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Assessment of Rapid Urbanization Effects on Land Use Dynamics: A Google Earth and GIS Approach in Kemalöz Neighborhood, Uşak, Türkiye - An Earth Science Perspective

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ABSTRACT

As urbanization continues to increase, the concerns about sustainable land use and management are also growing. Thus, there has been an increasing number of scientific research studies conducted on this phenomenon. In many cases, these studies have been performed using expensive remote sensing software with free but lower-resolution Landsat imagery (>30m). In contrast, Google Earth provides high-resolution imagery, offering a more detailed analysis of land use changes. On the other hand, Google Earth Pro imageries have a geometric resolution of 1.5 meters to 2 meters for most of the covered areas in the world. The objective of this study is to investigate changes in land use in the Kemalöz neighborhood of Uşak, Türkiye, which is the fastest-growing district, by utilizing Google Earth Pro and GIS for rapid assessment of land use change between 2005 and 2024, offering an alternative to remote sensing software and low-resolution Landsat imagery. The study also aims to evaluate the relative benefits of integrating geoscience to analyze land-use changes to provide insights to policymakers and local officials to make informed decisions about the most effective way to manage land to mitigate the negative effects of urbanization. The findings of this study indicated that the build-up land use has increased from 1,734 to 2,755 km^2 from 2005 to 2024. Vegetation land use has increased from 1,081 to 1,392 km^2 between 2005 and 2024. Agricultural land use has decreased from 1,781 to 1,149 km^2 between 2005 and 2024. Barren land use has decreased from 1,803 to 1,103 km^2. This suggests significant urban development or infrastructure expansion occurred in the study area over the 19 years.

Keywords: *Urbanization, Land Use, Google Earth, Earth Science*

Hızlı Kentselleşmenin Arazi Kullanım Dinamikleri Üzerindeki Değerlendirmesi: Kemalöz Mahallesi, Uşak, Türkiye'de Bir Google Earth ve CBS Yaklaşımı - Bir Yer Bilimleri Perspektifi

ÖZET

Kentselleşmenin artmasıyla birlikte, sürdürülebilir arazi kullanımı ve yönetimine yönelik endişeler de artmaktadır. Bu nedenle, bu fenomen üzerine yapılan bilimsel araştırmaların sayısı artmaktadır. Çoğu durumda, bu çalışmalar, ücretsiz ancak daha düşük çözünürlüklü Landsat görüntüleri (>30m) ile pahalı uzaktan algılama yazılımları kullanılarak gerçekleştirilmiştir. Buna karşılık, Google Earth yüksek

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çözünürlüklü görüntüler sunarak, arazi kullanımı değişikliklerinin daha detaylı bir analizini sağlamaktadır. Öte yandan, Google Earth Pro görüntüleri, dünya genelindeki çoğu alan için 1,5 metreden 2 metreye kadar geometrik çözünürlüğe sahiptir. Bu çalışmanın amacı, Türkiye'nin Uşak şehrinin en hızlı büyüyen mahallesi olan Kemalöz'ün arazi kullanımındaki değişiklikleri incelemektir. Bu inceleme, 2005 ile 2024 arasındaki arazi kullanım değişikliklerini hızlı bir şekilde değerlendirmek için Google Earth Pro ve Coğrafi Bilgi Sistemi (GIS) kullanarak, maliyetli uzaktan algılama yazılımlarına ve düşük çözünürlüklü Landsat görüntülerine alternatif sunmaktadır. Çalışma ayrıca, arazi kullanımı değişikliklerini analiz etmek için yer bilimlerini entegre etmenin göreli faydalarını değerlendirmeyi amaçlamaktadır, böylece karar vericilere ve yerel yetkililere kentselleşmenin negatif etkilerini azaltmak için araziyi en etkili şekilde yönetme konusunda bilgi vermektedir. Bu çalışmanın bulguları, inceleme alanında 19 yıl boyunca önemli bir kentsel gelişme veya altyapı genişlemesi olduğunu göstermektedir. 2005 ile 2024 arasında yapılan inceleme, yapılaşma alanının 1.734'ten 2.755 km^2'ye, bitki örtüsü kullanım alanının ise 1.081'den 1.392 km^2'ye arttığını göstermiştir. Tarım alanı kullanımının ise 2005 ile 2024 arasında 1.781'den 1.149 km^2'ye azaldığı tespit edilmiştir. Kullanılmayan arazi alanının ise 1.803'ten 1.103 km^2'ye azaldığı görülmektedir. Bu sonuçlar, inceleme alanında önemli bir kentsel gelişme veya altyapı genişlemesi olduğunu göstermektedir.

