefore they are prone to be severely degraded in the presence of some specific desertification driving forces.

The causes of desertification can be multiple. Usually they are grouped into two categories: the biophysical and the socio-economic causes. However, it is widely admitted by the scientific community that desertification drivers can not be regarded as a set of isolated drivers but rather as a complex interaction of multiple triggering factors. Therefore, from the latter observation derives the complexity of the desertification assessment task and the need for a multi-disciplinary integrated approach.

One characteristic of the desertification process is its capacity to evolve along time. Therefore, monitoring tasks are essential to follow the level of degradation of natural resources in the affected areas. The output from desertification monitoring is of high interest for decision makers that can utilize them in order to decide of the appropriate measures that have to be implemented in order to combat desertification.

Two types of actions/measures can be undertaken in order to preserve the fragile balance of the Mediterranean ecosystems. The preventive ones, on one hand, aim at avoiding the activation of the desertification process and shall be applied prior to the appearance of the first symptoms of desertification. The mitigation measures, on the other hand, contribute to reducing the degradations already endured in the affected area.

Objectives of the guide:

The present guide is one major output of the INTERREG III B ARCHIMED project MOONRISES (Integrated Monitoring System for Desertification Risk Assessment).
The SAD guide stands for Management and Strategic Action Development guide whose objectives are to (i) provide an overall description of the situation relative to the desertification in the North-Mediterranean region; (ii) describe the methodology adopted during the MOONRISES project for the assessment of desertification risks in some target areas of Greece and Italy; (iii) propose a first interpretation of the results (sensitivity degree to desertification, main causes of desertification in the study areas) after analysis of the various thematic maps generated and (iv) present a synoptic view of the desertification policy context and propose a series of recommendations and measures for the prevention, monitoring and mitigation of the desertification phenomenon.

Target audience:

The present SAD guide is targeted at two types of groups:
- Professionals, experts and institutions dealing with desertification and environmental assessment and monitoring issues
- Decision/policy makers at local and national levels.

Structure of the guide:

To achieve the objectives listed above the SAD guide contains five main sections. The first section is dedicated to the desertification process (definition, causes, impacts) with an emphasis on the particularities of the North-Mediterranean region. In the second section is presented the MOONRISES project (objectives, partners, target areas). The assessment of desertification is tackled in the third section where some desertification indicators are listed and a full methodology for assessing desertification in Greek and Italian study areas is described and tested. Some detailed recommendations for desertification monitoring are then proposed in the fourth section. The last section concerns desertification prevention and mitigation. Appropriate measures are proposed according to the desertification causes and risk identified in the study areas. The implementation of the proposed measures by decision makers would constitute an effective step in combating desertification and ensuring a sustainable development in the area.

2 Description of the desertification process

2.1 Evolution of the concept of desertification

The definition of desertification has evolved along time. For instance, the UNEP regularly upgraded its understanding of the desertification phenomenon. In 1977, desertification was considered as "the reduction or destruction of the biological potential of land that can lead to desert-like situations and an aspect of ecosystem degradation following a consistent reduction in their biological potential." Later in 1983, Dregne[1] presented desertification as "the impoverishment of terrestrial ecosystems under the effect of human impact, that can be measured by reduced productivity of useful plant species, reduced biomass and lesser diversity of micro and macro-fauna and flora, accelerated soil degradation and increased risks due to the presence of man". In 1984, the UNEP agreed with the FAO to define desertification as "All encompassing expression to indicate socio-economic, natural and anthropic processes causing a modification in the soil, vegetation, atmospheric and water balance of regions characterized by aridity induced by edaphic and climatic factors". In 1991, a third revision of the definition by the UNEP led to the identification of desertification as being the "Land degradation in arid, semi-arid and dry/sub-humid areas, due principally to negative human impacts", where the term land refers to soil and local water resources, land surface areas and natural vegetation. In 1994, the former definition was widened to include the climatic variations as one more cause together with human impact.

2.2 The causes of desertification in the North-Mediterranean region

The international community recognised the European Mediterranean region as being a region highly sensitive to desertification. In fact, in 1997, the UNCCD comported an Annex (Annex IV) dedicated to the particular physical and socio-economic conditions that characterize the North-

Mediterranean region and can explain the triggering/activation of the desertification process in the area. These conditions are:

- Semi-arid climatic conditions affecting large areas, seasonal droughts, very high rainfall variability and sudden and high-intensity rainfall.
- Poor and highly erodible soils, prone to develop surface crusts.
- Uneven relief with steep slopes and very diversified landscapes.
- Extensive forest coverage losses due to frequent wildfires.
- Crisis conditions in traditional agriculture with associated land abandonment and deterioration of soil and water conservation structures.
- Unsustainable exploitation of water resources leading to serious environmental damage, including chemical pollution, salinisation and exhaustion of aquifers.
- Concentration of economic activity in coastal areas as a result of urban growth, industrial activities, tourism and irrigated agriculture.

Also, in 2006 the European commission adopted the Thematic Strategy for Soil Protection that focuses on soil protection issues and consists of a Communication from the Commission to the other European Institutions, a proposal for a framework Directive (a European law), and an Impact Assessment. One of the reports of the working groups set up in preparation of the thematic strategy (Volume II) deals with the desertification issue and confirms the concern of the European commission about the intensification of land degradation due to the spread of desertification processes in South European countries. The strategy presents an analysis of the principal driving forces of desertification and its impacts on natural resources. Moreover, it points out that human activities did from historical times alter the ecosystem structure and that extreme cases of degradations are encountered when natural and social, economic and cultural circumstances coexist. The alarming aspect about desertification is considered to be "the exponential increase of human impact on the environment and the increase in degradation sensitivity". Therefore, the strategy encourages the Member states to undertake effective actions to prevent and mitigate desertification. The proposed means of actions are detailed in Section 6.

3 Description of the MOONRISES project

Objectives:

The literature review of projects and research programmes related to desertification and drought revealed that a great of deal of work has been done for the elaboration of desertification indicators. The aim of the MOONRISES project is not to extend the theoretic research on the subject by introducing new indicators but rather to:

- select the appropriate indicators according to the data availability in the area and its particular physical and socio-economic conditions;
- define the data collection requirements (source, type, collection procedure) according to the study areas;
- specify the methodology for data transformation into significant desertification indicators using Geographic Information Systems (GIS) techniques;
- develop a geodatabase (geographical database) in order to ensure the easy access to and the reusability of the desertification assessment and monitoring results.

The project will therefore lead to the creation of a fully operational integrated system for the assessment of desertification risks. During the duration of the project, the data will be collected

and the methodology will be applied in the target areas, therefore providing a set of relevant thematic maps.
Guidelines for desertification risk monitoring will also be provided. Thus, the time repeatability of the data collection and the frequency of the application of the model in the areas sensitive to desertification will be specified.
In order for the monitoring output to lead to concrete measures in the areas affected or threatened by desertification, will be also provide:

- recommendations for the interpretation of the output maps and the generation of meaningful statistics (meaningful from the viewpoint of desertification risk)
- guidelines for the selection of the appropriate prevention and mitigation measures to be applied by stakeholders for effectively combating desertification.

For a good understanding of the model proposed and an easy communication of the project's results, various documents were produced: technical guides, user's guides, maps and the Management and Strategic Action Development guide (SAD guide).

The project partners:

The project outputs will result from a trans-national cooperation since project partners are located in Greece and Italy. In fact, the following partners were involved in the MOONRISES project (see Figure 1):

- the region of Peloponnese in Greece (Lead partner P1);
- the region of North Aegean in Greece (P2);
- the region of South Aegean in Greece (P3);
- the region of Central Macedonia in Greece (P4);
- the department of remote sensing and GIS of the Aristotle University of Thessaloniki (AUTH) in Greece (P5) and
- the department of Crop Systems, Forestry and Environmental Sciences of the University of Basilicata (USB), Italy (P6)

The partner bodies are from two countries facing undoubtedly desertification problems and having ratified the UNCCD convention in 1997 (see details in Table 1). The teams will collaborate for the production of a desertification assessment model and its application in the study areas in order to produce desertification sensitivity maps. The participation of an Italian partner to the project is of great significance and support since Italy decided to take from 1997 a guiding role in the research on desertification indicators and hosted the First Conference of the Parties (COP-1) held in Rome the same year. In Italy is also established the National Observatory on Desertification having the task of studying problems, policies and financial resources concerned with combating the desertification at an international level.

Table 1 - Status of UNCCD ratification and entry into force for Greece and Italy

Country	Date of Signature	Date of Ratification	Date of Entry into Force
Greece	14/10/1994	05/05/1997	03/08/1997
Italy	14/10/1994	23/06/1997	21/09/1997

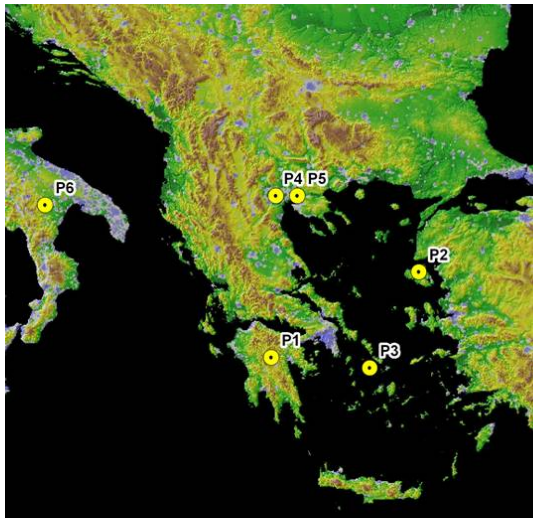

Figure 1 - Location of the project partners

The target areas:

The areas under consideration in the context of the MOONRISES project are:

- the island of lesvos in North Aegean;
- the island of Naxos in South Aegean;
- the prefecture of Kilkis in Central Macedonia;
- the prefecture of Argolida in the Peloponnese and
- the region of Basilicata

The five areas are to different extents threatened by desertification. It has to be mentioned that in the past various programmes relative to the study of desertification in the Mediterranean Basin did choose the same Greek and Italian areas. For instance, Argolida was one study area of the ARCHEOMEDES project. Similarly the three EU projects: MEDALUS, DESERTLINKS and MEDACTION selected the island of Lesvos and the Agri Basin in Basilicata as demonstration areas.

4 Desertification risk assessment

4.1 Indicators for desertification assessment

4.1.1 Sources and classification of desertification indicators

Sources of desertification indicators:

In 1994, the United Nations Convention to Combat Desertification (UNCCD)[2] was adopted, therefore providing guidelines to carry out national, sub-regional, and regional action programs. This increasing concern about desertification risks and its probable ecological and socio-economic effects led to the publication by international organizations (FAO[3], OSS[4], IDRC[5], ETCS[6]) of numerous reports, giving some hints about the desertification mechanisms and causes and describing various indicators that could be employed for monitoring purposes.

Moreover, the complexity of the desertification process, since it involves interactions between physical and socio-economic aspects, and the difficulty to supply unifying concepts for assessing it, explains the multiplicity of the research programmes that were dedicated to the study of the desertification processes.
A non exhaustive list of programmes dealing with desertification in the North Mediterranean countries is presented below:

a. ASMODE - Assessment of remote sensing techniques for monitoring the extent and progression of desertification in the Mediterranean area (1992 -1994)
ASMODE's objectives were to assess the potential of remote sensing techniques and GIS for the purpose of studying, monitoring, and possibly controlling the dynamics of desertification in the Mediterranean area and as well to close the "scale gap" between site experiments of energy and water exchange at the earth surface, and the desertification processes taking place at national to regional levels.

b. DeMon-1 & DeMon-2 - Satellite Based Desertification Monitoring in the Mediterranean Basin (1992-1999) **[7]**
The DeMon project, financially supported by the European Union, developed methods to monitor and to model Mediterranean land degradation processes. Remote Sensing techniques and GIS played a key role in these procedures. Computer simulation of degradation processes increased the understanding of the process, which is essential to take effective counter measures. The first phase, DeMon-1 (1992-1995), focused on the experimental development of monitoring and modeling methods. The second phase, DeMon-2 (1996-1999) aimed at refining the earlier developed methods. Study areas: Guadalantin (Spain), La Peyne catchment (France) and Asteroussia mountains (Crete).

c. DESERTLINKS - Combating desertification in Mediterranean Europe: linking science with stakeholders (2001-2004) **[8]**
DESERTLINKS aimed to support stakeholders at the local, sub-national and national level in combating desertification. It brought the results of past research on the physical and socio-economic aspects of desertification to bear on practical ways to combat it at various geographical scales from the local to the European. DESERTLINKS provided indicators to monitor desertification as well as syntheses of the understanding of the physical and socio-economic processes that cause it. It established the ways in which major current Mediterranean-wideband uses are affecting desertification. It showed how to mitigate its effects by taking different land management decisions at both the public policy and individual level and by adopting practical land management techniques.
Study areas: Alentejo Region (Portugal), Guadalentín Basin (Spain), Agri Basin (Italy) and Lesvos island (Greece)

d. DeSurvey: A Surveillance System for Assessing and Monitoring of desertification (2005-still ongoing) **[9]**
In spite of the relevance of diagnosis to help the success of desertification treatment, there is a lack of standardized procedures to perform it at operational scales. This project offers a contribution to fill this gap by complementing assessment of desertification status with early warning of risks and vulnerability evaluation of the involved land use systems. To this purpose the interactive effects of climatic and human drivers of desertification will be taken into account in a dynamic way. The project goal is to deliver a compact set of integrated procedures, with application and tutorial examples at the EU and national scales. The performance of DeSurvey in other areas outside Europe will be further tested against other expertise and available procedures

in Maghrebian and Sahelian countries as well as in central Chile and NW China. Study areas: Lagadas and Central Crete (Greece), La Mancha (Spain) and Alentejo (Portugal)

e. MEDALUS - Mediterranean Desertification and Land Use (1991-1999) **[10]**
The MEDALUS project has sought to improve understanding of a wide range of physical, environmental problems and to suggest and develop options for their amelioration. In its third phase MEDALUS III aimed at developing and applying a methodology for the use of desertification indicators to identify Environmentally Sensitive Areas (ESAs) at the local level. The work was carried out in target areas, all of which are sensitive to degradation; they were the Guadalentín-Segura Basin in Spain, the Agri Basin in Italy, the inner-lower Alentejo region in Portugal and the island of Lesvos in Greece. The project also explored opportunities to address the problems of desertification at a Mediterranean-wide large scale.

f. MEDIMONT & MEDIMONT-PECO – A multinational, multidisciplinary research program on the role and the place of the mountains in the desertification of the Mediterranean mountain regions (1992-1995)
The objective of MEDIMONT was to better understand the desertification process of Mediterranean mountains under various natural and human conditions, and to deliver recommendations for an appropriate management of these environments. Investigations were planned at the local-scale, in five selected pilot-zones in Andalucia, Corsica, Basilicata, Calabria and Crete, and at the regional-scale level, to extrapolate and give an overview of local results. The objective of MEDIMONT-PECO was to complete and enrich the regional dimension of MEDIMONT, by including new pilot-zones in Bulgaria, Albania and Slovenia.

Classification of desertification indicators:

As a result numerous desertification indicators can be found in the literature and due to their heterogeneity it is important to classify them according to a criterion that could be one of the following[11]:

- disciplinary fields of competence and environmental components (socio-economic, biophysical)
- objectives (prevention, monitoring, mitigation)
- logical framework (DPSIR, DI, PSR,…)
- spatial scales (local, regional, national)
- acquisition and/or measurement techniques (remote sensing, field surveys,…)

4.1.2 The Environmentally Sensitive Areas Index (ESAI)

The MOONRISES methodology for desertification assessment is inspired from the multi-factor approach developed during the 3-phase research programme MEDALUS. The latter programme represents the most advanced level of research on the topic. It defined the ESA Index for the identification of the Environmentally Sensitive Areas. This index combines a set of indices that reflect the quality of the soil, the vegetation, the climate and the management practices. Therefore, four quality indices were introduces:

- Climate Quality Index (CQI)
- Soil Quality Index (SQI)
- Vegetation Quality Index (VQI)
- Management Quality Index (MQI)

Each quality index is generated from a set of indicators as shown in Table 2. In this case, the classification criterion adopted is the disciplinary field.

Table 2 - Structure of the ESAI

	Climate quality	Soil quality	Vegetation quality	Management quality
Indicators	Rainfall Aridity Aspect	Texture Parent Material Rock fragment Depth Slope Drainage	Fire risk Erosion protection Drought resistance Vegetation cover	Land use intensity Policy enforcement

The MOONRISES approach consists in adopting the ESA Index as being one effective index for the identification of land sensitivity and vulnerability that was lately widely used for the implementation of National Action Programmes (NAPs) in north European countries. The ESAI will be nevertheless adapted to the specificities of the study area and to the data availability. For instance, if data relative to an indicator can not be collected, an alternative method/formula will be proposed to get an estimation of the desired factor. Moreover, a multi-criteria analysis will be performed to give weights to the indicators and to the quality indices in order to prioritize one factor on another. These modifications brought to the ESAI are described in Section 4.2.

4.2 Description of an easy-to-implement desertification risk assessment model

In the present section, the whole methodology proposed for transforming the collected data into intermediate thematic layers and providing a final risk desertification layer is described in details.

4.2.1 Climate layers

Mediterranean areas are characterized by a high climate variability. For the rainfall, the inter-annual and seasonal variations are important while for the temperature this phenomenon is more moderate. Moreover, it is widely admitted that climate variables are related to topography factors. The climate quality layer will therefore be created by combining three layers: the rainfall, the aridity and the aspect [10].

a) The rainfall layer

The rainfall data are provided by a network of national meteorological stations. Unfortunately, this network is not very extended in Greece and this constitutes one of the major problems encountered while trying to collect data. Once the discrete precipitation data obtained from a few stations, a prediction step is required to cover the whole prefecture. In previous studies, numerous variables were used to estimate the precipitation and temperature distributions [12]. Considering the characteristics of the study areas (area extent, location, topography), performing a linear regression based on the elevation factor seemed to be the most appropriate approach in order to produce a raster layer with the precipitation values for the whole area. Having the precipitation distribution in a raster format, three classes are created then according to the rain water amount. To each class, an index is assigned and a new raster layer is generated with three unique values reflecting the annual rainfall.

Table 3 - Classes of rainfall

Rainfall (mm)	Index
>650 mm	1
280-650 mm	1.5
<280 mm	2

b) The aridity layer

The aridity variable evaluates the degree of dryness in an area. Several indices such as the Bagnouls-Gaussen Index (BGI), the Index of Emberger, the index of de Martonne (1923) or the classification of Thornwaite (1931) allow the estimation of the aridity by using exclusively basic meteorological data. Later in 1997, the UNEP proposed an index based on the evapotranspiration which is another important factor of the hydrologic budget. The index is expressed by the ratio between the annual precipitation and the annual reference evapotranspiration (ET_0).

While in MEDALUS the BGI bioclimatic index was used for the mapping of the aridity, in the present study data was missing for the estimation of one term in the formula. The UNEP index also proved to be a good estimator of the aridity, but the estimation of ET_0 is rather complex. Therefore, the equation of de Martonne was used instead. The aridity index of de Martonne, is based on easily retrievable data and is calculated using the following formula:

$$I_M = \frac{P}{T + 10} \qquad \text{(Eq. 1)}$$

where, P is the annual average rainfall in mm and T is the annual average temperature in °C.
Based on the range of the aridity index, seven climatic classes are then identified and to each class an index between 1 and 2 was assigned (see Table 4).

Table 4 - Classes of aridity

Aridity index	Climate type	Index
0 - 10	Arid	2
10 - 20	Semi-arid	1.8
20 - 24	Mediterranean	1.6
24 - 28	Semi-Humid	1.4
28 - 35	Humid	1.2
35 - 55	Very Humid	1.1
>55	Extremely Humid	1

Elaboration of the temperature distribution layer

In order to obtain a raster of temperature values, the same approach as the one used for retrieving the raster of rainfall values is applied (a linear regression as a function of the elevation). The temperature values (T) are then adjusted according to the slope and the aspect following the methodology described in [13]. The proposed correction represents the variation of the insulation depending on the orientation and the inclination of the terrain. The slope and aspect layers are derived from the DEM and reclassified in, respectively, eight and five classes. A correction factor k is then defined for each combination of slope and aspect classes (see Table 5).

Table 5 – Correction factors "k" according to the classes of slope and aspect

Classes of Aspect ↓	**Classes of Slope ↓**							
	0°- 5°	5°- 10°	10°- 15°	15°- 20°	20°- 25°	25°- 30°	30°- 40°	> 40°
S	1.05	1.11	1.17	1.22	1.26	1.31	1.34	1.37
SE, SW	1.04	1.10	1.16	1.20	1.24	1.26	1.28	1.30
E, W	1.02	1.06	1.09	1.11	1.12	1.12	1.10	1.07
NE, NW	1.00	1.02	1.01	1.00	0.99	0.97	0.92	0.84
N	0.99	1.00	0.98	0.96	0.93	0.87	0.81	0.75

The corrected temperature values (Tc) can then be obtained from T by applying the following formula:

$$T_c = T + (4.4 + T \times 0.133) \times (k - 1) \qquad \text{(Eq. 2)}$$

, where k is the correction factor defined in Table 5.

c) The aspect layer

The aspect factor is also required for the creation of the Climate Quality Index (CQI). In fact, the solar warm distribution varies with the aspect variable and therefore affects the water availability in the area. Two major classes were identified: one corresponding to the South, South-West and South-East orientations and a second class including the remaining orientations. The indices that are assigned to the classes of aspect are shown in Table 6.

Table 6 - Classes of aspect

Slope aspect classes	**Index**
Flat, E, NE, N, NW, W	1
SE, S, SW	2

4.2.2 Soil layers

The Soil Quality Index (SQI) combines six parameters: the soil depth, the slope, the soil texture, the parent material, the rock fragment and the drainage. Since data relative to the rock fragment cover percentage are not available for the 4 study areas in Greece, only five soil layers were computed.

a) The soil depth layer

The data collected regarding the soil depth parameter was a layer in vector format. The layer presented nine classes of soil depths. The number of classes needs then to be restricted to four classes: deep, moderate, shallow and very shallow soils. The reclassified layer is used to create the soil depth layer, where a depth index is assigned to each pixel according to the depth class it belongs to.

Table 7 - Classes of soil depth

Soil depth classes	Index
Deep	1
Moderate	1.3
Shallow	1.6
Very shallow	2

b) The slope layer

The slope is a relevant factor of desertification since steep sloped terrains usually are characterized by an important runoff activity. The Digital Elevation Model (DEM) is used to generate a raster map with the slope percentages. The layer is then classified into four categories and the appropriate index is assigned to each category.

Table 8 - Classes of slope

Slope (%)	Class of slope	Index
<6	Very gentle to flat	1
6-18	Gentle	1.3
18-35	Steep	1.6
>35	Very steep	2

c) The soil texture layer

Soil texture is used as indicator of the water retention capacity of the soil. A sandy soil is for example less capable of retaining water than a clay textured-soil and is therefore more prone to drought. The data about soil texture not being available, the necessary data were extracted from the soil thematic map. For this purpose, each category of the initial map is assigned a class of texture (see Table 10). Once this step performed, the soil texture layer is generated by the assignment of the appropriate index to each class.

Table 9 - Classes of texture

Class of texture	Index
Good	1
Moderate	1.2
Poor	1.6
Very poor	2

d) The parent material layer

A layer in vector format with different categories of main parent material was available for the various target areas. A procedure similar to the one described above helped assigning the appropriate class of soil parent material quality to each category of parent material (see Table 10) A classification step is then required (see Table 10) for the creation of the parent material layer as required in [10].

Table 10 - Remap table of the soil map

Main parent material description	Soil quality		
	Parent Material class	Texture class	Soil Drainage class
Alluvium	Good	Good	Well drained
River beds	Good	Good	Imperfectly drained
Hard limestones	Moderate	Poor	Poorly drained
Mixed flysch	Moderate	Moderate	Imperfectly drained
Granite	Moderate	Good	Well drained
Peridotites	Moderate	Good	Poorly drained
Deposition cones	Poor	Good	Imperfectly drained
Tertiary deposits	Poor	Good	Well drained
Gneiss colluvium	Moderate	Good	Imperfectly drained
Schists	Good	Good	Imperfectly drained
Gneiss	Moderate	Good	Well drained

Table 11 - Classes of parent material

Class of parent material	Index
Good	1
Moderate	1.7
Poor	2

e) The drainage layer

The drainage term refers to how long does the water remain in the soil. For well drained soils, water is removed from the soil rapidly. Therefore, the soil is not wet enough near the soil surface. For imperfectly drained soils, water is removed from the soil slowly and the soil remains wet during the early growing period of the plants. In the case of poorly drained soils, water is removed from the soil so slowly that the soils are wet at shallow depth for long periods.
The layer is created using Table 10. Then the adequate index is assigned to each category of drainage according to Table 12.

Table 12 - Classes of drainage

Class of drainage	Index
Well drained	1
Imperfectly drained	1.2
Poorly drained	2

4.2.3 Vegetation layers

The vegetation plays an important role in the desertification process by affecting the run-off, the evapotranspiration, the soil composition, etc. The vegetation quality index is based on four layers:

the fire risk layer, the plant cover layer, the erosion protection layer and the drought resistance layer. Having no such data directly available, the field expertise was essential for the interpretation of the CORINE map and the extraction of the necessary data (see Table 14).

a) The erosion protection layer

Using the erosion risk map, available in each of the study areas, the nine existing classes are reduced to four classes considering the dominant erosion risk category. Once this task performed, the attribution of the appropriate indices is straightforward.

Table 13 - Indices assigned to the classes of erosion protection

Erosion protection classes	Index
Very high	1
High	1.3
Moderate	1.6
Low	1.8
Very low	2

b) The other vegetation layers

The three vegetation layers (plant cover, drought resistance and fire risk) are, as previously mentioned, extracted from the CORINE map, according to the remap table between the CORINE nomenclature and the three vegetation descriptors (see Table 14). The indices are then attributed to each class of plant cover, drought resistance and fire risk using Table 15, Table 16 and Table 17.

Table 14 - Interpretation of the CORINE nomenclature

CORINE code	Category description	Vegetation quality		
		Plant cover	Drought resistance	Fire risk
112	Discont. urban fabric	Very Low	Very Low	Low
121	Ind./comm. units	Very Low	Very Low	Low
131	mineral extraction sites	Very Low	Very Low	Low
211	non-irrigated arable land	Low	Moderate	Low
212	permanently irrigated land	Low	Low	Low
221	vineyards	Low	Moderate	Low
222	fruit trees/berry plantations	Moderate	Moderate	Low
242	complex cultivation	Low	Moderate	Low
243	land princ. agr. with nat. veg.	Moderate	Moderate	Low
311	broad-leaved forest	High	Very High	Moderate
312	coniferous forest	High	High	Very high
313	mixed forest	High	Very High	Moderate
321	natural grassland	Moderate	Low	Moderate
322	moors and heathland	Low	Moderate	Moderate
323	sclerophyllous vegetation	Moderate	High	High
324	transitional woodland shrub	High	Moderate	Moderate

331	beaches/dunes/sand plains	Very Low	Very Low	Low
332	bare rock	Very Low	Very Low	Low
333	sparsely vegetated areas	Low	Moderate	Low
411	inland marshes	High	High	Low
421	salt marshes	High	High	Low
511	water courses	Moderate	High	Low
512	water bodies	Moderate	High	Low

Table 15 - Classes of plant cover

Plant cover classes	Index
High	1
Moderate	1.6
Low Very	1.8
Low	2

Table 16 - Classes of drought resistance

Drought resistance classes	Index
Very high	1
High	1.2
Moderate	1.4
Low	1.7
Very low	2

Table 17 - Classes of fire risk

Fire risk classes	Index
Low	1
Moderate	1.3
High	1.6
Very high	2

4.2.4 Management layers

Social, economic and policy factors play an important role in accelerating or slowing down the desertification phenomenon in a particular area. The Mediterranean Basin, for instance, is severely affected by human induced landscape degradations.

Trying to take those parameters into consideration, the management quality layer is produced by assigning an index depending on the land use: crop land, pasture land, natural area, mining area or recreation area. Therefore, to each category of the CORINE nomenclature an index of management quality (high, moderate and low) is assigned, assuming that the management conditions within the same prefecture are similar for parcels having the same land use (see Table 19). According to the land use, a specific assessment criterion is used. The list of criteria is presented in Table 18.

Table 18 - Management Assessment criteria

Land use	Assessment criterion
Cropland	Land Use Intensity (LUI)
Pasture	Stocking rate
Natural area	General Management characteristics
Mining area	Erosions control measurements
Recreation area	Visitors ratio

Table 19 - Indices assigned to the Management Quality Index classes

MQI class	Index
High quality	1
Moderate quality	1.5
Low quality	2

4.2.5 Multi-criteria analysis

To compute the quality indices and the final ESA Index, the approach adopted by MEDALUS[10] is to assign equal weights to the layers/factors, ensuring this way the easy and straightforward application of the methodology to any region, provided that the necessary layers are all made available.

In the methodology proposed for MOONRISES, it is admitted that climate, soil, vegetation and management do not have the same effect on the desertification process and the contribution of each layer is either emphasized or diminished by the selection of adequate weights.
The advantage of this approach is that the weights can be tuned according to the area studied, therefore favouring one indicator rather than another depending on the characteristics of the region.

