Article

Evaluating the Degradation of Natural Resources in the Mediterranean Environment Using the Water and Land Resources Degradation Index, the Case of Crete Island

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Abstract: Natural resources degradation poses multiple challenges particularly to environmental and economic processes. It is usually difficult to identify the degree of degradation and the critical vulnerability values in the affected systems. Thus, among other tools, indices (composite indicators) may also describe these complex systems or phenomena. In this approach, the Water and Land Resources Degradation Index was applied to the fifth largest Mediterranean island, Crete, for the 1999–2014 period. The Water and Land Resources Degradation Index uses 11 water and soil resources related indicators: Aridity Index, Water Demand, Drought Impacts, Drought Resistance Water Resources Infrastructure, Land Use Intensity, Soil Parent Material, Plant Cover, Rainfall, Slope, and Soil Texture. The aim is to identify the sensitive areas to degradation due to anthropogenic interventions and natural processes, as well as their vulnerability status. The results for Crete Island indicate that prolonged water resources shortages due to low average precipitation values or high water demand (especially in the agricultural sector), may significantly affect Water and Land degradation processes. Hence, Water and Land Resources Degradation Index could serve as an extra tool to assist policymakers to improve their decisions to combat Natural Resources degradation.

Keywords: natural resources; contingency planning; spatial analysis; risk assessment; geographical information systems

1. Introduction

Numerous challenges are linked to natural resources degradation, such as pollution, water scarcity and stress, overexploitation, extreme hydrological events (droughts and floods) soil erosion and desertification [1–8]. In addition, the compound effect of anthropogenic interventions and inappropriate and/or uncoordinated management actions to use and/or protect natural resources could cause significant environmental degradation that may even be irreversible in vulnerable ecosystems [9,10]. A degraded ecosystem

may not rehabilitated beyond a critical point. Contingency planning incorporating an appropriate environmental design may play a major role in vulnerable cases, so as to prevent irreversible conditions and mitigate potential risks [10–15]. The combination of population growth accompanied by increasing demands, unsustainable natural resources use, and climate variabilities and changes have accelerated natural resources' degradation. Agricultural production practices, especially in developing countries may have dramatic socioeconomic impacts in such fragile states, including spurring potential conflicts and instability that may lead to higher internal and external migration fluxes [16,17]. It has been noted that the majority of the previously reported environmental or natural resources scarcity–induced conflicts have been proved to be processual [18]. It is essential for the policymakers to follow the guidelines, methods and strategies set by the experts for the integrated management of such ecosystems [19–21].

Water, the most widely used component of the Earth, covers about 70% of the planet's surface and is vital for any form of life [22,23]. It is also the most crucial solvent and transporter of ingredients in plants, animals, humans, and all-natural processes performed on Earth [24,25]. Water is in constant motion and usually represented through the hydrological cycle, and then water budgets. Thus, the increasingly intensive development of water resources projects on a global scale, simultaneously to continuously increasing water demands, has made imperative the implementation of integrated methods for water management [26,27]. The growth of the world's population, the intensity of urbanization, and the changes in land use affect water availability to the extent that its reserves would be significantly unable to fulfil the increasing demands, or become non-exploitable due to pollution and contamination [28]. The above reasons may cause conflicts among different users (urban use, irrigation, industry, and other uses) for accessing the needed water. For example, the total area of wetlands in the USA decreased from 890,300 km^2 before 1998 to 435,600 km^2 after 2004 [29].

Soil is one of the valued natural resources; the preservation of terrestrial life on the planet and its economy depends on the soil conditions at both local and global level [30–32]. Soil is the highest layer of the Earth's surface and divides the atmosphere from the lithosphere [33]. The soil is generally a mixture of decomposed geological material, mineral nutrients, voids, moisture, air, oxygen, and decomposed organic matter [34–36]. Soil is considered to be a renewable natural resource and it is formed at a prolonged low rate [37]. In brief, soil is the basis of agricultural and forestry production, and is the living space of organisms, the natural filter or contaminant, the first layer of groundwater reserves, and contributing to a large enough degree as the medium for the feeding of the population [31,38–40].

Urbanization through land-use changes leads usually to the fragmentation of ecosystems and poses a significant threat to wildlife [19]. At the same time, urbanization increases non-food species dominance in specific areas and alters the existing balances developed over time and through adaptation between edible species [41]. In the USA alone, more than 10% of the edible species are considered endangered [42]. The fragmentation of ecosystems and the expansion of non-food species may be the main factors such an endangerment of the edible species as they affect respectively the 85% and 49% of these species [43–45].