Anahtar Kelimeler: *Kentselleşme, Arazi Kullanımı, Google Earth, Yer Bilimleri*

I. INTRODUCTION

While the world's population growth is on, urbanization is one of the most significant problems to date. The latest World Urbanization Prospects of 2018 states that more than half of the world's population which is equal to 4.2 billion people already live in urban areas [1]. This figure is expected to be higher by 5.2 billion in 2030, according to the UN's estimate [1]. Thus, the trend of the rural population leaving the countryside to the city for the sake of gaining better jobs, health care, as well as educational opportunities, is observed. Urbanization can bring both positive effects and negative impacts. The possibilities include implanted infrastructures that are more innovative and sustainable, improved health care and education services, increased economic growth, cultural diversity, and cultural exchange, and the chance for the improvement of social connections and community development. However, the rapid growth of a town's population is a major problem, and this leads to an over-exploitation of resources and facilities, which eventually leads to socio-economic issues, environmental pollution, noise pollution, and traffic jams [2,3,4]. Sustainable policies targeted at controlling the expansion of urban areas and raising the standard of living of all residents can be crafted only with an appreciation of the complex processes of urbanization. Urbanization is a process in which there is a net outflow of people from the rural areas to the urban areas. This phenomenon especially takes place in developing countries [5,6,7]. Thus, the policymakers have to take the appropriate steps to reduce the size of the negative impact of the growing population in the cities. One of these steps in tackling the urbanization challenges is the proper management of the uses. The interrelation between people and the place they live in has been significantly affected by urbanization, which is causing momentous changes in this relationship. The evolutionary process of urban land use occurs through a gradual increase in the complexity of urban land use where smaller and less complicated ones are converted into larger and more complex ones [8,9,10]. The spatial structure of urban land use, therefore, also plays a key role when the relationship between the land and the people in the urbanization process is analyzed [10,11,12]. Moreover, precise and updated land cover and land-use change data are also an important factor for urban planning and management, and all kinds of environmental monitoring activities [13,14,15].

As concerns about correct land management in the current urbanization have grown, there has been an increasing number of scientific research studies conducted. In many cases, these studies have been performed using expensive remote sensing software with free but lower-resolution Landsat imagery (>30m). In contrast, Google Earth provides high-resolution imagery, offering a more detailed analysis of land use changes [16,17,18,19]. Fu and Weng [20] conducted a historical reconstruction of land-use and urban area changes from 1984 to 2011 by analyzing 507 Landsat images that were taken from 1984 to 2011 in order to understand the effect of land-use and urban area changes that were caused by human activities. Ha et al. [21] performed a 20-year land-use land-cover change in Vietnam using the Random Forest algorithm and Landsat imagery. Another urban land-use tracking study was carried out by Frimpong and Molkenthin [22] across the Random Forest algorithm and Landsat image data from 1986, 2013, and 2015. Many examples could be cited to illustrate the use of Landsat imagery in land use research. All of these studies have one thing in common: this very functionality is achieved by the Landsat dataset, which is often separated from other remote sensing datasets due to its low resolution when compared to the imagery provided by Google Earth [23, 24, 25]. The Global Landcover Facility (GLCF) provides free access to satellite data as a support of remote sensing research and is the source of satellite imagery in several studies [26]. However, there are drawbacks to the GLCF; images from sensors such as the Landsat Multispectral Scanner (e.g. Landsat 7) typically have lower to medium spatial resolutions, from 30 to 80 meters. In addition, a large financial commitment is often needed to obtain more recent and high-resolution imagery, which poses budgetary issues for any studies. On the other hand, Google Earth Pro imageries have a geometric resolution of 1.5 meters to 2 meters for most of the covered areas in the world (Figure 1). At these resolutions, Google Earth imagery makes it simple for human viewers to distinguish between the primary categories of natural land cover and to identify different components of the man-made landscape, including individual houses, industrial complexes, and road networks [27]. Numerous scholars have already begun to employ Google Earth Engine which is a rapidly expanding and openly accessible satellite imagery source [28,29,30,31,32]. Semiconductor devices such as sensors and transistors play a critical role in remote sensing technology by enhancing the accuracy and efficiency of data collection and processing [12,22].

***Figure 1**. The satellite imageries illustrate the different resolution levels of Google Earth Pro (a), Landsat 7 (b), and Landsat OLI (c) over the Changqi River Bay, China. (Modified from [33]).*

The objective of this study is to investigate changes in land use in the Kemalöz neighborhood of Uşak, Türkiye, which is the fastest-growing district, by utilizing Google Earth Pro and ArcGIS for rapid assessment of land use change, offering an alternative to remote sensing software and low-resolution Landsat imagery. The study also aims to evaluate the relative benefits of using higher-resolution Google Earth imagery over Landsat imagery to analyze land-use changes to provide insights to policymakers and local officials to make informed decisions about the most effective way to manage land in order to mitigate the negative effects of urbanization. This research will also contribute to the growing body of research on the use of Google Earth Engine as an openly accessible satellite imagery source for land use and urban planning studies. It will offer insights specific to the Kemalöz neighborhood in Uşak, Türkiye, addressing the need for localized studies in rapidly growing urban areas.

