Research Article

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The Social Importance Of University Campuses And Their Impact On Land Fragmentation: The Case Of Ktü Kanuni Campus And Its Surroundings.

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ABSTRACT

In recent years, increasing population and intense urbanization have negatively affected urban ecology and biodiversity, leading to a reduction in urban open and green spaces. This study evaluates the role of university campuses in urban areas and the environmental impacts of land fragmentation using the example of the Kanuni Campus of Karadeniz Technical University (KTÜ). The study was conducted in the Kanuni Campus of Karadeniz Technical University, located in the Ortahisar district of Trabzon in the Black Sea region. Remote sensing and Geographic Information Systems (GIS) techniques were used to examine land cover and temporal land use changes, and the Patch Analysis, an ArcGIS extension of the Fragstats software, was applied to determine the level of fragmentation of green spaces. The results showed that green areas decreased by 48% due to land changes, and the reduction of green areas negatively affected biodiversity according to the patch analysis results. This study emphasizes the potential of universities to preserve and enhance green spaces in cities, offering strategic recommendations for sustainable urban planning and aiming to develop solutions for environmental and health problems encountered in the urbanization process, along with the socio-economic, cultural, and political impacts of campuses.

Keywords : *University campuses, patch analysis, biodiversity, land use, green spaces.*

INTRODUCTION

In recent years, increasing population and rapidly advancing urbanization have disrupted human-environment harmony, causing significant harm to urban ecology. This situation threatens urban biodiversity and the existence of open-green spaces (Selim et al., 2015;Wu et al., 2024;Oertel et al., 2024). Anthropogenic pressures in cities, such as improper land use, fragmentation of natural habitats, soil fertility loss, and climate changes, lead to various environmental problems (Mac et al., 1998; Alberti, 2005; Bennett & Saunders, 2010; Kesgin Atak, 2020;Orozco et al., 2024;Browne et al., 2024). Moreover, these pressures exacerbate climate change, leading to the formation of urban heat islands, which negatively affect vegetation, human health, and air quality (Gill, 2006; Georgi & Zafiriadis, 2006; Bowler et al., 2010; Gillner et al., 2015; Melaas et al., 2016; Zipper et al., 2016; Vandentorren et al., 2006; Sarrat et al., 2006; Zhou et al., 2015; Çilek, 2022). Improper and purpose-driven land use in settlements causes irreversible damage to land (Doygun, 2003; Dengiz et al., 2006; Esen, 2017; Özçelik vd., 2021). In this context, ensuring ecological balance and protecting landscape areas become increasingly important, depending on social, cultural, and ecological factors (Vitousek et al., 1997; Fischer & Lindenmayer, 2006; Erdoğan et al., 2014; Kesgin Atak, 2020).

Considering all these environmental issues, determining and revealing land use changes in urban areas and their surroundings is of great importance for the use and management of natural resources (Miller & Small, 1999; Karabulut et al., 2006). Monitoring land changes over time is essential, especially in urban areas, to prevent the loss of natural and cultural resources and irreversible problems. Studies that reveal the physical changes of cities over time have gained importance in recent years. Revealing physical changes from past to present allows for identifying expectations and new requirements, contributing to the planned change, development, and transformation of cities (Üçok, 2019). To monitor and prevent unplanned development, temporal changes must be identified, and necessary planning work should be conducted. The dynamic nature of changes in the natural environment necessitates the acquisition of current and new data to monitor these changes. Developments in aviation and space technology offer new opportunities for solving such problems. In physical planning studies, Geographic Information Systems (GIS) and Remote Sensing techniques allow for the identification and presentation of natural and cultural resources without direct contact. Many data are produced by collecting, processing, and interpreting data obtained from satellite images and aerial photographs (Oke, 1993; Kelkit and Kırzıoğlu, 1996; Kızılelma et al., 2013;Özşahin, 2015; Mohapatra et al., 2016;Oğuztürk et al., 2017). Monitoring changes using satellite images, conducted in a short time and with up-to-date information, offers more successful results than classical methods and allows for the desired outcomes to be achieved (Tunay & Ateşoğlu, 2009; Benek & Şahap, 2016; Üçok, 2019;Bilgili vd., 2018; Sipahi &Yılmaz, 2022). GIS systems are used to monitor changes in the landscape over time at different scales; identifying land/land use and changes and making planning decisions to develop land management strategies are of great importance (Turgut & Tırnakçı, 2020; Ünlükaplan & Karagöz, 2022). Data on changes in the quantitative and qualitative aspects of land cover/land use (LC/LU) features resulting from environmental monitoring are a crucial step for ensuring the sustainability of land uses (Doygun & Berberoğlu, 2001). In parallel with these data, natural or artificial changes such as transportation, settlement patterns, agricultural and forest lands, coasts, are detected. To ensure the proper use of land resources, temporal changes in urban areas should be identified and managed by making planning decisions accordingly.