Overall, Indicators and indices (composite indicators) are either complex or simple ones. They provide information or describe a phenomenon and are recognized as valuable and powerful tools to characterize the situation of a process or a system [46,47]. The indicators are mostly derived from the appropriate selection of processes and of corresponding appropriate data. They are used to simplify, quantify and express information on complex phenomena, thus facilitating communication and decision-making [12,13,47–50]. The value of such tools increases when, due mostly to lack of direct measurable information, indicators may be the only means to provide the required relevant information [51]. The assessment of ecosystem services is an example of such use [44,48,49]. In other words, the indicators play the role of a communication channel between the parts of a complex reality and the policymakers [44,49,50]. There are two main categories of indicators, (i) simple

ones, using individual variables that describe specific dimensions of the phenomenon or system under study and provide limited information and (ii) composite indicators, created by groups of simple indicators so as to synergistically describe complex systems or phenomena [2,49,52–54].

The significance of such tools in policymaking and decision-making is usually reflected in the large and continuously-increasing number of composite indices synthesized from various usually more simple indicators, both to describe a multitude of phenomena and to assess the performance of different regions and countries in terms of specific objectives (i.e., environmental sustainability). However, complex indices have provoked many reactions related to their objectivity and reliability [55,56]. To some extent, these reactions may be considered justified, as the process of developing complex indices involves certain stages, at which the degree of subjectivity may be relatively high [53]. At such stages, the developers of an indicator usually select or create the various tools to carry out the indicator's aim. Thus, it may be considered appropriate that these stages would "bear the signature" of the developer concerned and they are characterized by the composite indicators reliability [9,10,46,52]. In this context, the central objective of the present work is to find common drivers for the pressures inflicted by drought and desertification as they portrayed by the application of WLDI (Water and Land Degradation Index) in the area. Furthermore, according to the well-known DPSIR (drivers, pressures, state, impact and responses) framework, driving forces are applying pressure on a system [12,57–59]. Thus, the main scope of the current study is to identify the soil and water resources degradation status through the application of the already developed composite index WLDI for the period 1999–2014 [59]. As described in detail by the index development process [59], it uses 11 indicators, namely Aridity Index (AI), Water Demand (WD), Vegetation Drought Impacts (VDI), Vegetation Drought Resilience (VDR), Water Resources Infrastructure (WRI), Land Use Intensity (LUI), Soil Parent Material (SPM), Plant Cover (PC), Rainfall (R), Slope (S), and Soil Texture (ST).

2. Materials and Methods

2.1. Study Areas and Data

Greece, as a Mediterranean country, faces frequently extreme hydrological events, especially droughts, and is considered as an ideal case for the development and application of the WLDI. In this work, WLDI applied in the Greek island of Crete (Figure 1) for the period 1999 to 2014.

Crete is the largest Greek island and the fifth largest one in the Mediterranean Sea. Administratively, it constitutes along with a number of small peripheral islands and islets, the Region of Crete, with Heraklion being the capital and the largest city of the island. According to the Hellenic Statistical Service, the population of Crete was 623,065 inhabitants in 2011. Crete has a Mediterranean climate, with mild, rainy winters and dry hot, sunny summers. According to the European Centre for Medium-Range Weather Forecasts (ECMWF), relevant climate parameters of Crete are in Table 1.

The climate data were taken from the ECMWF and were transformed in the referred time step [60]. Climate data used are Temperature (maximum, minimum and average), Relative Humidity (maximum, minimum and average), Precipitation, Wind Speed (maximum and average) and Solar Radiation from 22 grid cells ($0.25° \times 0.25°$) on a daily basis (Table 1). These parameters were used to estimate the various indicators (Potential Evapotranspiration (ETp), Aridity, and Rainfall).

The Water Demand indicator was calculated utilizing Evapotranspiration (ETp), the crop coefficients for each irrigated cultivation and the population water consumption including tourism [60–64]. Based on Landsat 7, sixteen annual Enhanced Vegetation Index (EVI) maps for drought events impacts have been collected [65–67]. Finally, the soil and vegetation parameters calculated based on soil mapping and databases according to the Corine Land Cover 2012 [68,69].

The current methodology for the WLDI development has followed the "XERASIA" framework as already described in [58,59,70]. It is important to note again that aridity, which occurs in areas with continuous low rainfall, and as a permanent climatic feature is quite different from temporary water shortages. The latter show a deviation from the average state, but they are still within the natural variability of the system. In addition, the induced changes such as desertification caused by human activities mostly by misuse of soil and water resources and unstainable cultivation practices must be distinguished from drought which has natural causes [58,59,70]. All such conditions signify water deficits. It is very difficult to find a definition of drought universally accepted by all societal activities, and at the same time by all the specializations of the scientific community [58]. Whatever the definition and the general context in which drought is portrayed, it should always be related to its impacts, taking into account the existing environmental, social, economic and technological characteristics [49,58,59,71].

Figure 1. Crete, Greece. The study area and the polygons (1–20) used for downscaling (Hellenic Geodetic Reference System 1987—HGRS87).

