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Original Article

Determination of land degradation according to land use types: a case study from the Gulf of Edremit, Turkey

Arazi bozulumunun arazi kullanım türlerine göre değerlendirilmesi: Edremit Körfezi örneği, Türkiye

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ABSTRACT

Land degradation has a long history and a significant effect on land management. Long-term changes in land use are among the important mechanisms of the land degradation process. According to the land use evolution, the main goal of this study is to determine the level of land degradation within the land use types by using the Environmentally Sensitive Areas (ESA) Index, and the Normalized Difference Vegetation Index in the Gulf of Edremit. The methods presented in this study can easily be applied to identify forces driving the land degradation from a small basin to regional scale for mitigation of desertification in sub-humid Mediterranean environmental conditions. The ESAs are calculated according to land use types within the context of soil, climate, vegetation, and management, through their special characteristics, and their interactions with each other. The main results, assessed with the proposed land degradation, showed that approximately 30% of the total study area is critically sensitive to degradation, and 50% of the study area is fragile. The ratio of critical areas in settlement areas and agricultural areas was found to be quite high, especially in coastal areas. The most striking result is that one-half of the forests were found to be fragile. The spatial variability of land degradation should be an important component of land use management to ensure environmental sustainability, especially in the Aegean coastal area.

Keywords: Land degradation, environmentally sensitive areas, land use categories, NDVI

ÖZ

Arazi bozulmasının uzun bir geçmişi ve arazi yönetiminde önemli bir yanı vardır. Arazi kullanımında uzun vadeli değişiklikler arazi bozulma sürecinin önemli mekanizmaları arasındadır. Bu çalışmanın amacı arazi kullanımındaki değişimlere göre Edremit Körfezi'nde ÇDAİ (Çevresel Duyarlılık Alan İndeksi) ve NFBİ (Normalleştirilmiş Fark Bitki İndeksi) kullanılarak arazi kullanım tiplerine göre arazi bozulma seviyesini belirlenmesidir. Bu çalışmada kullanılan yöntemler, yarı-nemli Akdeniz koşullarında çölleşmeyi azaltmak için yerel düzeyde arazi bozulumundaki itici güçleri tanımlamak ve belirlemek için oldukça uygun olduğu bilinmektedir. ÇDAİ ile toprak kullanım tiplerine göre toprak, iklim, bitki örtüsü ve arazi yönetimi bağlamında bir çok özellik ve bunlar arasındaki etkileşimlerden yararlanılarak hesaplanmaktadır. Bu çalışmada elde edilen temel sonuçlar, toplam çalışma alanının yaklaşık %30'unun kritik derecede ve %50'sinin kırılgan düzeyde çevresel duyarlılığa sahip olduğu göstermektedir. Yerleşim bölgeleri, tarım alanları ve kıyı kesiminde çevresel duyarlılık düzeyinin oldukça yüksek olduğu tespit edilmiştir. Çalışmadaki en çarpıcı sonuçlardan biri orman arazilerinin yarısının çevresel duyarlılık açısıdan kırılgan düzeyde olduğu belirlenmiştir. Arazi bozulumunun mekansal değişkenliği dikkate alındığında, özellikle Ege kıyıalrında başta orman ekosistemi olmak üzere çevresel sürdürülebilirliğin sağlanması konusunda en önemli itici etkenin arazi yönetimi olduğu sonucuna ulaşılmıştır.

Anahtar Kelimeler: Arazi bozulumu, çevresel duyarlı alanalar, arazi kullanım türleri, normalleştirilmiş fark bitki indeksi

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INTRODUCTION

The concepts of land degradation and desertification both imply an environmental collapse that adversely affects human and ecosystem survival (Bajocco et al., 2012). The United Nations Convention to Combat Desertification draws attention to the importance of solving land degradation problems at the local level (Sepehr and Zuca, 2012). Thus, the desertification phenomenon is an irreversible process of land degradation, where the land cannot recover by itself without human intervention (Briassoulis, 2019).

