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ARAŞTIRMA MAKALESİ **RESEARCH PAPER**

The Naturalness Level of Terrestrial Areas in Bartin Province (Northern Türkiye)

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Abstract: The level of naturalness of terrestrial ecosystems is the degree to which they are exposed to human influence. The high level of naturalness reflects low human impact and high biodiversity. Determining the level of naturalness of terrestrial ecosystems is extremely important for long-term land planning and conservation, sustainability, and resource management. This study examined the naturalness level of natural/anthropogenic areas within the administrative borders of Bartin province. Six spatial factors were used. These are settlement density, population density, road density, land cover/use, Normalized Difference Vegetation Index (NDVI), and Topographic Roughness Index (TRI). These six essential factors were inverted into the spatial fuzzy memberships using Geographic Information Systems (GIS). A final map was obtained by overlaying the fuzzy memberships in the fuzzy overlay model (FOM). According to this resulting map, the city center and its surroundings have a high anthropogenic impact and a low level of naturalness. The Küre Mountains National Park (KMNP) in the east of the province and the rugged mountain ranges in the south have a high level of naturalness, being remote from anthropogenic impact. Anthropogenic land degradation has expanded due to road construction, mining, and forestry activities. Uncontrolled economic activities constitute potential areas of human-induced degradation.

Keywords: Bartin, Degradation, Fuzzy overlay, Mapping, The level of naturalness.

Bartın İli (Türkiye'nin Kuzeyi) Karasal Alanlarının Doğallık Düzeyi

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Öz: Karasal ekosistemlerin doğallık düzeyini, insan etkisine maruz kalma derecesi belirler. Yüksek doğallık düzeyi, düşük insan etkisini ve yüksek biyolojik çeşitliliği yansıtır. Karasal ekosistemlerin doğallık düzeyinin belirlenmesi, uzun vadeli arazi planlaması ve korunması, sürdürülebilirlik ve kaynak yönetimi açısından son derece önemlidir. Bu çalışmada, Bartın ili idari sınırları içindeki doğal/antropojen alanların doğallık düzeyi incelenmiştir. Altı mekânsal faktör kullanılmıştır. Bunlar, yerleşim yeri yoğunluğu, nüfus yoğunluğu, yol yoğunluğu, arazi örtüsü/kullanımı, Normalize Edilmiş Fark Bitki Örtüsü İndeksi (NDVI) ve Topoğrafik Pürüzlülük İndeksidir (TRI). Bu altı temel faktör, Coğrafi Bilgi Sistemleri (CBS) kullanılarak mekânsal bulanık üyeliklere dönüştürülmüştür. Sonuç haritası, bulanık üyelerin fuzzy overlay modelinde (FOM) üst üste çakıştırılmasıyla elde edilmiştir. Ortaya çıkan bu haritaya göre, kent merkezi ve çevresi yüksek antropojenik etkiye ve düşük doğallık düzeyine sahiptir. İlin doğusundaki Küre Dağları Milli Parkı (KMNP) ve güneyindeki engebeli dağ sıraları, antropojenik etkiden uzak olmaları nedeniyle yüksek bir doğallığa sahiptir. Antropojenik arazi bozulması, yol yapımı, madencilik ve ormancılık faaliyetleri nedeniyle genişlemiştir. Kontrolsüz ekonomik faaliyetler, insan kaynaklı bozulmanın potansiyel alanlarını oluşturur.

Anahtar Kelimeler: Bartın, Bozulma, Bulanık Çakıştırma, Haritalama, Doğallık Düzeyi.

INTRODUCTION

Naturalness or natural area has been defined as being remote from human influence (Angermeier, 2000; Povilitis, 2002). The level of naturalness describes the degree of the influence of humankind on the natural environment (Potapov et al., 2017; Carver et al., 2013). Areas where naturalness has been disrupted or is in the process of being disrupted due to human intervention can be referred to as anthropogenic areas (under strong human influence). Naturalness, or the level of naturalness, estimates a gradual transition from less natural to more natural (Angermeier, 2000; Ekim et al., 2021). The boundaries among the different natural environments are fuzzy.