Universities, which have a significant role and extensive use within cities, are areas that highlight the socio-economic structure, cultural, and political characteristics of the society they are located in and have the potential to create alternative green spaces in cities (Korkut, 2011; Yıldız, 2020). Universities, while training high-level personnel needed by society, also offer their scientific studies for the benefit of individuals and communities and contribute to the development of the community in the regions where they are established (Önder, 2000; Özen, 2004; Tukker, 2008; Jackson, 2011).

The aim of this study is to highlight the importance of university campuses for urban ecosystems while revealing the ecological impacts of these campuses on the environment. In addition to providing ecological contributions, university campuses increase construction pressures due to the growing population and the resulting needs for housing, transportation, and food services. This process leads to a reduction in green spaces, land fragmentation, and a decline in biodiversity. This study aims to offer recommendations on how campuses can be more effectively protected in urban planning and how biodiversity can be sustainably supported.

In light of these data, this study emphasizes the urban significance of the KTÜ Kanuni Campus, which was chosen as the study area, focusing on its integrated urban life, natural environment, coastal culture, and changes in social, physical, and structural dimensions.

MATERIALS AND METHODS

The main material of this study is the KTÜ Kanuni Campus and its surroundings located in the Ortahisar district of Trabzon. Supporting materials include relevant literature, base maps obtained from public institutions (1/25000 scale map, satellite photos, ortho-photos), zoning plans, observations made in the study area, photographs taken in the field, notes and reports taken during field surveys. The study area is located on G43b1-F43c4 sheets of 1/25,000 scale topographic maps. WGS84 datum and UTM Zone 37 geographic coordinates were used for digitizing and processing ortho-photos with ArcGIS 10.6 software and Google Earth Pro packages. The maps; written and drawn materials related to the study area were obtained officially from public institutions and private organizations (**Table 1**).

Table 1. Data table of the study area.

Data Used for the Study Area		
Base Maps	**Source**	**Year**
Raster Map 1/25000	General Directorate of Mapping	2021
1955, 1973, 1989, 2002, 2015, 2019, and 2021	General Directorate of Mapping	2021
Zoning Plan	Ortahisar Municipality	2021
Climate Data	11th Regional Directorate of Meteorology, Trabzon	1955-2021

Ortho-photos and satellite images from the years 1955, 1973, 1989, 2002, 2010, 2015, and 2021 were analyzed to reveal the changes in the KTÜ Kanuni Campus from its establishment year (1955) to the present day (2021) (**Figure 1**).