Land degradation is being increasingly recognized as a global phenomenon that not only changes the land use, but also includes the interaction between climatic environments and soil, vegetation, and water structures (Conancher, 2009). Land degradation is important at both the local and global level on the sustainability of land use (Kadovic et al., 2016; Salvati and Bajocco, 2011). Land degradation is a stationary process that occurs in many types of land use, such as natural areas, semi-natural areas, agricultural lands, urban and peri-urban areas, and this is mainly due to the change in the use of land resources in the Mediterranean landscape (Bajocco et al., 2012). Further, there is a significant relationship between land degradation and land use types (Maitima et al., 2009). In short, the relationship with the current land use cannot be ignored in the description of land degradation.

Generally speaking, the land health and environmental sensitivity are associated with ecological conditions such as the soil quality, vegetation, and climate, and human activities such as agriculture, uncontrolled urbanization, deforestation, overgrazing, and tourism pressure (Bajocco et al., 2012; Ladisa et al., 2012). The most common causes of negative impacts on the environment among these natural and human-induced factors are consequent changes in the land cover (Liu et al., 2012). The studies about the land use/land cover changes show that the transformation of the landscape increase the sensitivity to land degradation in several environmental conditions, which originates from the individual relationship between human activities and land resources (Zambon et al., 2017). Also, the percentage of species and plant diversity has started declining where places were used mostly by people (Maitima, 2009). The human-induced land degradation is generally represented by land use changes (Nachtergaele et al., 2012). It is known that the land degradation is more apparent in the places like the Mediterranean region, which are exposed to a rapid land use change (Tanrivermis, 2003).

The land use/land cover changes to be considered regarding land degradation are the economic pressure and policy decisions (Vu et al., 2014). Also, the importance of human-induced land use emerges within the behavior of society and global activities such as tourism, coastal fisheries, transportation, trade, etc. (Arunachalam et al., 2011). The first reflections of economic and political pressures could be seen with the changes in land use. The land use conflicts involve political, cultural, and societal systems, and natural processes within the scope of uncertainty (Mann and Jeanneaux, 2009). It is inevitable that the natural environment will turn into land used by humans with the interaction between humans and nature. To appropriately explain this phenomenon, it is important to define and visualize the trends in the land use tendency and driving forces that cause land degradation. Furthermore, this situation captures pressures on the land such as soil losses due to urban sprawl, erosion as a result of deforestation and other land-human interactions which negatively affect land and environment (Hersperger et al., 2010).

Environmental systems are almost in a dynamic adjustment among different habitats because they are affected by both natural cycles and human influence (Canadell et al., 2010). For this reason, the methods used to identify extent of land degradation such as GLADA (Global Land Degradation Assessment), WOCAT (World Overview of Conservation Approaches and Technologies), MEDALUS (Mediterranean Land Degradation and Land-Use) have to deal with a wide range of environmental components (Bai et al., 2011; Lyden et al., 2012; Boudjemline and Semar, 2018). Most of these methods, with the exception of MEDALUS, have been used to determine land degradation on a global scale.

The MEDALUS approach is preferred to identify Environmentally Sensitive Areas (ESAs) used in many studies for monitoring sensitivity conditions of land incorporating vegetation, climate, land, and soil quality indicators within the scope of driving forces (Saleh et al., 2018). Also, this method was used to identify land degradation, especially in the Mediterranean region and in many countries from different places (Basso et al., 2012; Ladisa et al., 2012; Lavado Contador et al., 2009; Pravalie et al., 2017; Salvati et al., 2013).

In several studies, vegetation indices such as the Normalized Difference Vegetation Index (NDVI) or Enhanced Vegetation Index (EVI) were used to describe land degradation, and its driving factors (Jendoubi et al., 2019). Using remotely sensed vegetation data to determine the land degradation conditions commonly explain by time-series analyses (Eckert et al., 2015; Verbesselt et al., 2010). However, a single NDVI image of the same period was used to compare the ESA result that was not serial. The objectives of this research are to determine the conditions of land sensitivity to degradation based on the land use types in the Gulf of Edremit and to assess the similarities and differences between the ESA and NDVI results within the scope of environmental sensitivity.

MATERIALS AND METHODS

Study Area

The study area is located on the western coast of Anatolia (Figure 1). The Gulf of Edremit starts from the Babakale headland to Ayvalik. In the section extending from the Altinoluk shores to Gomec, coastal changes, and the elements that create pressure on the land are quite extensive. The boundaries of the study area starting from Altinoluk to Gomec were drawn from the water section (Figure 1). Also, the boundaries of the Ida Mountain National Park are located inside the study area.