Table 1. Monthly values for Temperature (minimum, maximum and average) Relative Humidity (maximum, minimum and average), Wind Speed (average) and Solar Radiation (1999–2014).

ID	Tmin (°C)	Tmax (°C)	Tavg (°C)	Rs (W/m^2)	RHmin (%)	RHmax (%)	RHavg (%)	WSavg (m/s)
1	16.0	19.4	17.5	217.5	66.8	82.2	74.8	5.3
2	14.3	19.6	16.8	214.5	65.8	82.0	74.2	4.4
3	14.1	18.0	15.8	217.1	66.8	82.5	75.0	4.5
4	11.4	18.6	14.8	214.5	65.9	82.1	74.3	3.4
5	13.8	20.1	16.7	217.2	66.4	82.5	74.8	3.4
6	15.8	19.4	17.5	214.9	66.1	81.9	74.4	4.1
7	13.1	20.0	16.2	218.2	66.4	82.5	74.8	3.5
8	17.6	19.7	18.6	215.4	66.4	82.0	74.6	5.0
9	17.3	20.0	18.5	221.1	66.8	81.5	74.5	5.0
10	12.1	18.3	14.9	218.4	66.3	82.3	74.7	3.3
11	16.2	18.7	17.4	216.6	66.5	81.9	74.6	4.5
12	17.2	20.1	18.5	221.0	66.6	81.2	74.2	5.2
13	12.3	19.0	15.3	218.5	66.2	81.9	74.5	3.5
14	17.0	20.0	18.3	221.1	66.5	81.0	74.1	5.5
15	12.3	19.4	15.5	218.5	66.2	81.8	74.4	3.6
16	16.8	19.6	18.0	221.4	66.5	80.9	74.1	5.1
17	12.0	19.0	15.1	218.7	66.2	81.6	74.3	3.6
18	17.3	19.8	18.5	221.5	66.3	80.5	73.7	5.3
19	16.7	19.3	17.9	219.8	66.4	80.9	74.0	5.5
20	17.5	20.2	18.7	222.0	66.2	80.4	73.7	5.5
21	16.4	20.0	18.0	220.7	66.3	80.8	73.9	5.4
22	16.8	20.4	18.4	221.5	65.9	80.4	73.5	5.8

2.2. Methodology for the Indicators Calculation in WLDI

The spatial results of WLDI computed based on remote sensing information, demographics, and soil data described in the previous session as described in detail [59]. It is just pointed out that the WLDI calculated on a multiannual time step (1999–2014) as the degradation of natural resources usually has a slow onset and development. Briefly the steps for the WLDI implementation highlighted in the following [59].

The Bagnouls-Gaussen aridity index (BGI) is calculated using Equation (1), where T_i is the monthly average temperature, P_i the monthly precipitation and k the factor symbolizing the cases of the month where $2T_i - P_i$ is positive. Then:

$$\text{BGI} = \sum_{I=1}^{n} (2T_i - P_i) \times k \qquad (1)$$

Based on the Enhanced Vegetation Index (EVI) annual values, the Vegetation Drought Impacts indicator was derived for the referred period 1999–2014 [67]. The values of EVI transformed drought impacts based on Jenks Natural breaks and presented in the following Table 2.

Table 2. Transformation from EVI spatial values to Drought Impacts Indicator.

EVI Classes	Vegetation Drought Impacts	Description
−1.00–0.14	3.0	>50% Losses
0.14–0.27	2.0	16–50% Losses
0.27–0.62	1.0	15% Losses
0.62–1.00	0.0	None

The indicators participating in the Vegetation Drought Resilience, Land Use Intensity, and Plant Cover (Vegetation parameters) produced from Corine Land Cover 2012, the Soil Parent Material and the Soil Texture are reclassified according to the procedure [59,69,72]. Then, ECMWF climate data are used to calculate monthly and annual values of the pertinent parameters [59,60]. The precipitation downscaling transformation from polygons to spatial distribution used the simple co Kriging based on semi-variograms and covariances (Figure 1 Map 6). Copais ET method was employed due to its better estimations comparing to other models, including Penman-Monteith formula, standardized by the Food and Agriculture Organization (FAO-56PM) [59,73–75].The Water Demand indicator calculated according to the ET Copais method. Crop coefficients were used for each irrigated cultivation water consumption introduced as noted [59]. The water demand used includes domestic and touristic consumptions during the summer season, as suggested [60–64,76,77]. Finally, slope indicators are extracted from the Shuttle Radar Topography Mission (SRTM) data [78]. The Principal Components Analysis (PCA) statistical method Equation (2) applied and produced Equation (2) using all the above-mentioned data, according to the WLDI development as described [59].