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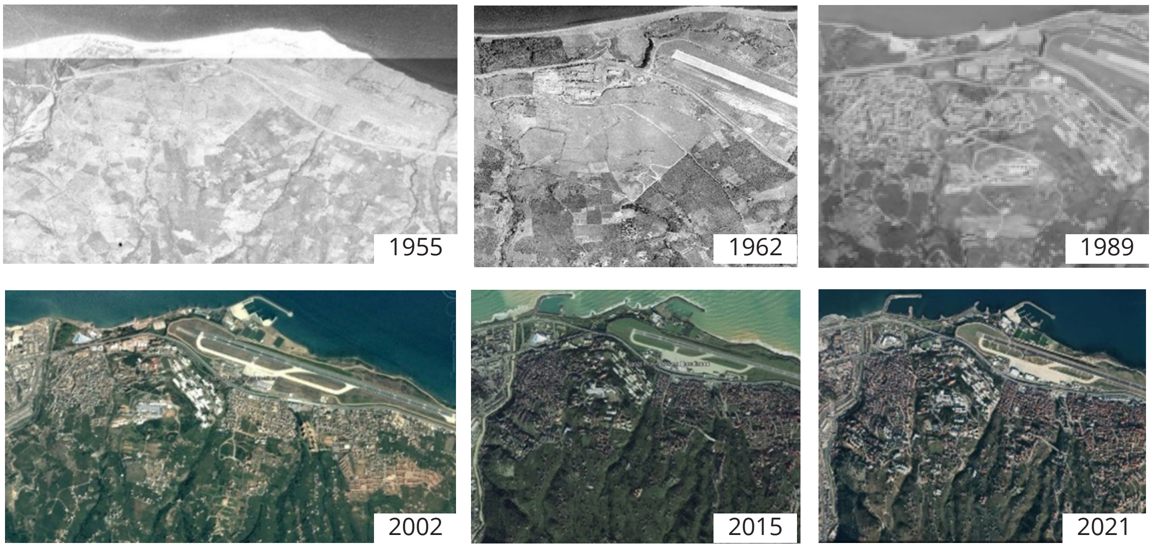
Figure 1. Satellite images of KTÜ Kanuni Campus at different times.

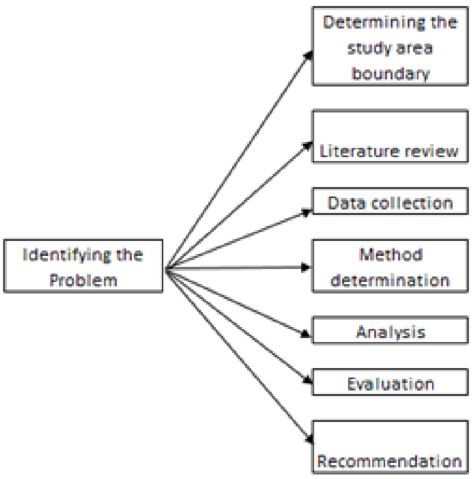


The study area consists of the Karadeniz Technical University (KTÜ) Kanuni Campus and its surroundings, located within the Ortahisar district boundaries of Trabzon province in the Eastern Black Sea region of the Black Sea region. The study area is situated between the latitudes of 40° 59′42.93″ N and the longitudes of 39° 46′25.80″ E (**Figure 2**).

Figure 2. Location map of the study area in the World (a), in Turkey (b), in the Black sea region (c), in Trabzon (d) and the the area boundary (e) (URL-1).

The study incorporates both quantitative and qualitative research methods (**Figure 3**) and utilizes remote sensing and GIS techniques to examine the land cover/use changes in the KTÜ Kanuni Campus and its surroundings from past to present. Changes in land cover and use types were analyzed. To quantitatively determine the level of fragmentation of green spaces, Patch Analysis, an ArcGIS extension of the Fragstats software, was used (McGarigal & Marks, 1995). Additionally, accuracy analysis was performed to calculate overall accuracy, producer accuracy, user accuracy, and the Kappa coefficient through comparisons between topographic maps, land use maps, and high-resolution satellite images obtained from various dates for the study area.

Figure 3. Methodology Diagram.



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Determination of the Study Area

The KTÜ Kanuni Campus was selected as the study area due to its high usage potential, its relationship with the city, and its openness to development. Neighborhood boundaries were considered in determining the study area's borders.

Literature Review Stage

Domestic and international literature on the study topic was reviewed, and concepts of temporal land use change in university campuses were defined. Criteria that should be included in design and planning decisions for universities to be characterized as ecological, sustainable, and holistic campuses were identified and introduced.

Data Collection Stage

Verbal and numerical data related to the study area were obtained from relevant institutions. The study utilized orthophotos from 1955, 1959, 1962, 1973, 1975, 1978, 1982, 1989, 2004, 2015, 2019, and 2021 provided by the General Directorate of Mapping; 2021 aerial photographs obtained from Google Earth; satellite images; 1/25,000 scale raster maps; topographic maps; zoning plans obtained from the Ortahisar Municipality; the Forest Management Plan produced by the Trabzon Forest Enterprise Directorate; climate data obtained from the 11th Regional Directorate of Meteorology; and photographs taken of the study area.