II. STUDY AREA

The research area is located in the city center of Uşak province in the inner-western Anatolian region of the Aegean Region in Türkiye. It is a frontier between the Aegean and Central Anatolian regions, positioned at 38°40'24.64"N - 29° 24'20.88"E. The area of the province is about 5,341 square kilometers and the total population is around 377,000 according to the 2024 census. According to the Köppen-Geiger system, Uşak's climate is broadly classified as Csa, with warm temperatures and hot, dry summers [34]. The average annual temperature in Uşak is 12°C with annual precipitation ranging between 430 mm and 700 mm [17].

Kemalöz neighborhood, which is located in Uşak province, Türkiye, is one of the rapidly urbanizing districts in the region, thus offering an excellent research area to investigate urban growth processes. Kuyucak and Hacikadem villages, where the agricultural activities are intensive, form the southern and western borders of the Kemalöz neighborhood. The local administration of the Central Municipality in Uşak agreed to annex the villages of Kuyucak and Hacikadem to its municipal body in 2015. Therefore, the southern and western borders of Kemalöz neighborhood extended to the south and west, encompassing large agricultural fields. The study area, which covers an approximate area of 6.5 square km, has experienced evident population growth during the past years (Figure 2). Its population grew from 17,836 in 2005 to 40,007 by 2023 (Figure 3). This consistent population increase since 2005 is an intriguing case study of fast urbanization. Notably, the population density of the Kemalöz neighborhood is extremely high, with 6,154 people per square kilometer. This figure contrasts considerably with the global average population density of 59.22 people per square kilometer, highlighting the significant level of urbanization in this region. Such a dense city framework presents novel difficulties and opportunities for urban planners and policymakers, needing a solid understanding of land use dynamics and their implications for sustainable urban planning and development. The population growth in the Kemalöz district from 17,836 in 2005 to 40,007 by 2023 can be attributed to both urbanization and the administrative expansion that occurred when Kuyucak and Hacikadem villages were annexed to the Central Municipality of Uşak in 2015. While a portion of the population increase is undoubtedly linked to the physical growth of urban infrastructure and housing developments, the annexation of these villages also contributed to the overall population rise. However, the population density figures calculated in this study specifically pertain to the urban core of Kemalöz, excluding the impact of the villages' total population. Therefore, while the expansion of administrative borders increased the total land area, much of the observed growth is still indicative of significant urbanization within the original boundaries of the district.

The study area lies on the geologic Asartepe Formation [35]. It is a multicolored, generally red and orange, occasionally white, loosely lime, tuff, clay cemented, laminated with coal seams, semi-rounded pebbly conglomerate-sandstone succession. This formation sometimes contains thin marly calcareous beds and is thought to be formed in a fluvial environment. The Lower Quaternary Asartepe Formation unconformably overlays the Ulubey Formation, and it is underlain by Quaternary alluvium [35]. The maximum thickness is 200 m. It crops out in large areas in the western part of Uşak city where the study area is situated.