Geomorphological structure of mountainous areas in this region rise to the back of the coastal and alluvial plains. The Mount Ida reaches 1774 meters; the Eybek Mountains peaking at 1298 meters are the most important elevations in the study area. The fertile and vast area between the mountains in terms of agriculture is the Edremit plain, which covers more than 200 km^2 (Kocadagli, 2009). Especially the mountainous areas in the north of the study area elevate rapidly from the coastal plains (Figure 1).

The rivers such as Zeytinli, Karinca, and Havran have developed abrasive surfaces by eroding in the high sections of the site, forming alluvial plains where the slope decreases in the middle of the area. Inceptisol and rocky terrains have been observed in the upper course of the rivers due to geomorphological characteristics of the region. Entisols are generally observed in the central plain, and histosols are encountered in the areas where the rivers reach the sea (Figure 1).

Considering the general climate features of the study area, the average monthly precipitation is 650 mm with an average temperature of 20°C in summer in accordance with the Mediterranean climate type. Over 100 endemic plant species have been identified in the region, especially the Ida Mountain, which is very rich in terms of plant diversity (Ozturk et al., 2011). Also, the Mount Ida is one of Turkey's very important regions where endemic and rare plants are rich in wilderness locations (Kalankan et al., 2015). The surroundings of the Burhaniye, Edremit, and Gomec settlements are covered with olive trees up to the highest parts of the mountains. Therefore, a significant part of the Mount Ida section is protected as a national park. Pine forests (*Pinus pinea*, *Pinus nigra*) spread in the higher parts of the mountains, especially inside the protected area boundaries. Another characteristic of the study area is that the total population of Altınoluk, Akcay, Edremit, and Burhaniye reaches 1 million during summer from 350,000, mainly due to tourism activities (Alevkayali, 2018).

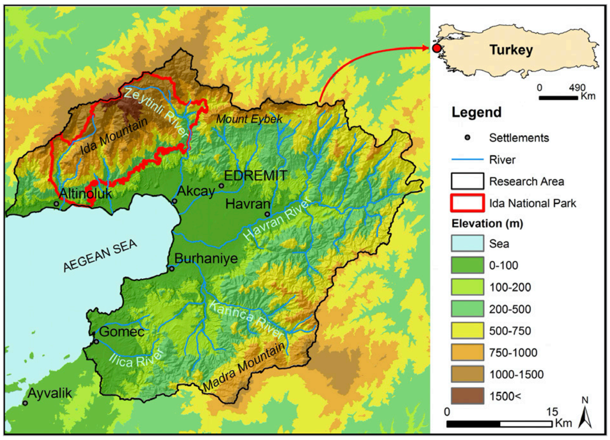

Figure 1. Location of the study area

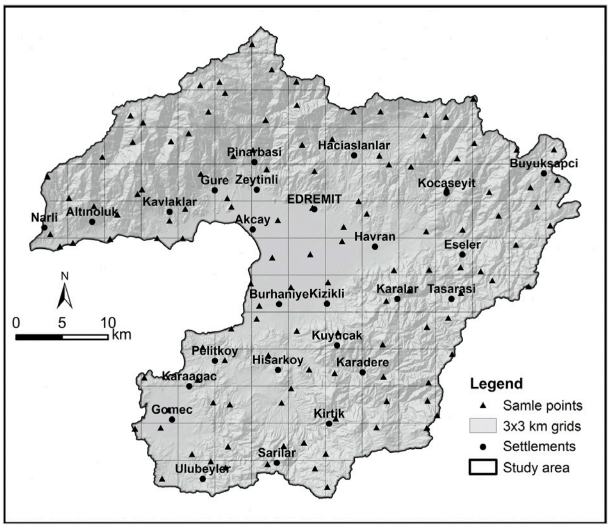

Figure 2. Grid divisions and soil sample points of study area

Sample Collection

The ESA index used for assessing the environmental sensitivity in the MEDALUS project consist of several parameters, such as soil quality indicators (e.g., soil texture, drainage, slope); climate quality indicators (e.g., rain, aridity); vegetation quality indicators; and management quality indicators (Kosmas et al., 1999).