Human impact on natural ecosystems, based on balance and order, can be traced back at least 3000 years. During this period, the anthropogenic transformation of terrestrial ecosystems, particularly, has reached a global

scale (Ellis, 2015; Newbold et al., 2015; Ellis, 2021). In the history of human civilization, migrations, wars, agricultural and livestock systems, and the establishment and collapse of civilizations have all been significantly influenced by the natural environment. It is not possible to adequately explain the course of historical events and the establishment of archaeological sites and early settlements without considering the relationships between humans and the natural environment or without sufficient knowledge of the characteristics of the natural environment (Atalay, 2022).

Anthropogenic impacts on the natural environment have various effects that lead to a decrease in biodiversity and the degradation of natural resources. Human-caused degradation of water resources is particularly significant. This situation, combined with human-induced climate change, is expected to have much more significant impacts in the future (Findell et al., 2017; Morelli et al., 2020). The degradation of the natural environment humans use for their well-being and consumption inevitably has negative consequences for their future.

Land use/cover degradation is also directly related to population growth and industrialization (Duran & Günek, 2007; Findell et al., 2017). Approximately 41% of the Earth's surface has been subjected to human-induced land degradation. One-fifth of the affected land is in sub-Saharan Africa. South Asia is the most affected region, with 41% of its land area affected, and 70% of the affected area is severely degraded. This is followed by Southeast Asia, West Asia, and South America. These estimates do not include deserts. Human-induced degradation affects 34% of agricultural land. Expanding agricultural land into marginal areas leads to soil erosion and decreased soil-bound biodiversity. The intensive use of inorganic fertilizers in agricultural lands affects drainage systems and contributes to the degradation of water resources (FAO, 2024).

The Global Human Footprint Index (GHFI) is widely utilized in fields such as environmental research, natural resource management, the analysis of human impact, and the spatial assessment of habitat loss (Venter et al., 2016). However, the GHFI operates on a global scale. There are also different scientific studies on human-caused natural area degradation (Lambin et al., 2001; Reba et al., 2016; De Jong et al., 2021; Duran, 2024). Additionally, studies on natural areas need to be protected (Turoglu & Ozdemir, 2005; Şen & Erkan Bugday, 2015; Tunckol et al., 2020; Altunel et al., 2021). However, these studies do not include a study on spatial density reflecting human impact. A comprehensive geographical study within the administrative boundaries of Bartin province was not found.

This study investigates the spatial relationships between the natural environment and anthropogenic activities in Bartin province. The administrative border of the province was determined as the study area. Administrative boundaries are generally precisely defined units. It provides advantages in terms of conservation, resource management, and sustainability. Official (standardized) environmental data are typically collected by considering administrative boundaries, which allows for a comparative analysis of temporal and spatial changes. Multi-dimensional (integrated) plans and land-use policies can be implemented more effectively by decision-makers within these defined administrative units. The primary objective of this research is the gradual (fuzzy) determination of the naturalness level in Bartın province. It is also designed to serve as a basis for investigating future spatial changes. It also aims to identify spatial localities where human-induced degradation is intense and to develop sustainable management strategies. It will contribute to the literature by providing an example of studies that aim to reveal the level of naturalness in a local area.

MATERIAL AND METHOD

Study area: Bartin province is located north of Turkey and on the Black Sea coast. The geographic location of the province lies approximately between 41°17'00"-41°50'56" North latitude and 33°31'00"-32°06'20" East longitude. The administrative boundaries of Bartin cover an area of about 2120 km2. Its rough terrain is situated in parts of the Eastern and Southern. The Bartin River forms the western border of the Küre Mountains. The western part of the Küre Mountains National Park (KMNP) is located in this section. Bartin River flows north-south direction through the city center of Bartin. The valleys and lowlands formed by the Bartin River and its tributaries also include plains.