The drawback of the approach is that this assignment requires a prior knowledge of the physiological, meteorological and management characteristics of the region. The help of an expert is therefore needed to determine the appropriate weights for each layer.
The problem that has to be solved is how to decide about the desertification risk existing in a specific area taking into account various parameters (physical and socio-economic) that do not have the same priority. The Analytic Hierarchy Process (AHP) proposed by Saaty is widely used to perform such a multi-criteria analysis [14][15]. The approach consists in assigning priorities to conflicting criteria, by using pair-wise comparisons based on forming judgments between two particular variables rather than attempting to prioritize an entire list of elements [16].

In order to perform the multi-criteria analysis a Multi-Criteria Decision Support System (MCDSS) has been developed. The application takes as input a set of rasters and provides a Graphical User Interface (GUI) in order to fill in the pair comparison matrices with the preference value between each two rasters. The Analytic Hierarchy Process is then performed and a new raster is generated according to the preference/pair comparison matrix.

The pair comparison matrices used to combine the layers corresponding to the study areas in Greece are presented in Table 20, Table 21 and Table 22.

Table 20 - Pair comparison matrix for the climate layers

Climate quality	Rainfall	Aridity	Aspect
Rainfall	1	1/3	3
Aridity	3	1	5
Aspect	1/3	1/5	1

Table 21 - Pair comparison matrix for the soil layers

Soil quality	Soil texture	Parent material	Drainage	Depth	Slope
Soil texture	1	3	1	1/3	1/3
Parent material	1/3	1	1/5	1/5	1/3
Drainage	1	5	1	1/3	1/3
Depth	3	5	3	1	1
Slope	3	3	3	1	1

Table 22 - Pair comparison matrix for the vegetation layers

Vegetation quality	Fire risk	Drought resistance	Vegetation cover	Erosion protection
Fire risk	1	1/5	1/3	1
Drought resistance	5	1	3	3
Vegetation cover	3	1/3	1	3
Erosion protection	1	1/3	1/3	1

Once the quality layers are obtained they are reclassified into three quality classeses using Table 23, Table 24 and Table 25. The classified layers are then combined using the pair comparison matrix presented in Table 26.

Table 23 - Classification of the Climate Quality layer

CQI class	Index
High quality	1
Moderate quality	1.3
Low quality	1.6

Table 24 - Classification of the Soil Quality layer

SQI class	Index
High quality	<1.13
Moderate quality	1.13 – 1.46
Low quality	>1.46

Table 25 - Classification of the Vegetation Quality layer

VQI class	Index
High quality Moderate quality Low quality	1 - 1.14 1.14 - 1.4 1.4 - 2

Table 26 - Pair comparison matrix for the adapted quality index layers

Desertification risk index	Climate quality	Vegetation quality	Soil quality	Management quality
Climate quality	1	5	3	5
Vegetation quality	1/5	1	1/3	3
Soil quality	1/3	3	1	3
Management quality	1/5	1/3	1/3	1

Once the desertification risk map is obtained it is reclassified into eight classes of risk as shown in Table 27.

Table 27 - Classification of the desertification risk layer

Risk class	Index
Critical 3	>1.53
Critical 2	1.43 – 1.53
Critical 1	1.38 – 1.42
Fragile 3	1.33 – 1.38
Fragile2	1.27 – 1.33
Fragile 1	1.23 – 1.27
Potential	1.17 – 1.23
Non affected	<1.17

4.3 Application of the desertification risk assessment model in the target areas

4.3.1 Application of the model in the region of Kilkis

The annual precipitation and temperature are the two meteorological variables needed for the calculation of the Climate Quality Index. In the prefecture of Kilkis, data can be collected from two meteorological stations located in Kastaneri and Kipos (see Figure 2 and Table 28).

Table 28 - Meteorological data for the Kilkis area

Variables	Kastaneri	Kipos
Elevation (m)	1140	562
Mean annual rainfall (mm)	893	587
Mean monthly air temperature (°C)	9,48	13,6

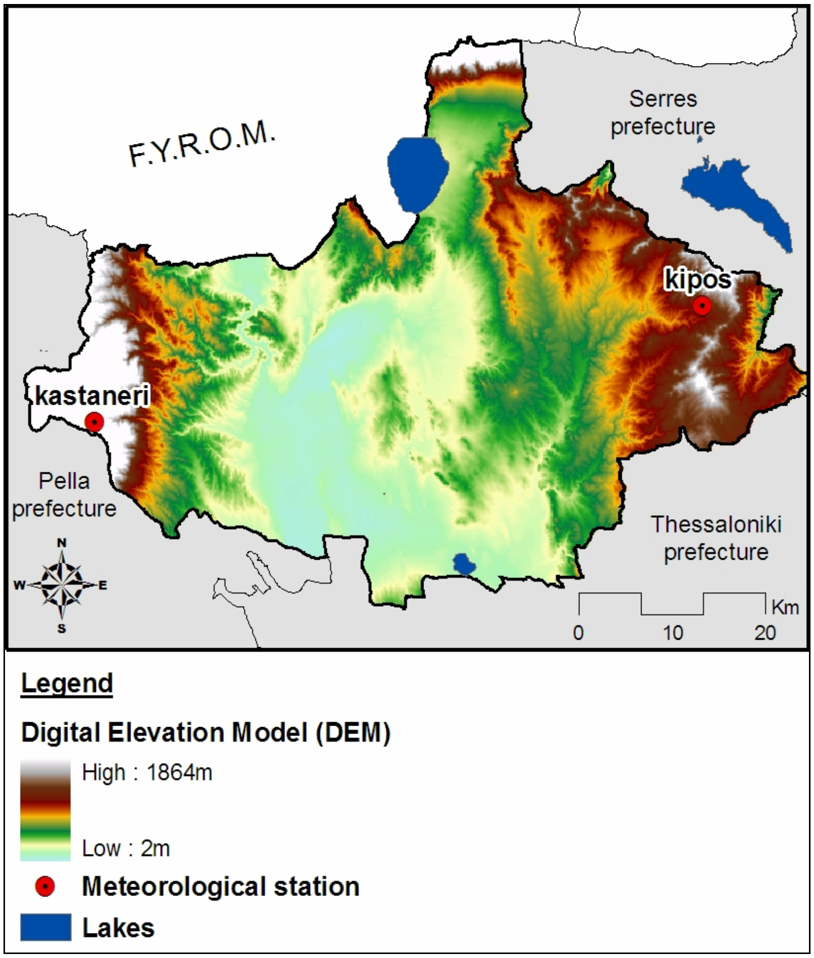

Figure 2 - Location of the meteorological stations in the prefecture of Kilkis

The regression analysis of the meteorological variables along with the elevation (see Figure 3 and Figure 4) allowed the generation of two new raster layers of rainfall and temperature distributions. Then the produced temperature distribution has been modified according to the approach described in Section 4.2.1 in order to take into account the effect of the aspect and the slope parameters (see Figure 5 and Figure 6).

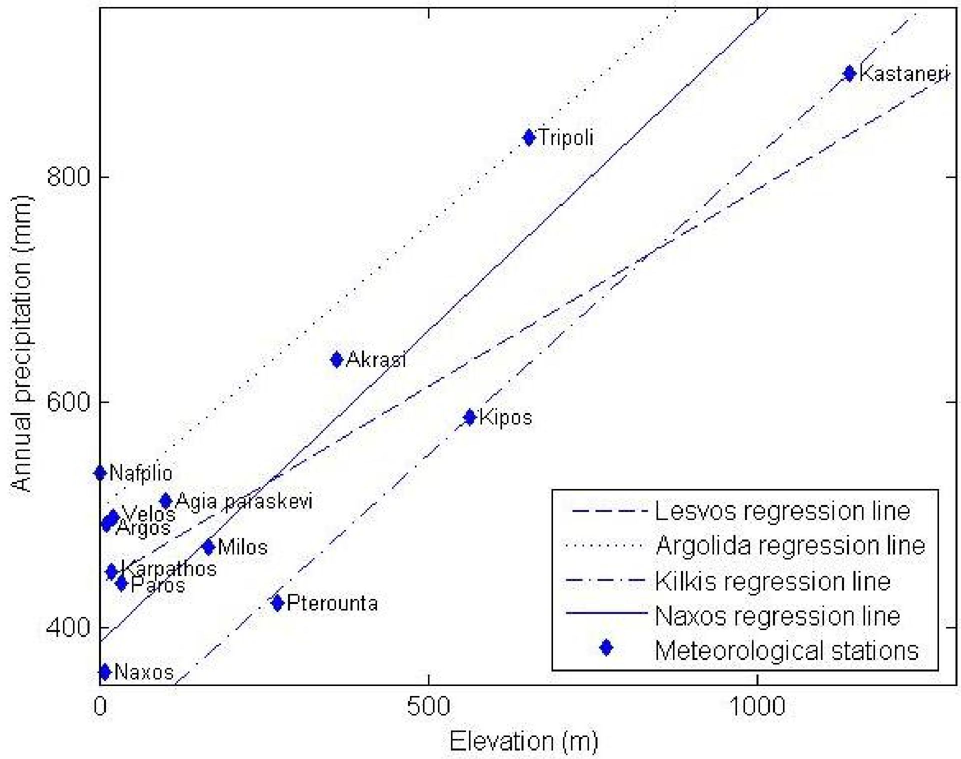

Figure 3 – Regression analysis of the precipitation data collected in the four target areas in Greece

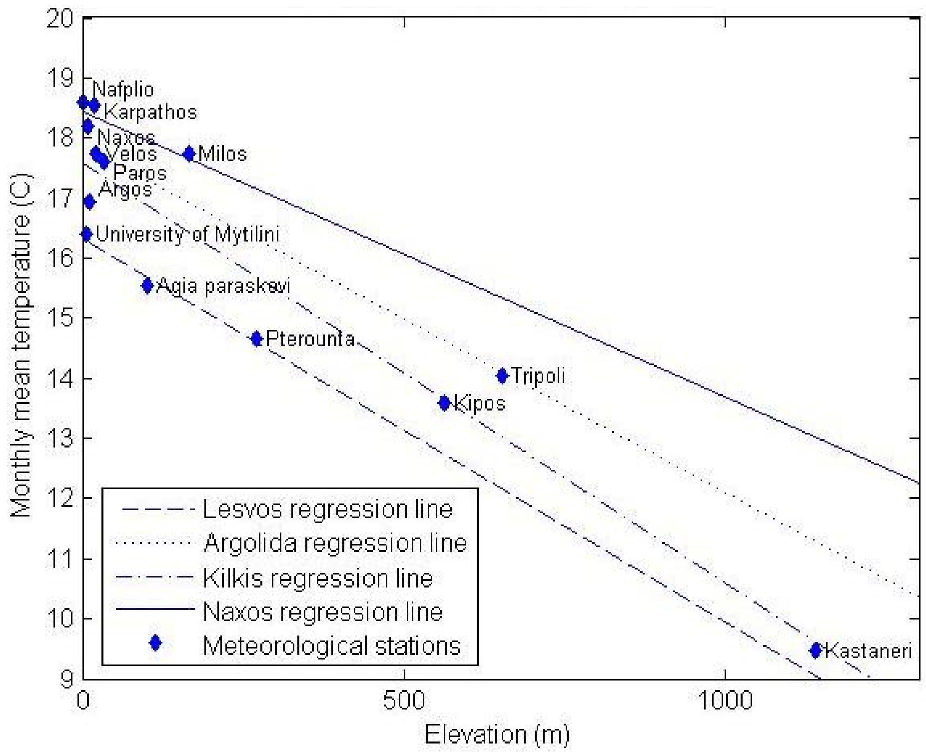

Figure 4 – Regression analysis of the temperature data collected in the four target areas in Greece

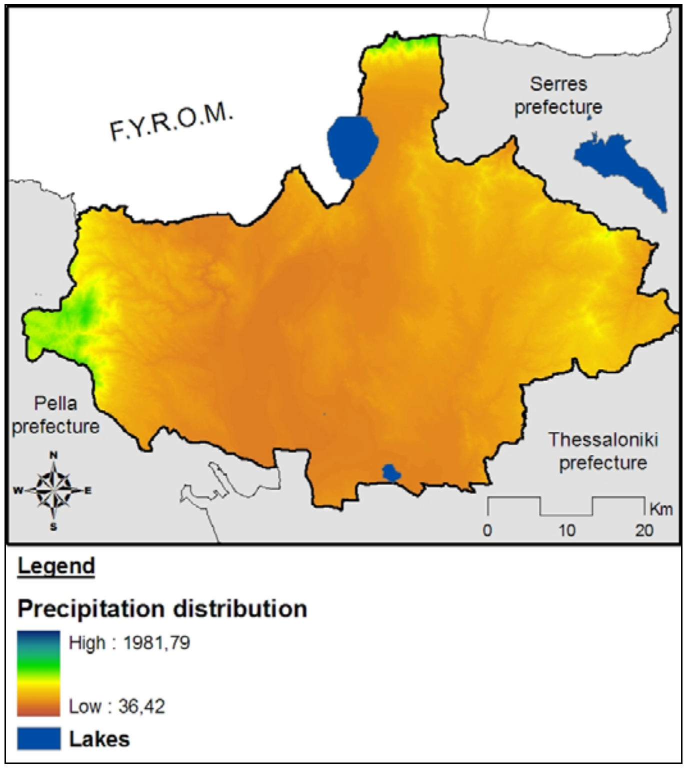

Figure 5 – Rainfall distribution in the prefecture of Kilkis

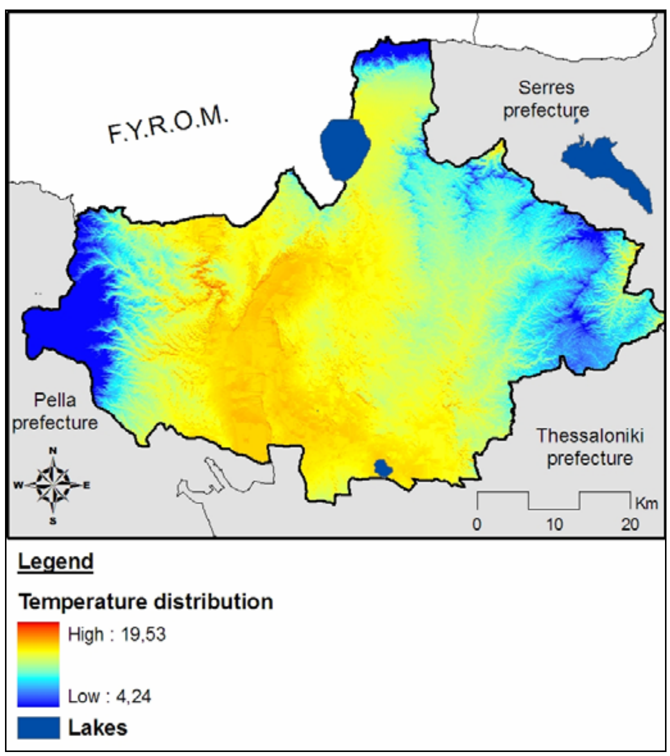

Figure 6 – Temperature distribution in the prefecture of Kilkis

Once the latter layers are produced, the climate quality layers can be easily computed (see Plate 1).
Using the various thematic map relative to the prefecture of Kilkis that have been collected (CORINE map, erosion map, parent material map and depth map), the soil and vegetation layers are produced following the approach described in Section 4.2 (see Plate 2 and Plate 3). From these layers are derived the four quality layers of Plate 4. The final desertification sensitivity map for the area of Kilkis is presented in Figure 7.

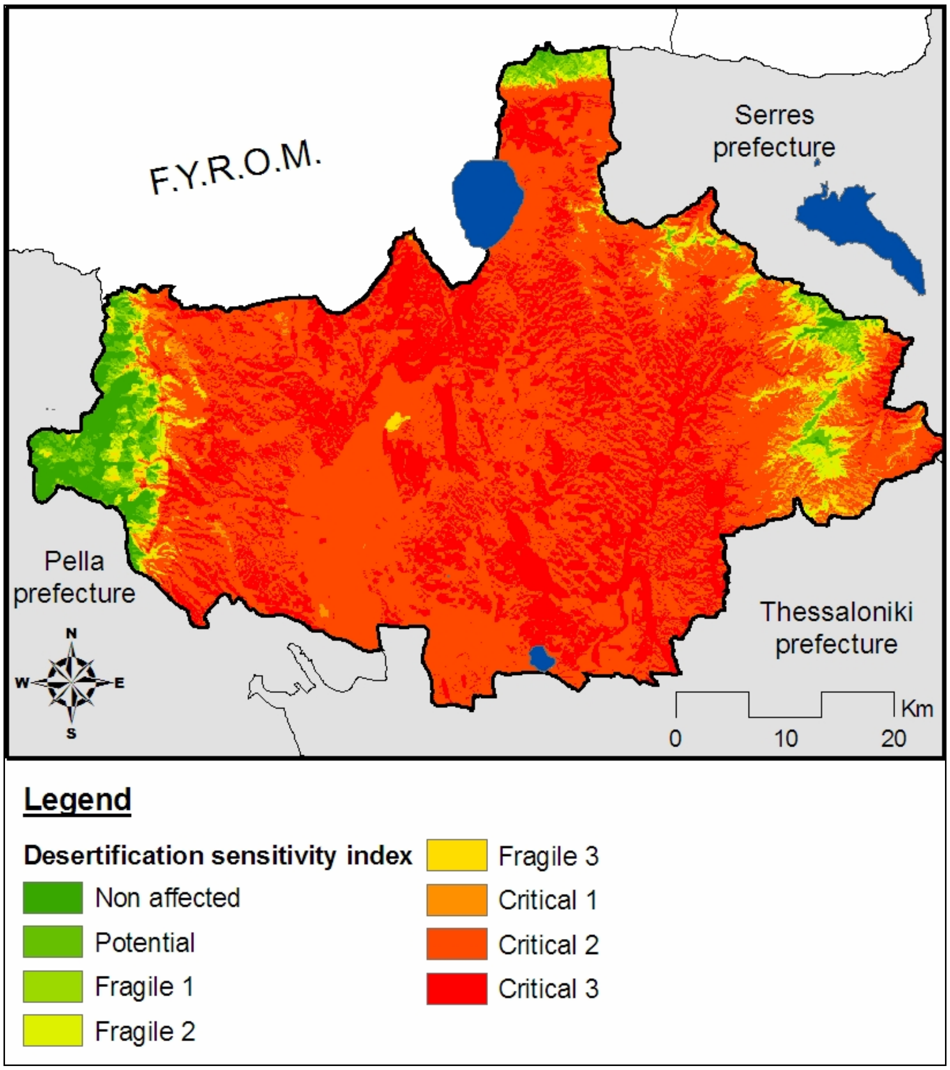

Figure 7 – Final Desertification sensitivity map for the prefecture of Kilkis

From the final desertification sensitivity map, some statistics can be computed in order to put into evidence the distribution of the various desertification sensitivity categories throughout the prefecture of Kilkis (see Table 29).