In this study, soil, climate, vegetation, and land use data are used to determine the land degradation phenomenon. The slope and parent material properties were obtained from the Digital Elevation Model, and the geology map was obtained from the General Directorate of Mineral Research and Exploration (Table 1). Climate quality parameters were calculated using data from 10 meteorological stations in the study area (Table 1). Vegetation quality parameters except for NDVI were organized using the forest stands designed by the General Directorate of Forestry. The design of management quality indicators was based on classified Landsat 8 ETM images and inventory maps prepared by the Ministry of Food, Agriculture, and Livestock (Table 1).

The soil quality is important for the study because it is directly affected by climate changes, vegetation, and land use/land cover. All soil quality parameters except the slope and parent material were prepared under the 120 sample points determined by the random sampling method (Figure 2).

Modeling ESA

The Environmentally Sensitive Area Index (ESAI) consists of four main indicators: Soil Quality Index (SQI), Climate Quality Index (CQI), Vegetation Quality Index (VQI), and Management Quality Index (MQI) composed of many datasets (Equation. 1). The establishment of a spatial system such as ESA is an appropriate application to detect specific and delimited processes that cause land degradation:

$$SQI+CQI+VQI+MQI)^{1/4} = \text{ESAI} \qquad (1)$$

The basic principle of ESAI is to elaborate on the components of the environment such as soil, vegetation, climate, and land use where human impact on the environment is best observed. All indexes and parameters used to calculate ESAI are weighted as different quality classes and are of equal importance in the upper index (Equation 1). The parameters score used in this study and the degradation process was described by Kosmas et al. (1999). Moreover, some additions were made to the original sub-indexes to obtain stronger results in terms of environmental sensitivity.

According to the original index, some parameters have been added to the original index to obtain more effective results. For example, soil reaction is added to the index to explain soil chemical properties (Table 2). The importance of the soil reaction is associated with metal incidence rates for vegetation development. The soil chemical reaction was measured using a glass electrode pH meter.

The CQI includes precipitation, aridity conditions, and aspect and a VQI composed of the fire risk, erosion protection, drought resistance, and plant cover indicators in the concept of the original index. In this study, the potential evapotranspiration parameter included in the CQI for further demonstration of the effect of temperature, and NDVI values was added to the index to represent the level of viability in the VQI (Table 2). Potential evapotranspiration was used to express the capacity of evaporation. Thus, potential evapotranspiration was calculated to estimate the amount of water that could evaporate and transpire from the landscape with the Thornthwaite method, which is one of the preferred methods (Yang et al., 2017). Monthly temperature and precipitation values are used for in this method. The reason for using NDVI is to add a parameter representing the live mass to the index.

The MQI is a combination of policy and land use intensity; however, land use values play a dominant role in determining the quality of management since current land use characteristics are a spatial form of political decisions. The land use intensity was obtained by weighting the land use/land cover conditions with land usage density that identifies with field observations. The policy criteria included in the system are regulated and maintained according to their protection status. Moreover, all indicators were equally weighted in the calculation of ESAI, and all data used in the analysis were processed and implemented and performed using the Geographical Information Systems.

Point data such as soil sample points and climate station data were interpolated with the Inverse Distance Weighting (IDW) method. This method obtains successful results at the interpolation of soil and climate data (Bhowmik and Cabral, 2011; Wang

Table 1. Source of Parameters Used for Environmentally Sensitive Areas

Index	Parameter	Scale	Time	Source
Soil Quality Index	Texture	1:30,000	2016	Field sampling
	Parent Material	1:25,000	2015	Geology map (GDMRE)
	Rock Fragments	1:50,000	2016	Field sampling
	Slope	1:25,000	2015	Digital Elevation Model
	Soil Depth	1:30,000	2016	Field sampling
	Drainage	1:30,000	2016	Field sampling
	Soil Reaction (pH)	1:30,000	2016	Field sampling
Climate Quality Index	Annual Rainfall (mm)	1:25,000	1980-2015	Meteorological Service
	Aridity	1:25,000	1980-2015	Meteorological Service
	Pot. Evapotransp.	1:25,000	1980-2015	Meteorological Service
	Aspect	1:25,000	2015	Digital Elevation Model
Vegetation Quality Index	Fire Risk	1:25,000	2015	Stand data map (GDF)
	Erosion Protection	1:25,000	2015	GDF
	Drought Resistance	1:25,000	2015	GDF
	Plant Cover (%)	1:25,000	2015	GDF
	NDVI	30×30m	2016 Aug.	Landsat 8 ETM
Management Quality Index	Cropland	1:25,000	2015	Inventory map (MFAL)
	Pasture	1:25,000	2015	MFAL
	Natural Areas	1:25,000	2015	MFAL
	Mining Areas	1:25,000	2015	MFAL
	Recreation Areas	1:25,000	2015	MFAL
	Policy	1:25,000	2015	MFAL
	Land Use	1:25,000	2015	MFAL