Method Determination Stage

The condition of the campus from past to present (1955-2021) was analyzed using maps digitized and obtained from the ArcGIS program. It was observed that ArcGIS programs are widely used in literature studies to reveal the temporal change of the area and that Patch Analysis gives good results for the fragmentation level in terms of ecological outcomes. Hence, these methods and evaluations were preferred.

Analysis Stage

Based on the work of Anderson (1976), interpretation and analysis revealed that five main land use and land cover classes exist in the study area. The land use classes were identified as settlement areas (residential and university buildings), commercial areas, transportation networks, and open green spaces. Using satellite images and aerial photographs, the land use capability and land use types were determined spatially and proportionally with ArcGIS 10.6 software. Digital elevation models (DEM) were produced to determine maps of the study area's basic geographical features. To quantitatively reveal the level of fragmentation of green spaces, Patch Analysis, an ArcGIS extension of the Fragstats software, was conducted (McGarigal and Marks, 1995). Landscape indices were calculated using Patch Analyst. Larger patches were observed in areas where the Class Area (CA) and Largest Patch Index (LPI) values, which provide information about the spatial extent of landscape patches, were higher. In the context of landscape ecology and connectivity, expanding the patch area is sometimes more important than the area size itself (McGarigal & Marks, 1995; Rempel et al., 2012; Güneroğlu et al., 2013). Calculated Area-Weighted Mean Shape Index (AWMSI) and Area-Weighted Mean Patch Fractal Dimension (AWMPFD) values indicated higher urbanization rates. Additionally, accuracy analysis is an essential measurement method for determining the accuracy of a classified image produced by remote sensing. This method shows the accuracy of any point in the classified image using a reference source (Myint et al., 2011). Land use maps of classified images analyzed for the study area in 1955, 1973, 2002, 2015, and 2021, topographic maps, high-resolution satellite images, and aerial photographs were compared to calculate user accuracy (commission error), producer accuracy (omission error), overall accuracy, and the Kappa coefficient. The Thornthwaite Climate Classification method was considered when determining the climatic characteristics of the Trabzon province (Thornthwaite, 1948). The number of reference pixels (samples) used is critical to obtaining the most accurate and precise result in the classification accuracy. Since 250 or more reference pixels are needed to estimate the accuracy of a class within a +5% and -5% range (Congalton, 1991), 100 random sample points were generated for each accuracy analysis for each year in this study for all areas (green space, university campuses, residential and commercial areas, transportation, and other areas). Land use maps of classified images analyzed for the study area in 1955, 1973, 2002, 2015, and 2021, topographic maps, high-resolution satellite images, aerial photographs, and fieldwork were compared to calculate user accuracy (commission error), producer accuracy (omission error), overall accuracy, and the Kappa coefficient.

Evaluation Stage

As a result of the analyses, land changes over 66 years in the campus area were revealed, and ecological problems experienced in and around the campus were evaluated.

Recommendation Stage

Recommendations were developed to eliminate and halt the progress of ecological problems identified as a result of the analyses.

Findings

In this study conducted on the KTÜ Kanuni Campus, the changes in land use within and around the campus due to population growth (**Figure 4**) between 1955 and 2021 and the resulting needs were examined. The study revealed increases in the circulation routes (**Figure 5**), the number of buildings

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(university buildings, dormitories, cafes, and restaurants) (**Figure 6**), and the decrease in green spaces (**Figure 7**) within and around the campus. This process highlighted how the campus area and its surroundings have changed over time.

Figure 4. Population growth graph of KTÜ Kanuni Campus (students, academic, and administrative staff).