The classification of the WLDI outputs is depicted in Table 3 accordingly [49,59].

$$
\begin{aligned}
\text{WLDI} = {} & 18.2 \times \text{AI} + 7.2 \times \text{VDI} + 6.8 \times \text{VDR} + 9.4 \times \text{WRI} + 8.0 \times \text{LUI} + 10.6 \times \text{PC} \\
& + 7.6 \times \text{R} + 9.4 \times \text{S} + 7.7 \times \text{SPM} + 4.1 \times \text{ST} + 11.0 \times \text{WD}
\end{aligned}
\tag{2}
$$

According to the stated the methodology, the first step of the whole effort includes the calculation and visualization of the indicators within the area of interest [59]. Then, all the parameters transformed into their respective scaled values and the WLDI was calculated and visualized. Using the data from the above-mentioned indicators, the composite index calculated to identify the study area's soil and water resources degradation for the specific period in accordance to the produced map. The result of this composite index scaled values presented in Table 4.

The most vulnerable areas to degradation, for the 1999–2014 period, determined by calculating WLDI and then deriving the common drivers' characteristics. The used time scale corresponds to the available data for climate, soil, vegetation and economic indicators [59].

Table 3. WLDI components and degradation scales [45,68,69,76,77].

Aridity Index (BGI Range)		Water Demand		Vegetation Drought Impacts		Vegetation Drought Resilience		Water Resources Infrastructure		Land Use Intensity		Soil Parent Material		Plant Cover		Rainfall		Slope		Soil Texture	
<50	1.0	No Deficits	0.0	None	0.0	Very high	1.0	No Deficits	0.0	Low	1.0	Good	1.0	High	1.0	>650	1.0	<6	1.0	Good	1.0
50–75	1.1	15% Deficits	1.0	15% Losses	1.0	High	1.2	15% Deficits	1.0	Medium	1.5	Moderate	1.7	Low	1.8	280–650	2.0	6–18	1.2	Moderate	1.2
75–100	1.2	16–50% Deficits	2.0	16–50% Losses	2.0	Medium	1.3	16–50% Deficits	2.0	High	2.0	Poor	2.0	Very Low	2.0	<280	4.0	18–35	1.5	Poor	1.6
100–125	1.4	>50% Deficits	3.0	>50% Losses	3.0	Moderate	1.4	>50% Deficits	3.0	-	-	-	-	-	-	-	-	>35	2.0	Very Poor	2.0
125–150	1.8	-	-	-	-	Low	1.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-
>150	2.0	-	-	-	-	Very Low	2.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 4. WLDI scaled values of degradation degree [49,59].

Classes	Values	Description
1	<94	No degradation
2	94–118	Very Low Degradation
3	118–142	Low Degradation
4	142–167	Mild Degradation
5	167–191	Moderate Degradation
6	191–215	High Degradation
7	>215	Extreme Degradation

3. Results

3.1. Results of WLDI Used Indicators

The spatial distribution of the values of the indicators used for the calculation of WLDI in the study area presented in Figure 2. For example, in terms of the Aridity Index, high values presented in southern and south-eastern Crete. In terms of Rainfall, high values are in western Crete, and, in terms of Slope, high values presented mainly in the mountainous areas. According to the weights and the maximum value of indicators, the more significant factors are the Aridity index, Rainfall and Water Demand [59].

In addition, vegetation factors play a significant role. Especially, Vegetation Drought Resistance, Vegetation Drought Impacts and Pant cover indicators represent the 24.6% of WLDI values in the equation. However, there are annual agricultural crops and annual grasslands (Figure 2, Map 3) which have very low drought resilience.

Specifically, BGI values (Figure 2, Map 1) evaluated in Crete Island are found between 112 to 227, corresponding to Dry and Very Dry Climate Type; higher values are depicted in the South and East with the mountainous areas having lower values. The EVI ranges from −0.57 to 0.67 (Figure 2, Map 2), and the negative values present the lowest vegetation drought impacts for the referred period. The indicator Vegetation Drought Resilience represents the plant type's ability to "survive" in dry periods (either seasonality or drought events), and the results appear in Map 3). The percentage of the Very High class (1.00) is 38.9%, the second class is 3.4% (1.20), the third class (1.30) is 24.0%, with Low vegetation, drought resilience is 22.5%, and the Very Low class (2.0) is 0.8%. However, there are not high values of land use intensity (Figure 2, Map 4). Similar conditions prevail for plant cover indicator (82.2%, 13.1% and 4.7% respectively 1.00, 1.80 and 2.00). The annual rainfall map based on daily data (1991–2014) and the co-kriging (rainfall and Digital Elevation Model) interpolation method transformed the point data to spatial values. However, the rainfall map may vary greatly, even more than 1400 mm annually (orographic rain as there are peaks above 2400 m) between west and east Crete. There are not significant issues from Slope and Soil Texture indicators as depict in Figure 2 (Maps 7 and 9). Water Demand Indicator has attributed high-water demand during the summer seasons (agricultural and touristic needs), and the lower water consumption during the winter seasons (agricultural and touristic needs are minimal). The Reservoirs on the Crete Island shows in Table 5.