NDVI: Normalized Difference Vegetation Index; GDMRE: General Directorate of Mineral Research and Exploration; MFAL: Ministry of Food, Agriculture, and Livestock; GDF: General Directorate of Forestry et al., 2011). The best interpolation results were acquired with IDW; however, other methods have been tried, but the desired results could not be achieved. All polygon data such as geology and vegetation cover have been used by converting polygon to raster.

In this study, an accuracy analysis was performed to test the index reliability. For the accuracy of the testing method, 200 control points were randomly established in the study area. All values of the control points were scored based on expert assessments and environmental sensitivity levels (high, moderate, and low quality) with field observations. Thus, the multi-linear regression (MLR) and geographically weighted regression (GWR) analysis used for modeling and analyzing variables between, original ESAI (CQI, VQI, MQI, and SQI), and modified ESAI, which were used in this study. According to 200 control points, the MLR and GWR analysis show that the original with ESAI was not found to be significant for assessing the environmental sensitivity with R^2 coefficient values calculated <0.7. The coefficient of determination R^2 for modified ESAI is calculated as 0.86 (MLR) and 0.81 (GWR) for 200 points.

Table 2. Description, Weighing, and Quality Types for Modified Parameters Used for Estimation of Environmentally Sensitive Areas

	Climate Quality Index		
Parameter	Description	Quality	Score
Potential evapotranspiration (mm)	<1000	Very high	1
	1000-200	High	1.5
	>2000	Very low	2
	Vegetation Quality Index		
NDVI	Reflection value 0.3 to 1	Very High	1
	Reflection value 0.2 to 0.3	High	1.3
	Reflection value 0 to 0.2	Low	1.7
	Reflection value -1to 0	Very low	2
	Reflection value 0.3 to 1	Very High	1
	Soil Quality Index		
Parameter	Description	Quality	Score
Soil Reaction (pH)*	Extremely acid	Very low	2
	Strongly acid	Low	1.7
	Moderately acid	Moderate	1.5
	Slightly acid	High	1.3
	Neutral	Very high	1
	Slightly alkaline	High	1.3
	Moderately alkaline	Moderate	1.5
	Strongly alkaline	Low	1.7
	Extremely alkaline	Very low	2

NDVI: Normalized Difference Vegetation Index

RESULTS AND DISCUSSION

The spatial distribution of ESAI in the study area was calculated based on soil, climate, vegetation, and management quality indicators by a multitude of algebraic analysis. Thus, the basic components of ESAI (climate, soil, vegetation, and management quality indices) should be specified to understand the evaluation of environmental conditions in the study area. The overall results about four quality indicators (CQI, VQI, MQI, and SQI) are respectively represented on three quality scales (high, moderate, and low), while the ESA index is evaluated as four, and eight classes at different scales (Figure 3). Considering the sub-indexes in terms of land degradation, climate, and vegetation data are positive, and soil and land management data are negative in the Gulf of Edremit (Alevkayali, 2018).

The CQI is one of the important components in explaining the change and deterioration of the environment, and it provides the indication of changes originating from local properties of the study area. The spatial variability of CQI was determined as a total of the study area (43%) of high quality, while the rest of the area (57%) was of medium quality (Figure 3). These calculations on climate parameters show that this region is partly fragile in terms of climate quality in low elevated lands. Climatic factors generally do not have dominant-negative effects within the scope of land degradation in the study area.