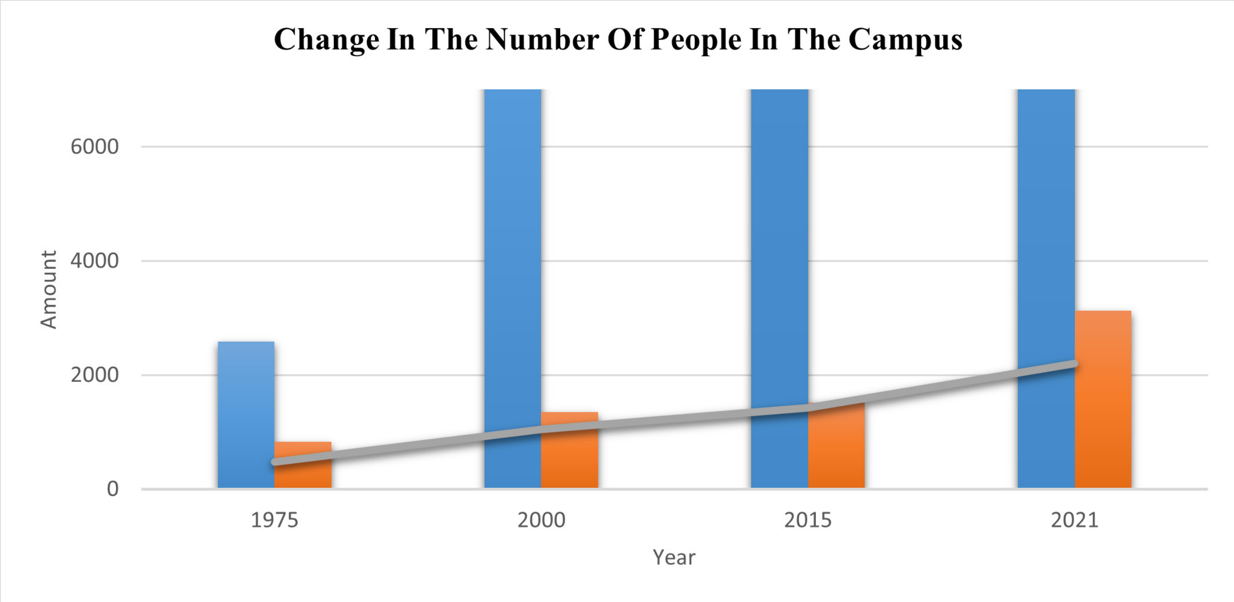

Figure 5. Change in circulation routes within and around KTÜ Kanuni Campus between 1955 and 2021.

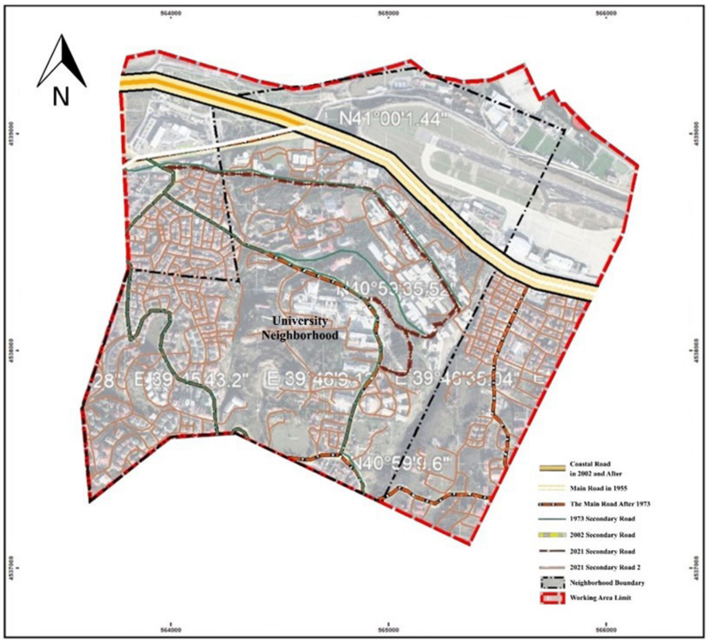

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Figure 6. Urban development within and around KTÜ Kanuni Campus between 1973 and 2021.