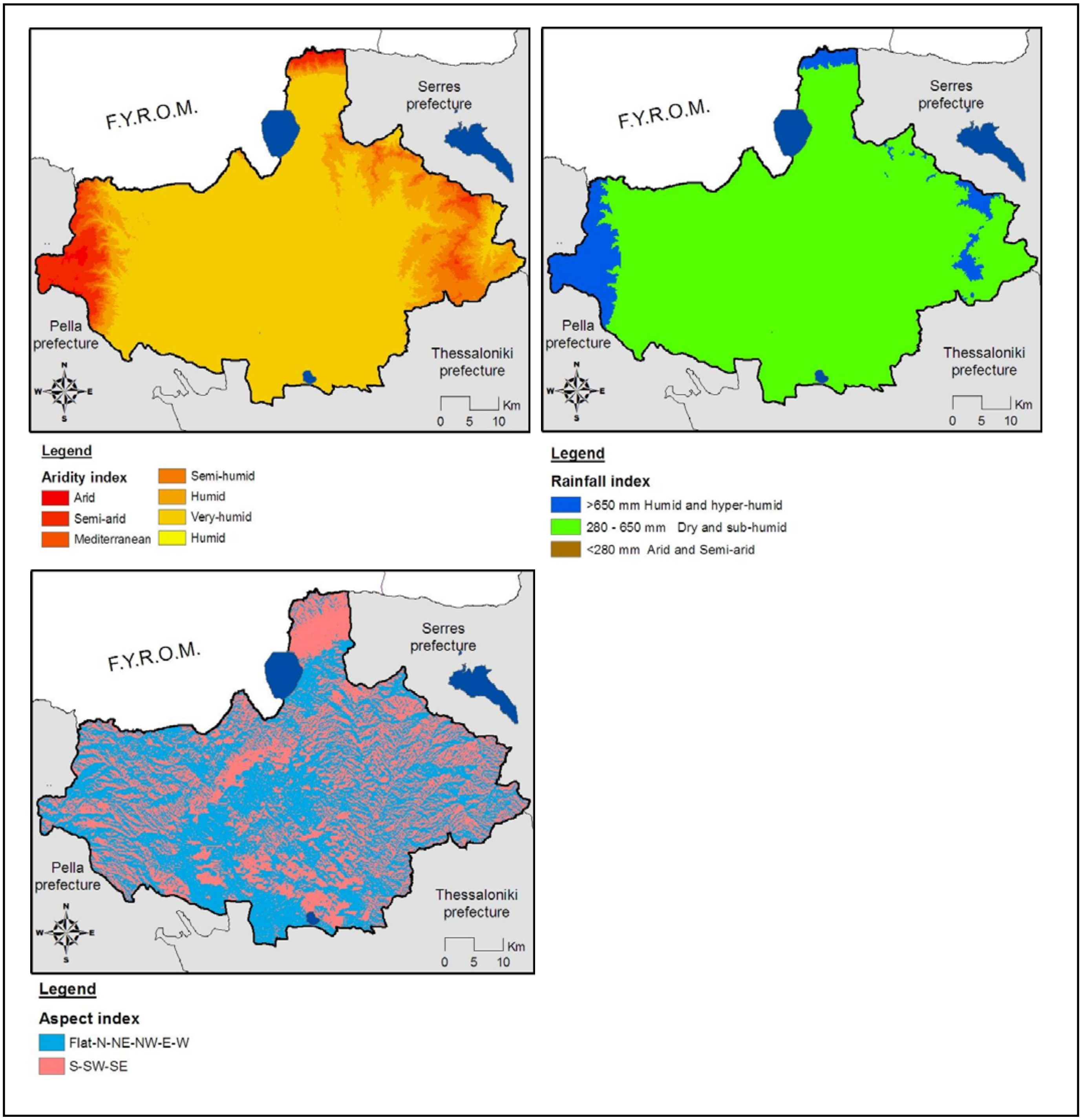

Plate 1 – Climate layers for the prefecture of Kilkis

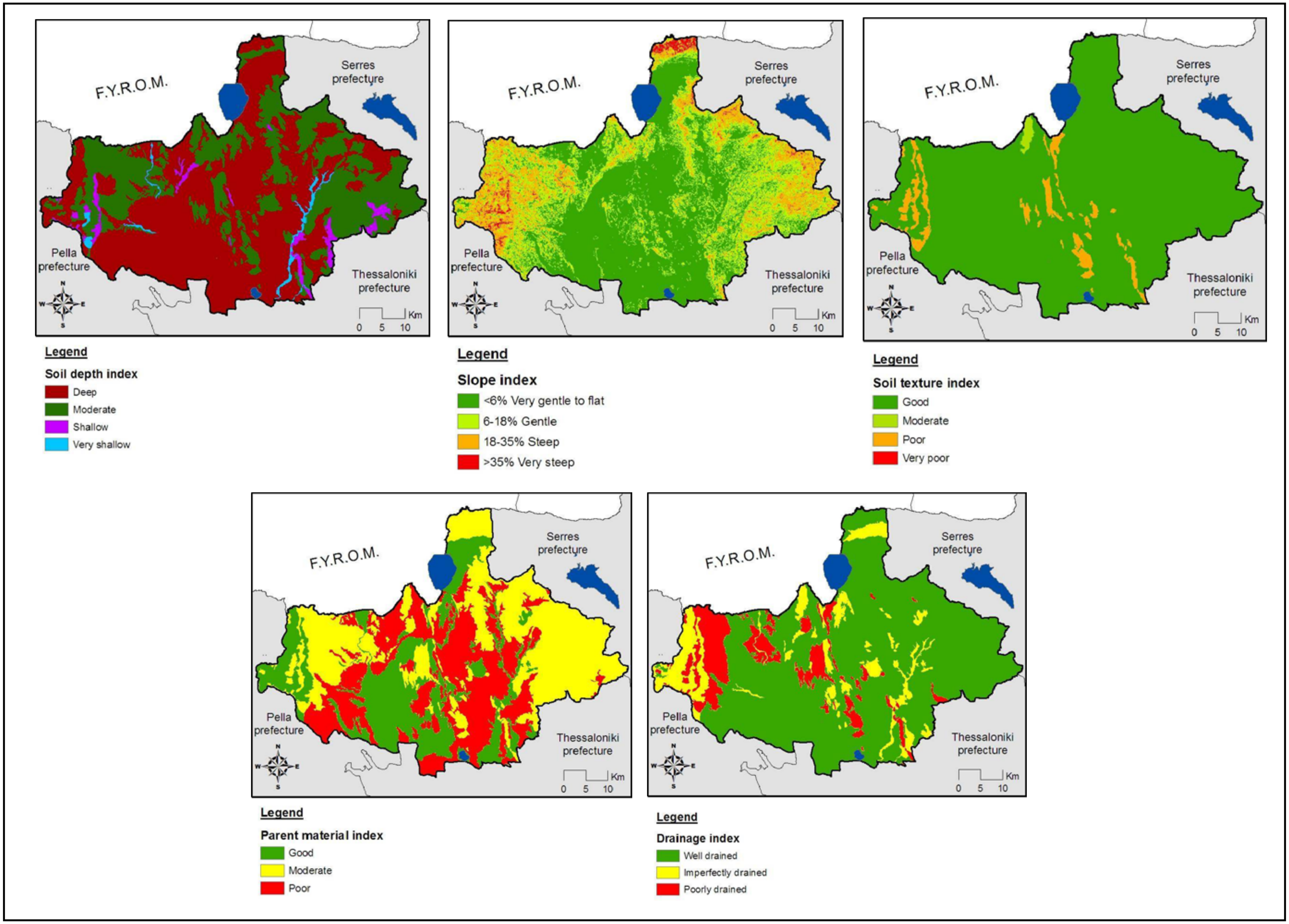

Plate 2 – Soil layers for the prefecture of Kilkis

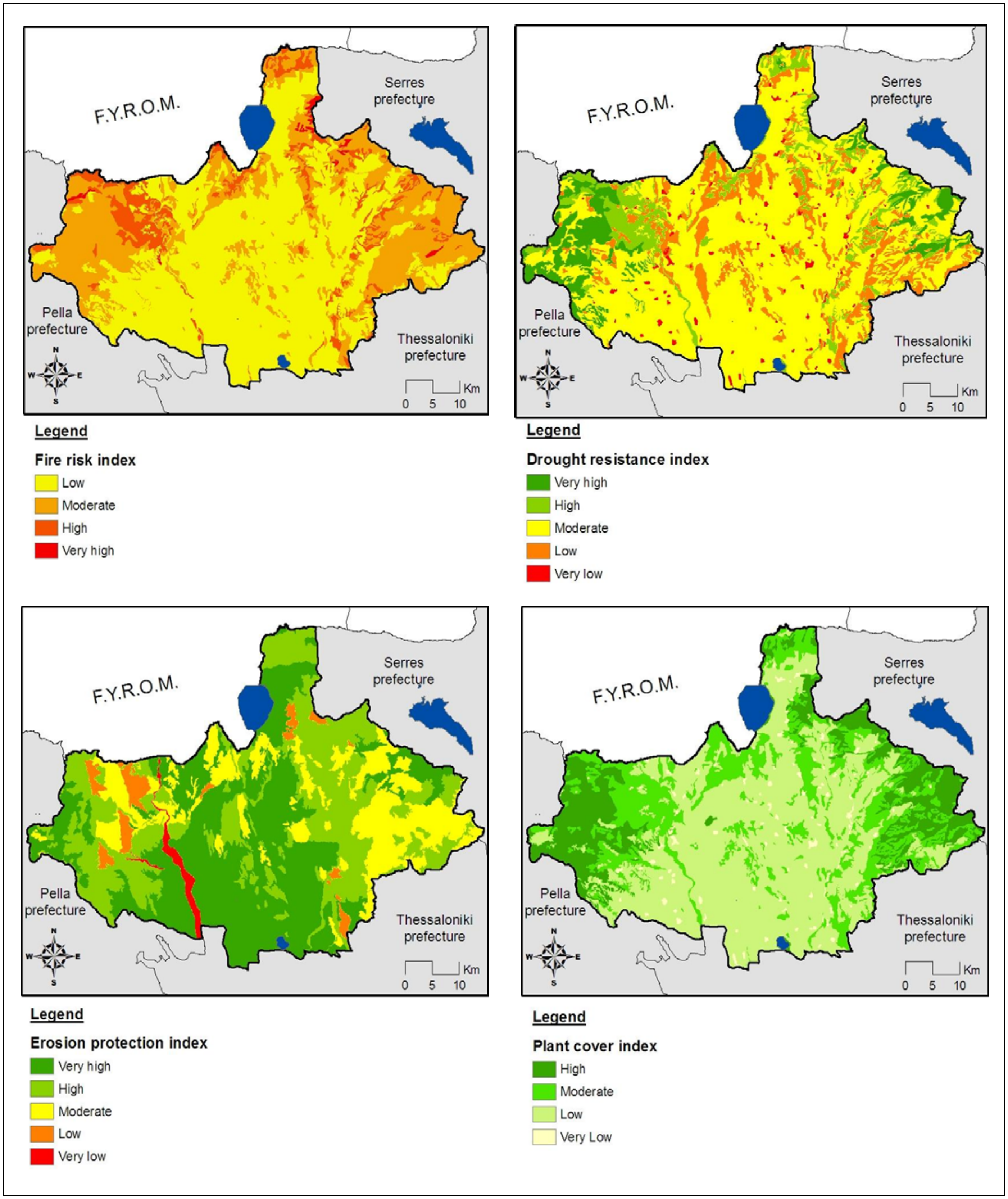

Plate 3 - Vegetation layers for the prefecture of Kilkis

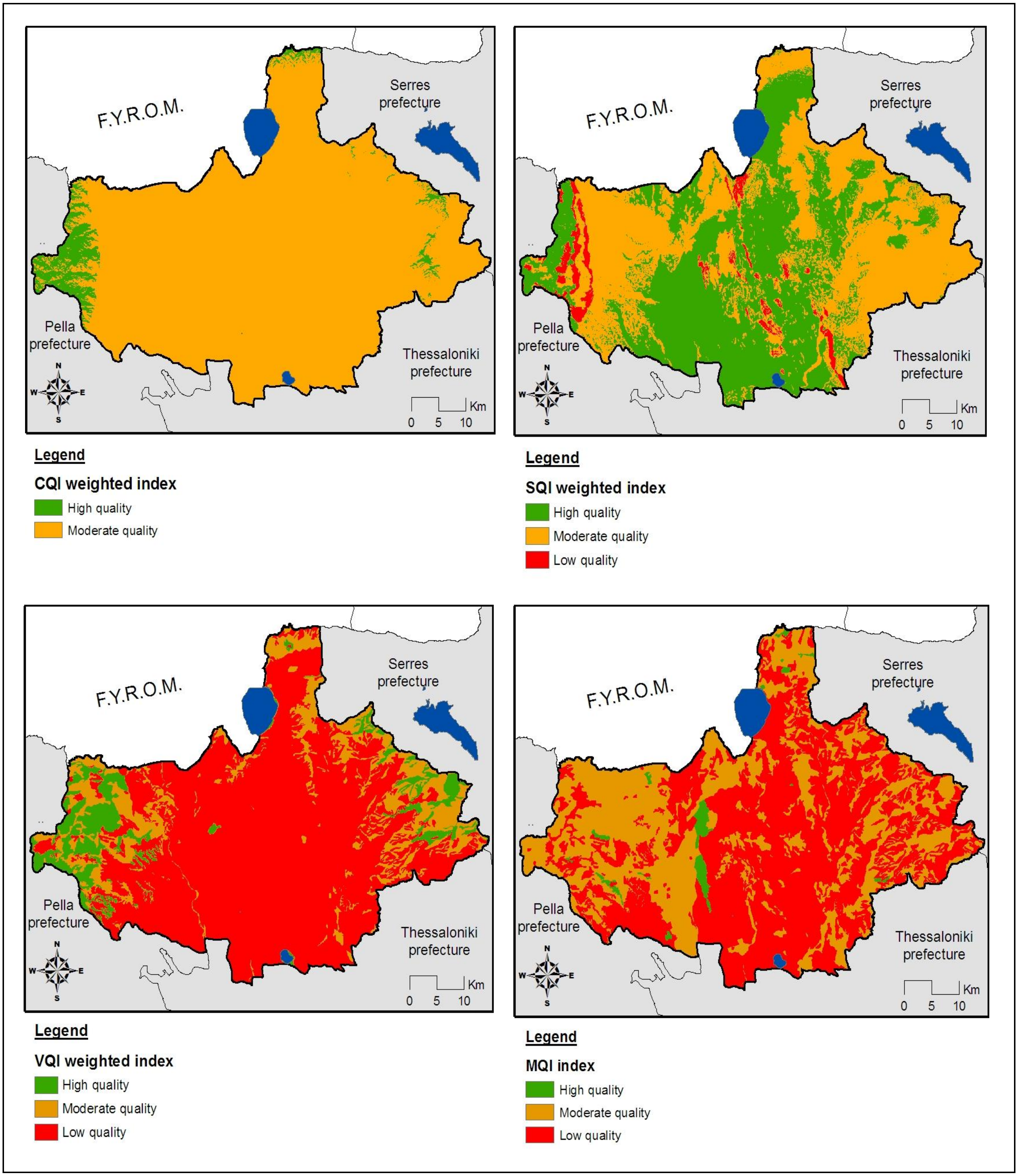

Plate 4 – Quality layers for the prefecture of Kilkis

Table 29 - Distribution of the desertification sensitivity classes in the prefecture of Kilkis

Sensitivity to desertification classes	**Area percentage**
Non affected	2,994 %
Potential	2,202 %
Fragile 1	1,589 %
Fragile2	2,213 %
Fragile 3	2,467 %
Critical 1	3,855 %
Critical 2	54,764 %
Critical 3	29,916 %

4.3.2 Application of the model in the prefecture of Argolida

Meteorological data have been collected from four stations in the Peloponese that are located around the prefecture of Argolida (see Figure 8 and Table 30). Two linear regression operations were performed in order to transform the collected data into a precipitation and temperature distributions. The regression lines were characterised by an R-square value of respectively 0,98 and 0,89.

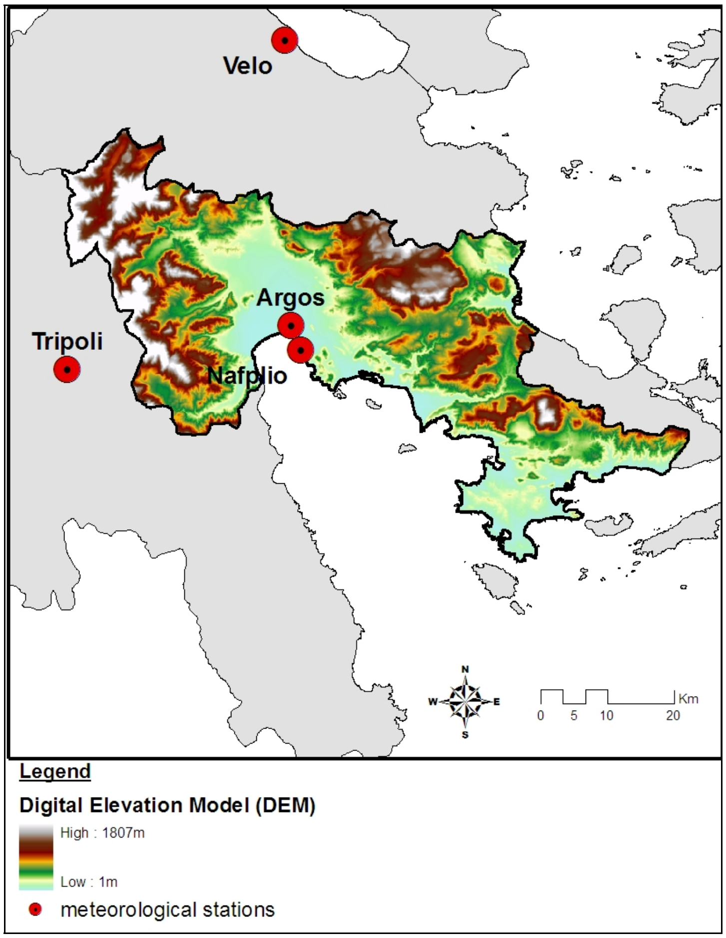

Figure 8 - Location of the meteorological stations in and around the prefecture of Argolida

Table 30 – Collected meteorological data for the prefecture of Argolida

Variables	Nafplio	Velos	Argos	Tripoli
Elevation (m)	2	20	11	651.9
Mean Annual Rainfall (mm)	537.7	498.87	492.06	835.76.8
Average Temperature (°C)	18.6	17.75	16.94	14.05

The precipitation and temperature distribution provided by the regression analysis are presented in Figure 9 and Figure 10.

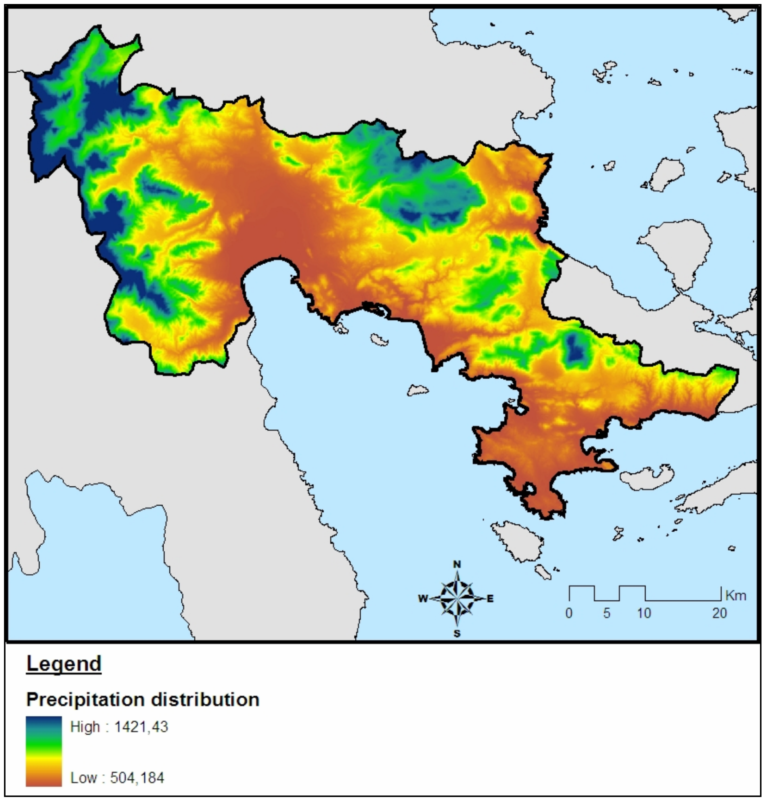

Figure 9 – Precipitation distribution in the prefecture of Argolida

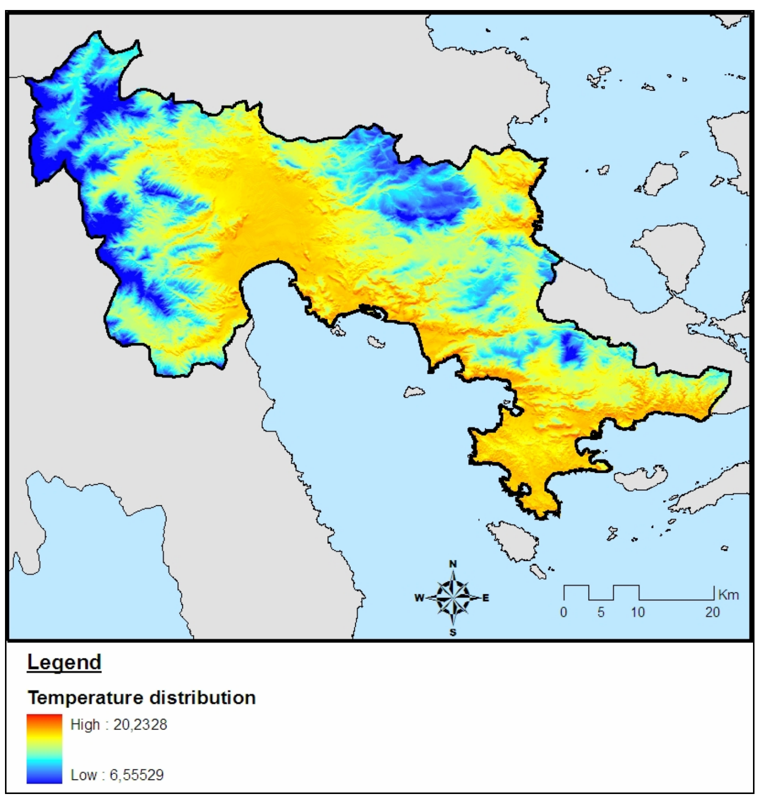

Figure 10 – Temperature distribution in the prefecture of Argolida

The climate, soil, vegetation and management layers have then been produced based on the various collected data for the prefecture of Argolida. The results are respectively presented in Plate 5, Plate 6 and Plate 7. The quality layers are then produced (see Plate 8) and the final desertification sensitivity map is derived from the previous layers (see Figure 11).

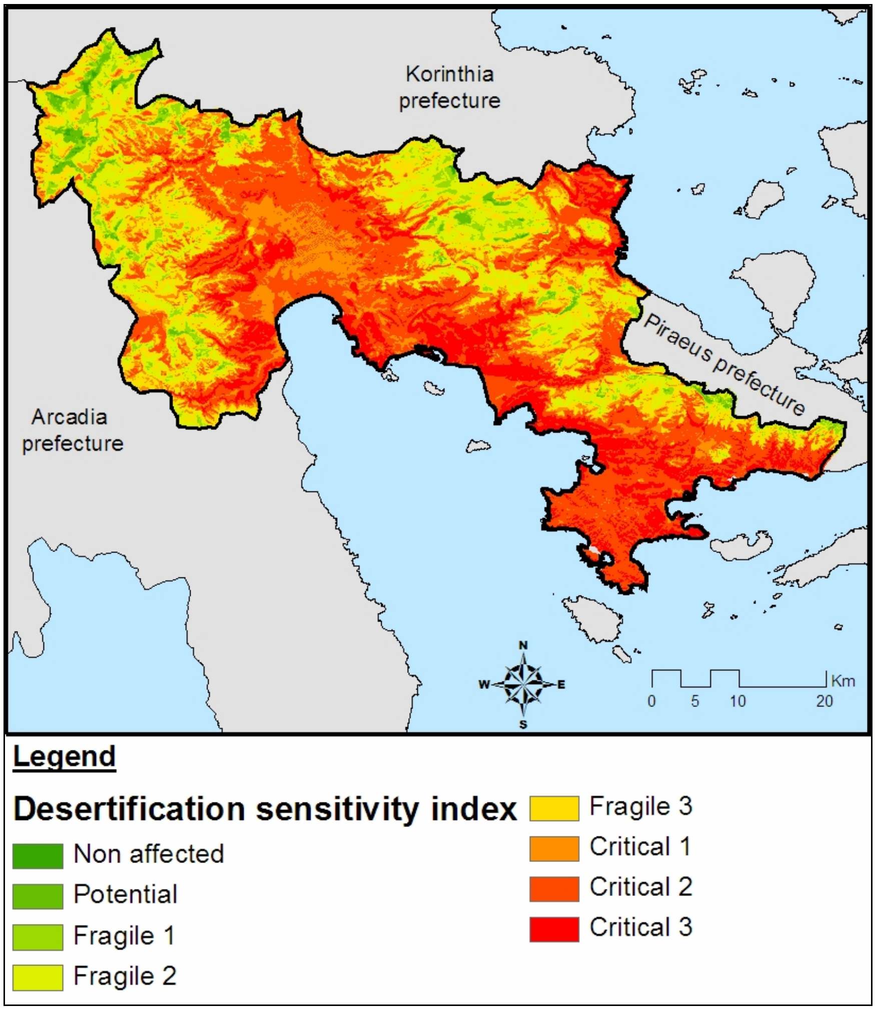

Figure 11 – Final desertification sensitivity map for the prefecture of Argolida

The analysis of the final desertification sensitivity map provides the table of statistics below (see Table 31)

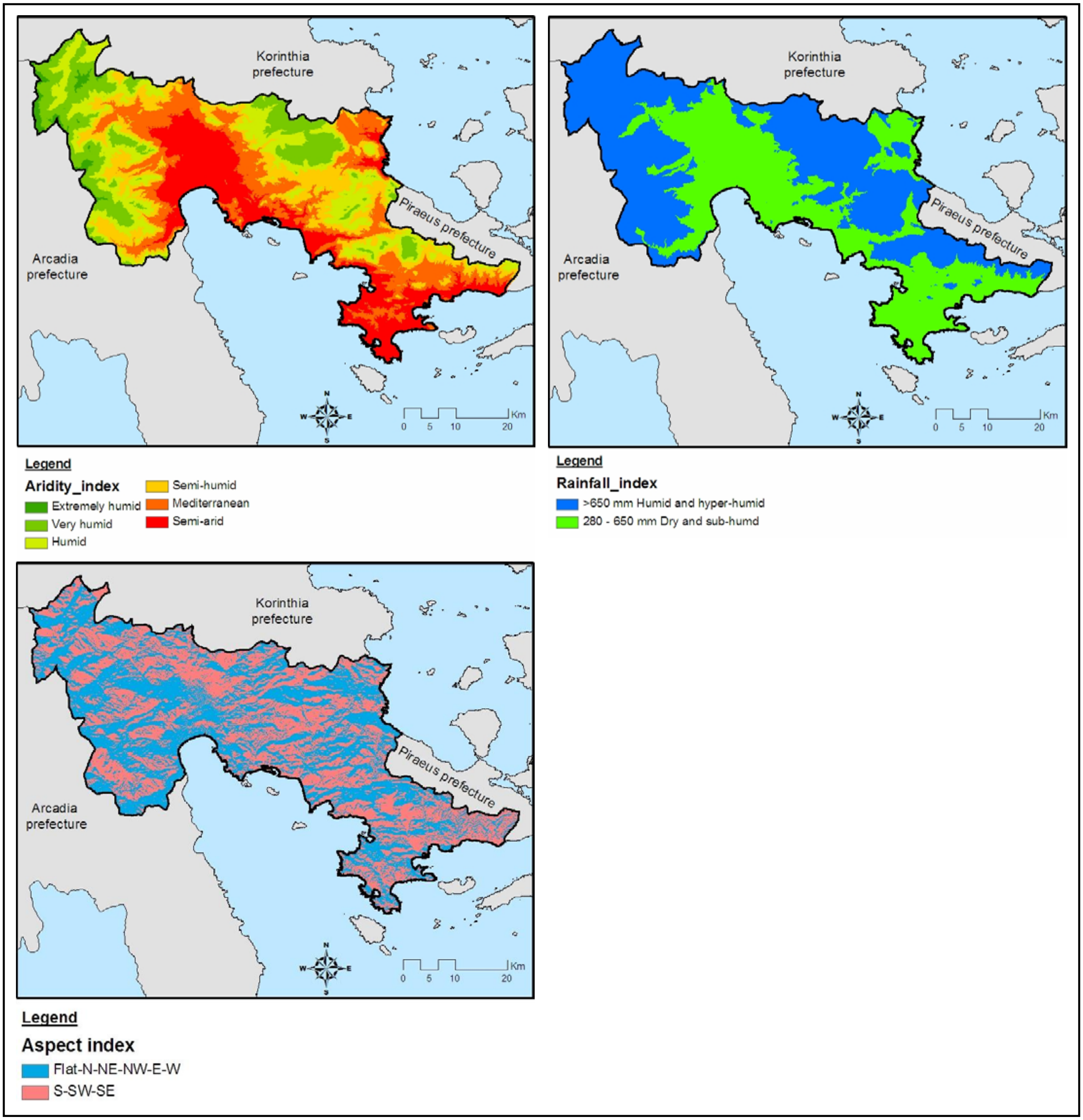

Plate 5 – Climate layers for the prefecture of Argolida

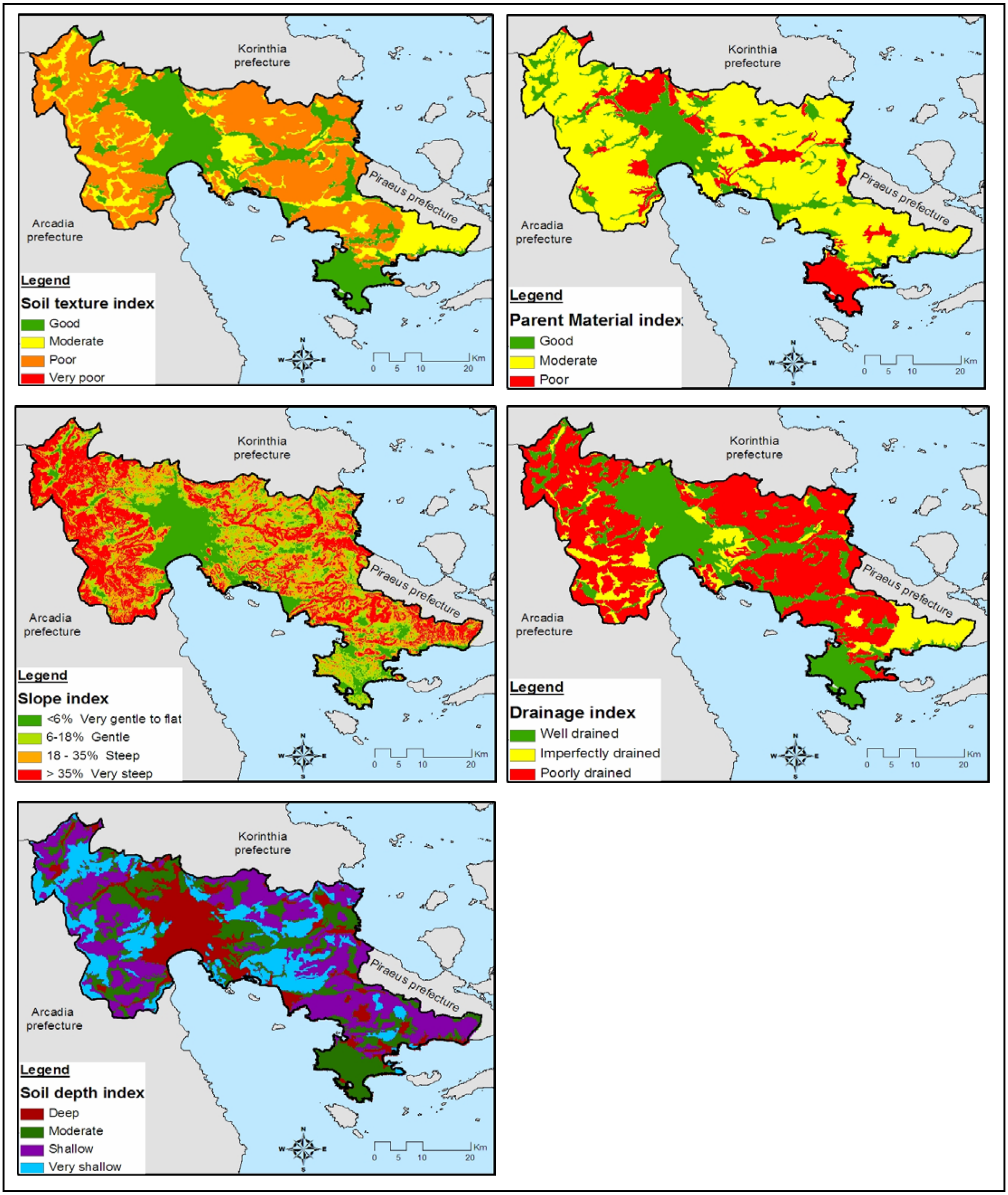

Plate 6 – Soil layers for the prefecture of Argolida

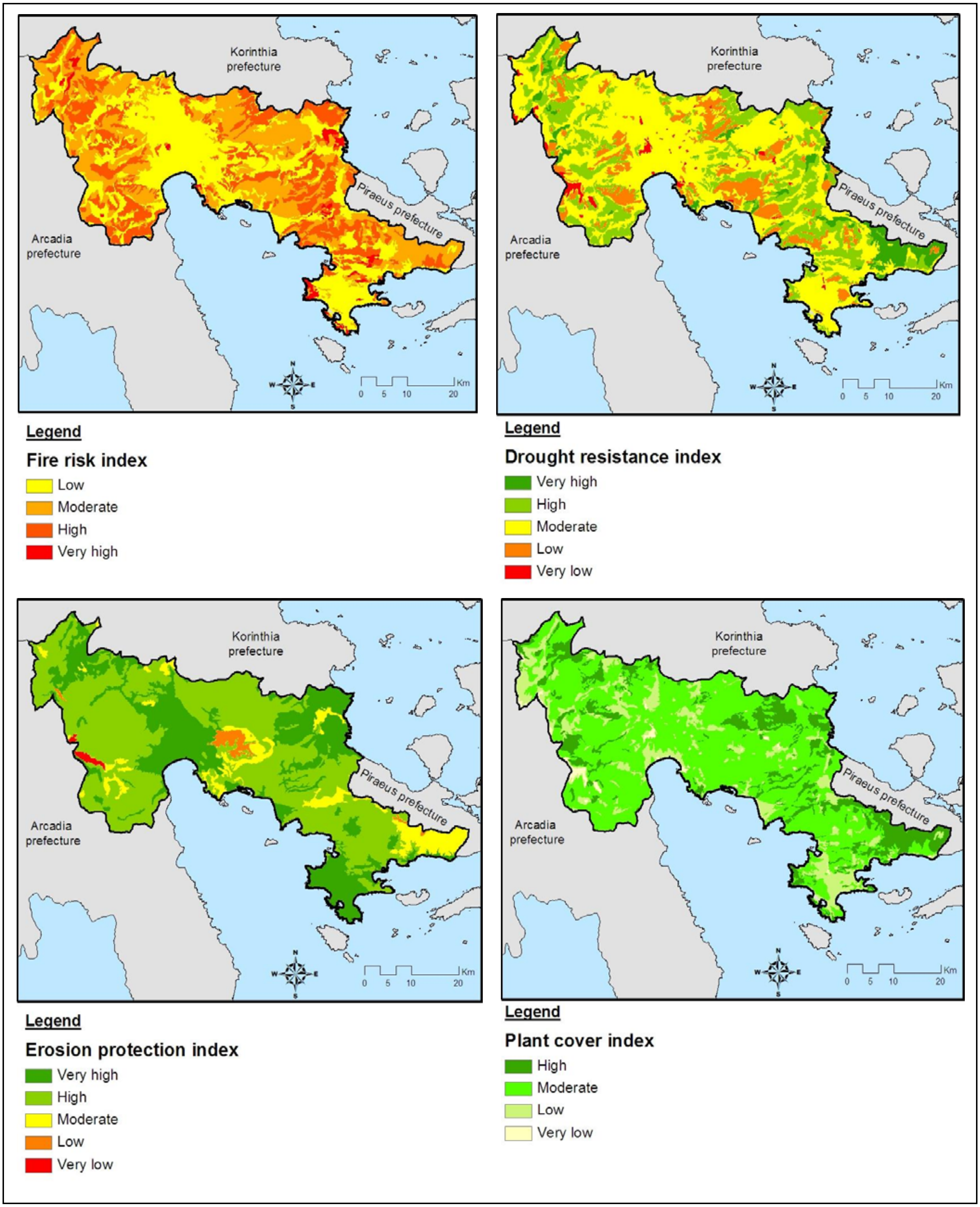

Plate 7 – Vegetation layers for the prefecture of Argolida

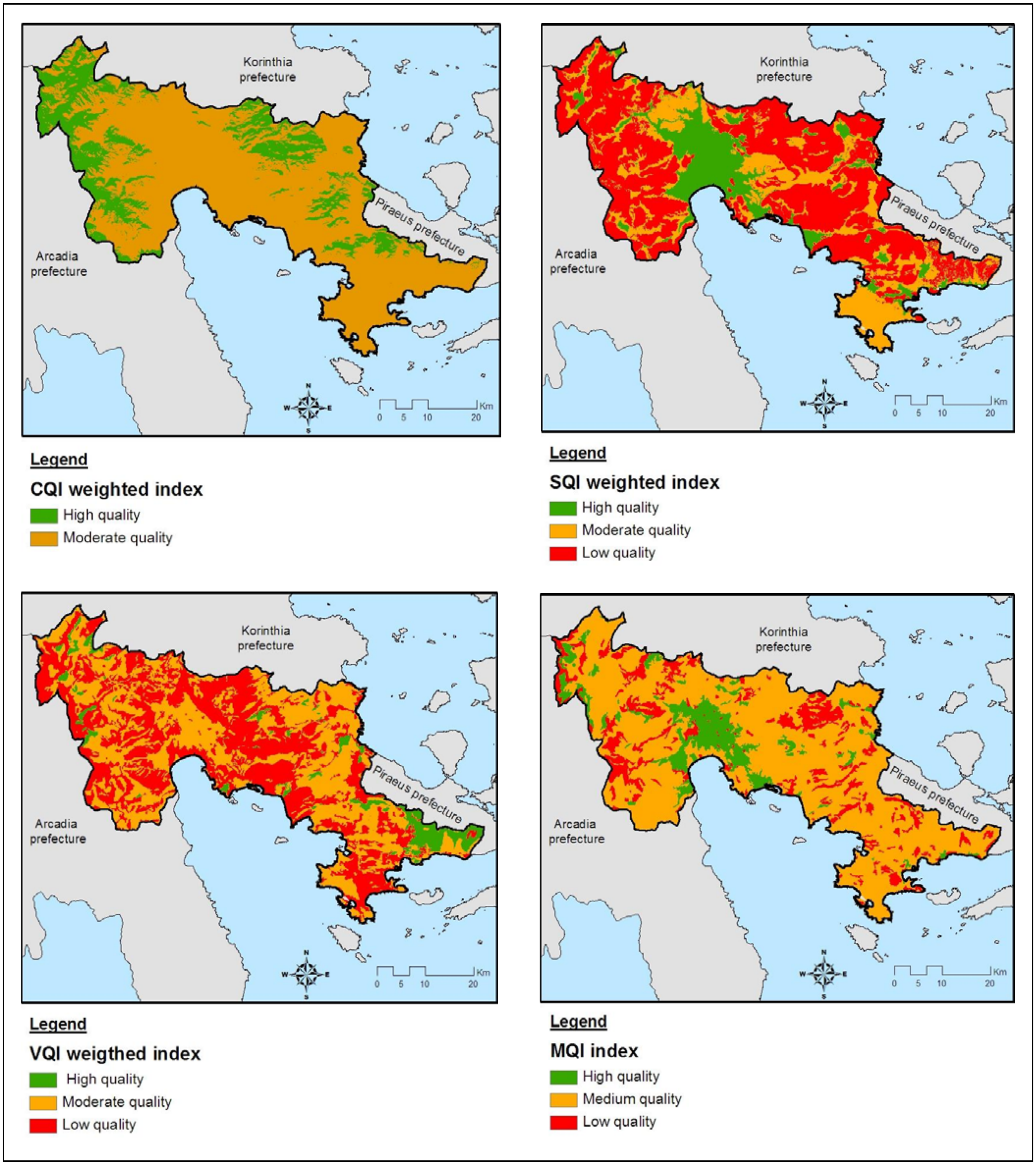

Plate 8 – Quality layers for the prefecture of Argolida

Table 31 - Distribution of the desertification sensitivity classes in the prefecture of Argolida

Sensitivity to desertification classes	Area percentage
Non affected	0,26 %
Potential	1,89 %
Fragile 1	4,37 %
Fragile2	15,51 %
Fragile 3	16,73 %
Critical 1	15,88 %
Critical 2	30,89 %
Critical 3	14,45 %

4.3.3 Application of the model in the island of Lesvos

Table 32 presents the meteorological data that has been collected in the island of Lesvos. The precipitation and temperature distribution could then be produced by performing a linear regression using collected data from three meteorological stations. The precipitation and temperature regression lines are characterized by an R-square value of respectively 0.18 and 0.97. Thus, two new maps could be generated and are presented in Figure 13 and Figure 14.