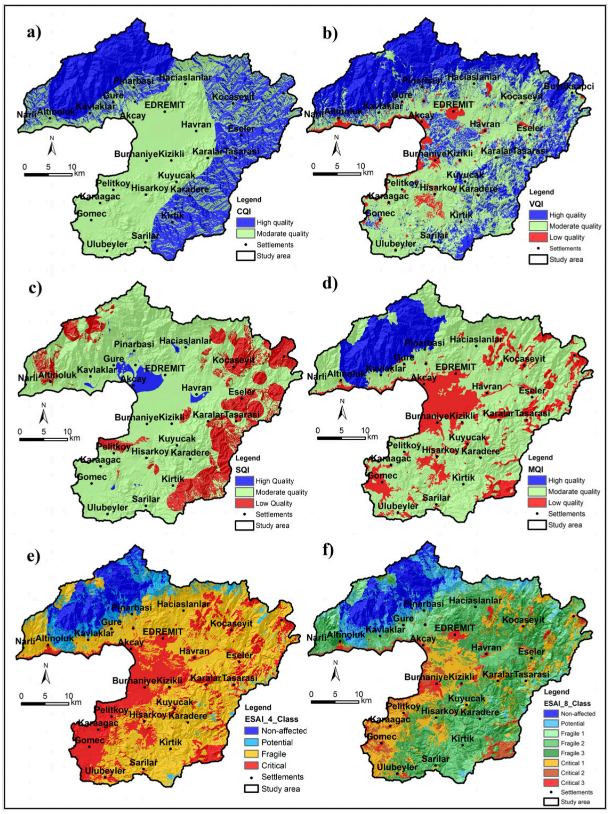

Figure 3. a-e. a) Climate Quality Index, b) Vegetation Quality Index, c) Management Quality Index, d) Soil Quality Index, e) Environmentally Sensitive Areas with four classes, f) Environmentally Sensitive Areas with eight classes

The VQI was obtained by calculating five indicators: fire risk, drought resistance, erosion protection, plant cover, and NDVI. Vegetation quality indicates that a large part of the study area is of high vegetation quality represented by mountainous areas (40%); more than half is of moderate quality (54%), and only 6% is of low quality (Figure 3). The areas calculated as low quality according to VQI are spread over the coastal areas and settlements. The moderate quality vegetation areas mainly exist in the hillside that consists of orchards (almonds, olives, walnuts, and citrus groves). Forests and scrubs have the highest quality values in terms of great water absence durability with a high land coverage ratio.

Soil is one of the most important components of environmental sustainability on the account that it provides the medium for plants, habitat for fauna, and many facilities to living things such as the filtration of water and water storage. Thus, high soil quality is very important in reducing environmental sensitivity. The soil quality was generally determined to be medium, but also high and low quality areas took a considerable percentage in the study area (Figure 3). The high soil quality land located between the Edremit and coast where the good condition alluvium soil was detected totaled 5% of the study area (Figure 3). The areas with less slope and high soil depth were determined to be of medium quality due to insufficient drainage, a poor soil reaction quality, and a poor soil fragmentation quality. On the other hand, the highest rates of low quality soils was found especially in the high regions around the Madra Mountain. A significant part of the areas with low soil quality corresponds to rocky areas where the soil depth is very low or lack soil formation. Considering the different parameters, it was determined that the soil development was lower in the higher parts of the mountains than in the plains.

A fundamental part of land degradation is land use management quality indicators that reflect directly on the social and economic policy decisions (Ahmad and Pandey, 2018). Increasing land degradation is a result of poor land use management practices, such as soil erosion, soil salinization, agricultural or natural vegetation water stress, and overgrazing (Kairis et al., 2013). The poor land management practices are thought to cause vegetation stress and low soil quality in the study area. Especially, the risk of soil loss increases in areas opened for agriculture and settlement. The impact of the quality management on land degradation indicates that on a fourth of the study area detected (25.1%) as low quality, more than half of land (55%) was of moderate quality, and one-fifth (19.9%) was of high quality, on the territory that represented protected area (Figure 3). The results regarding the land use quality management show that shores and plains where human activities were intensive had a high degree of land sensitivity (Figure 3).