3.2. Results of the Degradation Degree on Water and Land Resources

Figure 3 summarizes the results of the WLDI with high values in the mountains and coastlines and low in the Heraklion County and the urban areas. Figure 3 shows that the average degradation of the examined region is 119.5—portraying Low Scale Degradation. Only 1% out of the f the study area displays Moderate Degradation ($\geq$119). The locations with Moderate Degradation are mostly located in the coastline and the mountain tops. Moreover, Figure 3 shows that the maximum and minimum WLDI values correspond to the moderate degradation of water and land resources class on a small scale (Figure 2, Map 2).
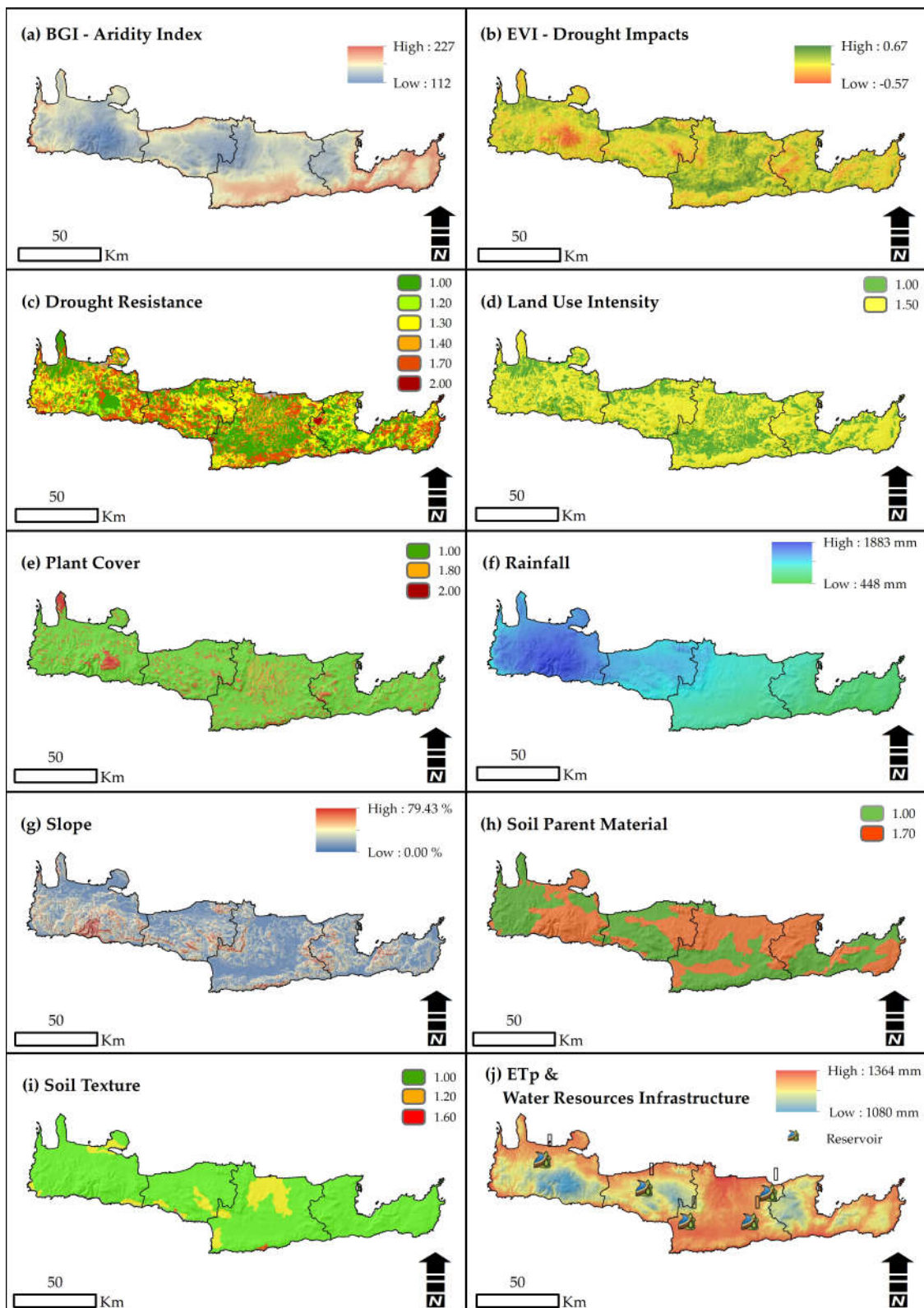
Figure 2. The inputs and indicators for the calculation of WLDI. (**a**) BGI Aridity Index, (**b**) EVI—Vegetation Drought Impacts, (**c**) Vegetation Drought Resilience, (**d**) Land Use Intensity, (**e**) Plant Cover, (**f**) Rainfall, (**g**) Slope, (**h**) Soil Parent Material, (**i**) Soil texture and (**j**) ETp and Water Resources Infrastructure.