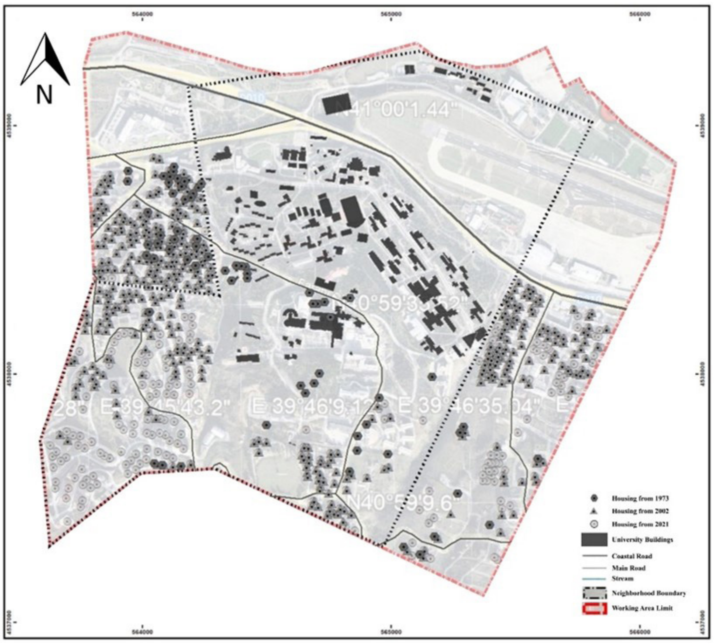

Figure 7. Change in green spaces within and around KTÜ Kanuni Campus between 1955 and 2021.

It has been demonstrated through GIS techniques that green spaces within the campus have decreased by 48% due to increasing urban development over time (**Table 2**). To highlight the reduction in biodiversity resulting from the decrease in green spaces, Patch analysis was applied in the study.

Table 2. Changes over time within the campus.

	1955	2021	Rate of change
Green spaces	247.000 m²	127.000 m²	-%48
Hard surface	814.118 m²	934.118 m²	+%14,7
Residential area	-	709.814,78 m²	
Commercial area	-	83.814,95 m²	
Transportation network	4.820,84 m	58.556,77 m	+%1114

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Landscape metrics were calculated to show the level of fragmented green cover in the study area. The temporal changes in green spaces within the KTÜ Kanuni Campus for the years 1973, 2002, and 2021 were revealed using patch analysis. The 1955 data were not included in the patch analysis because the green area was a single, continuous piece.

The calculated landscape metrics revealed the degree of urban sprawl and fragmentation for the KTÜ Kanuni Campus and its surroundings, considered the study area. The landscape patches were incompatible with each other and generally had a compact shape, resulting in a relatively low AWMPFD (Area-Weighted Mean Patch Fractal Dimension) value of "1.39," which indicates high fragmentation. Similarly, other shape-related metric values for the study area were calculated as "2.04" for AWMSI (Area-Weighted Mean Shape Index) and "0.68" for MPS (Mean Patch Size). These values confirmed the fragmentation of the study area due to increasing population and urban development.

AWMPFD (Area-Weighted Mean Patch Fractal Dimension): The area-weighted mean patch fractal dimension calculated based on land use indicates what type of metrics can define the landscape of the study area. The metrics obtained from the evaluation of land use layers include area, edge, and shape metrics. These are AWMSI, MPAR, MSI, AWMPFD, MPFD, ED, TE, MPE, NumP, MPS, PSCoV, and CA (**Table 3**).

Table 3. Landscape metrics for land use.

	Data by Year		
Metrics	**1973**	**2002**	**2021**
AWMSI	1.42059	1.98323	2.03996
MSI	1.38111	1.52175	1.62267
MPAR (m/ha)	208.394	1267.45	1595.92
MPFD	1.28212	1.4296	1.16609
AWMPFD	1.24826	1.37244	1.38657
TE (m)	15238.9	76175.3	71126
ED (m/ha)	84.1192	481.272	556.962
MPE (m/leke)	1904.86	420.858	378.33
MPS (ha)	22.6448	0.874469	0.679275
NumP	8	181	188
PSCoV	125.188	251.094	274.481
CA (ha)	181.158	158.279	127.704

Area-Weighted Shape Index (AWMSI) values are higher for larger and more fragmented patches compared to relatively smaller patches. Accordingly, in the study area, the patch size in 2021 was 2.04, followed by 1.99 in 2002 and 1.42 in 1973 with AWMSI values. These values indicate that the area was covered by larger patches.

Mean Shape Index (MSI) is an important metric for determining the shape characteristics of the landscape. Specifically, MSI provides critical information regarding the size of the patches that make up the landscape. The MSI value was 1.62 for 2021, which had larger patch characteristics, and was represented by values of 1.39 and 1.52 for the years 1973 and 2002, respectively, which had slightly smaller spatial use characteristics.