Bartin province comprises four district administrations (including the central district), four towns, and 260 village settlements. The total number of settlements established in the province is 268. According to the Turkish Statistical Institute data (TurkStat, 2023), the total population is 207238. Bartin province is one of the leading provinces in terms of natural areas. Bartin shares the Black Sea's climatic condition, which is found in the region of North Türkiye. The province has humid climate conditions. Bartin province shares administrative borders with Kastamonu, Zonguldak, and Karabük (Figure 1). Analyzing naturalness levels based on administrative boundaries provides a suitable foundation for sustainability by directly integrating it into management plans.

Method: This study aimed to assess the human impacts on the natural environment of Bartin province using a Geographic Information System (GIS). Various spatial data, including topographic maps, digital elevation models, land use/cover data, road data, and socioeconomic data, were integrated to create a comprehensive spatial database.

Six key indicators of human activity - settlement density, population density, road density, land use/cover,

Normalized Different Vegetation Index (NDVI), and Topographic Roughness Index (TRI)-were selected and inverted into fuzzy membership functions to account for the inherent uncertainties and gradual transitions in human-environment interactions. These fuzzy layers were combined using a fuzzy overlay method (FOM) to produce a spatial map delineating the extent and intensity of human impacts across the study area. Compared to traditional brutal classification methods, this approach provides a more nuanced understanding of the complex relationships between human activities and the natural environment (Figure 2). The study is similar to the "GHFI". The factors that better represent the local area were selected

Figure 1. Location map of the study area

This study utilized open-source ESA Sentinel-2 imagery (processed-licensed by Esri 2021) and land use/cover data. Open-source land use/cover data provided by Esri offers a publicly accessible spatial dataset for characterizing the Earth's surface. This resource facilitates various environmental and geographical analyses. This study classified settlements and agricultural areas as land use areas exposed to human impact. Forests were categorized as areas remote from human influence. Pastures, open areas, and sparse vegetation areas were classified as areas with a secondary level of human impact.

As human settlements increase, naturalness decreases. High settlement density exacerbates human-induced degradation of the natural environment. Areas with concentrated settlements in the spatial distribution of settlements also reflect human impact. The study area was mapped using kernel density interpolation in a GIS layer. The Kernel Density method calculates the density of settlement features (point features) in the study area. Areas with high population density indicate high human impact, while areas with decreasing population density are remote from human influence.

As the distance between rural settlements decreases/increases, the number of people per km² also decreases/increases. To determine population density, a specific area needs to be defined. Thiessen polygons are a simple and commonly used method for delineating the boundaries of rural settlements. This study also employed them to define the spatial density of rural population density. Boundaries were established at an equal distance between the village settlement center (point layer) and other neighboring settlements. All the sample points are connected to form a series of triangles. Then, the perpendicular bisectors of the triangle sides are drawn. Population data obtained from the address-based population registration system of TurkStat were divided into areas of Thiessen polygons (the population density per km²). Thus, a population density layer was created in the GIS. The obtained layer was converted into a fuzzy membership layer.

Another factor is road network density. Road networks, which provide human accessibility, were identified as artificial surfaces. In areas with low road density, human impact is typically lower. High road density, however, indicates fragmentation of natural areas and widespread human influence. Line density interpolation was used to define this factor in a GIS layer. The road data obtained from the Open Street Map was corrected by checking with platforms that provide open-access satellite imagery (with high-resolution images of Google Earth). The road network density using the line density tool was created by weighting the significant primary, secondary, and other roads.

NDVI is a standard index that measures the amount and health of vegetation using remote sensing data (usually satellite imagery). It is an index of dense vegetation and non-vegetation. High (positive) NDVI values indicate high levels of naturalness, while low (negative) NDVI values indicate low levels of naturalness. NDVI image is obtained by using 4, 5 bands of Landsat9 satellite imagery (=Bant 5 – Bant 4) / (Bant 5 + Bant 4).