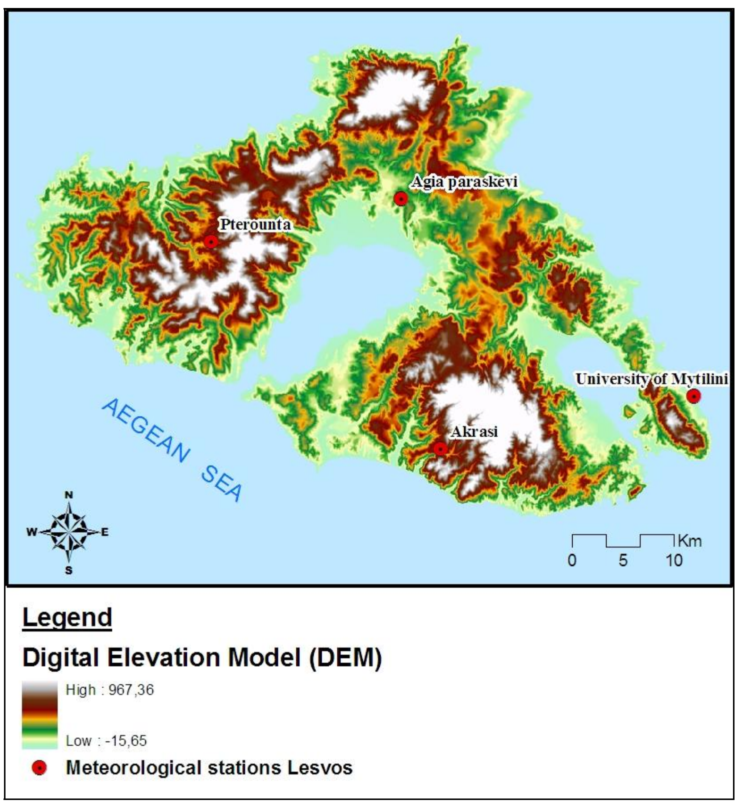

Figure 12 – Location of the meteorological stations in the island of Lesvos

Table 32 – Collected meteorological data for the island of Lesvos

Variables	Akrasi	Agia paraskevi	Pterounta	University of Mytilini
Elevation (m)	360	100	270	5
Mean Annual Rainfall (mm)	638.95	513.2	421.566	-
Average Temperature (°C)	-	15.55	14.66	16.4

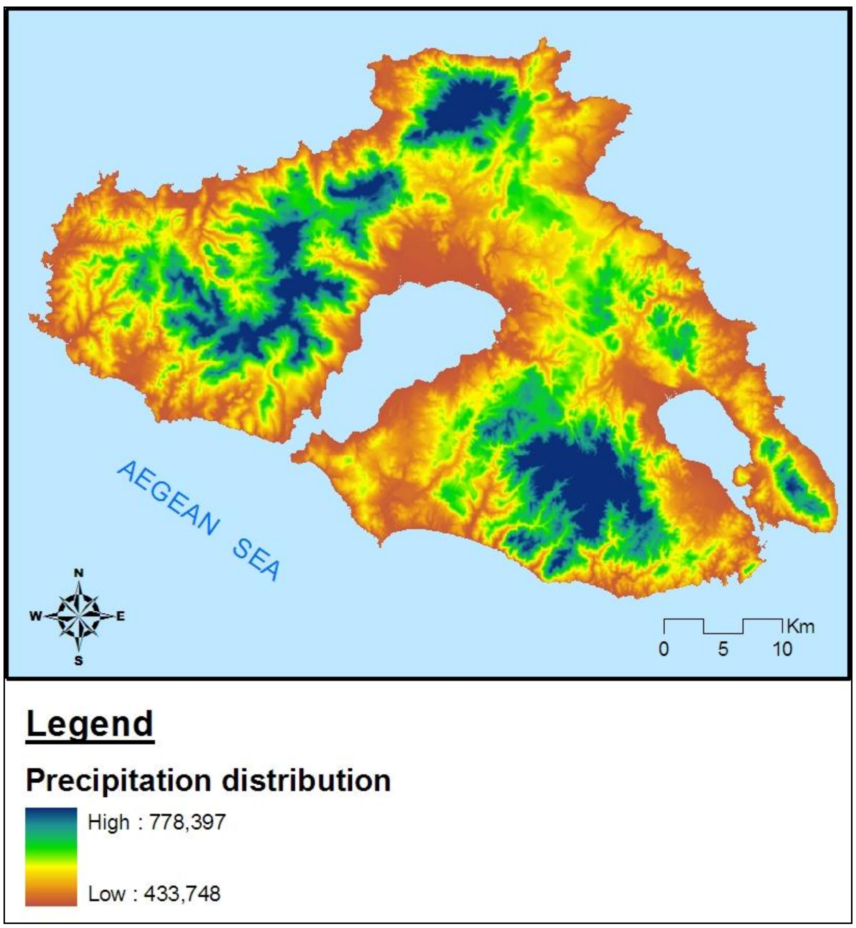

Figure 13 – Precipitation distribution estimated using data from three meteorological stations: Akrasi, Pterounta and Agia paraskevi

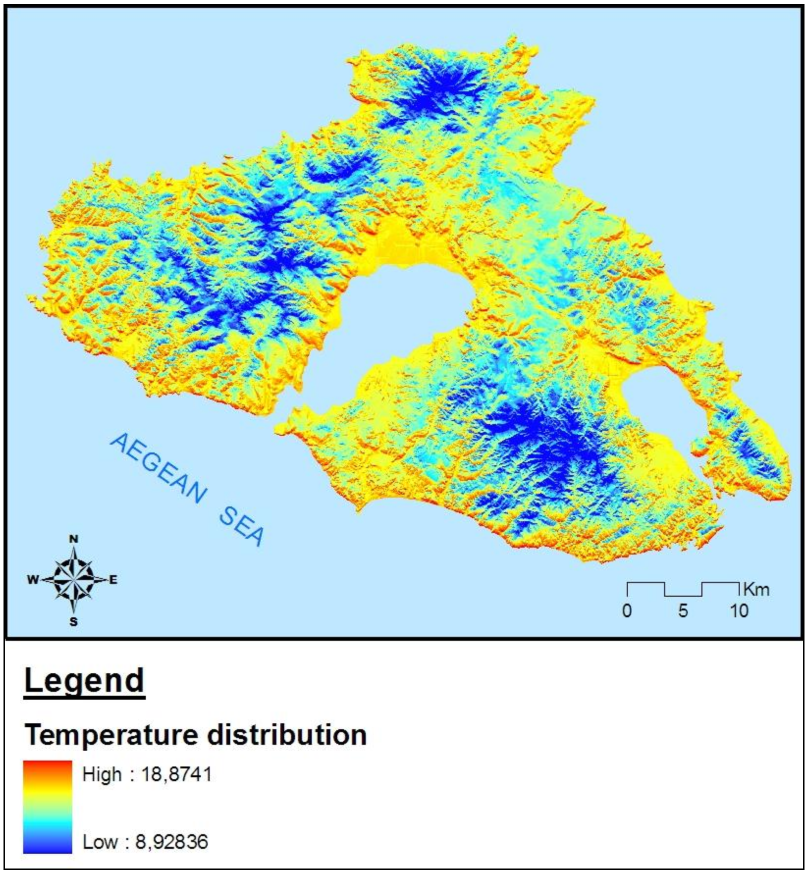

Figure 14 - Temperature distribution estimated using data from three meteorological stations: University of Mytilene, Pterounta and Agia paraskevi

For the island of Lesvos, the application of the proposed desertification assessment model produced the maps below (see Plate 9 to Plate 12 as well as Figure 15).

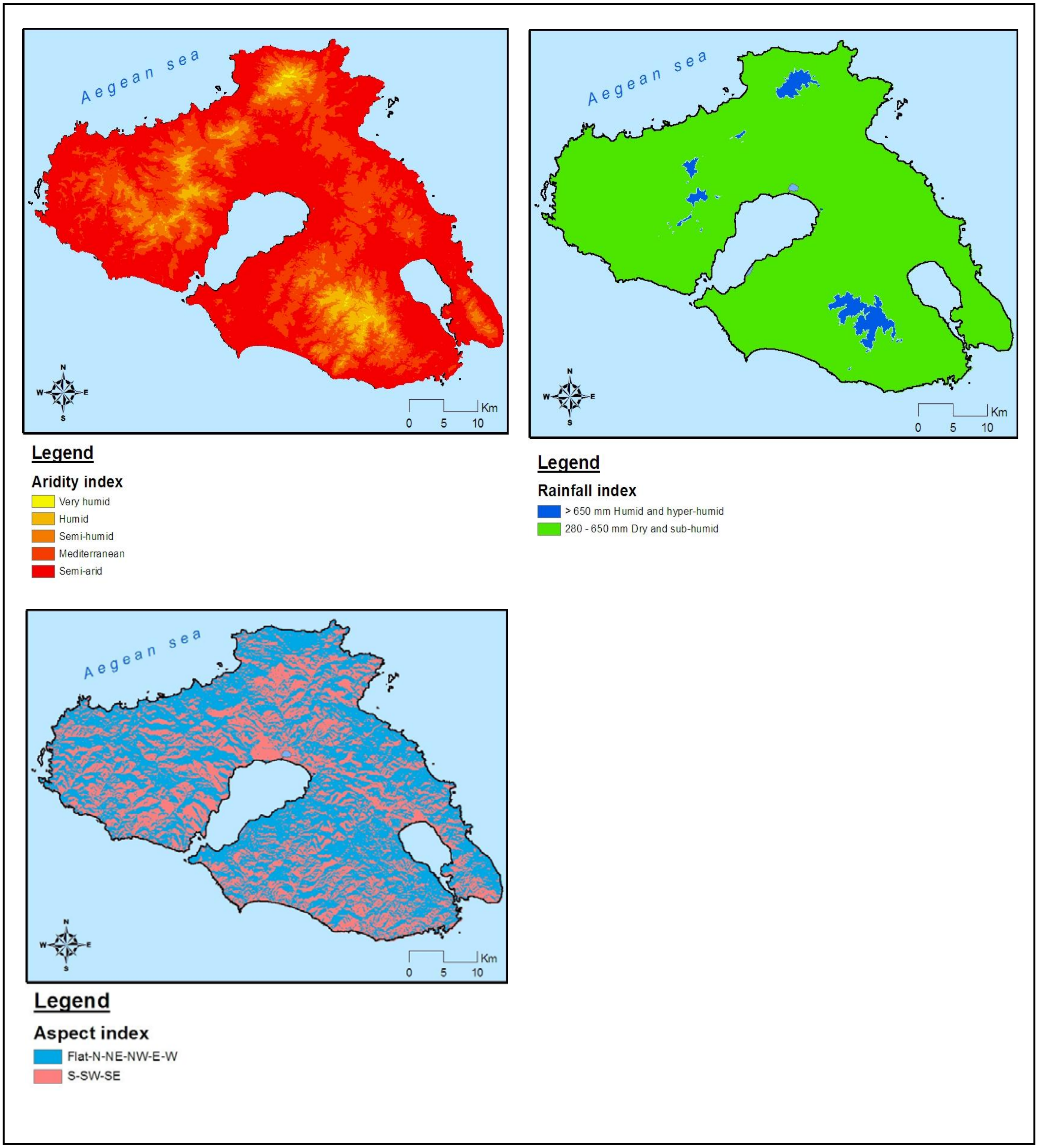

Plate 9 – Climate layers for the island of Lesvos

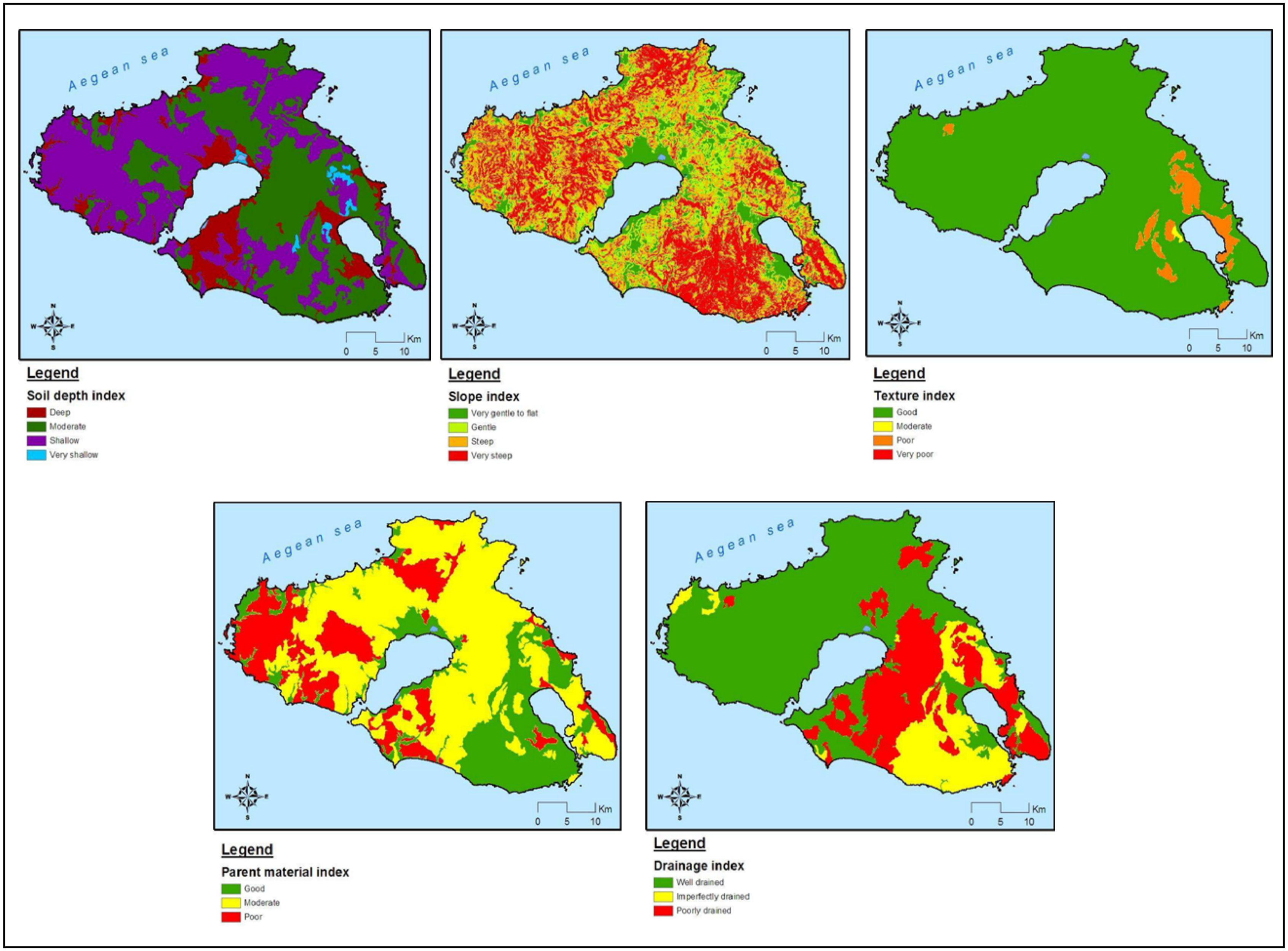

Plate 10 – Soil layers for the island of Lesvos

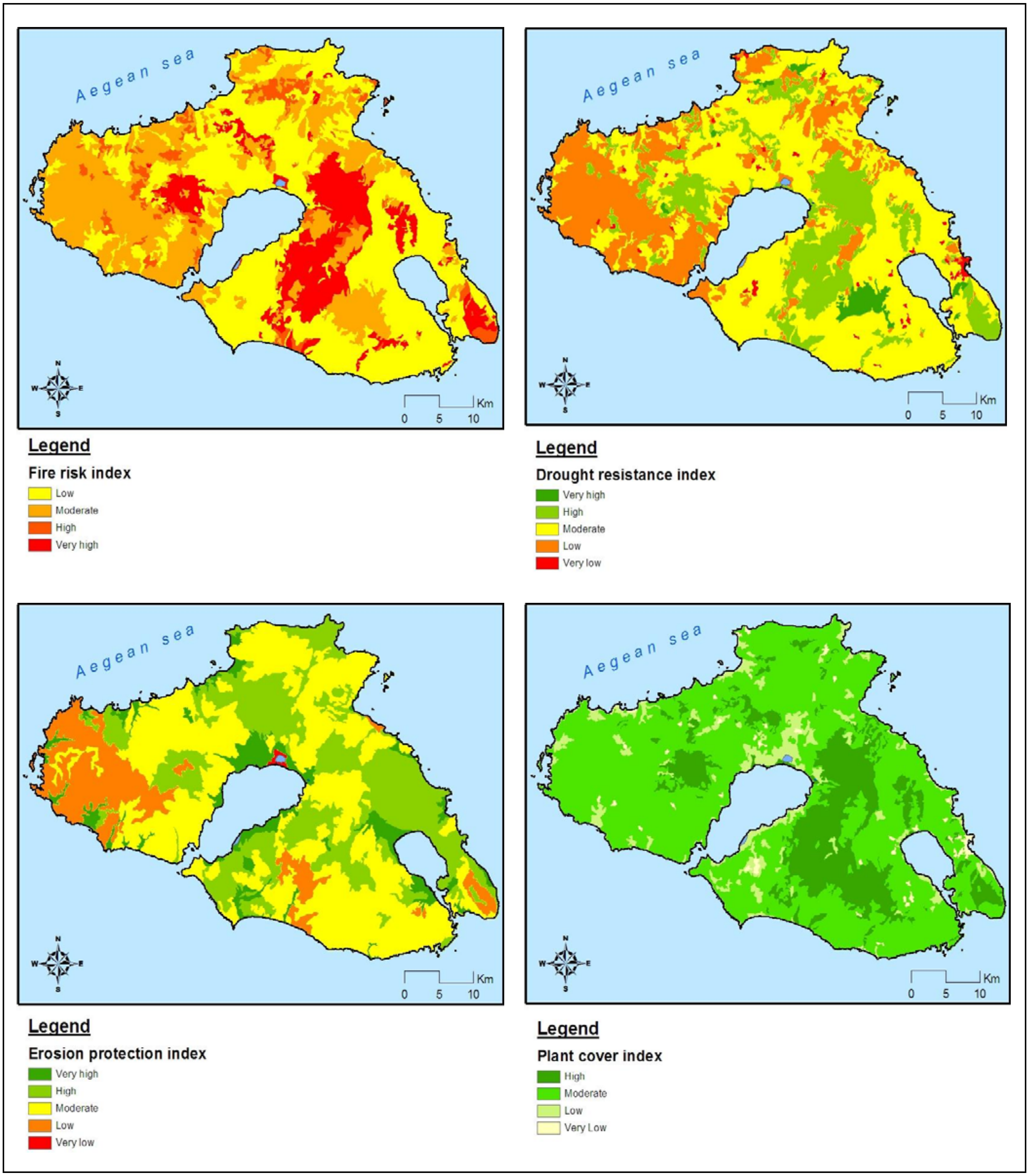

Plate 11 – Vegetation layers for the island of Lesvos

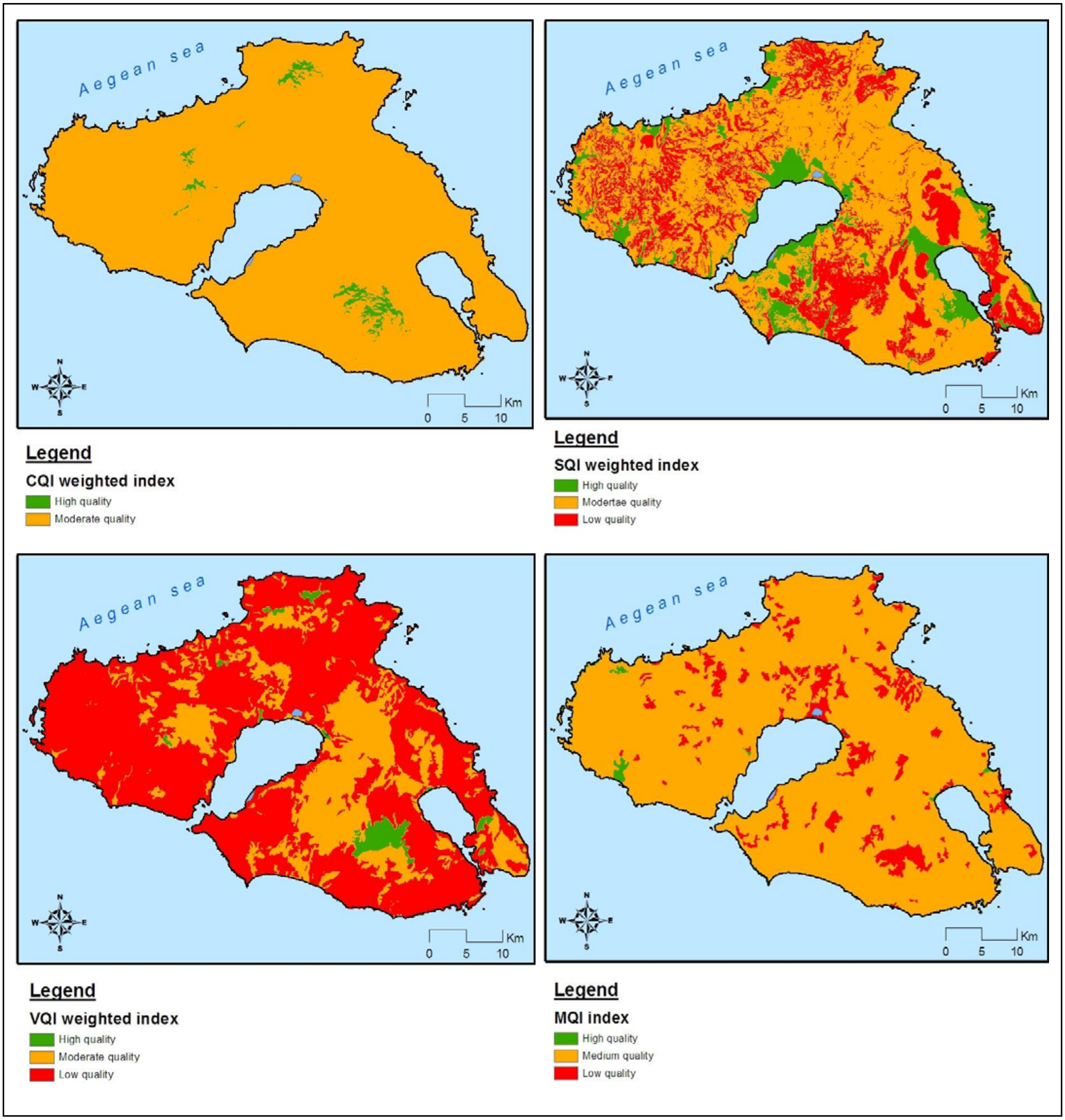

Plate 12 – Quality layers for the island of Lesvos

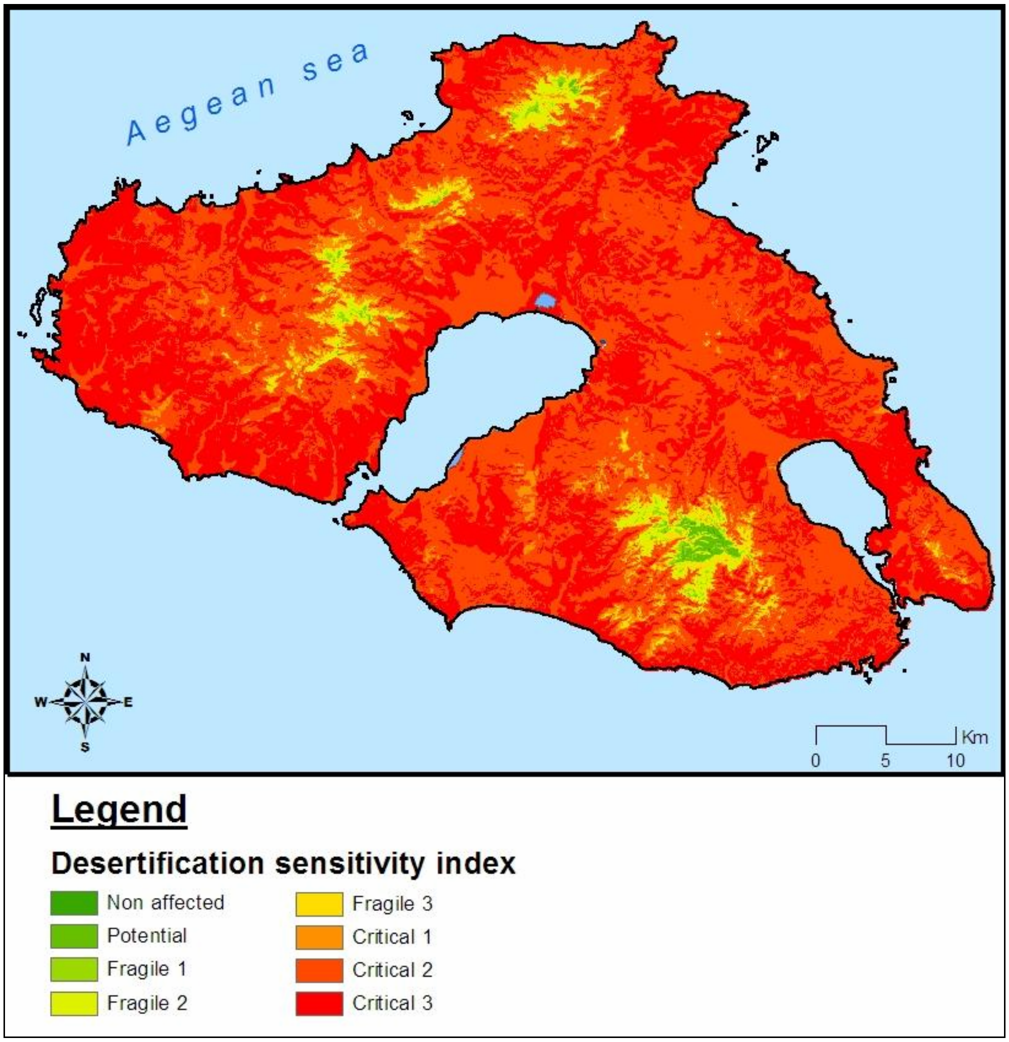

Figure 15 - Desertification sensitivity map for the island of Lesvos

Table 33 - Distribution of the desertification sensitivity classes in the island of Lesvos

Sensitivity to desertification classes	Area percentage
Non affected	0.05 %
Potential	0.41 %
Fragile 1	0.6 %
Fragile2	1.68 %
Fragile 3	2.35 %
Critical 1	4.63 %
Critical 2	47 %
Critical 3	43.27 %

4.3.4 Application of the model in the island of Naxos

In order to generate the precipitation and temperature distributions for the island of Naxos, meteorological data have been collected from three different stations located on the island of Naxos and on the neighbouring islands of Milos and Paros (see Table 34 and Figure 16).