Table 5. Reservoirs on the Crete Island.

Name	Prefecture	Volume (10^6 m^3)	Purpose	Construction Year
Mpramianon	Lasithi	16.00	Irrigation	1986
Partiron	Heraklion	1.50	Irrigation	2000
Iniou	Heraklion	1.75	Irrigation	2002
Damanion	Heraklion	1.50	Irrigation	2003
Amourgeles	Heraklion	1.56	Irrigation	2004
Armanogeion	Heraklion	1.50	Irrigation	2004
Faneromeni	Heraklion	19.67	Irrigation	2005
Potamon	Rethymno	22.50	Domestic-Irrigation	2008
Aposelemi	Heraklion	27.30	Irrigation	2012
Valsamioti	Chania	5.50	Irrigation	2014

3.3. Validation of the Degradation Degree on Water and Land Resources

For the evaluation process of WLDI two indices were used, namely, Soil Organic Carbon (SOC) using the Map from the Food and Agriculture Organization of the United Nations (FAO) and the Normalized Difference Water Index (NDWI) for Land and Water Resources, respectively [79,80]. SOC received values from the FAO database and adapted them in the case study. However, NDWI calculated based on annual values from the Google Earth Engine for the investigated period 1999–2014 [67]. Figure 3 presents the referred indices with the various spots for quantitative validation. In addition, it was done a statistical analysis through ArcMap 10.8 (Toolbox: Band Collection Statistics) between individual layers. Specifically, WLDI and NDWI had a negative correlation (-0.286). This is a logical result since the high values in the first corresponds to low values in the second. In addition, a positive correlation computed between SOC and WLDI (0.223). The correlation values seem low, but they are valid because WLDI consists of climatic, soil, geological, infrastructure, and agricultural data. Additionally, the above results may be validated from Figure 4 with the selected spots. Particularly, the high values of WLDI (d2) portray similar conditions with SOC (a2). Different situations depicted in the NDWI spots (b2 and c2), where the mountain tops restrain snow cover. Similar behavior shows with the low values of the WLDI (d1) with the other maps (a1, d1 and c1). Finally, the case study produced a polynomial equation dependent on the WLDI and the independent variables SOC and NDWI. The produced equation is:

$$WLDI = 103.675 - 2.12652 \times NDWI - 0.121078 \times SOC \tag{3}$$

The R-Squared statistic indicates that the model as fitted explains 0.583049% of the variability in WLDI. The adjusted R-squared statistic, which, is more suitable for comparing models with different independent variables values, is 0.565%. The standard error of the estimate shows a standard deviation of the residuals of 9.040. The mean absolute error (MAE) of 7.452 is the average value of the residuals. The Durbin-Watson (DW) statistic tests the residuals to determine if there is any significant correlation based on the order in which they occur in your data file. Since the *p*-value is less than 0.05, there is an indication of possible serial correlation at the 95.0% confidence level. Plotting the residuals versus row order to see if there is any pattern appears. In determining whether the model can be simplified, it is noted that the highest *p*-value on the independent variables is 0.024, belonging to NDWI. Since the *p*-value is less than 0.05, that term is statistically significant at the 95.0% confidence level.
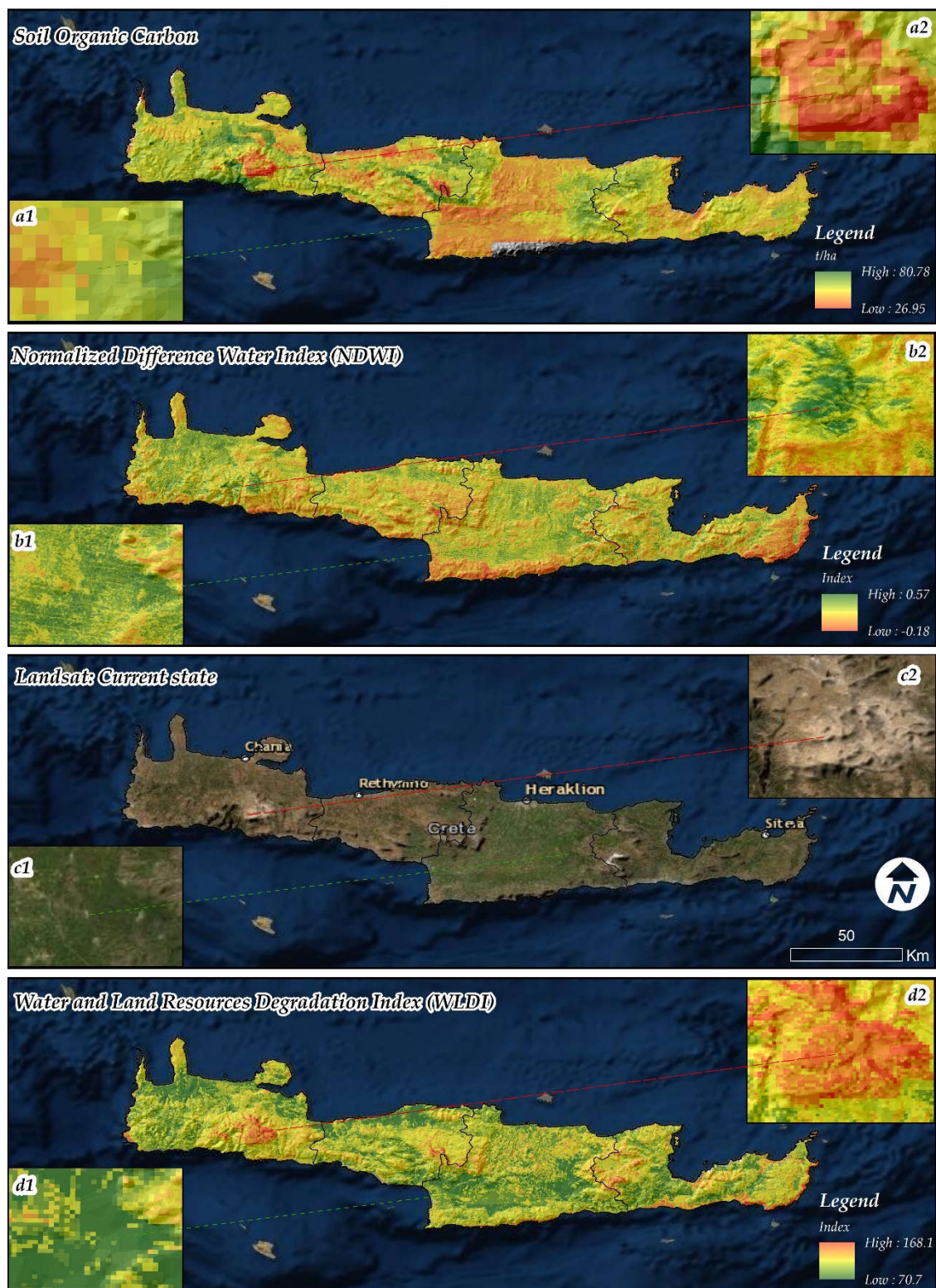
Figure 3. SOC, NDWI, WLDI and Landsat maps in Crete Island. (**a1**) Spots with low values of Soil Organic, (**a2**) spots with high values of Soil Organic (**b1**), spots with low values of Normalized Difference Water Index, (**b2**) spots with high values of Normalized Difference Water Index, (**c1,c2**) spots with low values of Landsat current state, (**d1**) spots with low values of Water and Land Degradation Index and (**d2**) spots with high values of Water and Land Degradation Index.
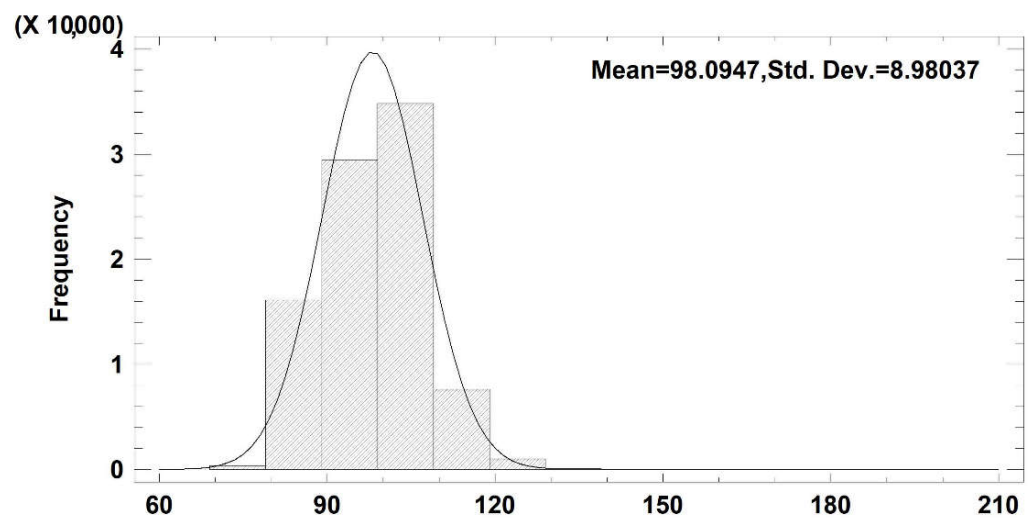
Figure 4. Histogram (Index classes) of WLDI and application in Crete islands (1999–2014).