The morphology of the land also limits human impact. Rough terrain limits human activity. As the roughness increases, naturalness increases. The decrease in roughness means a decrease in naturalness. TRI determined morphological roughness in the study area. TRI was calculated as the difference between a cell's maximum and minimum values and eight surrounding cells. TRI performed better than the Topographic Position Index (TPI). DEM data

"Produced using Copernicus data and information funded by the European Union - EU-DEM layers with 25 m resolution."(OpenDEM)

The naturalness level of the study area was determined using the fuzzy logic method. Fuzzy logic is preferred for identifying uncertain or intertwined situations without definite boundaries in the real world (Kainz, 2007). FOM is based on set theory, where a set generally corresponds to a class. The combining analysis step in FOM analysis quantifies each location's possibility of belonging to specified sets from various input rasters. The equation fuzzy Gaussian function is used. Spread defines the membership of the Gaussian function. It generally ranges from 0.01 to 1. Increasing the spread causes the fuzzy membership curve to become steeper. FOM quantifies the possibilities of each cell or location to a specified set based on membership value (Baidya et al., 2014; Çakıt & Karwowski, 2018; Tennakoon et al., 2023). It has advantages over set theory thanks to its membership process and flexible use. The analytical Hierarchy Process was not applied in the study. This assumes that the impact of each parameter on the output is equal.

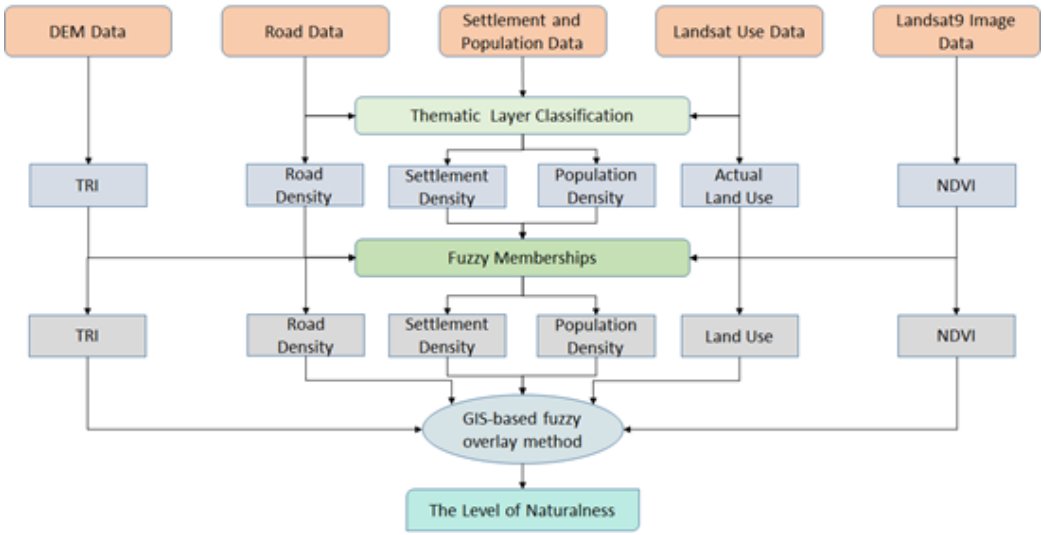

Figure 2. Flow chart of the FOM used to create the level of naturalness map.

RESULTS

Settlement density: Increased density in settlement areas results in the loss and fragmentation of natural habitats, consequently reducing biodiversity (McKinney, 2002; Seto et al., 2012). The settlements in the province are primarily located in mountainous, rugged terrain, coastal areas, and flatter lands around watercourses. The settlement pattern is generally dispersed throughout the province. The densest settlements are found along the courses of the Bartin Stream (central district settlement) and the Arit Stream, formed by the confluence of these two streams. Settlements established on the coast and nearby areas also constitute another high-population-density region. The construction of second homes for summer use in coastal areas has also contributed to the expansion of settlements (Figure 3).