Table 34 – Collected meteorological data for the island of Naxos

Variables	Naxos	Paros	Milos
Elevation (m)	8	33.5	165.4
Mean Annual Rainfall (mm)	361.4	439.61	472.43
Average Temperature (°C)	18.2	18.53	17.61

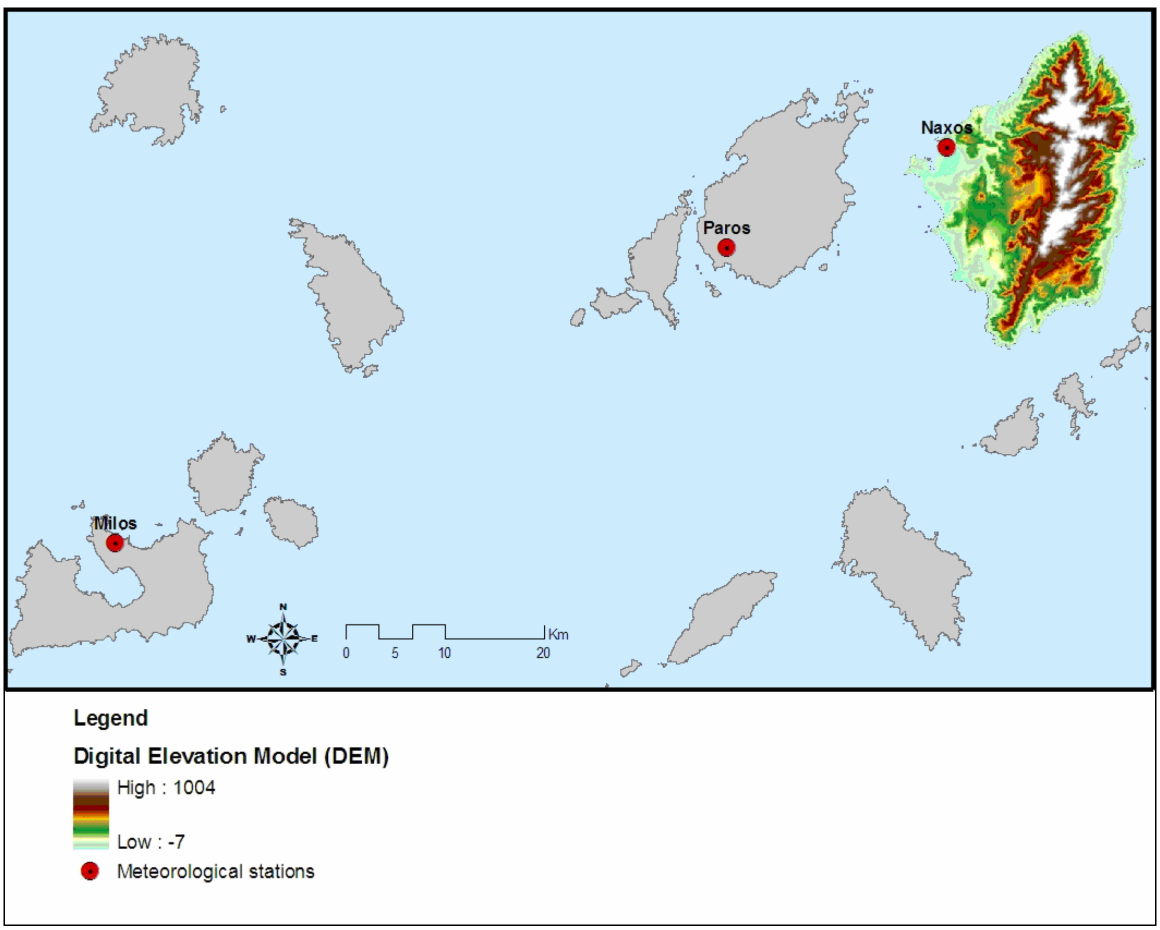

Figure 16 – Location of the meteorological stations in Naxos, Paros and Milos

A linear regression has been performed to provide the precipitation distribution ($R^2 = 0.677$) and the temperature distribution ($R^2 = 0.756$) (see Figure 3 and Figure 4). The temperature distribution was then modified to take into account the effect of the slope and the aspect according to Eq. 2. The resulting distributions are presented in Figure 17 and Figure 18.

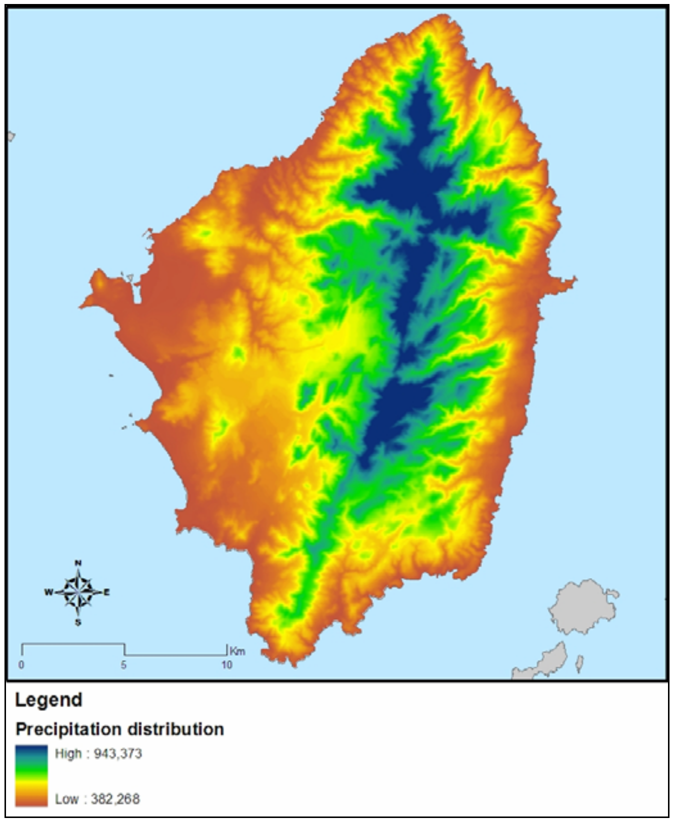

Figure 17 – Precipitation distribution in the island of Naxos

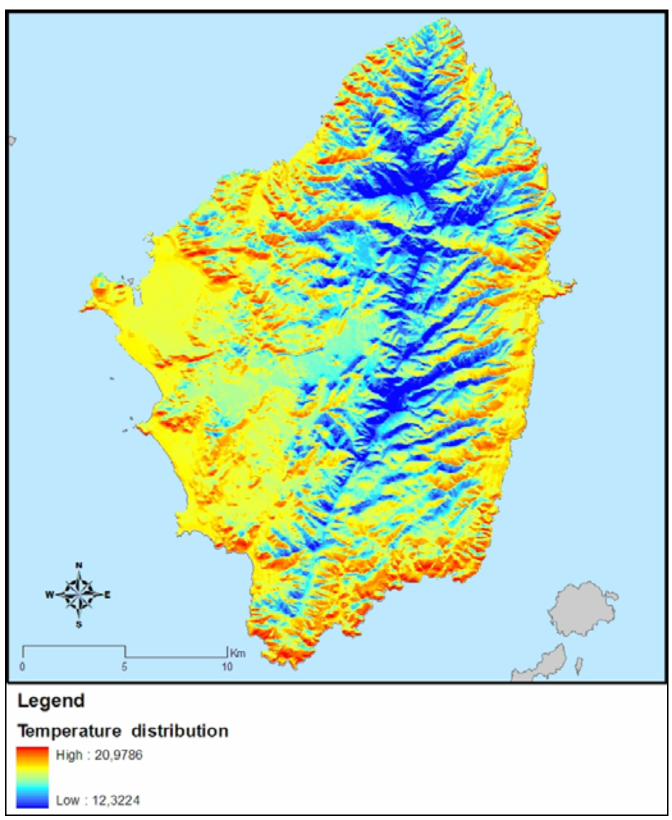

Figure 18 – Temperature distribution in the island of Naxos

The three climate layers have then been produced, based on the above distributions (see Plate 13). Also, the soil and vegetation layers have been generated following the methodology presented in Section 4.2. The results are shown on Plate 14 and Plate 15 respectively.
Plate 16 presents the quality layers corresponding to the climate, soil, vegetation and management data. Based on the latter layers the final desertification sensitivity map was produced (see Figure 19).

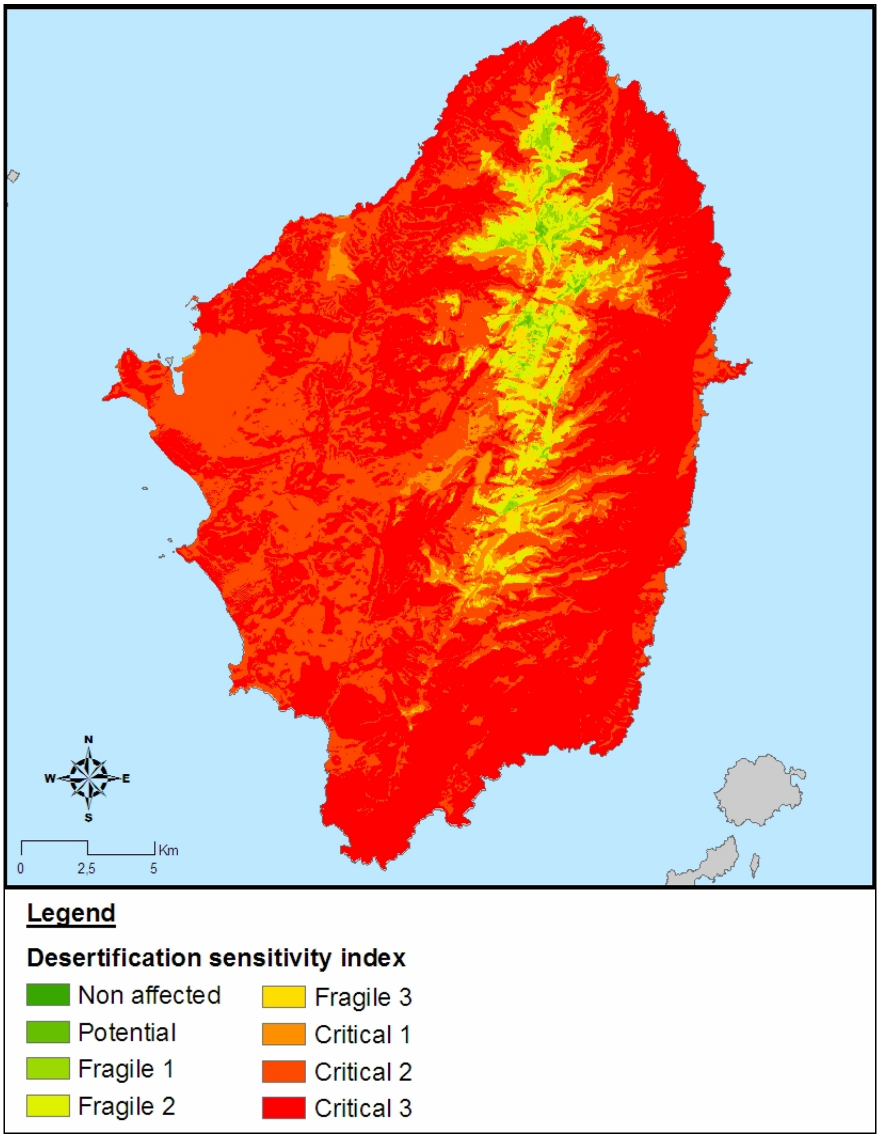

Figure 19 - Desertification sensitivity map for the island of Naxos

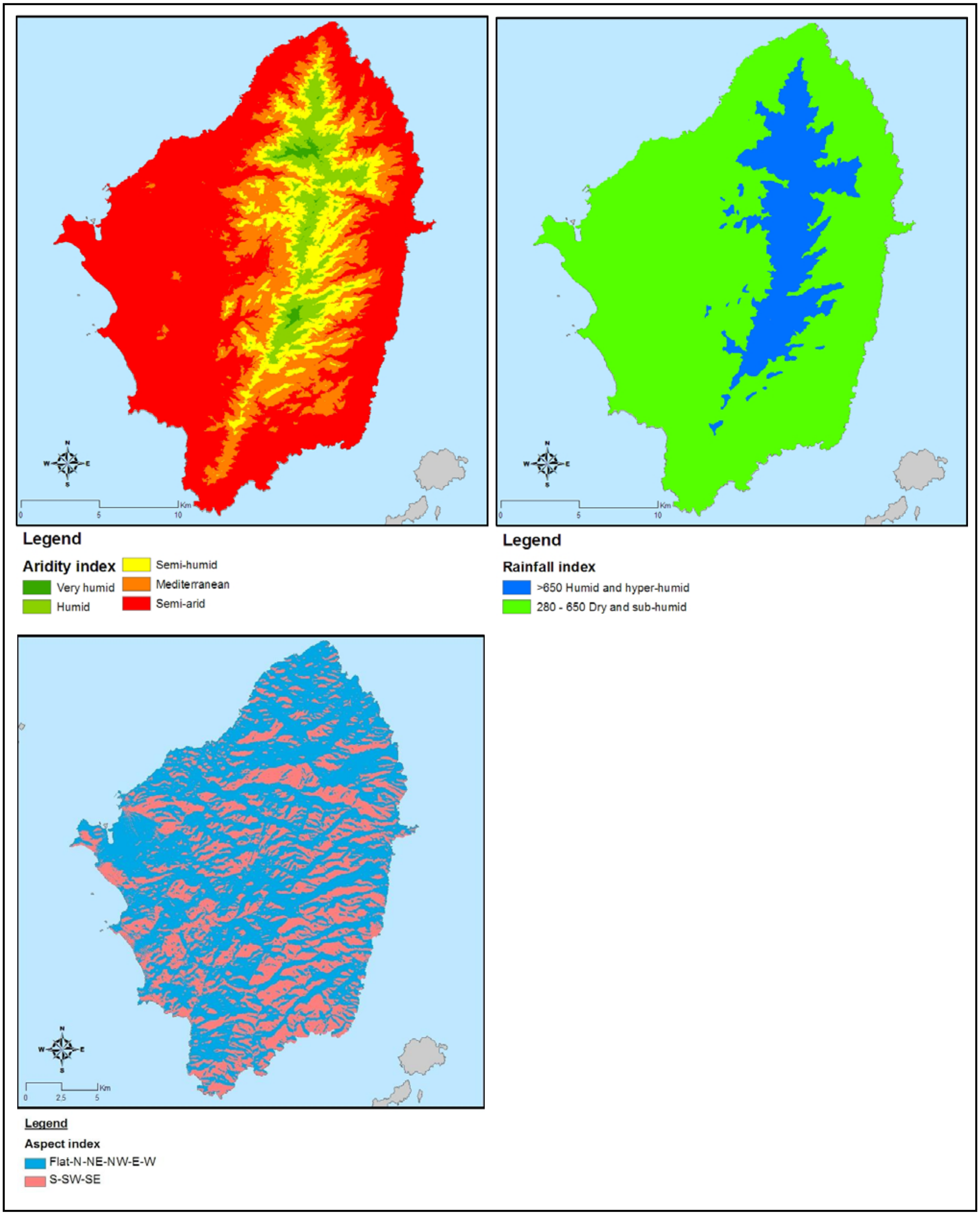

Plate 13 - Climate layers for the island of Naxos

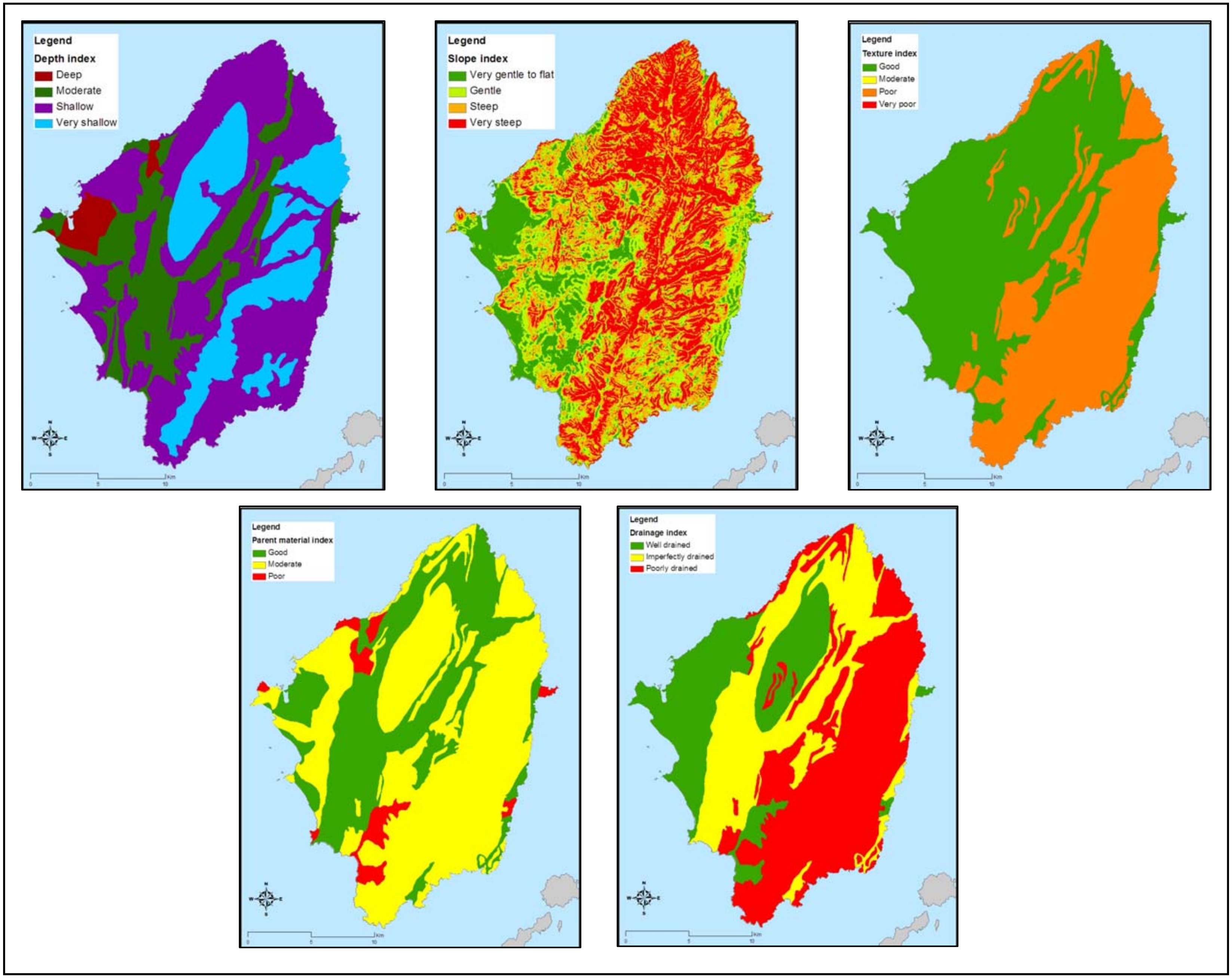

Plate 14 - Soil layers for the island of Naxos

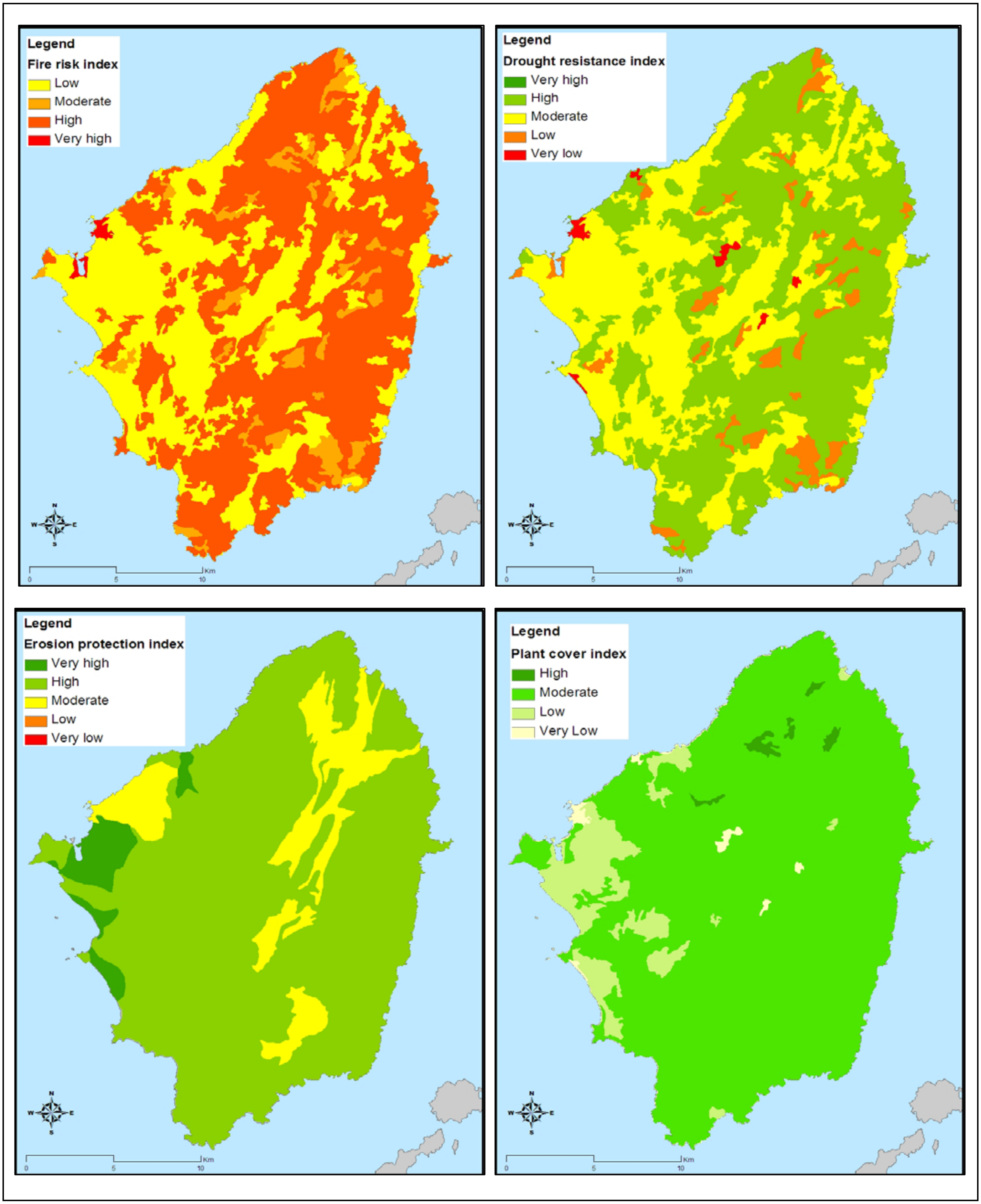

Plate 15 - Vegetation layers for the island of Naxos

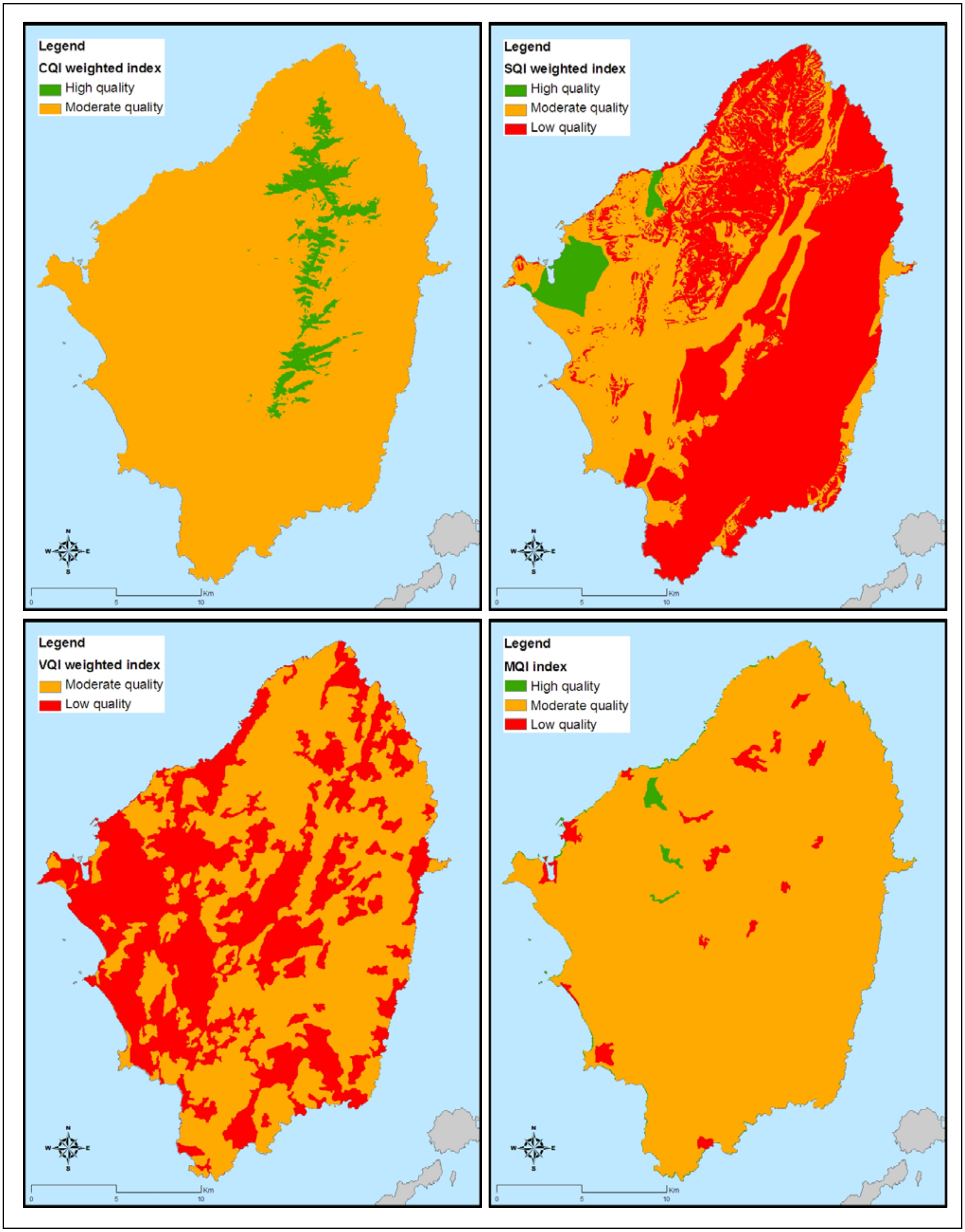

Plate 16 - Quality layers for the island of Naxos

Table 35 - Distribution of the desertification sensitivity classes in the island of Naxos

Sensitivity to desertification classes	Area percentage
Non affected	$9.33\ 10^{-5}$ %
Potential	0.145 %
Fragile 1	0.83 %
Fragile2	3.34 %
Fragile 3	3.74 %
Critical 1	4.97 %
Critical 2	32.35 %
Critical 3	54.6 %

5 Desertification monitoring

5.1 Desertification monitoring objectives

The monitoring of desertification consists in reporting at different time scales the current situation relative to the desertification processes. If well conducted, a monitoring programme can provide crucial information about desertification evolution. In fact the periodic desertification assessment of a study area can lead to the detection of first signs of degradation of the natural resources, it can provide hints about the stabilization or deterioration of the process. Therefore, it can provide early-warnings of any potential risks of desertification, so that the appropriate measures can be planned at an early stage. It can also provide a feedback on previously implemented measures and thus help evaluating their impact, in order to launch corrective actions if necessary.

In order to proceed to the monitoring of desertification, it is necessary to:

- identify the parameters that vary in time and those that can be considered constant in time;
- determine the appropriate time interval for monitoring taking into account the time required for data collection and analysis/transformation, the cost of the latter tasks and the rapidity of evolution of the degradation processes;
- describe a methodology for analyzing trends: statistics, graphs; and
- in case prevention and mitigation measures were implemented, evaluate their efficiency using the analyzed trend.

5.2 European desertification monitoring recommendations

A report from the Working Groups set up in preparation of the **Thematic Strategy for Soil Protection** [17] provided some main recommendations regarding soil monitoring. Such recommendations are sound for desertification monitoring since the Soil Quality layers presented in Section 4.2.2 are major components of the desertification risk model. Within the thematic strategy on soil protection are emphasized the following issues:

- the necessity for data harmonization so that maximum value can be obtained from past and current monitoring activities;
- the necessity of harmonizing the monitoring activities by including protocols for, but not necessarily restricted to, the setting up and maintenance of monitoring sites, site and soil descriptions, sampling strategies, laboratory procedures, data handling and storage, and quality assurance;
- the urgent necessity to decide the degree of sensitivity to which parameters need to be measured; and
- the need for a formal cost-benefit analysis of monitoring activities.

Recommendations were also provided for the monitoring of erosion and desertification control in [20]. Concerning the monitoring indicators, it was recommended to select those that satisfy criteria of:

- relevance to the objectives defined
- efficiency regarding the use of the resources
- relevance for the study of the spatial distribution of the effects
- time-sensitivity in order to reflect trends and fluctuations over time
- applicability in terms of cost

For an efficient monitoring of erosion and desertification processes, it is also advised to:

- set independent monitoring units to take in charge the regular control
- establish the units under the responsible agency for data collection and monitoring

5.3 Description of the monitoring methodology

5.3.1 The desertification monitoring module

The flowchart of Figure 20 presents an overall view of the desertification assessment and monitoring modules. The modules are decomposed into tasks and the inter-task links are illustrated. This way, the SAD guide user can better understand (i) the MOONRISES achievements consisting in the state-of-the-art and the development and application of the desertification risk assessment model and (ii) the monitoring tasks that have to be performed at different time scales: collection of upgraded data, application of the model to generate new thematic maps and analysis of the monitoring outputs to eventually propose preventive or corrective actions.