MPAR (Mean Perimeter-Area Ratio) is a crucial metric used to reveal complex shape characteristics by representing the ratio of the total perimeter to the area for each patch and their sum. In this study, the MPAR value showed a high value of 1595.92 m/ha for the year 2021. This suggests that as the size of the geographic objects represented in the study area decreases, the shape irregularity increases inversely.

MPFD (Mean Patch Fractal Dimension) is another index that indicates the shape irregularity of the patches that make up each class. When the shapes of the patches are closer to basic geometric shapes, the MPFD value approaches '1,' and as shape irregularity increases, it approaches '2.' When examining the MPFD values for the study area, the highest value was observed for the year 2021, while the lowest value belonged to 1973. This indicates that the area generally consists of patches with significant shape irregularities.

AWMPFD (Area-Weighted Mean Patch Fractal Dimension) is another metric used to determine the shape complexity ratio for each class and patch, depending on the size of the patches that make up the area. The AWMPFD value was found to be 1.39 for the year 2021 and 1.25 for 1973. This indicates that when the patches that make up these two classes were weighted according to their area, shape irregularity increased in 2021 and decreased in 1973.

Edge Density (ED) is the parameter that can be used to compare the edge densities of patches that make up the landscape. ED represents the edge density per unit area. This metric is particularly important in class-level analyses for showing which types of patches dominate the area. In the study, the ED value for the patches in 2021 was expressed as 556.96 m/ha, which is the highest value. This was followed by the year 2002 with 481.27 m/ha and the year 1973 with 84.12 m/ha. This metric also provides information related to patch size and configuration.

MPE (Mean Perimeter-Edge) is another important metric related to edge characteristics. MPE provides the average edge length per patch for each class. This metric provides information about the shape characteristics and sizes of the patches. When examining the MPE values for the study area, the highest MPE value was observed for the year 1973 with 1904.86 m/patch, followed by the year 2002 with a value of 420.86 m/patch. The lowest MPE value in the study belonged to the year 2021 with 378.33 m/patch.

MPS (Mean Patch Size) expresses the average patch size at both the class and entire area levels. It provides the ability to compare the class-level classes with each other and the area or landscapes in terms of patch size at larger scales. When evaluating the area over the years, it is noteworthy that the patches with the largest values were observed in 1973 with 22.64 ha and in 2002 with 0.87 ha. In 2021, the smallest patch size was observed with 0.68 ha.

The number of patches, expressed as NumP, is an important parameter for evaluating the ecological status of each class or the entire area in terms of landscape metrics. In this study, the highest number of patches was 188 in 2021. In addition, 181 patches represented the year 2002, and 8 patches represented the year 1973.

PSCoV (Percent of Standard Coefficient of Variation) expresses the percentage change in patches from year to year in terms of how they differ from each other in the area. Accordingly, the year with the most change in average patch size was 2021 with a value of 274.48. This indicates that the average patch size in 2021 showed significant variation. The year with the least change was 1973, with a PSCoV value of 125.19.

The CA (Class Area) value indicates the area size of each year in hectares. Patch density (PD) at the class and entire area levels is one of the most important basic metrics related to the fragmentation of the area. High metric values for any given year indicate the level of fragmentation exhibited throughout the area for that year. This metric is an important measure for several ecological applications. One of these is measuring habitat loss, which is an important byproduct of habitat fragmentation (Reddy et al., 2013; Doğan, 2016). The CA value for the study area decreased from 181.15 ha in 1973 to 127.704 ha in 2021.

CONCLUSION AND DISCUSSION

The findings of this study largely align with previous research (Mac et al., 1998; Alberti, 2005; Bennett & Saunders, 2010; Kesgin Atak, 2020). Over time, the changes have increased anthropogenic pressures within and around the campus, leading to various issues such as improper land use, the reduction of green spaces, and their degradation (Haaland & Van den Bosch, 2015). This study thoroughly examined the negative effects of increased construction and urbanization processes on green spaces using the KTÜ Kanuni Campus as an example. The results indicate the decline in air quality, biodiversity, and the reduction of comfort and recreation areas within the campus (Alshuwaikhat & Abubakar, 2008; Dover, 2015; Susilowati et al.,2021). Additionally, the increase in energy use and the rise in impervious surfaces have exacerbated ecological environmental problems (Booth et al., 2002; Ma & Wu, 2016).