Settlements are spread over larger areas on alluviums carried and deposited by rivers from highlands. Rural settlements have less infrastructure compared to urban settlements. In recent years, human-induced degradation of the natural environment has increased significantly. Natural risks such as landslides, floods, and earthquakes can be prevented with plans that will reduce the negative impact of settlements on nature.

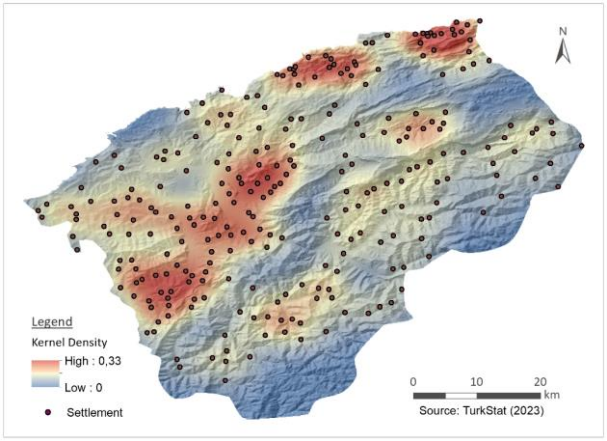

Figure 3. Kernel density estimation map of human settlements.

Population density: Population growth and density are central to research on the sustainability of natural resources (Crist et al., 2017). Natural ecosystems experience greater pressure in regions with high population density (McKee et al., 2003). Population density is typically calculated by dividing the total population of a settlement by its total area (or administrative boundary). However, in this study of Bartin province, geographic Thiessen polygons, which reference distance rather than administrative boundaries, were constructed to determine

population density. Boundaries between neighboring rural settlements were defined by bisecting the distance between them. The population density of the Bartın city center and its surrounding settlements is remarkably high. Amasra, Kurucaşile, Kumluca, Abdipaşa, and Ulus settlements also have high population density (Figure 4).

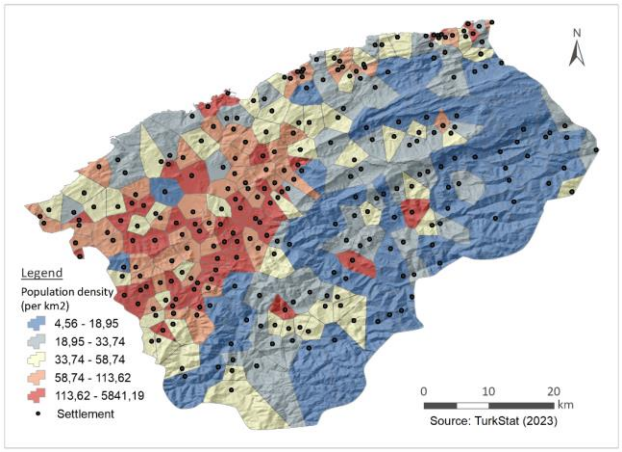

Figure 4. Population density map created with Thiessen polygons.

Road network density: The road network causes habitat fragmentation by breaking up natural landscapes. The differential effects of various road types and traffic volumes on habitat fragmentation and species movement have been identified (Fahrig & Rytwinski, 2009; Grilo et al., 2021). The road network in Bartin province is irregular due to the province's rugged topography. Road density was calculated using line density analysis. Road density generally includes significant roads from the city center to other district centers. Village roads connected to major roads have Secondary road density. The road density increases significantly along the corridor SW-NE and NW-SE directions within these routes. The road network and density decrease as distance from the coast and central settlements increases (Figure 5).

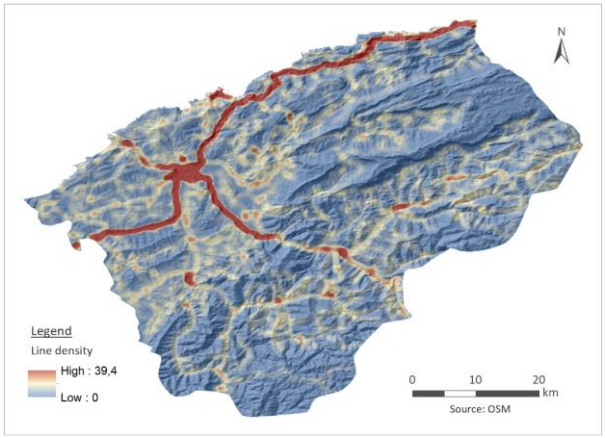

Figure 5. Line density estimation map of road network.