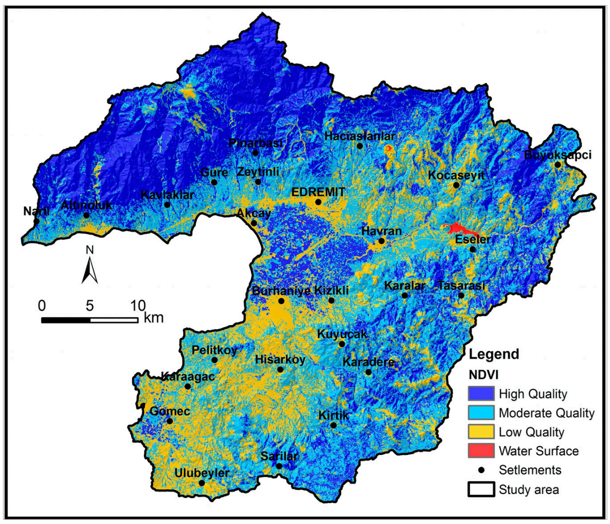

Figure 4. Visualization of classified Normalized Difference Vegetation Index

The calculation of each indicator in the ESAI has different meanings, and the combination of these indexes (CQI, VQI, SQI, and MQI) provides having a sensitivity to land degradation where desertification causes risks for land evolution (Lahlaoi et al., 2017). The results of the final index were basically listed as non-affected, potential, fragile, and critical that each of levels has various meanings that express land degradation is less or more (Figure 3). Critical and fragile areas mean a lower quality of land productivity, while non-affected and potential areas mean a better quality (Lavado Contador et al., 2010).

The results of four classes ESAI show that non-affected areas represented to the Mount Ida protected the area, and potentially affected areas included the woodland that surrounds the protected area. Other regions in the fragile class are mainly the agricultural areas and critical lands represented by settled and cultivated agricultural lands (Figure 3).

In addition, the study area was divided into eight classes to obtain more detailed information on land sensitivity. Accordingly, critical ESAI results for land degradation covered one-fourth (26%) of the study area and included three subtypes. In terms of ESAI, considerable areas with high land degradation and poor eco-efficiency (Critical 3) were determined as highly populated residential areas, and the areas where largely lost environmental efficiency (Critical 2) overlap with minefields, while environmentally the least critical places (Critical 1) correspond to cultivated farms and orchards. However, these areas were classified as low quality management and moderate quality management according to VQI (Figure 3). However, these areas were classified as low quality management and moderate quality management according to VQI (Figure 3).

Another assessment tool of the land degradation process were the NDVI results. The NDVI calculations indicated that the general appearance of the study area except for residential areas, drylands, and rocky surfaces showed a live vegetation reflection (Figure 4). Also, when comparing the northern part of the study area with the south, NDVI varied for more than 0.7, but low reflection values were measured in the slope area. High reflection values were observed in the flats of Burhaniye, Edremit, and Akcay, which were located in the center of the study area.

The results of the MEDALUS model on sensitivity ratings according to land use types show that residential areas and grain farming lands, as well as irrigated areas, are almost measured at the critical levels (Figure 5). Also, the NDVI values of dry farming and settlement areas were largely calculated as being in a poor condition. The results of both methods indicate that half of the orchards and forests were identified as fragile with partly damaged land productivity. Although olive groves have the lowest land sensitivity among agricultural areas, three-quarters of these lands are fragile (Figure 5). Olive groves are positively perceived as being in a fragile, rather than critical, state to other agricultural areas, which creates a positive display in terms of ESA. On the other hand, the fragility of olive groves indicates that there are risks in terms of yield. In a similar study conducted in the Messara Valley (Crete, Greece), it was determined that the degradation of the land decreased as a result of the expansion of the olive groves (Karamesouti et al., 2015). Olive cultivation does not indicate a critical level in terms of land degradation in the study area (Figure 5); however, the events that occurred in NDVI shows that olive cultivation will increase environmental sensitivity when the viability of trees is examined. So, both results from ESA and NDVI show that the important part of the forests and agricultural land was determined as being of critical environmental sensitivity in the study area.

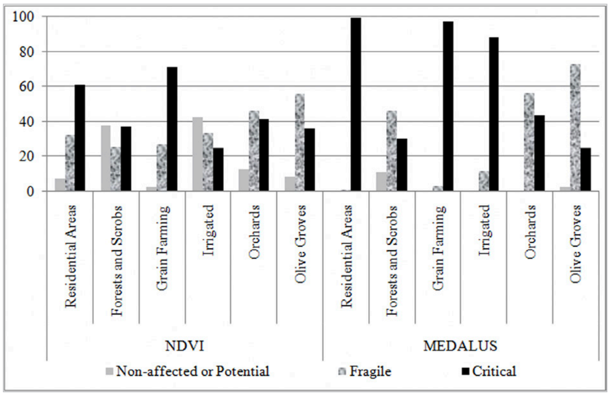

Figure 5. Percentage of land degradation sensitivity levels with main land use types