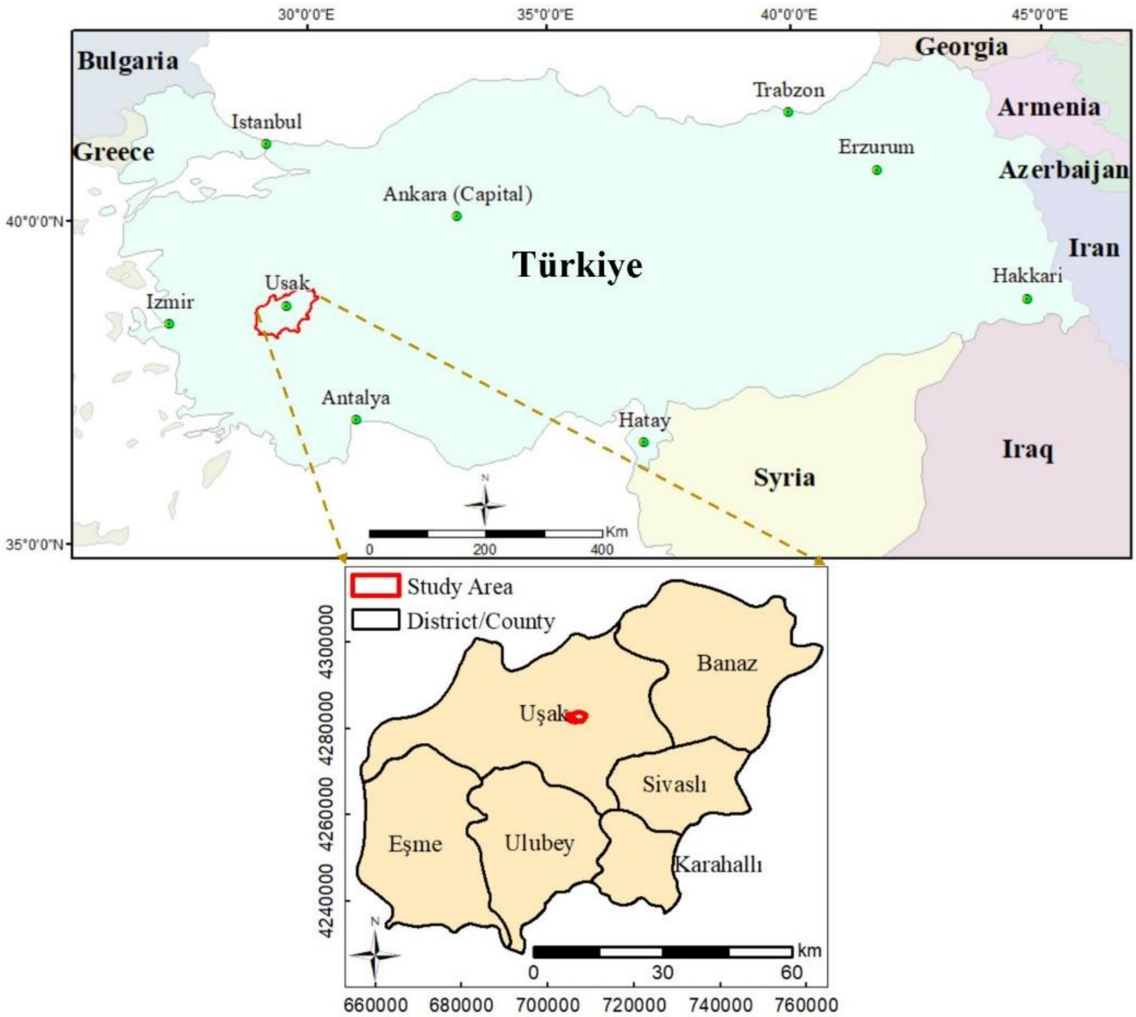

__Figure 2__. Maps illustrating the study area's location. The map at the top is based on a Geographic Coordinate System (GCS), while the one at the bottom utilizes a Universal Transverse Mercator (UTM) Zone 35N projection, with the European Datum of 1950 (ED1950).