Land use/cover in Bartin province: The human-caused transformation of natural areas leads to habitat loss, biodiversity decline, and the degradation of ecosystem functions. Numerous studies have emphasized the importance of preserving natural land cover for sustainability (Foley et al., 2005; Sala et al., 2000). Global-scale land use projections have identified critical regions for future biodiversity losses (Rosa et al., 2023). It is the factor that directly affects how natural an area is. Land use in Bartin province is significantly influenced by its topography. Agricultural and settlement areas have been created on the foothills of mountainous terrain, on alluviums deposited by streams, and in irrigated areas. The slopes of the high mountain ranges are covered with forest cover. There are uses such as sparse/degraded vegetation, bare land, and pasture between forest and agricultural areas. Most artificial surfaces are around residential areas. Agricultural areas created around settlements are also areas where human activity is high. The areas with the lowest level of human impact are forest areas (Figure 6).

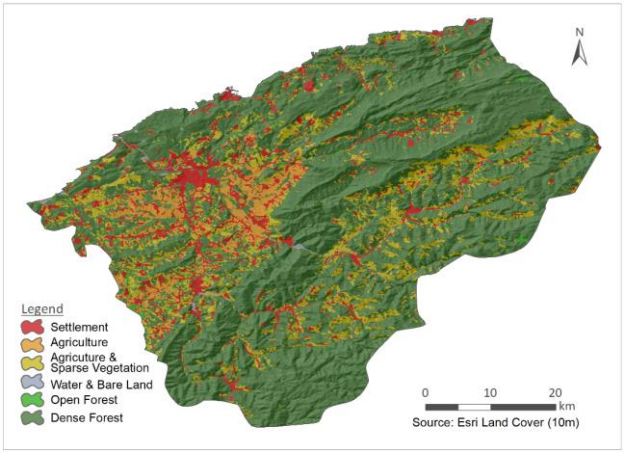

Figure 6. Actual land use in Bartin province.

Normalized Different Vegetation Index (NDVI): The NDVI measures vegetation density on the ground. The index is a value between -1 and 1. A positive (1) index value indicates dense vegetation, and a negative (-1) value indicates no vegetation. NDVI is high when green plants cover the entire pixel and low when there are no green plants. It also eliminates the effects of different solar angles. Decreased vegetation cover and degraded ecosystems due to human intervention have been observed to result in lower NDVI values (Goward et al., 1994; Lambin & Ehrlich, 1997). Human activities on natural environments, the impacts of climate change, and land degradation in arid and semi-arid regions are monitored using NDVI and trend analyses (Wang et al., 2021; De Keersmaecker et al., 2023). The NDVI in the study area ranges from -0.134 to 0.767. The negative index indicates artificial surfaces such as settlements, agriculture, and road networks without vegetation. A high positive index indicates natural areas with dense vegetation (Figure 7).

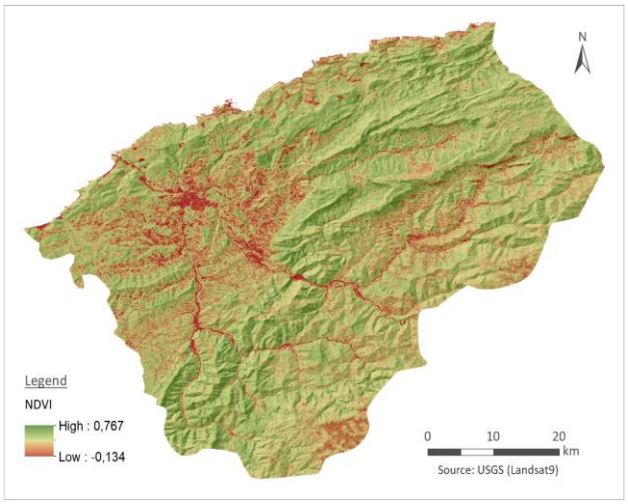

Figure 7. NDVI map in Bartin Province.