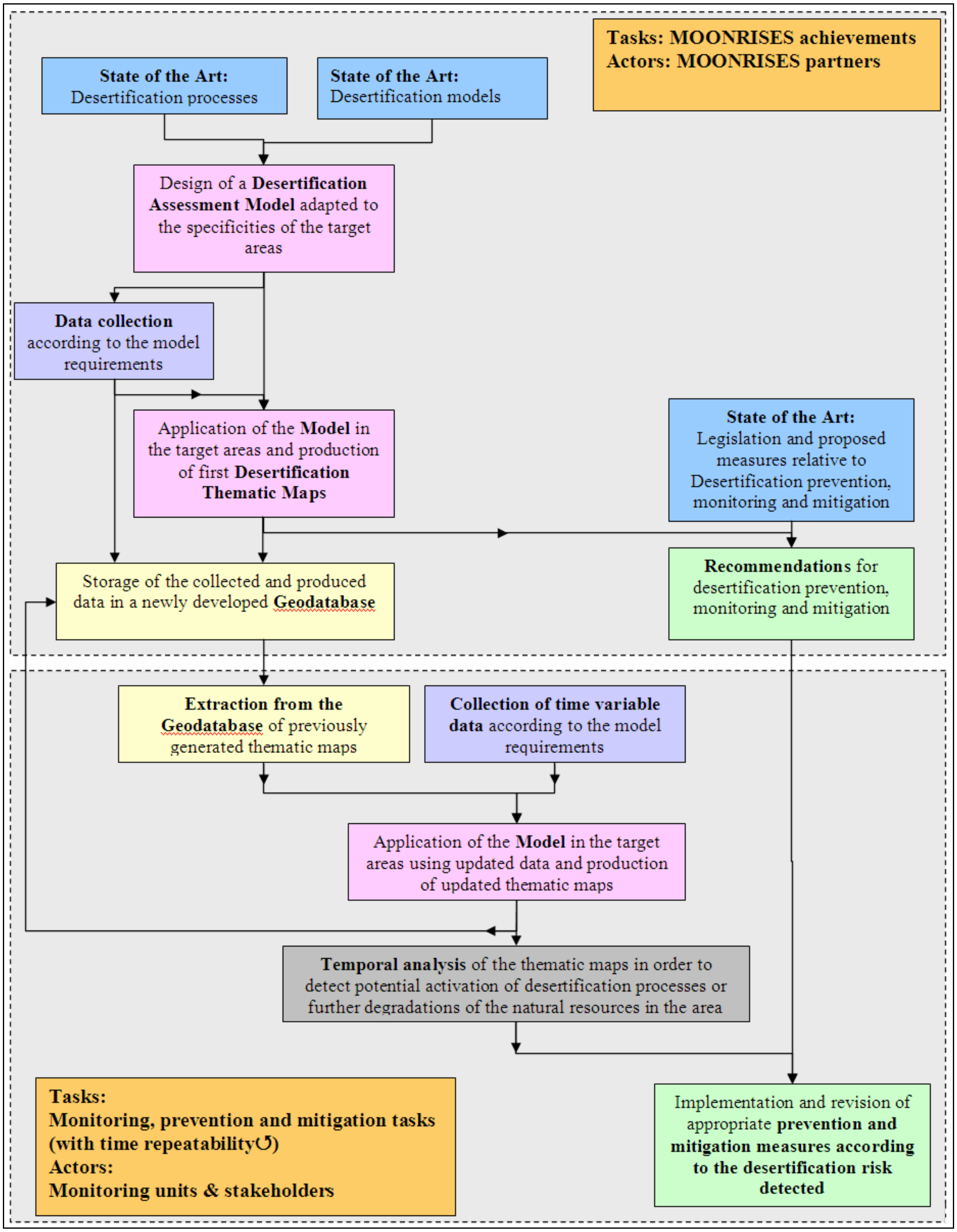

Figure 20 - Flowchart illustrating the tasks achieved during the duration of the MOONRISES project in connection with the tasks relative to the prevention, monitoring and mitigation of desertification.

5.3.2 Recommendations relative to data collection

In order to ensure the data comparability between monitoring results it is crucial to harmonize the data (scale, format, etc) and apply the same data processing approach. The latter issue being solved since the desertification assessment methodology is in-deep described in Section 4.2, remains then to ensure that similar input data are provided for processing. The necessary data are listed in Table 36.

Table 36 - Description of the collected data

Thematic layers	Description	Data type
Land use	Polygon layer of land uses classified according to the CORINE nomenclature.	Polygon features
Main parent material	Polygon feature layer with the main parent material (Alluvium, Granite, Schist, etc…).	Polygon features
Soil depth	Polygon feature layer with 9 categories of soil depth. A dominant and minor depth level is provided for each polygon as follows: Deep; deep and shallow; deep and bare; shallow and deep; shallow; shallow and bare; bare and deep; bare and shallow and bare.	Polygon features
Soil erosion	Polygon feature layer with 8 categories of erosion. A dominant and minor erosion level is provided for each polygon as follows: None; none and moderate; none and severe; moderate and none; moderate and severe; severe and none; severe and moderate and severe.	Polygon features
Prefecture boundaries	Polygon feature layer with the borders of the study areas.	Line features
Meteorological stations	Point feature layer with the meteorological stations in the prefecture. The mean annual temperature and mean annual precipitation is the minimum dataset to provide for each station.	Point features
DEM	Raster layer corresponding to the Digital Elevation Model with a cell size of 20m.	Raster

5.3.3 Recommendations relative to the time repeatability

In this section are identified the layers that are variable in-time. Such information is useful since only variable data will need to be again collected at each monitoring action. In Table 37, for each variable parameter is proposed a time interval for data collection that could provide a significant change between two data collections or measures.

Table 37 - Time variability and time repeatability of the collected data

Collected data	Constant in time	Variable in time	Data collection time repeatability
Land use		X	10 years
Main parent material	X		-
Soil depth		X	1 year
Soil erosion		X	1 year
Meteorological stations		X	1 year
DEM	X		-

Note: For the assessment of desertification risk in the Greek study area the CORINE Land Cover 2000 has been used. The CORINE Land Cover 2000 is an updated version of the CORINE Land Cover 1990. The European Environment Agency gives free access to its Land cover datasets on its website (http://www.eea.europa.eu).

Theoretically, the monitoring can have a time step equal to the least time repeatability of the parameters data collection. So a time step of one year could be advised. Nevertheless, the time repeatability should take into account:

- the fact that desertification leads to multiple degradations that need time to take place;
- the cost of the monitoring activities;
- the time necessary for collecting and processing the data and
- the fact that the impact of prevention and mitigation measures could be evaluated only after a certain period of time.

Therefore the monitoring time step could be increased to 2-3 years.
However, the time repeatability could be ignored if a major hydrologic event affects the target areas (floods, long droughts, severe forest fires). In such a particular case, an evaluation of the new desertification risk could be undertaken to estimate the impacts and consequences of the hazards endured.

5.3.4 Recommendations relative to data storage

The long-term storage of the generated data at each monitoring step ensures the efficiency of the monitoring actions and the reliability of the monitoring results. Therefore, building a geodatabase was one priority task of the MOONRISES project. The choice was oriented towards the implementation of a personal geodatabase, where only a user at a time can access the database in order to retrieve or store geodata.

The management of the MOONRISES geodatabase can be easily done using a complete suite of tools provided within ArcCatalog. The size of the geodatabase is limited to 2 GB. Consequently, one geodatabase was implemented for each study area, the occupied space does not exceed the fourth of its maximum storage capacity, thus several monitoring actions can be performed before the creation of a complementary database is required.

5.3.5 Recommendations relative to the hardware and software

The installation of the ArcGIS Desktop is required to be able to perform the management of the geodatabase within ArcCatalog and the processing of the data within ArcMap. For this purpose, a modern PC running the Windows operating system with at least 512 MB of RAM is necessary. Enough free space on the hard disk should be dedicated to the storage of the geodatabase files (at least 2GB).

5.4 Guidelines for the analysis of the monitoring output

The analysis of the new thematic maps that result from the monitoring actions provide updated information on the situation regarding the desertification risk in the area. However, the newly generated results must not be analyzed independently of the previously generated desertification risk maps. In fact, the comparative analysis of the series of maps available from the monitoring actions provides crucial information on how the desertification process evolves within the area and highlights the effectiveness of the already implemented measures in the area. For instance, a basic approach could be to follow the variation along time of the percentage of the territory under study characterized by each category of desertification risk (see Table 29). These overall statistics can be then enriched by the identification of areas where the desertification risk is of a higher category than in the previous assessments. If in such areas no measures were undertaken in the past, some prevention and mitigation measures should be implemented following the recommendations made in Section 6. If mitigation actions were already applied in those areas, then the monitoring put into evidence that they were not effective and thus need to be revised.

For the monitoring phase to be successful and effective the conclusions derived from the analysis of the monitoring results have to be communicated to the policy makers in order for them to propose new action programmes or upgrade the previously implemented ones.

6 Desertification prevention and mitigation

The prevention actions are aimed at avoiding the activation of the desertification process and are usually tackled from the point of view of sustainability of land use management while the mitigation actions are proposed once the process is already active in the area. The latter measures aim at alleviating the effects of the desertification and drought by reviving some of the environmental functions that have been to some extent compromised.
In order to implement efficiently such measures, the answers to the following questions should be provided:

- <u>Where to apply the measures?</u>

The identification of the areas threatened by desertification is achieved by the application in the study area of the assessment model described in Section 4.2.

- <u>What measures to apply?</u>

The critical issue of defining the appropriate measures to be applied in the area knowing the existing desertification risk is addressed in Section 6.4.

- <u>How to ensure the practical implementation of the measures?</u>

For the effective implementation of the measures a plan, program or specific framework has to be adopted in order to provide decision-makers with legal context/tool for the implementation of the necessary measures. This legal/policy context for desertification is analyzed in Section 6.1 and Section 6.2.

6.1 The desertification policy context

a) At the European level

The European Union possesses a wide range of legislations among which some can have direct or indirect impacts on the desertification situation. An exhaustive list of such policies were provided by the MEDACTION programme and result from an in-deep analysis of the policies related to desertification [18]. Here, a few of them are mentioned:

- Rural development policies: Common Agricultural Policy (CAP); Agri-environmental regulations; Rural development programs (example: LEADER).
- Water resources policies: European Water Framework Directive; Protection and management of NATURA 2000 freshwater sites.
- Biodiversity protection policies: European Landscape Convention; Habitat and Birds Directives and NATURA 2000 network.
- Horizontal environmental policies: Environmental Impact Assessment Directive; Strategic Environmental Assessment Directive (SEA); Integrated Pollution, Prevention and Control Directive (IPPC).

The Desertification Policy Support Framework (DPSF)

The Manual on Policy Analysis for the Mitigation of Desertification is a major output of the MEDACTION project that stresses the need for a Desertification Policy Support Framework for the European Union (DPSF-EU). The DPSF-EU would constitute a policy making level between the international level of the UNCCD and the Member States signatories of the UNCCD convention and would propose an integrated scheme to support regions affected by desertification. The Scheme should be based on synthesized, carefully planned and coordinated policies that will help minimizing the threat of conflicting policies and maximizing the synergies.

The EU Thematic Strategy for Soil Protection

The Thematic Strategy for Soil Protection was adopted by the European Commission in September 2006 and aims to ensure an adequate level of protection for all soil in Europe. The strategy consists in:

- A Communication from the Commission to the other European Institutions (COM(2006) 231) that defines the frame of the Strategy, explains why further action is needed to ensure a high level of soil protection, sets the overall objective of the Strategy and explains the kind of measures that must be taken.
- A proposal for a framework Directive (a European law) (COM(2006) 232). The proposal sets out common principles for the protection and the sustainable use of soils across Europe.
- An Impact Assessment (SEC(2006) 1165 and SEC(2006) 620) that contains an analysis of the economic, social and environmental impacts of the different options that were considered in the preparatory phase of the strategy and of the measures finally retained by the Commission.

b) At the national level

- **The National Action Plan (NAP)**

In order to apply the recommendations of the UNCCD, countries having signed the convention are requested to establish National Action Plans (NAPs). The NAPs provide several guidelines and measures in order to address the issue of land degradation and desertification in the affected areas. One essential aspect that maximizes the benefits from the implementation of the NAP is proposing measures that are integrated among them and well coordinated with other development interventions. The NAP process is a consultative process which includes all stakeholders. NAPs sources of finance can be the state budget, EU funding, contributions of groups to be benefited by the measures to be taken or other contributions.

In Greece, National Desertification Action Plans for Combating Desertification have been drafted in 2000[21] and 2002[22] in order to describe the main guidelines and mechanisms to be followed in an effort to deal with the dangers and effects of desertification, both in agricultural and forestry land. The plans have been proposed by the Greek National Committee for Combating Desertification (GNCCD), approved for application by a ministerial decree and adapted by the Ministers of Foreign Affairs, Finance, Agriculture, Environment and Development. More financial support is needed though, as well as basic institutional and legislative measures.

In Italy, on 21 December 1999, the Inter-Ministerial Committee for Economic Programming (CIPE) approved the National Programme to Combat Drought and Desertification (NAP) (Resolution 229/99). In order to present details on how the country carries out its commitments under the Convention, three reports (in 2000, 2002 and 2006) were submitted to the Conference of the Parties (COP) and the Committee for the Review of the Implementation of the Convention (CRIC).

- **The DPSF-country**

The Desertification Policy Support Framework (DPSF-country) is at the country level what the DPSF-EU is at the European level. Its goal is to provide an integrated, holistic, strategic platform for policy synthesis that addresses the present and future desertification concerns of the affected and sensitive regions of each country.
The DPSF-country would offer a common frame of reference for action, including the elaboration of NAPs and would be customized in order to fit the environmental and socio-economic profile and development priorities of the country.

6.2 Review of European desertification prevention and mitigation measures

At the European level a series of desertification prevention and mitigation measures were proposed. From the overview provided in [19][20] , where measures are classified according to the cause of the degradation, the following possible prevention and mitigation actions were selected:

a) Degradation caused by water management:

Prevention measures

- Aridity modelling to prevent crises
- Technical measures for the preservation of water sources
- Protect existing wetlands
- Prevent salinization of soils
- Adopt the most appropriate solution for increasing the water supply. A complete environmental study of the possible impacts should be performed

Mitigation measures

- Efficient management of existing water supply systems: Operational rules for reservoirs, reduction of leakage and waste, water recycling and reuse
- Encourage rain water harvesting
- Limit the drilling of new wells
- Building earth dams (rather than large concrete structures) across suitable watercourses to collect winter rains
- Support activities for the waste water collection and treatment necessary for hygienic and environmental needs
- Waste water collection and treatment plants
- Phytodepuration and Lagging
- Treat waters from different uses (industrial, urban, agricultural) to minimize the pollution of aquifers
- Discourage water-demanding crops and substitution of irrigated crops with rainfed crops that can resist low water conditions.
- Compare the different type of forest cover and their effect on rainfall interception in order to change the hydrological cycle
- Economical use of irrigation water by appropriate pricing rather than trying to increase supplies to meet an unrestrained demand

b) Degradation caused by wildfires

Prevention measures

- Protection of slopes from erosion
- Provide a subsidy of fodder to discourage the shepherds from burning, since 90% of intentional fires were started by stock farmers who wanted to stimulate the resprouting of fodder.
- Maintenance of firebreaks
- Avoid fuel accumulation to reduce the probability of fire by: the thining of plantations, the pruning of shrubs and the introduction of species with a good recovery rate, in the context of an integrated resource management system.

Mitigation measures

- Reducing the impact of fires by seeding and mulching
- Support revegetation programs
- Protect lands from grazing (for at least five years) to obtain a faster recovery of the vegetation

c) Degradation caused by grazing

Since grazing and forestry are closely linked, the proposed measures are:

Prevention and mitigation measures

- In general, management of forests and wildlands should be multipurpose, including recreation and grazing.
- Forests should be protected from fires, illegal cutting and destructive grazing. Suitable grazing and the collection of firewood can reduce the fire hazard.
- Management of rangelands (designated for grazing) should aim at mosaic-type patterns by proper grazing and occupational burning, so that productivity and resistance to wildfires is increased.
- Each township should organise grazing of communal lands on a long-term basis.

A more drastic set of measures was also proposed:

- Totally prohibit grazing in the forest (in many communes it is currently limited to regeneration periods)
- Abolish all regional or EU-subsidies for herding. Before the application of such a measure, the impact of the disappearance of a traditional activity such as sheep herding should be evaluated (probable loss of a culture and therefore degradation of the environment)
- Introduce additional taxation for those who don't use tabulation
- Incentives and subsidies should be transferred from pastoralism to landowners that intend to plant trees
- Launch initiatives to change the mentality of shepherds. For instance, the community could pay for the instruction of the shepherds' children to address their training towards naturalistic or forestry sectors.
- Evaluate the damage that ungulates could cause in protected areas before reintroducing some species in natural parks.

d) Degradation caused by cultivation

Prevention measures

- Unlike the Common Agrarian Policy (CAP) that caused a significant change in land uses and increased in some cases the land degradation due to erosion processes, the implementation of new policies should be preceded by the essential assessment of its global impact on the resource base.
- Moreover, trans-national policies such as the CAP or other environmental EU policies have to be viewed against the different scales at which they are relevant.
- The EU should consider the semi-arid issue more specifically because some of the principles that form the basis of the EU policy may not apply to the semi-arid regions of the Mediterranean.

Mitigation measures

- Appropriate preparation of the soil
- Good water management
- Appropriate crop rotation
- Suitable choice of crops

- Intensive cultivation should be concentrated in areas that present the best possible combination of climatic and edaphic condition.

e) Degradation caused by soil degradation and erosion

Prevention measures

- Appropriate soil management and rational, low-impact agricultural practices such as the agro-forestry activities could reduce runoff
- Avoid the degradation of existing plant cover.

Mitigation measures

- Assist the recovery of the degraded plant cover in the form of forest cenoses
- When the natural cover recovery is limited, avoid the mechanized reforestation actions consisting in terracing, use of bulldozers (causing earth movements) and thus laying bare large areas and eliminating existing natural vegetation. Such actions lead to an increased erosion.

6.3 National Action Plans (NAPs) in Greece and Italy

The NAP of Greece

The main measures proposed within the NAP of Greece in 2002 are listed in Table 38.

Table 38 - Measures proposed within the NAP of Greece 2002

Sector	Proposed measures
Agricultural Sector	- Biological agriculture - Biological animal production - Long period set- aside of agricultural lands - Reduction of ground water- pollution by nitrogen of agricultural origin - Conservation and reconstruction of terraces on inclined lands to limit the erosion impacts. - Formulation of Codes of Good Agricultural Practice, which constitutes the regulatory frame in which agricultural activities will be applied.
Forest Sector	- The Forest Functional Plan - Clarification of the land ownership status in forests is continued, according to the national cadastral plan. - Soil classification - Mapping of forest lands - Forest management - Forest plant nurseries - Protection of mountainous water sheds.
Water Resources	- Institutional measures for the implementation of the EU. Directive 2000/60 - Preparation of integrated water resources management plans for every water district. - The provision of institutional tools for better co-ordination of water resources management. - The extension of the water storage facilities (dams, reservoirs and artificial water recharging. - Development of coastal and inland karstic water resources.

Socio economic sector	- Keeping the population in the agrarian areas by establishing plans of early retirement for farmers of advanced age and the promotion of developing Agro-tourism in mountainous and other marginal lands. The plans are implemented with apriority to areas with demographic problems, many of which are located in desertification threaten territories.
Infrastructure	- Plan and construct a network of major public works like motorways, bridges, schools and hospitals in order to improve the economical basis of the country and the population
Countryside Development	- The improvement of the competitiveness of the Greek Agriculture. - The viable and integrated development of the countryside. - The ensuring of the social cohesion and the security for the entire agrarian population. - The subsidizing of young farmers. - The encouragement of biological farming. - The provision of medical assistance to the population of agricultural areas.

The NAP of Italy

Since the land degradation situations are different from the north to the south Italian areas only measures implemented in the area of Basilicata are mentioned.

In 2002 [23], the National Committee to Combat Desertification (NCCD) mentioned in its second report on the implementation of the UNCCD a need for further studies dedicated to the analysis of water and soil resources, the dynamics and evolution of the phenomena of transformation, degradation and renewal, the natural risk, vulnerability to desertification, and environmental responsiveness.

In 2006 [24], the following actions performed in the region of Basilicata were reported:

- Forestation and re-vegetation programmes
- Forestation programme for hydrogeological protection
- Woodland naturalization and reconstitution
- Environmental continuous quality control and environmental monitoring system development
- Integrated hydrological resources system improvement and procurement, water-drainage, dispose and depuration net rationalization control
- Reduction of the impact of productive activities
- Environmental safeguard and protection from different types of pollution through an integrated waste management and reclamation of the existent situation
- Strengthening, requalification, restraint of the regional energetic offer
- Cross-cutting Measures
- Environmental safeguard and protection
- Environmental sustainable economic activities

6.4 Proposed prevention and mitigation measures according to the desertification risk identified in the study areas

Regardless their non-systematic application, prevention and mitigation measures can be classified into a set of groups and finally applied in a more logical system looking at it from both the (multi)functional and aesthetic viewpoint (see Table 39).

Table 39 - Classification of desertification prevention actions

Location and implementation → Action↓	By catchment management	By technical solution	By agricultural management	By forestry management	By general area management (organizational)
With catchment management	Water management	*Flat and gentle slopes on contour lines*	*Bottom of valleys (aside main or major water course)*	*Shallow soil, steep slope (obligatory more than 15 degrees), terrain edges*	*Exclude grazing in forests (for whole year), terrain edges and plant belts (in dry season)*
With technical solution	Water canal construction (irrigation)		*Pastures fencing, slope terracing if declination more than 15 degrees*		*Redistribution of agricultural land by governmental institution*
With agricultural management	Water pond construction	Fencing, slope terracing, water pond construction	Olive trees planting, contour line agriculture	*Tree lines along water courses, river beds, terrain edges, parcel edges, roads, larger industrial, agricultural production sites and concentrations of services (shops), residential areas*	*Individual farmers overtake responsibility for stabilizing elements on their parcels (tree, shrub and/or plant belts)*
With forestry management	Reforestation	Mulching after fires	Wind breaks	Planting Mediterranean oaks, planting deciduous oaks	*Reforestation of public (state, community, military) lands*
With general area management	Grazing regulation	Wind breaks, planting vegetation	Winter grazing, wind breaks, bush growth	Fencing, reforestation, wind breaks, bush growth	Adoption of European landscape stabilizing legislature

The areas mostly endangered by the running desertification process (or areas at maximum risk) can be improved using an integrated approach based on the application of the landscape planning procedures. The latter include:

- Agricultural land redistribution – according to the optimum soil quality distribution (after redistribution the original land owner will posses areas with the same soil quality proportion as before), soil erosion prevention, agricultural roads use (with respect to area accessibility, multipurpose use, general protection measures).
- Land use optimizing – with respect to the best use given by area potential and area carrying capability identified by territorial and landscape planning (incl. EIA procedure).

- EECONET construction [25] – as multipurpose landscape stabilizing system with functional, aesthetic, protective and positive supporting impact on neighbouring territory.

All of these procedures are based on a multi-criteria area analysis and request Geographic Information Technologies (GIT) applications. Because the desertification process is a trigger for starting necessary land management procedures, the EECONET planning and construction can overcome processes of agricultural land redistribution and urban planning procedures (including land potential assessment, EIA) and could be implemented first. The agricultural land redistribution and urban planning can respect the priority of desertification prevention and accept elements of local ecological network (EECONET) as parts of their solutions.

6.4.1 Introduction of principles of EECONET in landscape management and use

EECONET stands for the European Ecological Network. It consists of more stable (and landscape stabilizing) areas = BIOCENTRES and connects linear "green ways" = BIOCORRIDORS. Both of these main EECONET components play many other roles in present landscape, among others the desertification prevention and impacts mitigation. This multipurpose solution probably constitutes the most efficient solution.

Landscape ecological background:

EECONET is a network of ecologically more significant landscape segments located in the territory respecting functional and territorial criteria and fulfilling a set of purposes. It is a mutually linked system not only natural, but also other stable ecosystems altered by humans having positive impacts on the landscape stability. The system consists of optimally operating set of biocentres, biocorridors and interactive elements. All these components are of various importance depending on the role they play in the process of keeping or improving the landscape stability.
The main aims of ECONET construction are as follows:

- the biodiversity protection (species and societies diversity),
- the protection of unique landscape features,
- ensuring positive impact on nature, on agricultural and forest canopies, and
- the support of multifunctional landscape use in a sustainable way.

The level of ecological landscape stability is given by the skeleton of landscape stability represented by important segments of landscape where the EECONET has to be constructed. Such stabilizing role can be played by forests, perennial tree, shrub or grass cultures, water bodies, old orchards, etc. Present level of presence of stabilizing landscape elements is extremely low in the areas most endangered by desertification and MUST be improved. *"The ECONET is based on the idea that the dynamics of natural (or human accelerated) processes dealing with the landscape stability and balance can be effectively regulated by the sufficient network of connected (linked) stable natural, semi-natural and semi-cultural areas."*

The process of a conscious ecological landscape stabilizing was started in the U.S.A. by the construction of "greenways" in early 1970s. Later it was transferred to Europe and was developed into the principles of construction of European Ecological Networks (EECONETs). The idea of EECONETs is based on the biogeographical "island theory"[26]. The landscape and habitat fragmentation is the result of human activities in the landscape. Now the less stable agrarian and urban areas are dominating, while more stable forest, shrub, water, grass areas are in minority. Only few of them are so large and able to ensure continuous existence of species, their populations and societies. If some of them ("islands") can play the role of a pool, from those areas the others can be resettled if local population extinct. The network of islands and connections between them can ensure survival of natural and for human useful plant and animal species. Because these species are linked with special environments, it is necessary to select and protect representative areas (biocentres) and links (biocorridors) between them for these purposes in any territory. Such ECONETs operate on local, regional, national and continental levels. Greece as other EU member states is responsible for the support of ECONET construction on its territory. The most unstable (ecologically) areas are those endangered by the desertification. Successfully combating desertification can start with the construction of local ECONETs as multifunctional stabilizing systems (not only ecological, but also economical and social) in the most desertification affected or endangered areas. For an example of ECONET constructions, see Figure 21.

Composition of local ECONETS as preferential ways for efficiently combating desertification:

The local *biocentres* play the stabilizing role on a "cadastral" level. They are usually represented with small pieces of land (0,5-1-3-5 ha = 5-10-30-50 stremas), it is not necessary if some protected plant and/or animal species live there. Another much more important role in the desertification risk management can be played by this relatively stable area (forested, and/or with shrubs and/or with grass and/or with abandoned fruit trees and/or water body/wetland) as a factor reducing wind velocity (thus reducing the evapotranspiration), increasing air humidity (thus effectively reducing evapotranspiration), protecting soil cover on the sites predominately exposed to soil erosion (soil cover keeps water in the landscape and reduces surface runoff) and shadowing the soil surface.

Biocorridors are linear landscape segments linking, according to the island theory, areas of biocentres. Also these ones are multifunctional ones serving biotic diversity and improving landscape stability, soil protection and water resources. Corridors linking physically and biologically similar areas are called *connecting biocorridors*, those linking different areas are called *contacting biocorridors*. The maximum biocorridor length on the local level is app. 1-2 km and minimum width is about 10-20 m

Interaction elements are usually very small areas surrounded with intensive agricultural parcels. The transfer of biocentre impacts into the wide unstable landscape represents their role.

The ECONET planning and construction in the landscape on local, regional etc. levels are a part of the territorial planning documentation in many EU member states and it is supported and controlled by laws. Land owners and land users are eligible to apply for financial support from EU funds.

ECONET construction, as a tool for landscape stabilizing, is able to improve the territory resistance to desertification. It consists of multipurpose area and linear elements (see Figure 21). The real composition of the local EECONET respect the land parcels and presence of relatively more stable areas and belts (lines), usually stabilized by forest trees, shrubs, old orchards and non-agricultural herbs, incl. Water bodies accompanied with hygrophylle vegetation.