The data obtained from this study highlight the impact of improper urban planning and management strategies on natural and cultural landscapes, providing critical insights for sustainable urban development efforts (Lau et al., 2014; Ten Brink et al., 2016). Preserving and increasing green spaces in campus planning has the potential to maintain ecological balance and enhance the quality of life (Vukmirovic, et al. ,2019). This study offers a scientific foundation for urban planners and administrators to develop sustainable urban development strategies. It also emphasizes the necessity for future research to focus on identifying more comprehensive strategies for preserving and increasing green spaces (Heidt & Neef, 2008; Panagopoulos et al., 2016).

The analysis of landscape metrics in the study area provided a comprehensive assessment of structural and ecological changes over the period from 1973 to 2021. The observed changes in metrics such as Area-Weighted Shape Index (AWMSI), Mean Shape Index (MSI), and Area-Weighted Mean Patch Fractal Dimension (AWMPFD) indicate that land use has evolved towards more regular structural layouts over time. Specifically, the reduction in AWMSI and MSI values suggests that the landscape has become less fragmented and more regular in structure, while the decrease in MPFD and AWMPFD values indicates that patch shapes have become less complex (Güner et al., 2001; Paudel & Yuan, 2012; Güneroglu et al., 2013).

The decreases in Edge Density (ED) and Edge Features (MPE) metrics suggest that the pressure of urban development on the boundaries of natural habitats has lessened, though significant ecological impacts remain. The increase in Mean Patch Size (MPS) and Number of Patches (NumP) values indicates a trend towards larger but more fragmented structures within the landscape. These findings underscore the importance of strategic green space planning to mitigate the ecological impacts of urban development (Alberti & Waddell, 2000; Wang et al., 2009; Huang et al., 2020).

In conclusion, this study provides a scientific foundation for urban planners and decision-makers to develop sustainable urban development strategies. Preserving and increasing green spaces is crucial for maintaining ecological balance and enhancing the quality of urban life (Tzoulas et al., 2007;Tiemela et al., 2010; Kasim et al., 2019; Zhang & Qian, 2024). Future research is expected to contribute to the identification of more comprehensive and long-term strategies.

Recommendations

Establishment of Green Corridors and Ecological Networks

Creating green corridors and ecological networks can strengthen biological connections between ecosystems by reducing habitat Deconstruction. These corridors can contribute to the conservation of biodiversity by providing safe transit routes for wildlife. Thus, green corridors supported by vegetative landscapes in and around cities can help to ensure ecological sustainability.

Sustainable Urban Planning

Urban planning processes should include arrangements that protect ecological values and support the natural features of the landscape. The protection and restoration of large patch areas is of critical importance for maintaining ecological integrity. During the expansion and development of cities, it is necessary to make holistic and long-term plans for the protection of green areas and natural habitats.

Water Management and Drainage Systems

Solutions such as sustainable drainage systems (SuDS) can help protect water resources by supporting the natural cycle of rainwater. These systems can reduce the risk of flooding, especially in urban areas, while meeting the moisture needs of natural habitats. SuDS can be supported by applications such as green roofs, permeable surfaces, rain gardens.

Comprehensive Environmental Monitoring and Assessment

Regular monitoring and evaluation of landscape measurements is important for understanding the ecological effects of land use changes. These monitoring activities ensure timely intervention and increase the effectiveness of sustainable management strategies. With environmental monitoring programs, critical parameters such as air quality, water quality and biodiversity can be monitored.

Community Participation and Education

Increasing the environmental awareness of community members and local governments is a very important step in achieving the sustainable development goals. Educational programs and public participation encourage local communities to actively participate in environmental processes. This participation allows decisions and projects at the local level to be more effective and sustainable. In addition, community-based projects make important contributions to the protection of local resources and increasing ecological awareness.

These recommendations should be evaluated as part of steps to manage structural changes in the work area and protect ecological integrity.

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