Figure 6. A view from the Madra Mountain forest areas that were determined as having critical environmental sensitivity

Considering the results obtained from different areas, humidity and dryness of the land are not the main criterion determining the level of land degradation (Pravalie et al., 2017; Salvati et al., 2013). The analysis on spatial variations of the land sensitivity showed that the negative statement of land degradation such as poor eco-efficiency and risky ecosystems due to poor land management quality, and decreases in the vegetation quality generally refers to unprotected areas with government policies.

Nearly one-fourth of forest and shrub areas were classified as non-affected or with potential sensitivity at a high quality level, and a significant part of these areas is fragile, but some of them at the risks of low quality (Figure 5). The Madra Mountains and the Mount Ida are hosting important habitats and ecosystems, with large sections of these areas being detected as vulnerable to land degradation (Figure 6). In addition to natural pests, the effects of the human beings in the study area increase the extinction pressure on the forests and shrubs. The ESA values identified in forests raise concerns about the ecosystem health in the study area.

The Edremit plain, where the highest percentage of critical environmental sensitivity was measured in the study area, is of great agricultural importance. Also, the Gulf of Edremit is specialized in the production of table olive and olive oil. However, increases in the land vulnerability to degradation could lead to irreversible damage in the agricultural area. That means that the environmental sensitivity should be taken into consideration, first in the preparation of land use planning in terms of agricultural sustainability since the study area is a typical example of the Aegean coasts.

According to the general results regarding land degradation in the study area, it was determined that the main problem emerged from improper change of land use and excessive agricultural production on the plains. It is the fact that the natural environment in the Ida Mountains and the Madra Mountains has turned into agricultural landscapes or residential areas over the years (Tagil, 2014; Uzun and Somuncu, 2013). Even though the study area is located in sub-humid and humid areas that are expected climatically less sensitive, they are suspected to land degradation according to an inadequate land use management. For instance, 1.5 million olive trees logging for construction of the secondary regimentals in the Gulf of Edremit, and that situation shows that tourism plays a very effective role in devastating urban sprawl (Kocadagli, 2009).

Finally, critical areas according to the ESAI and NDVI results show that the land degradation process is the most powerful in the coastal area and is characterized by a significant impact of the population increase in the summer time, violating the shoreline marginalization, and the construction of natural areas constitutes an important environmental threat in the Gulf of Edremit (Irtem and Karaman, 2004). Thus, these changes in the landscape due to improper land management are observed in the proximity of the Aegean and Mediterranean coastal side.

CONCLUSION

As observed in many parts of the world, land degradation is one of the major environmental problems in Turkey and the Gulf of Edremit. The monitoring of land degradation with the ESAI, which is the MEDALUS framework, and NDVI was conducted for the first time, to the best of author's knowledge, on the Aegean coast using this method. Both measurements show that the degradation process is more effective in settlement areas and dry agricultural areas. The results regarding land degradation show that the coast is negatively affected by the spread of residential areas due to tourism activities and improper agricultural activities.

One of the results of this study shows that a large part of the forested areas is fragile. Therefore, it is understood that the main problem in the degradation of the land is caused by a low management quality, incorrect land use decisions, and partially insufficient vegetation under the pressure of the agricultural applications. In addition, the results of the land degradation calculated in the Gulf of Edremit in the context of ESAI show that the olive groves are adaptable to the environment in terms of vegetation, soil, and climate; however, these areas were detected as fragile because of human-induced pressures. To combat the land degradation of forest areas, the boundaries of the protected area in the Ida Mountains should be extended, and the forest critical to land degradation should be protected under the conservation status on the Madra Mountain.

A high correlation between the environmental sensitivity, land management, and vegetation quality suggests that the land use efficiency has more effect on land quality in a humid or sub-humid region. In addition, forest and shrub areas that have a low environmental sensitivity indicate that the way to fight land degradation can be achieved by protecting these areas. Therefore, the spatial variability of land degradation should be an important component when making administrative decisions on urbanization, tourism, and agricultural issues to ensure environmental sustainability or solving spatial environmental problems, especially in Aegean coastal areas.

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