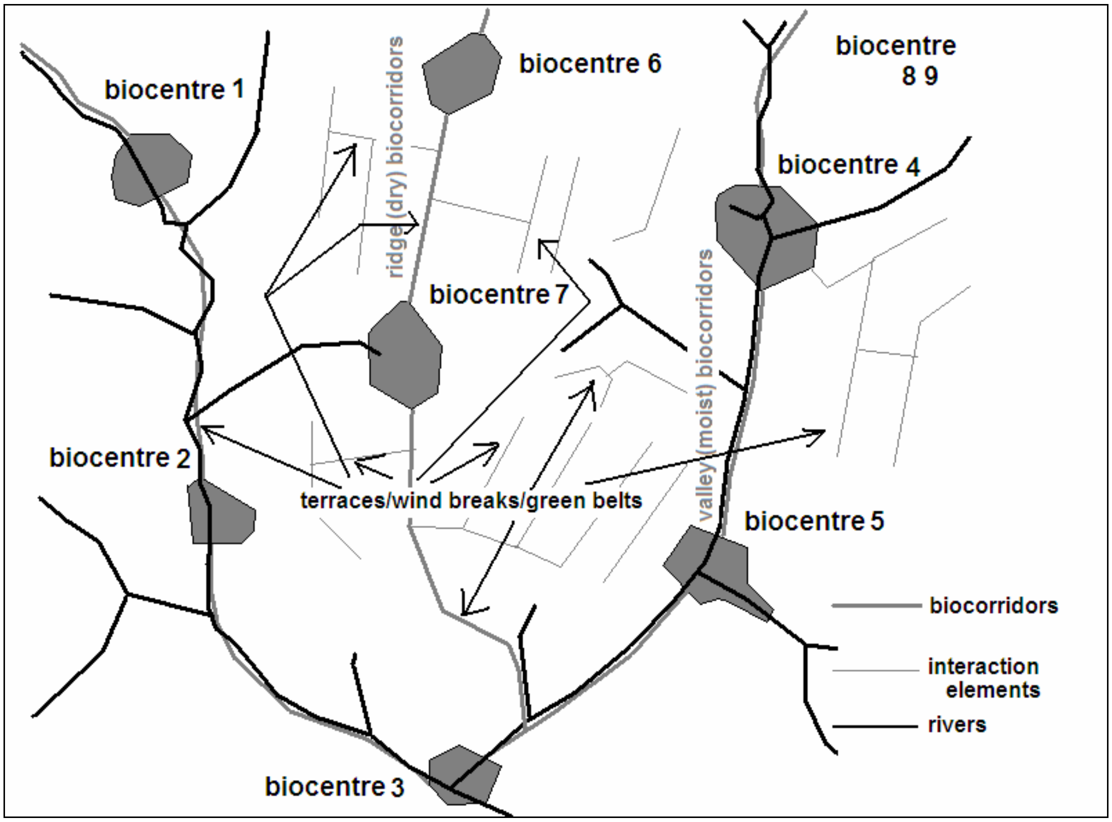

Figure 21 - Example of EECONET construction

The EECONET planning and construction is based on the preliminary "landscape and risk mapping". The landscape mapping consists in the inventory of (1) territory geographical conditions (both the physical and biological) and (2) present land utilizing. The "risk mapping" serves the decision making on the way to define the time table for measures ***selection, location and application*** (including construction). The risk mapping consists in the output desertification risk map provided by the application of the proposed model (see Section 4.2) in the individual study areas (Kilkis, Lesvos, Naxos and Argolida).

6.4.2 Measures reducing the desertification risk by application of EECONET solution

a) Description of the approach - Present land management assessment in natural homogenous units (areas)

Prevention and mitigation actions have to be addressed to real existing territories, where the areas are most endangered by desertification. It means that the solution (action selection, location and application) does not depend on the affected area only (usually represented by parcel, slope section, groups of these, etc.), but must be incorporated into the wider situation and territory. It is necessary because all the introduced solutions can impact wider neighbouring areas.

To proceed to the selection of prevention and mitigation actions, the steps mentioned below should be followed:

Step 1:

Identification of desertification **sensitive areas and their classification** according to their need for a solution/action. Prior to this step the desertification assessment model defined in Section 4.2 should be applied to provide the risk map with eight basic risk classes (see Table 27). The map should then be reclassified into three classes as follows:

- Class N°1: Non affected, Potential, Fragile 1, Fragile 2 and Fragile 3 areas
- Class N°2: Critical 1 and Critical 2 areas
- Class N°3: Critical 3 areas

Step 2:

Identification of possible desertification **target areas that are homogenous** from the viewpoint of at least the desertification cause/triggering and influencing background factors ("natural only" – as they serve as a frame for the selection and introduction of human activities). In practical sense, the procedure starts with the selection of decisive climatic, terrain and soil factors (here they are temperature, slope and depth). The overlay and intersection of the classified data layers in GIS leads to the detection and delineation of areas homogenous from the viewpoint of important (to desertification) climatic, terrain and soil features. These homogeneous areas can be coded by vectors using individual feature classes (vector coordinates are individual feature class numbers).

Step 3:

Provide **introductory desertification statistics for homogenous area classes** about the situation differentiating the classes of homogenous areas from the viewpoint of the percentage (%) of their participation to all desertification threatened areas in the study territory (the ones that contain more than 10% of the total study area affected by the highest desertification risk C3).

Step 4:

Identification of the 50 largest **individual homogenous areas most affected by desertification** (risk) – then restriction of the selection to the 10 that present a higher concentration of C3 pixels, meaning that these areas are more critical from the desertification view point. This task is performed using the geostatistic tools of the GIS software.

Step 5:

Identification of the **present land use structure of the most affected homogenous unit (area) classes** – according to the land use structure given in proportion (%) of any land use in the area of any individual homogenous area class. Four land use forms were considered in this study: Arable land (A), Permanent cultures (P), Green land (G) and Forests (F). The correspondence between these land use forms and the CORINE nomenclature is detailed below:

Table 40 - Correspondence between these land use forms and the CORINE nomenclature

Land Use forms	**CORINE nomenclature**
Arable land (A)	211 - non-irrigated arable land
	212 - permanently irrigated land
	242 - complex cultivation
Permanent cultures (P)	221 - vineyards
	222 - fruit trees/berry plantations
Green land (G)	321 - natural grassland
	323 - sclerophyllous vegetation
Forests (F)	311 - broad-leaved forest
	312 - coniferous forest
	313 - mixed forest
	324 - transitional woodland shrub

Step 6:

Land use identification of the **most endangered homogenous units** (areas) within individual unit classes.

Step 7:

Propose and select the **general prevention/mitigation actions** (as listed in Table 41) to most endangered homogenous area classes – these serve at this level of geodata processing as “black boxes” since their total internal land use description is statistical only. These can be as shown as possible and applicable examples representing whole individual homogenous unit classes (see Table 42).

Table 41 - List of measures applicable in territorial management for desertification mitigation

Measures →	**Geometry ↓**		
	Area (A)	**Line (L)**	**Point (P)**
	- Reforestation (RF) - Permanent cultures (PC) - Water ponds construction (WP) - Biocentre construction (BC)	- Green belt (GB) - Terraces (TE) - Wind breaks (WB) - Fire breaks (FB) - Biocorridor construction (BR)	- Tree/shrub (TS) - Rock outcrop preservation (RO)

Table 42 - Proposed general prevention and mitigation actions (*Solution No.*) related with present land use statistics in the most endangered homogenous unit class

Targeted example area class↓ (with features - code)	LU situation ↓											
	A>80 %			A>60 %, P=5-10 %, G>5 %, F<5 %			A>50 %, P=10-20 %, G>10 %, F>5 %			A>20 %, P>20 %, G>15 %, F>10 %		
	Proposed general prevention and mitigation action(s)↓											
	Area	*Line*	*Point*	*Area*	*Line*	*Point*	*Area*	*Line*	*Point*	*Area*	*Line*	*Point*
411 (15-17°C, flat, deep soils)	PC BC	GB WB BR	TS S1	PC BC	GB WB BR	S5	PC BC	WB BR	S9	BC	BR	S13
421 (15-17°C, gentle slope, deep soils)	PC WP BC	GB WB BR	TS RO S2	PC WP BC	GB WB BR	TS S6	PC WP BC	GB WB BR	S10	WP BC	BR	S14
422 (15-17°C, gentle slope, other soils)	RF PC WP BC	TE WB GB BR	TS RO S3	RF PC WP BC	TE GB BR	TS RO S7	PC WP BC	TE GB BR	RO S11	WP BC	TE BR	S15
432 (15-17°C, steep slope, other soils)	RF PC BC	GB BR FB	TS RO S16	RF PC BC	GB BR	TS RO S16	RF BC	BR FB	TS S17	BC	BR FB	S18
511 (17-20°C, flat, deep soils)	PC BC	WB BR	TS S4	PC BC	WB BR	S8	PC BC	BR	TS S12	BC	BR	S13
522 (17-20°C, gentle slope, other soils)	RF PC WP BC	TE WB GB BR	TS RO S3	RF PC WP BC	TE GB BR	TS RO S7	PC WP BC	TE GB BR	RO S11	WP BC	TE BR	S15
532 (17-20°C, steep slope, other soils)	RF PC BC	GB BR FB	TS RO S16	RF PC BC	GB BR	TS RO S16	RF BC	BR FB	TS S17	BC	BR FB	S18

Step 8:

Selection and location of **real prevention/mitigation actions** to most endangered homogenous areas – these serve at this level of geodata processing as “examples” because every member of natural homogenous unit, regardless its desertification situation, is unique. Some of them can be shown as possible and applicable examples representing individual homogenous units (see Table 45 and Figure 24).

The identification of sources of critical state (situation) has to reflect both the viewpoint of land use (CORINE land use forms participation in %) and selected (“most important”) “natural background conditions” in homogenous areas with “uniform” soil conditions (one soil depth class), climatic conditions (yearly average temperature varies between 3 degrees) and terrain conditions (slope declination varies in predefined interval). It is partially clear from viewpoint of indexing of factors (desertification risk identification), but statistical results going back to the real territory may present (see Table 46) the typical combinations of factors (for desertification risk). Theoretically, the Principle Component Analysis (PCA) can be run using all index values, as well as original data values.

b) Identification of the prevention and mitigation measures to be applied in the different study areas

❖ Results in the prefecture of Kilkis

The application of the methodology proposed in Section 6.4.2a to the prefecture of Kilkis provides the results in Table 43 to 47 and Figure 21 to 23.

Table 43 - Participation of the homogeneous area classes to the desertification threatened areas (with risk C3)

Area unit of class (code)	% of the total area characterized as having a risk C3 in each homogeneous area class
121	0
122	0
131	0
132	0
211	0
212	0
221	0
222	0
231	0
232	0
311	0,037
312	0,0087
321	0,05
322	0,702
331	0,0002
332	0,4726

411	**14,555**
412	4,114
421	**18,069**
422	**25,821**
431	0,3187
432	7,089
121	0
122	0
511	**14,559**
512	2,007
521	5,139
522	5,041
531	0,1337
532	1,88

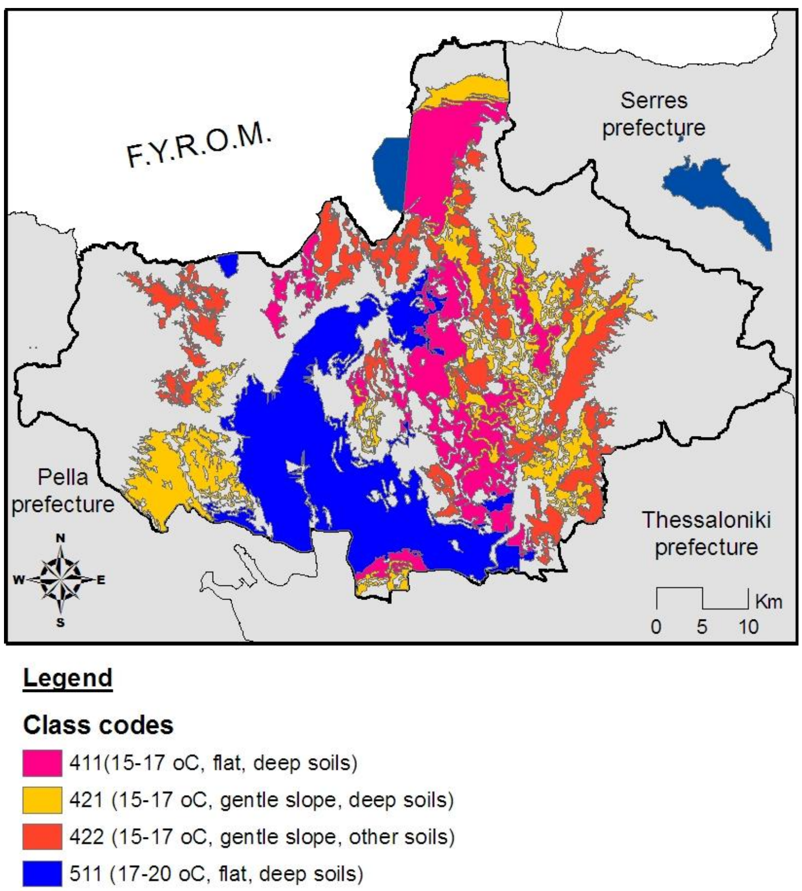

Figure 22 - Location of the 50 largest individual homogenous areas most affected by desertification

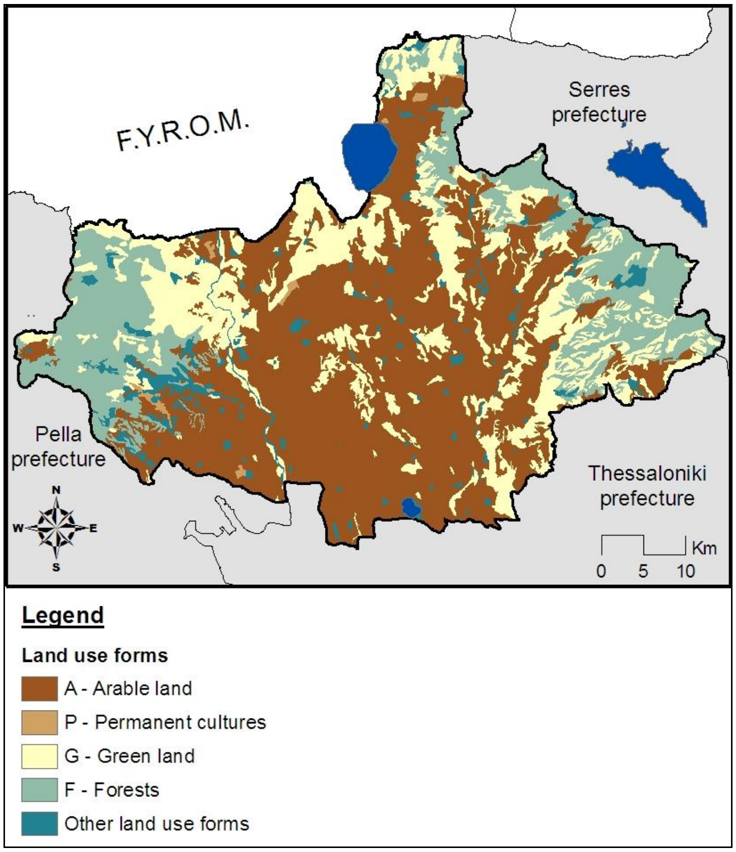

Figure 23 – Land use forms in the prefecture of Kilkis

Table 44 - Present land use situation (in %) in the most endangered homogenous unit classes identified for the area of Kilkis

LU form → **Targeted area class↓** **(with class code)**	**Arable land** **(A)**	**Permanent cultures** **(P)**	**Green land** **(G)**	**Forests** **(F)**
421 (15-17 °C, gentle slope, deep soils)	87,47 %	0 %	12,52 %	0 %
422 (15-17 °C, gentle slope, other soils)	28,87 %	0 %	68,8 %	1,12 %
511 (17-20 °C, flat, deep soils)	98,98 %	0 %	0 %	0 %

Table 45 - Proposed general prevention and mitigation actions (*Solution No.*) related to the present land use statistics in the most endangered homogenous units selected following the general rules in Table 45

Targeted area unit of class (code)	Most endangered homogenous units (Polygon ID)	Proposed solution number	Land use form↓				Percentage of the polygon characterized by a risk C3 (%)
			Arable land (A)	Permanent cultures (P)	Green land (G)	Forests (F)	
421	polygon 83	**S2**	87,47	0	12,53	0	57,27
422	polygon 38	**S11**	56,04	0	43,14	0	64,56
	polygon 46	**S11**	58,51	0	38,44	0	100
	polygon 55	**S15**	14,87	0	85,12	0,01	93,14
	polygon 56	**S15**	14,14	0	85,05	0	64,81
	polygon 68	**S15**	23,61	0	73,45	1,09	58,9
	polygon 70	**S15**	48,04	0	43,72	4,85	57,88
511	polygon 74	**S13**	33,75	0	64,1	1,97	70,03
	polygon 6	**S4**	100	0	0	0	90,26
	polygon 93	**S4**	98,39	0	0	0	80,3

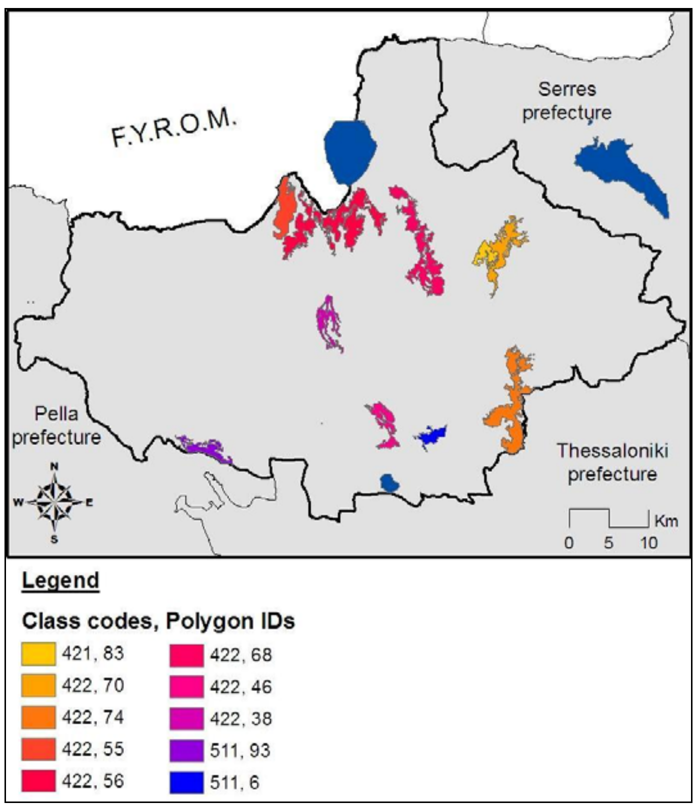

Figure 24 - Assignment of the solution to the 10 most endangered homogenous units representing individual unit classes in the study territory area of Kilkis

Table 46 - Land use statistics for all the homogenous unit classes in the study territory of Kilkis

class codes ↓	LU situation↓ (%)				Percentage of the class area characterized by a risk C3 (%)
	Arable land (A)	Permanent cultures (P)	Green land (G)	Forests (F)	
121	0	0	16,563	83,437	0
122	0	0	49,004	50,996	0
131	0	0	20,26	79,464	0
132	0	0	25,622	74,356	0
211	94	0	5,265	0,113	0
212	100	0	0	0	0
221	18,052	0	13,137	67,782	0
222	31,155	0	22,492	36,785	0
231	1,009	0	17,298	78,537	0
232	4,605	0	15,728	76,752	0
311	82,151	0	8,399	2,249	4,632
312	80,588	0	14,322	0,708	1,16
321	39,158	0,011	17,015	29,551	0,506
322	17,683	0,033	39,318	39,738	2,855
331	0,601	0	20,247	74,593	0,004
332	1,064	0,022	22,126	75,105	2,05
411	87,323	0,892	4,182	0,196	28,55
412	69,872	0	22,828	1,035	75,987
421	72,331	0,903	15,402	5,1	35,778
422	26,011	0,059	63,589	7,688	56,48
431	21,34	0,158	12,696	55,583	19,75
432	0,997	0,24	53,083	42,254	38,748
511	90,165	0,666	4,209	0,061	26,034
512	67,94	0,447	19,721	0,768	84,367
521	74,334	2,386	14,196	3,309	44,04
522	34,639	0,749	55,933	2,499	80,678
531	3,655	0	34,829	1,04	74,41
532	1,656	0	91,364	5,16	82,434

- **Results in the prefecture of Argolida**

The application of the 8 steps to the study territory of Argolida provided the statistics presented in Table 48 to 51 as well as 4 maps (see Figure 24 to 26).

Table 47 - Participation of the homogeneous area classes to the desertification threatened areas (with risk C3)

Area unit of class (code)	% of the total area characterized as having a risk C3 in each homogeneous area class
222	0
232	0
311	0

312	0
321	0
322	0
331	0
332	0
411	0
412	0,1
421	0,02
422	4,48
431	0,02
432	**9,44**
511	1,83
512	3,76
521	1,35
522	**45,69**
531	0,19
532	**33,11**

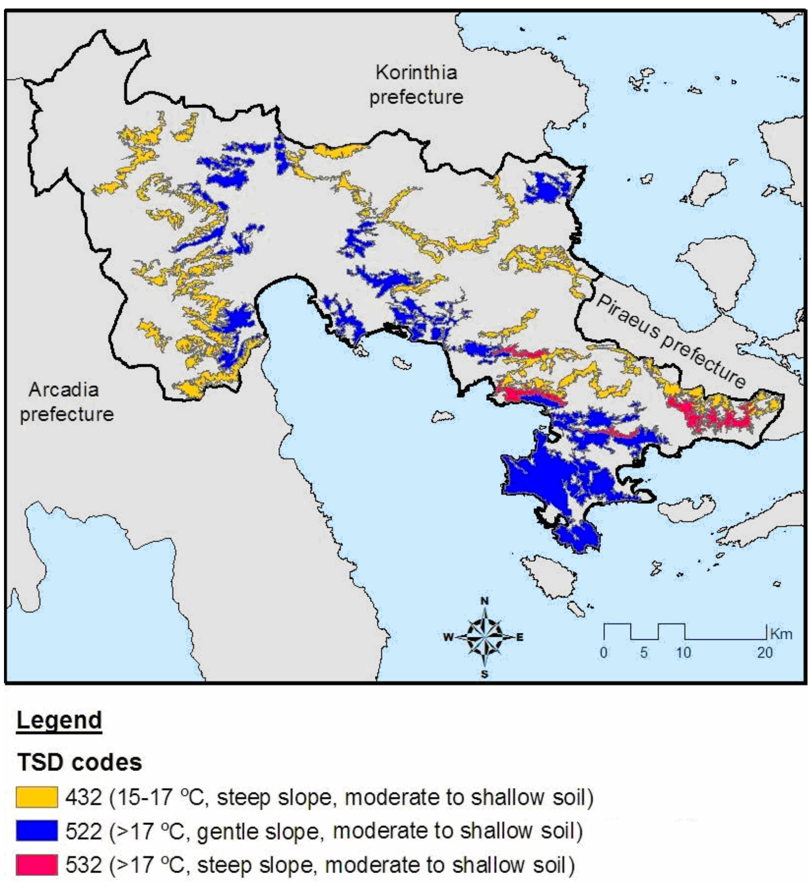

Figure 25 - Location of the 50 largest individual homogenous areas most affected by desertification

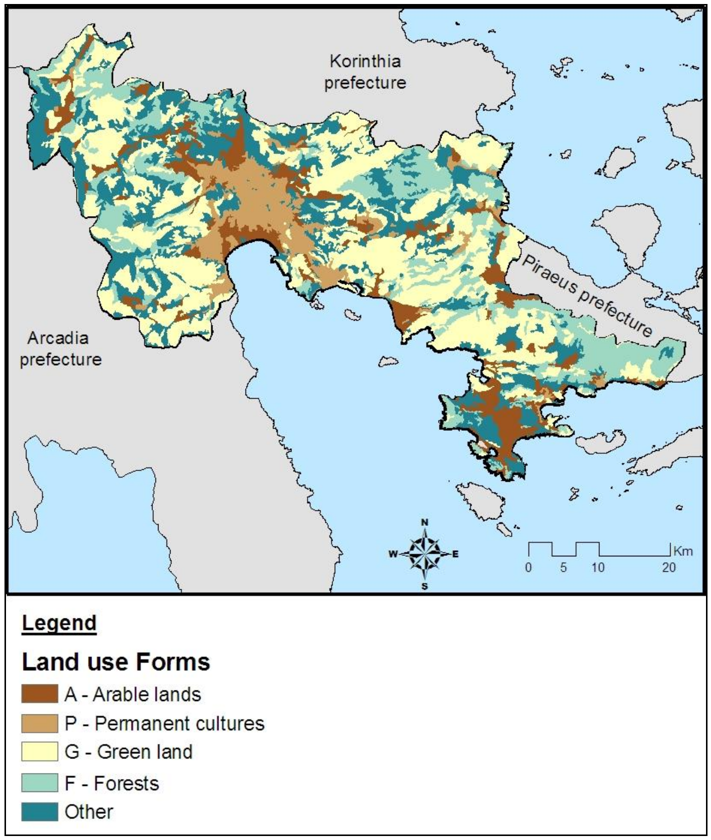

Figure 26 – Land use forms in the prefecture of Argolida

Table 48 - Present land use situation (in %) in the most endangered homogenous unit classes identified for the area of Argolida

LU form → **Targeted area class↓** **(with class code)**	**Arable land (A)**	**Permanent cultures (P)**	**Green land (G)**	**Forests (F)**
522 (>17 ^{o}C, gentle slope, deep soils, moderate to shallow soil)	15,291 %	1,53 %	39,95 %	11,18 %
532 (>17 ^{o}C, steep slope, moderate to shallow soil)	0,443 %	0 %	57,33 %	15,79 %

Table 49 - Proposed general prevention and mitigation actions (*Solution No.*) related to the present land use statistics in the most endangered homogenous units selected following the general rules in Table 45

Targeted area unit of class (code)	**Most endangered homogenous units (Polygon ID)**	**Proposed solution number**	**Land use form↓**				**Percentage of the polygon characterized by a risk C3 (%)**
			Arable land (A)	**Permanent cultures (P)**	**Green land (G)**	**Forests (F)**	
522	**polygon 6**	**S15**	0,13	6,90	59,54	10,92	54,7
	polygon 7	**S15**	0	0,08	84,83	15,09	82,04
	polygon 78	**S15**	5,03	2,11	73,59	3,45	76,18
	polygon 80	**S15**	9,29	4,35	60,87	9,31	89,09
	polygon 83	**S15**	0	0	36,67	1,86	78,27
	polygon 93	**S15**	12,03	0	30,06	16,53	51,91
	polygon 96	**S15**	45,16	0	1,70	10,92	59,98
532	**polygon 84**	**S18**	0	0	8,78	17,39	55,71
	polygon 86	**S18**	0	0	93,03	4,54	72,31
	polygon 90	**S18**	2,16	0	33,07	39,24	82,12

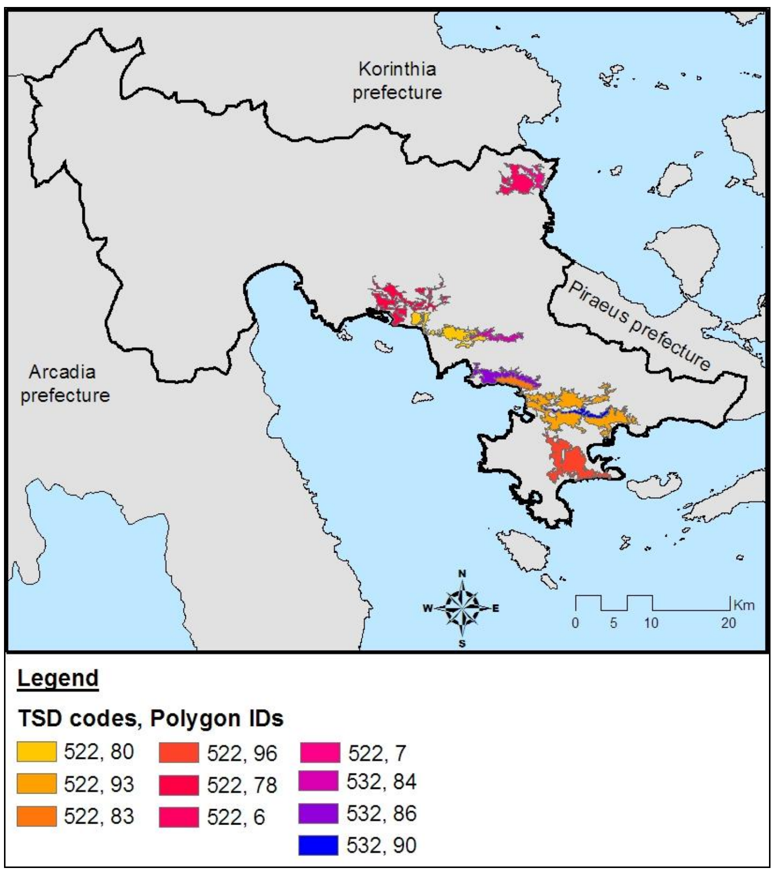

Figure 27 - 10 most endangered homogenous units representing individual unit classes in the study territory area of Argolida

Table 50 - Land use statistics for all the homogenous unit classes in the study territory of Argolida

class codes ↓	LU situation↓ (%)				Percentage of the class area characterized by a risk C3 (%)
	Arable land (A)	Permanent cultures (P)	Green land (G)	Forests (F)	
222	0	0	50,84	6,58	0
232	0	0	21,48	31,2	0
311	66,92	14,61	4,52	2,87	0
312	10,01	1,92	25,39	47,17	0
321	30,92	9,11	4,52	9,73	0
322	4,58	0,62	45,02	26,85	0
331	7,68	0	17,06	43,28	0
332	0,77	0,12	49,27	26,36	0
411	47,95	14,53	3,13	0,11	0
412	42,01	5,68	7,97	0,31	1,81
421	24,02	5,51	15,69	12,86	0,14
422	9,4	3,2	43,57	15,89	3,72
431	4,39	1,82	30,74	50,96	1,31
432	**1,1**	**0,6**	**58,07**	**25,93**	**8,71**
511	29,37	58,38	1,26	0,15	2,39
512	57,12	10,35	10,39	1,41	37,72
521	25,33	17,23	12,62	3,07	5,70
522	**16,03**	**2,60**	**33,30**	**12,85**	**45,32**
531	17,58	5,31	37,89	14,64	14,62
532	**1,94**	**1,08**	**56,00**	**25,36**	**66,69**