Topographic Roughness Index (TRI): The influence of landforms on terrestrial ecosystems is versatile, including ecosystem patterns, the spatial distribution of vegetation, and soil erosion. The TRI measures variability in the landscape surface. Topographic roughness is the land surface variability of a particular area and is a proxy for describing the potential of terrestrial propagation (Stambaugh & Guyette, 2008). The combination of difficult accessibility and rugged terrain keeps forests relatively undisturbed by human activities. High TRI (1) indicates a rugged terrain surface. A low TRI value (0) is a low, rugged terrain surface. TRI in the study area varies between 0.028 and 0.97. The low index is in the river network and its surroundings. The high index is a mountainous, hilly area (Figure 8).

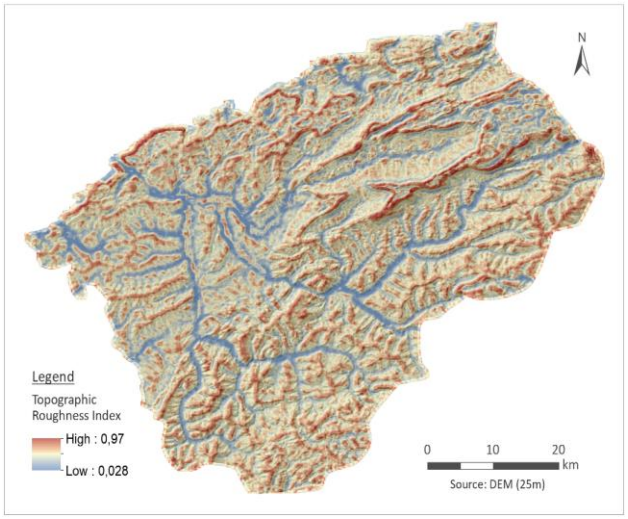

Figure 8. TRI map in Bartin Province

The Naturalness Levels of Bartın Province: Environmental degradation can be defined based on the presence of anthropogenic factors. Areas that overlap with various human-induced factors exhibit a high degree of degradation. Conversely, the absence of human-induced factors indicates a low level of spatial environmental degradation.

The naturalness level of any given land parcel can be determined based on the presence or absence of influential factors. Consequently, multi-criteria decision-making methods are widely employed for such assessments. Spatial clustering of these criteria aids in the classification of foreground regions/sub-regions. This study is similar to the GHFI, but it better describes the local characteristics of the province. This study identified six fundamental spatial criteria-land use/cover, population density, settlement density, road density, NDVI, and TRI-. Each criterion was converted into a fuzzy membership (Figure 9). The analytical hierarchy method (AHP) was not used. All factors were considered equally weighted. Overlaying these memberships resulted in a final map. The map range defines values from 0 to 1, where zero values are mainly formed from artificial surfaces. High values indicate naturalness (values approaching 1). According to this map, human-induced land change areas (anthropogenic areas) are concentrated in the central and coastal regions of the province. Remote from human influence, natural areas are found in rugged, high-elevation areas. Due to their functions in preserving naturalness, water, and soil, these rugged terrains are continuously covered by vegetation (absolute forest) and thus require protection. Semi-natural areas, with limited human impact, are potential degradation areas. Increasing human influence could transform these areas into anthropogenic ones. Fuzzy logic enables a more gradual visualization of spatial definitions. It is impossible to establish definite boundaries between natural and anthropogenic areas. Today, human accessibility and technological capabilities make conserving natural areas more challenging (Figure 10). Areas with a high level of naturalness are priority areas for sustainable land management and protection services.