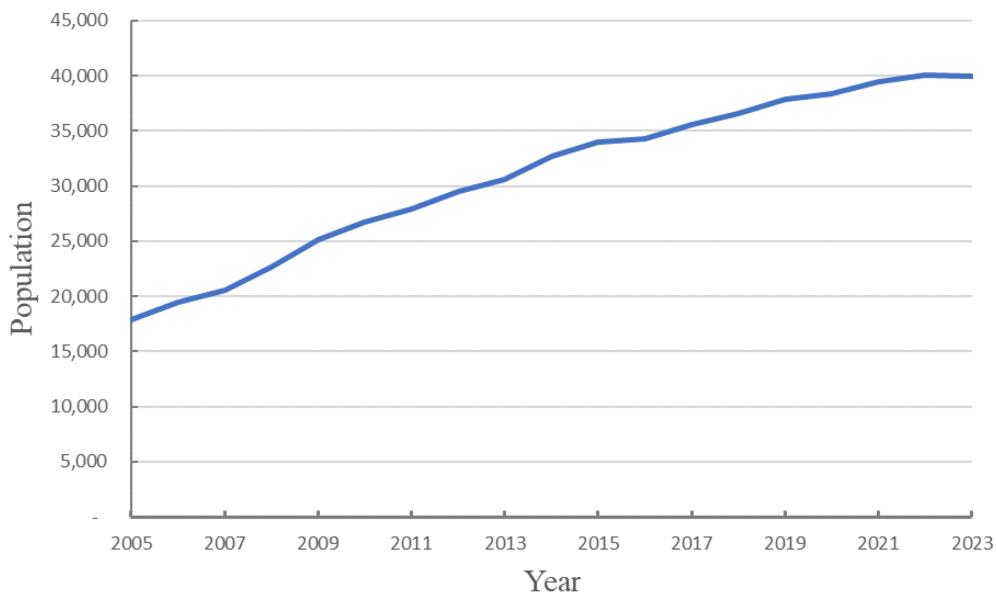

***Figure 3.** The chart illustrates the population changes over time in Kemalöz neighborhood , Uşak, Türkiye.*

III. METHODS

A. DATA COLLECTION

Firstly, the boundary of the Kemalöz neighborhood was obtained from the General Directorate of Land Registry and Cadastre then it was digitized and converted into a shapefile in ArcGIS 10.7 [36]. Subsequently, 12 control points encompassing the boundaries of the Kemalöz neighborhood were marked in Google Earth 7.3.6. [23]. Historical satellite images from 5/18/2005 and 4/30/2024 were selected and downloaded to the computer, ensuring that the chosen images were cloud-free and clear. These imageries were then georeferenced and transformed from the geographic coordinate system to a projected coordinate system using the Universal Transverse Mercator (UTM) projection with European Datum 1950 in ArcGIS 10.7. Afterward, the images encompassing the district boundary were clipped using the digitized district boundary shapefile in ArcGIS 10.7.1. The following land use classes were evaluated in the current study: built-up areas, vegetation, agricultural areas, and barren/open terrain. There were no water bodies in the study area, hence the waterbody class was ignored.

The built-up area encompasses all urbanized regions and associated infrastructure like buildings and roads, while barren/open land encompasses vacant areas, rocky terrain, scrubland, and agricultural zones where crops and fruits are cultivated. Vegetation includes all non-agricultural forests and woodlands (Figure 4). Subclasses were not further categorized into specific uses since the study aims to analyze the overall extent of urbanization without focusing on specific subclass uses such as residential, commercial, industrial, institutional, and recreational land uses.

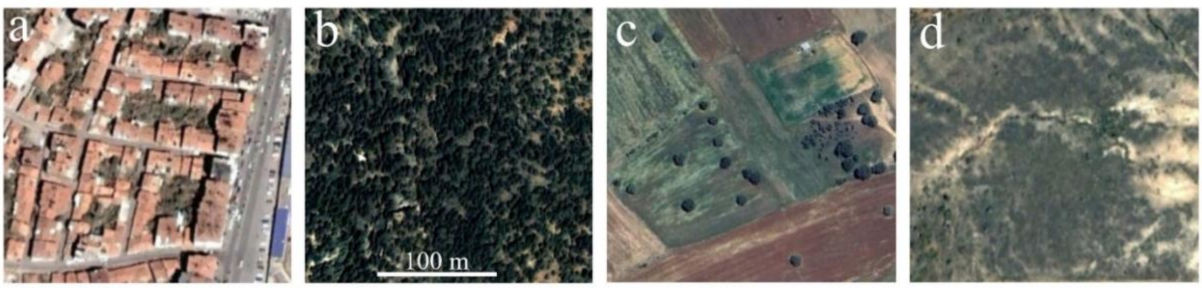

Figure 4. *Training image samples of high-resolution Google Earth imageries of different land use classes (a- built-up; b- vegetation; c- agricultural; d- open/barren). The white scale bar applies to all images and is 100 meters long.*

B. DATA ANALYSIS TECHNIQUES

The land use analyses were performed in ArcGIS 10.7.1, by utilizing the classification tool. Previously clipped imageries were selected in this tool, and the circle or polygon option was selected to create training samples on the imageries, and training sample signatures were saved to be used in the subsequent operations. Later, the Maximum Likelihood Classification (MLC) algorithm was employed to generate training samples for each class. Subsequently, appropriate colors were assigned for each class (e.g. green for vegetation, gray for built areas, etc.). The MLC algorithm is widely used in land use studies to perform a supervised classification of raster imageries into different land use classes. This tool operates on the cells within each class sample in a multi-dimensional space, taking into account that they follow a normal distribution. The tool provides this feature by picking the cell in the signature file and also considering the means and covariances of the class signatures. The assumption of normality in a class sample denotes that, a class is described by a mean vector and a covariance matrix [36]. The tool performs the classification taking into account these features for every cell value. Using them, the tool calculates the statistical probability of a class to identify the class to which the cells belong. In the context of the study, the "EQUAL" option for priory probability weighting is set into the system to get the class to which the cell has the maximum chance of belonging [36].

IV. LIMITATIONS

While the methodology employed in this study provides a detailed analysis of land use changes, several limitations must be acknowledged. Firstly, the georeferencing of historical satellite images may introduce positional inaccuracies due to variations in the original image resolution and quality. Although every effort was made to ensure precision by using control points and a standard projection system (UTM with European Datum 1950), small misalignments may still occur. Additionally, the Maximum Likelihood Classification (MLC) algorithm assumes that the spectral data within each land use class follow a normal distribution, which might not hold true for all classes, especially in heterogeneous or mixed land use areas. Furthermore, the absence of subclasses, such as differentiating between residential, commercial, or industrial zones within built-up areas, limits the granularity of the analysis. Another limitation is the reliance on satellite imagery alone, as the study does not account for other data sources such as field surveys or socio-economic factors that may influence urbanization trends. Lastly, this study assumes that land cover changes between 2005 and 2024 are solely related to urbanization and natural vegetation shifts, without considering other external drivers such as policy changes or economic factors that could affect land use dynamics.