❖ **<u>Results in the island of Lesvos</u>**

Below are presented the results obtained from the application of the proposed methodology for the prevention and mitigation desertification in the areas the most at risk (see Table 13 to 16 and Figure 7 to 9)

Table 51 - Participation of the homogeneous area classes to the desertification threatened areas (with risk C3)

Area unit of class (code)	% of the total area characterized as having a risk C3 in each homogeneous area class
222	0
232	0
311	0
312	0,03
321	0
322	1,12
331	0

332	6,19
411	0,71
412	2,51
421	1,81
422	**42,95**
431	0,33
432	**34,67**
511	0
521	0,35
522	3,53
531	0,24
532	5,55

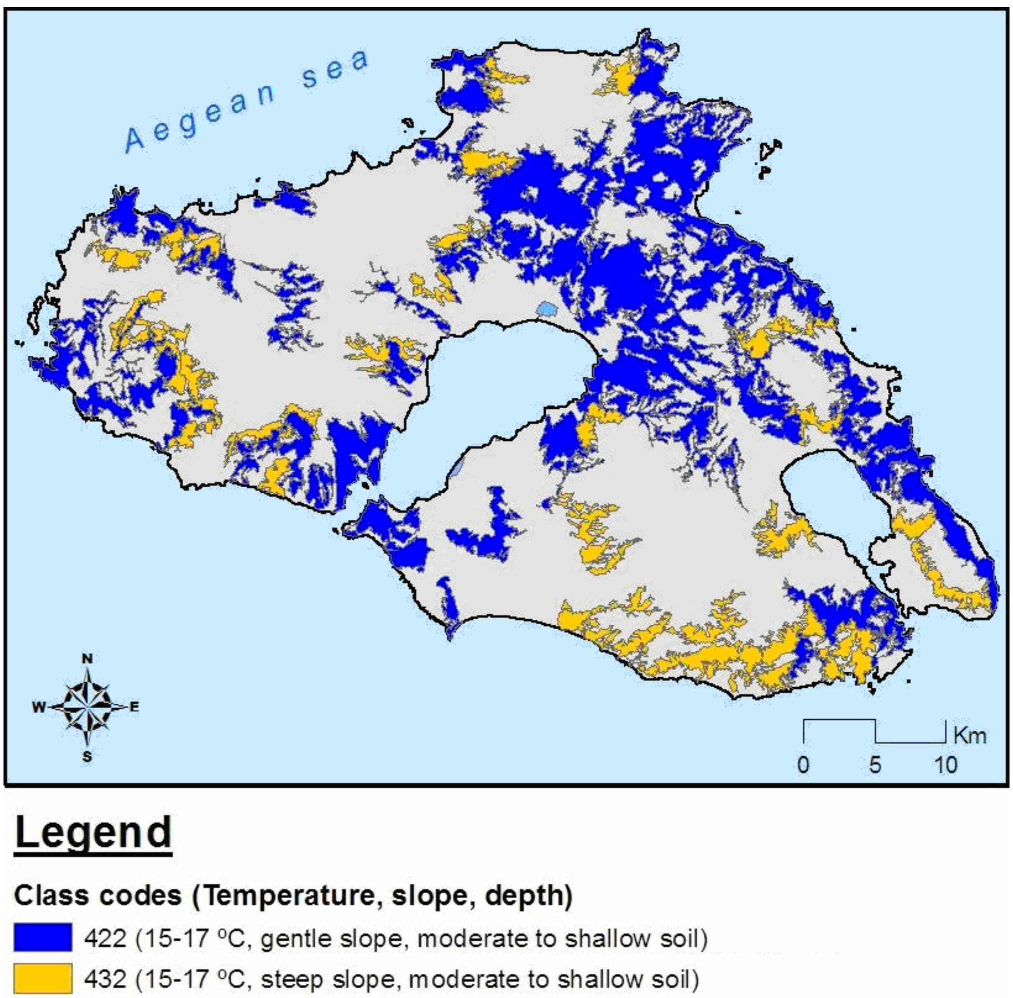

Figure 28 - Location of the 50 largest individual homogenous areas most affected by desertification

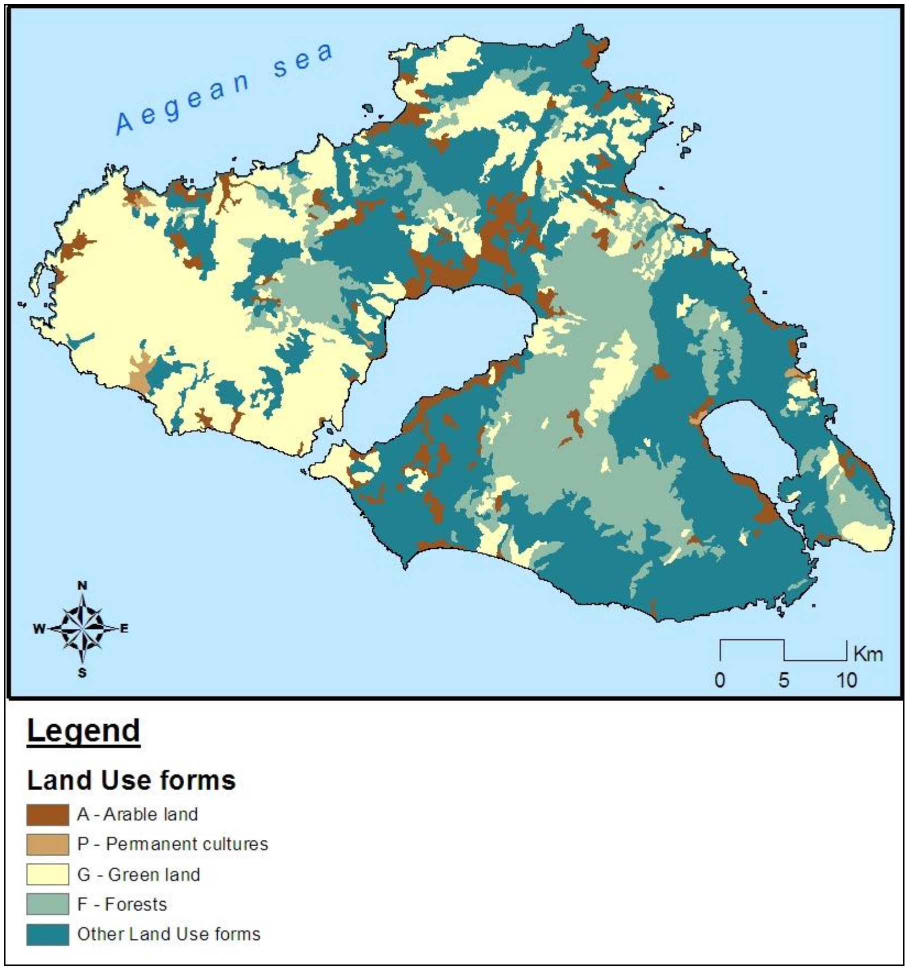

Figure 29 – Land use forms in the island of Lesvos

Table 52 - Present land use situation (in %) in the most endangered homogenous unit classes identified for the island of Lesvos

LU form → **Targeted area class↓** **(with class code)**	**Arable land** **(A)**	**Permanent cultures** **(P)**	**Green land** **(G)**	**Forests** **(F)**
422 (15-17 ºC, gentle slope, deep soils, moderate to shallow soil)	3,91 %	0,181 %	72,352 %	0 %
432 (15-17 ºC, steep slope, moderate to shallow soil)	0,207 %	0 %	97,505 %	0 %

Table 53 - Proposed general prevention and mitigation actions (*Solution No.*) related to the present land use statistics in the most endangered homogenous units selected following the general rules in Table 45

Targeted area unit of class (code)	Most endangered homogenous units (Polygon ID)	Proposed solution number	Land use form↓				Percentage of the polygon characterized by a risk C3 (%)
			Arable land (A)	Permanent cultures (P)	Green land (G)	Forests (F)	
422	**Polygon 10**	**S15**	0,56	0	95,62	0	88,43
	Polygon 12	**S15**	0	0	99,13	0	92,35
	Polygon 21	**S15**	0	0,99	94,88	0	94,72
	Polygon 34	**S15**	12,80	0	13,77	0	92,34
432	**Polygon 14**	**S18**	0	0	100	0	92,81
	Polygon 15	**S18**	0	0	100	0	92,02
	Polygon 16	**S18**	0	0	100	0	90,55
	Polygon 20	**S18**	0	0	97,97	0	88,55
	Polygon 24	**S18**	1,37	0	97,50	0	92,34
	Polygon 26	**S18**	0	0	89,02	0	89,77

Table 54 - Land use statistics for all the homogenous unit classes in the island of Lesvos

class codes ↓	LU situation↓				Percentage of the class area characterized by a risk C3 (%)
	Arable land (A)	Permanent cultures (P)	Green land (G)	Forests (F)	
222	0	0	30,65	69,27	0
232	0	0	23,49	71,99	0,02
311	73,22	0	0,91	4,49	0
312	12,08	0	53,16	23,11	2,72
321	31,80	0	1,46	7,45	0,04
322	3,60	0	33,41	36,95	5,21
331	0	0	4,00	19,33	14,84
332	0,18	0	28,17	39,68	15,18
411	42,94	4,74	2,05	0,04	5,10
412	20,21	0,37	26,30	11,64	48,17
421	14,19	1,14	7,02	0,31	15,59
422	5,51	0,19	34,28	15,63	57,55
431	1,39	0,05	9,81	4,51	49,12
432	1,06	0	37,06	15,43	73,02
511	22,58	6,45	0	0	26,67
521	12,44	2,31	23,13	0	50,99
522	2,95	1,01	48,78	7,25	97,91
531	1,95	0	27,72	3,02	92,78
532	0,52	0	44,52	7,42	99,26

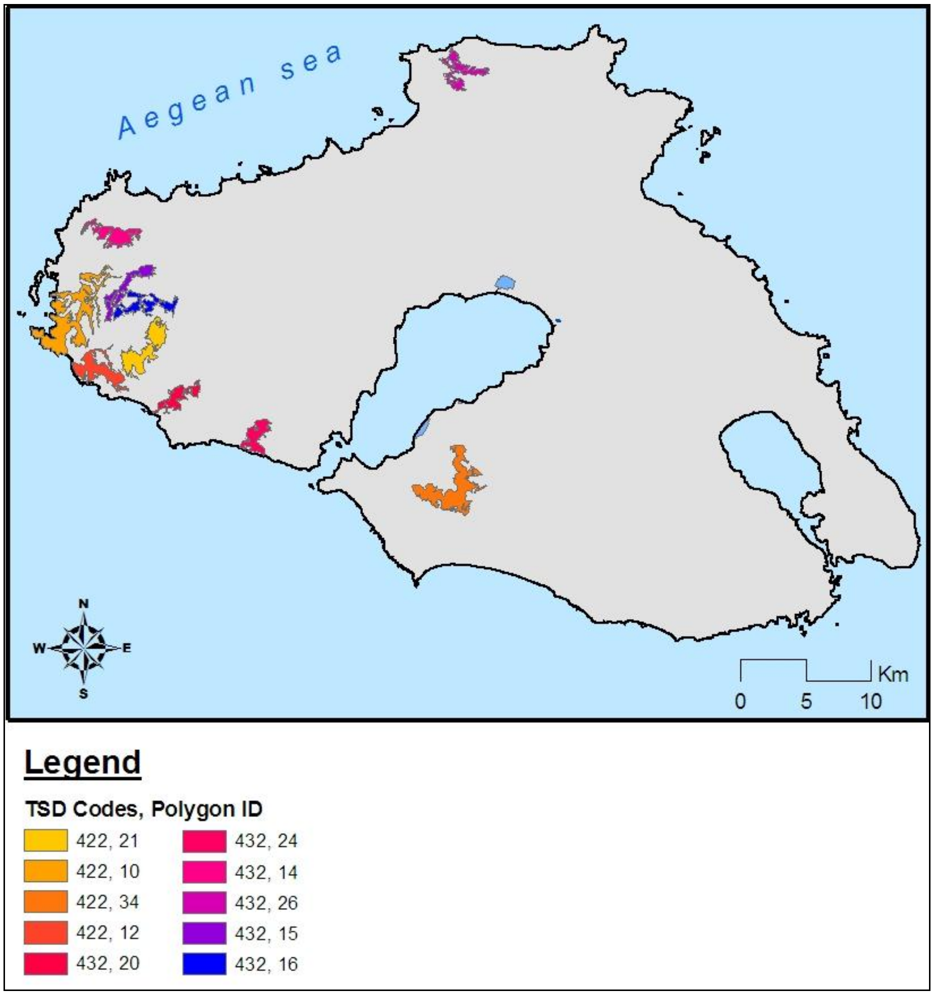

Figure 30 - 10 most endangered homogenous units representing individual unit classes in the island of Lesvos

❖ <u>Results in the island of Naxos</u>

Below are presented the results obtained from the application of the proposed methodology for the prevention and mitigation desertification in the areas the most at risk (see Table 17 to 20 and Figure 10 to 12)

Table 55 - Participation of the homogeneous area classes to the desertification threatened areas (with risk C3)

Area unit of class (code)	**% of the total area characterized as having a risk C3 in each homogeneous area class**
322	0
332	0
412	0
422	0,73

431	0
432	**10,05**
511	0,14
512	3,61
521	0,03
522	**38,4**
531	0
532	**47,04**

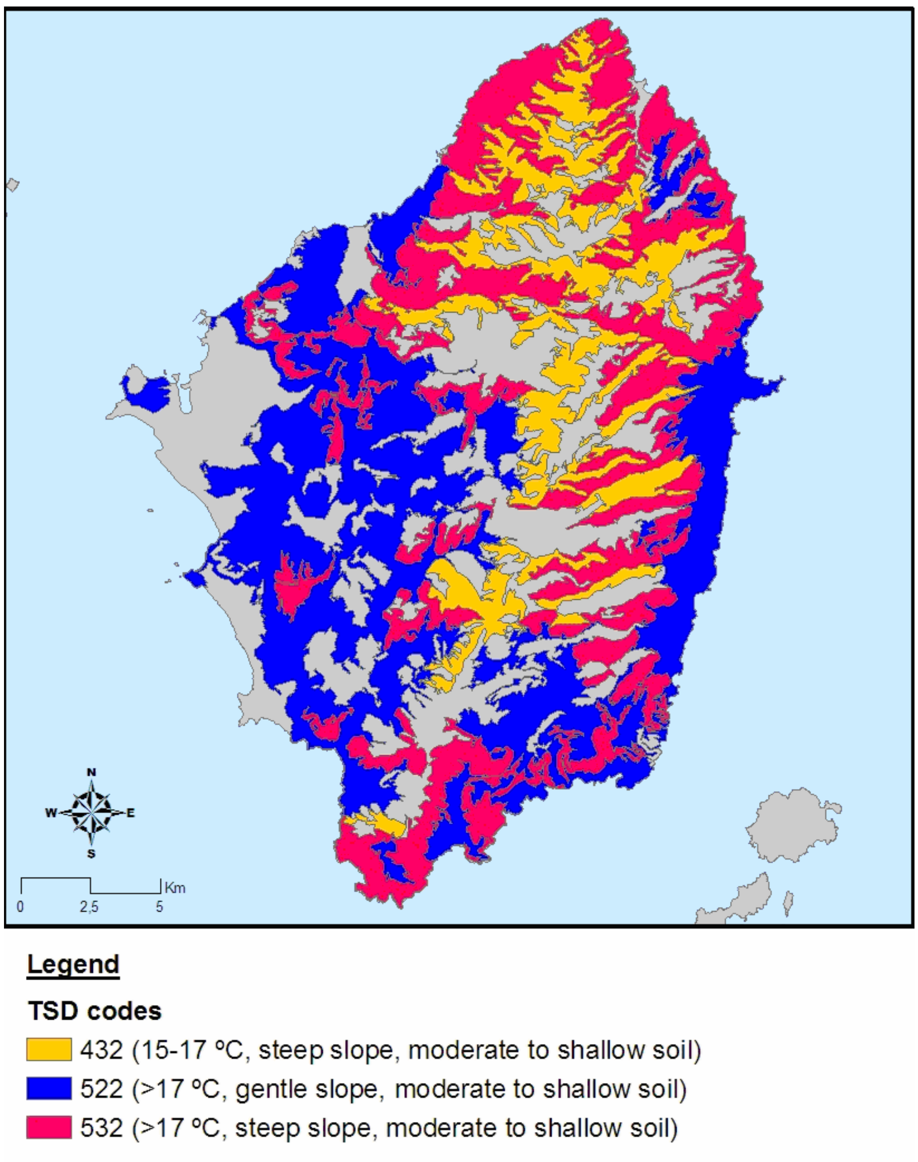

Figure 31 - Location of the 50 largest individual homogenous areas most affected by desertification

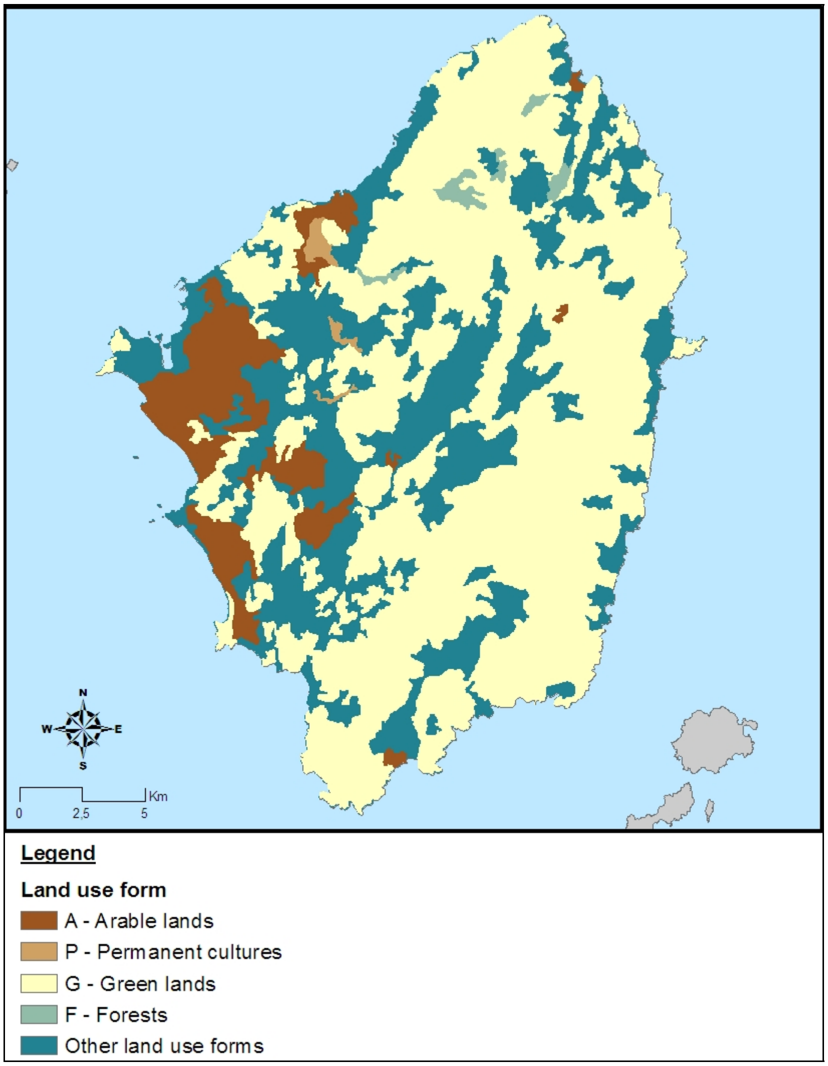

Figure 32 – Land use forms in the island of Naxos

Table 56 - Present land use situation (in %) in the most endangered homogenous unit classes identified for the island of Naxos

LU form → **Targeted area class↓** **(with class code)**	**Arable land** **(A)**	**Permanent cultures** **(P)**	**Green land** **(G)**	**Forests** **(F)**
522 (>17 °C, gentle slope, deep soils, moderate to shallow soil)	0 %	0 %	71,744 %	0 %
532 (>17 °C, steep slope, moderate to shallow soil)	0,781 %	0 %	88,67 %	0 %

Table 57 - Proposed general prevention and mitigation actions (*Solution No.*) related to the present land use statistics in the most endangered homogenous units selected following the general rules in Table 45

Targeted area unit of class (code)	Most endangered homogenous units (Polygon ID)	Proposed solution number	Land use form↓				Percentage of the polygon characterized by a risk C3 (%)
			Arable land (A)	Permanent cultures (P)	Green land (G)	Forests (F)	
522	**polygon 28**	**S15**	0	0	71,74	0	100
532	**polygon 13**	**S18**	6,49	0	64,85	0	98,16
	polygon 20	**S18**	0	0	100	0	98,05
	polygon 21	**S18**	0	0	94,79	0	96,80
	Polygon 22	**S18**	0	0	99,57	0	98,70
	Polygon 24	**S18**	0	0	94,67	0	98,05
	Polygon 25	**S18**	0	0	99,97	0	98,85
	Polygon 44	**S18**	0	0	100	0	99,22
	Polygon 48	**S18**	0	0	99,43	0	96,29
	Polygon 49	**S18**	0,26	0	82,78	0	99,46

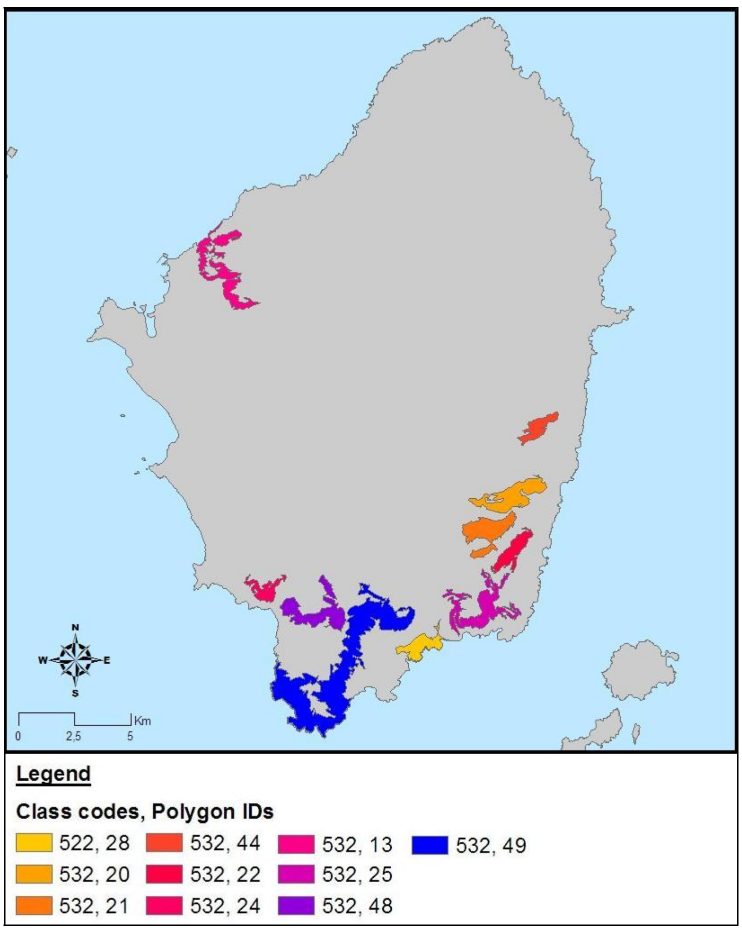

Figure 33 - 10 most endangered homogenous units representing individual unit classes in the island of Naxos

Table 58 - Land use statistics for all the homogenous unit classes in the island of Naxos

class codes ↓	**LU situation↓ (%)**				**Percentage of the class area characterized by a risk C3 (%)**
	Arable land (A)	**Permanent cultures (P)**	**Green land (G)**	**Forests (F)**	
322	0	0	61,04	1,30	0
332	0	0	73,78	5,77	0,03
412	0	0	75,30	0	0
422	0,11	0	61,09	0,17	10,22
431	0	33,33	0	0	0
432	0,18	0,01	80,13	2,94	31,63
511	74,25	6,73	0,04	0	2,55
512	56,65	0,49	6,60	0	34,66
521	48,32	23,94	11,86	0	4,99
522	8,47	0,53	45,80	0,08	60,79
531	59,09	31,82	6,82	0	6,82
532	0,41	0,14	79,86	0,52	79,73

General rules for any local ECONET construction can be stated based on the natural background (natural features represented with homogenous units: parent material, climate, soils, etc.) and present land use structure, and the degree of sensitivity to desertification. Most of ECONET elements were represented with the measures listed in Table 41, but here are connected and mutually balanced in a representative multipurpose, efficiently operating landscape stabilizing system (see Figure 34).

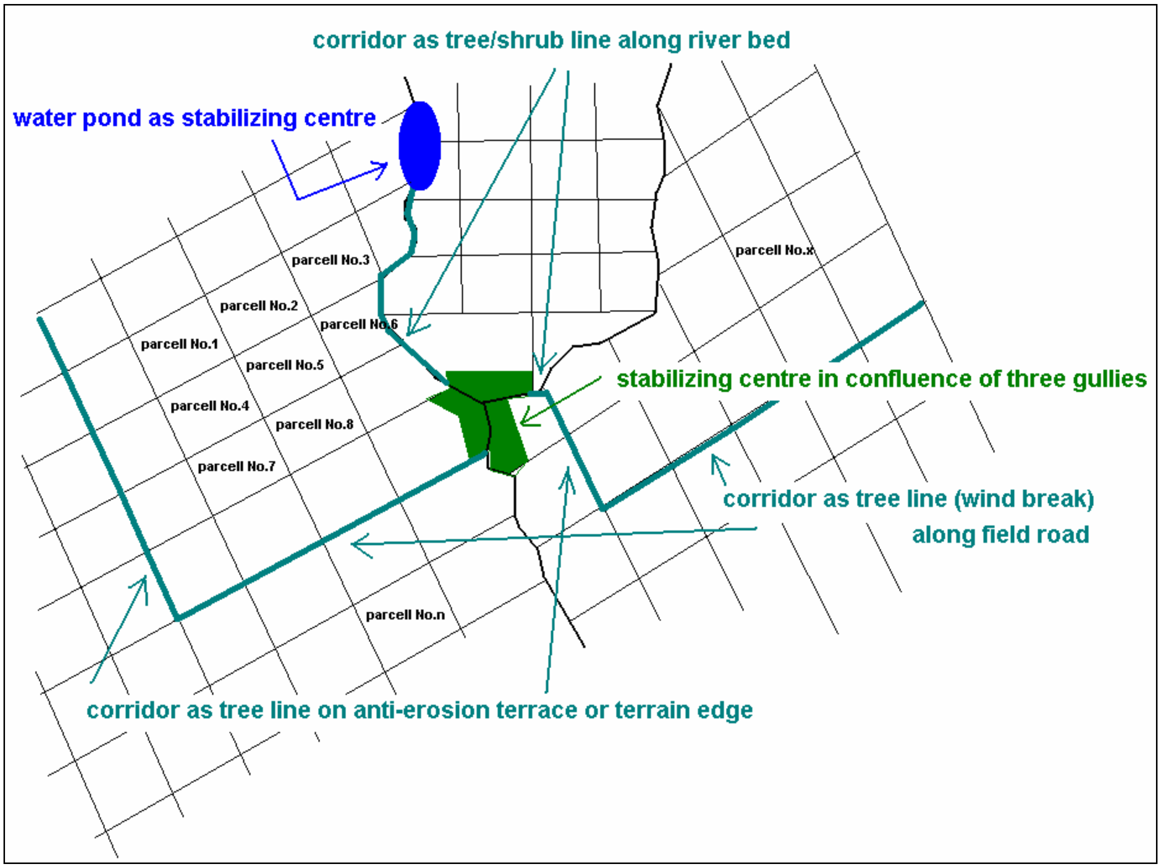

Figure 34 - Composition of the local EECONET

7 Conclusion

The present SAD guide presents a detailed analysis of the methodology that can be followed in order to effectively combat desertification. In fact, the approach developed by the MOONRISES project for the identification of the areas the most affected by desertification was applied and results were presented in the guide. The MOONRISES, unlike some past project, was not aimed at extending the knowledge of the desertification processes but rather to acquire and adapt this knowledge in order to develop and test an easily applicable method for assessing the desertification risk in various target areas.

Since the European Commission stresses the need for prevention and mitigation measures in order to respectively avoid and limit the spread of desertification, the guide also describes a methodology for the selection of the appropriate measures to be applied in areas identified as critically sensitive to desertification. Also, the policy context described in this guide permits to figure out how the selected measures can be integrated in a national or regional plan in order to be effectively applied.

Moreover, the monitoring is presented as a crucial issue for the evaluation of the measures efficiency. It is even more important since the foreseen change of climate conditions may increase the pressures on the environment and thus increase the risk of desertification. The regular and long-term monitoring of desertification will therefore help a rapid detection of any increase in desertification risks.

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