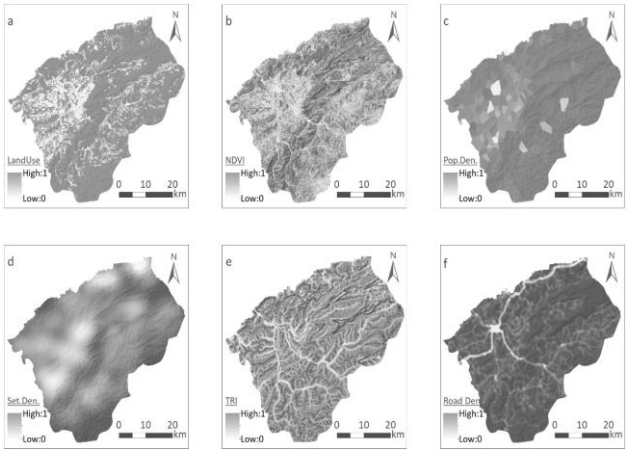

Figure 9. The six main factors are: a. Fuzzy member of the land use, b. Fuzzy member of the NDVI c. Fuzzy member of the population density d. Fuzzy member of the settlement density e. Fuzzy member of the TRI f. Fuzzy member of the road density

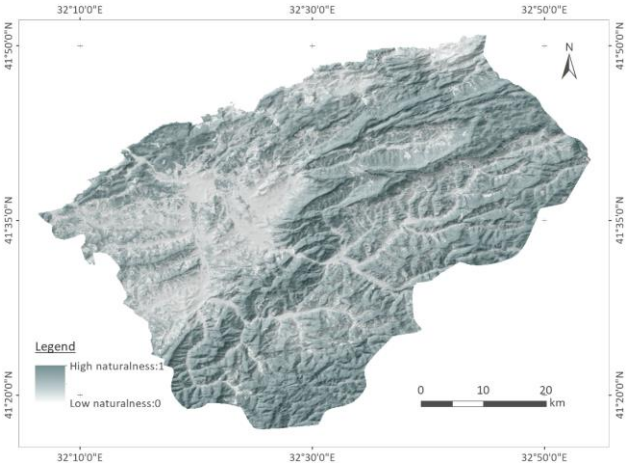

Figure 10. The naturalness level of Bartin province. (Combined pattern of six fuzzy members in the FOM).

CONCLUSION

Bartin province, renowned for its diverse physical geography, exhibits a high degree of naturalness due to limited human influence. However, the very attractiveness of its natural environment poses a risk of future degradation. To ensure sustainable land use and management, identifying priority areas for conservation and assessing the spatial sensitivity and direction of natural degradation processes are crucial. Furthermore, this study contributes to restoration efforts in human-induced degraded areas.

Topographic variations shape land use classes in Bartin province. Alluvial plains formed by rivers are intensively used for agriculture. The high mountainous regions in the east and south (West of the Küre Mountains) are covered with forests. Agricultural and settlement areas represent human-transformed landscapes, while forests are relatively undisturbed by human activities. Pasturelands, sparsely vegetated areas, and bare rocks constitute natural or human-induced semi-natural areas.

In conclusion, the naturalness level of a specific area can be correlated with human impact. Areas with high human influence exhibit low naturalness. Using the FOM, this study identifies Bartin's naturalness levels. Spatial results indicate that steep, rugged areas are priority conservation zones with high naturalness. Areas with moderate slopes, often covered by sparse vegetation, are semi-natural and moderate-level natural. A mix of settlements and agriculture areas characterizes flat and near-flat areas, typically found on alluvial deposits. These areas have non-natural and low-level naturalness. Steep and rugged terrains are less susceptible to socioeconomic pressures such as agriculture and grazing. Additionally, these areas offer pastoral and recreational opportunities.

The selected factors reflect the diverse impacts of human activities on natural environments. Therefore, their combined evaluation provides a scientifically justified approach to understanding an area's naturalness level and predicting future changes. Land use planning and policies should incorporate multi-faceted management models, especially in ecologically constrained areas, to ensure ecosystem sustainability, productivity, and rural development.

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