IV. RESULTS

Maps illustrating different land-use classes in 2005 and 2024 are presented in Figures 5 and 6 respectively. The build-up land use has increased from 1,734 to 2,755 km^2 from 2005 to 2024. The total population increase in the study area is likely influenced significantly by both urbanization and the expansion of administrative borders. The significant rise in built-up areas from 1,734 km^2 in 2005 to 2,755 km^2 in 2024 also suggests that urbanization plays a major role in attracting people to the district. As urban areas expand, they often provide more housing, jobs, and services, which can lead to population growth. The annexation of Kuyucak and Hacikadem villages to the Central Municipality in 2015 expanded the district's borders. This expansion likely contributed to the population increase by incorporating additional residents from these villages into the overall population count of Kemalöz. This clearly suggests significant urban development or infrastructure expansion over the 19 years. Vegetation land use has increased from 1,081 to 1,392 km^2 between 2005 and 2024. This indicates a slight increase in green cover, possibly due to afforestation efforts or natural regrowth. Agricultural land use has decreased from 1,781 to 1,149 km^2 between 2005 and 2024. This suggests a decline in agricultural land due to urbanization or possibly changes in farming practices. Barren land use has decreased from 1,803 to 1,103 km^2. This indicates a reduction in barren or unproductive land, possibly due to reclamation efforts, afforestation, or urban development. A summary of land use between the years 2005 and 2024 is presented in Table 1.