4. Discussion

According to the weights and the maximum value of the indicators, the more significant factors are the Aridity index, Rainfall, and Water Demand. The degradation of water and land resources based on WLDI from the crops occurs mainly in the areas with the highest agricultural activity, due to the intensive use of water resources. This exacerbates the degradation according to the Water Demand indicator. These indicators (Water Demand indicator, Drought Vegetation Resistance and Land Use Intensity) coincide mostly with areas depending on rain fed agriculture, which exhibited impacts on the vegetation (EVI) due to drought events. In other words, they exhibit high water demands accompanied by serious supply deficits and thus, having significant environmental impacts. Generally, the southwest-center side of the island displays higher values of degradation. Overall, under the occurred conditions, the island of Crete displayed Very Low and Low Degradation for the referred period (Figures 2–4).

Based on climatic zones (Tables 1 and 6, Figure 1), zonation similarities occur in the index application. The zones refer to the natural ecosystems and with the application of the specific indicators; they related to anthropogenic actions and interventions directly associated to the corresponding ecosystems. There are a variety of factors (climate, geomorphology, land use, etc.) such as air temperature, precipitation, parent material, relative humidity, soil texture, solar radiation, altitude and land use that are related to the specifications and categories of the zones [81–84]. The zones with the minimum, maximum, average, and standard deviation values of WLDI portrayed in the following Table 6. Natural Resources Degradation are increased in alti-Mediterranean snow zone due to the high values of soil erosion, since there are significant impacts in the first zone (0–300 m) from the human activities [58].

Table 6. Zonal Statistics for WLDI according to the various zones [82].

Elevation	Zones	Min	Max	Mean	Standard Deviation
0–350	Thermo-Mediterranean	70.70	159.10	94.33	9.36
350–600	Mesomediterranean	70.70	127.19	96.71	7.67
600–1200	Super-Mediterranean	75.40	127.19	98.07	6.00
1200–1700	Montane	88.79	157.19	100.08	6.21
1700–2600	Alti-Mediterranean	97.49	168.10	101.34	5.23

It is clear that high values of WLDI occur mainly in the mountainous areas, such as the "White Mountains" in Chania Region, the "Psiloritis" mountain between Rethimnon and Heraklion Region and the "Dikti" mountain between Heraklion and Lasithion Region.

In addition, high values of WLDI occur at the Lasithion Region, and especially the coastal areas (Figures 1 and 3).

As stated, complex indicators have provoked many reactions related to their objectivity and reliability [55,56]. In some cases, those factors may be relatively high, mainly due to the uncertainty that lies in certain development stages [53].

However, in the present case, the developed index is composed of individual indicators, which incorporated in the structure of two well-established indices in the field of environmental sciences. Namely, the Standardized Drought Vulnerability Index (SDVI) and the Environmentally Sensitive Areas Index (ESAI) [30,33]. Finally, the results of the present effort maybe highly correlated with the findings of similar research efforts on the field of drought impact assessment and the environmental sensitivity assessment in the island of Crete [85–89].

Thus, the aforementioned features increase the reliability of the proposed index and they allow its application to be expanded to other regions with similar or related climates. However, and despite the first positive results regarding the application of the index, additional analysis is required.

5. Conclusions

Based on the inputs and indicators used for the calculation of Water and Land Resources Degradation Index in Crete from 1999 to 2014 showed that water resources' degradation is greater than that of land resources. This deterioration occurs mainly in the areas with the highest agricultural activity. The increased use of water resources due to irrigation exacerbates the degradation, according to the Demand Indicator. A master plan in areas with increased demand due to irrigation is imperative. It is proposed to change crops or to choose varieties demanding less water. Infrastructure shortages such as storage, transport, distribution, water and wastewater treatment processes are posing additional obstacles and lead in degrading available water resources.

According to the weights and the maximum value of indicators, the more significant factors are the Aridity index, Rainfall, and Water Demand. The results of the applied methodology of the Water and Land Resources Degradation Index can be expanded to other regions with similar or different climates, since the index is developed using indicators from two tested composite indices, namely Standardized Drought Vulnerability Index (SDVI) and the Environmentally Sensitive Areas Index (ESAI) [30,33,85]. Thus, there seems to be high reliability on the use of this index, because many applications are based on these indices, and may be found on global scale [29,30,85–87].

However, decision-support tools must be implementable not only in the short but also in a longer time horizon. It is necessary to assess the progress in assimilating and using such systems in a short period of time and simultaneously to sustain the interest, effort, and participatory conviction of decision-makers throughout the whole process for a few future decades.

Even if the sustainable development concept takes into account awareness, there are not general acceptant guidelines established about it. The use of this index emphasizes the need to organize and control the dynamics and complex interactions between anthropogenic activities and natural resources to promote their coexistence and general growth. This effort exhibits and develops qualitative and quantitative data along with formal links between decision-making and precautionary techniques in natural resources management.

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