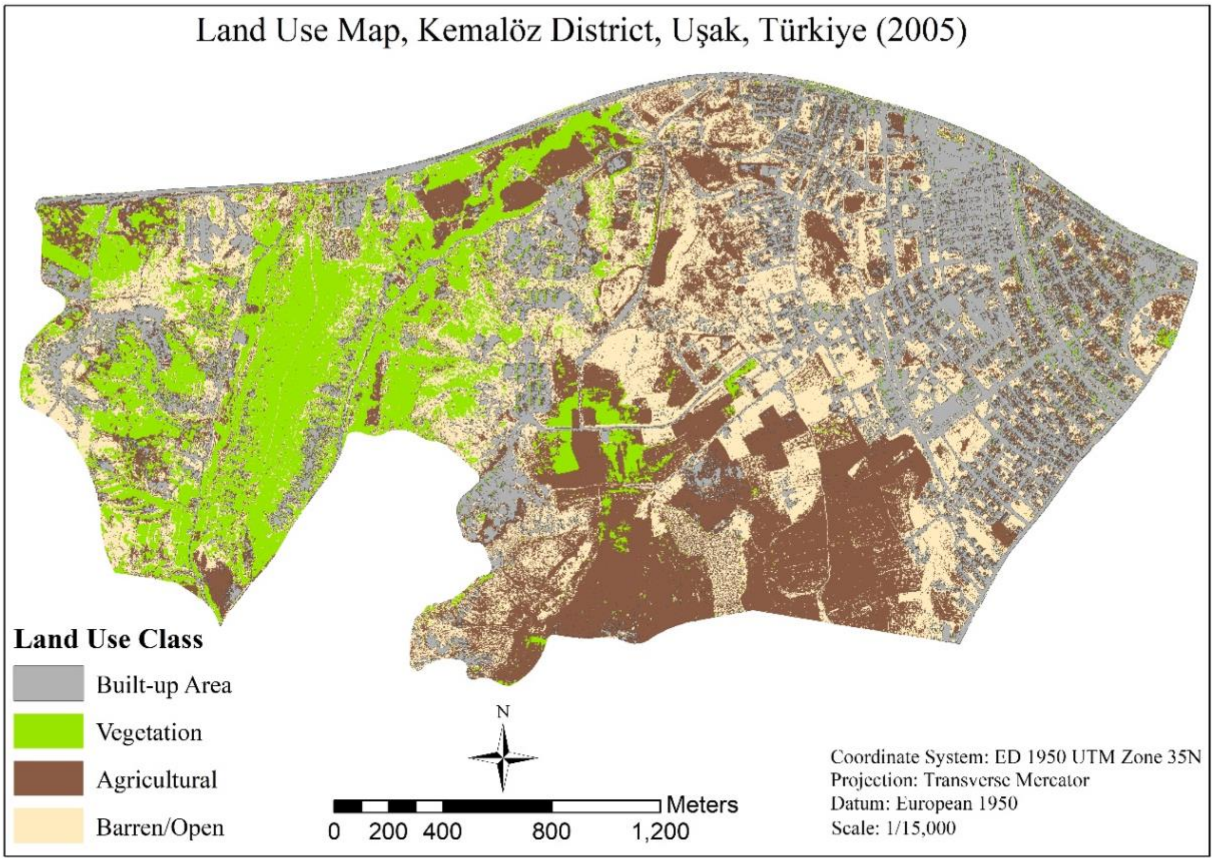

Figure 5. *Map illustrating different land-use classes in 2005.*

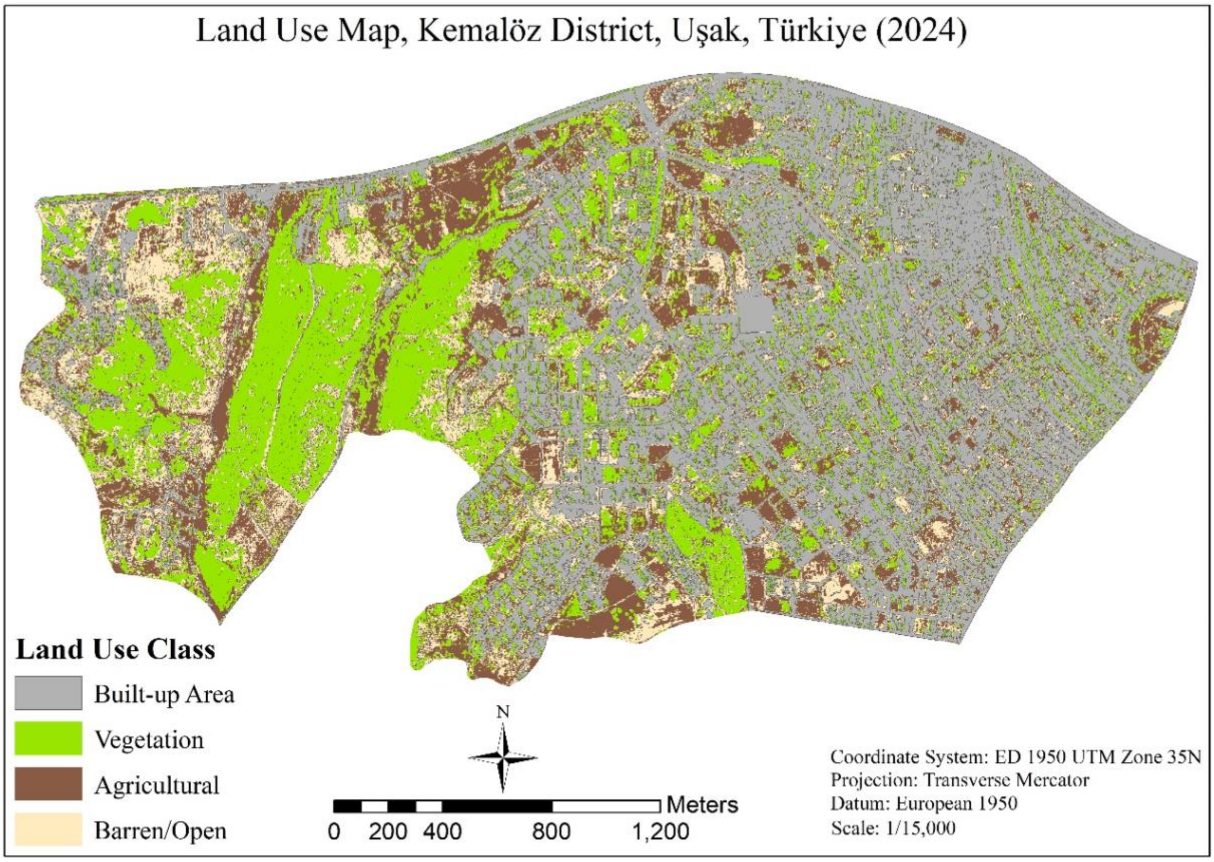

Figure 6. *Map illustrating different land-use classes in 2024.*

Table 1. *The table presents the data for the land classes (Building, Vegetation, Agricultural, and Barren) for the years 2005 and 2024. The numbers indicate the areas, which are in km^2, covered by each land class in the respective years.*

Land Class	2005	2024
Building	1,734	2,755
Vegetation	1,081	1,392
Agricultural	1,781	1,149
Barren	1,803	1,103

The percentage distribution of various land uses across different zones is displayed in Figure 7. The study area comprises a total surface land area of 6,398 km². In 2005, the land was categorized as follows: 27% as build-up, 17% as vegetation, 28% as agricultural, and 28% as open/barren land. By contrast, in 2024, the distribution of land use shifted, with 43% designated as build-up areas, 22% as vegetation cover, 18% as agricultural land, and 17% as barren or open land (Figure 5).

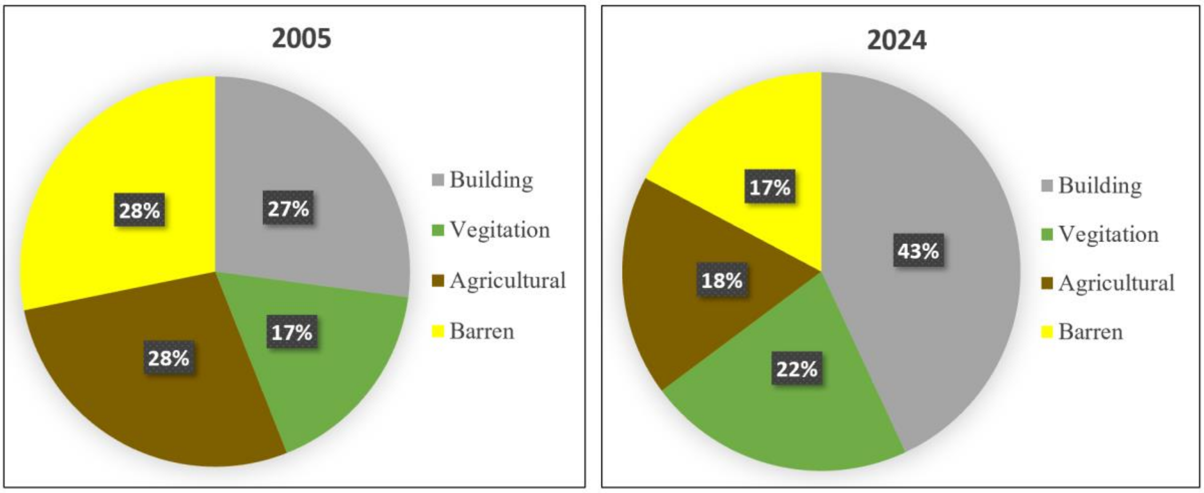

Figure 7*. Charts showing the distribution of land use classes for 2005 on the left, and 2024 on the right.*

The maps from 2005 and 2024 vividly illustrate the significant changes in land use over the span of 19 years, particularly highlighting the substantial increase in urbanization and the notable decrease in agricultural lands. In the map from 2005, the landscape is characterized by relatively smaller pockets of built-up areas amidst larger expanses of agricultural land and open/barren areas. However, in the map from 2024, the built-up areas have visibly expanded, forming extensive urban clusters that dominate the landscape. Figures 5 and 6 clearly show that the urban development and the infrastructure construction have been going at an increasing speed over the years. Moreover, the maps also show the decrease in agricultural lands from 2005 to 2024. What was a large amount of farmland in 2005 is now an urban area and the amount of farmland has been reduced by 2024. The land use change in this regard, most certainly, indicates the effects of urbanization on agricultural landscapes and it is the result of factors that include population growth, industrialization, and land use changes. Also, the maps show an increase in the vegetation range from 2005 to 2024, but this is overshadowed by the rapid growth of built-up areas. Although the measures taken for afforestation or natural regeneration are mostly helpful, the overall trend towards urbanization is the largest influence on the dynamics of land use. Visually, the maps from 2005 and 2024 confirm the counter-intuitive and impressive capacity of urbanization to manifest physically as a change in the landscape and also agricultural land use. Such changes not only demonstrate the urban area's socio-economic condition but also show the importance of sustainability in land management in the case of fast urban growth.

The geological setting comprising the entirety of the Kemalöz neighborhood, which is a part of the Lower Quaternary Asartepe Formation [35], influences the pattern of land use and urbanization tendencies. The Asartepe Formation implies unconventional conditions for sustainable soil management. For instance, the lithological composition will determine whether there is enough fertile soil, proper drainage, and stable land, thus affecting agricultural and urban development strategies. Comprehending the geological background is fundamental in the land use planning and management process as this assists in identifying the areas that are at risk of geological hazards, including landslides and soil erosion, and regions suitable for particular land use, such as agriculture and urban development.

V. DISCUSSIONS

This research examined the land use changes in the Kemalöz neighborhood , a rapidly developing area in Uşak-Türkiye, using Google Earth Pro and GIS tools. It was demonstrated in this study that there were statistically significant changes in land use patterns from 2005 to 2024 with a rise in urban areas and a decline in agricultural areas. This indicates the significant imprint of urbanization on the landscape and calls for acceptable land use management solutions to avoid adverse effects.

Considering the rapidly growing built-up areas and infrastructures in the Kemalöz neighborhood area, it is predicted that more agricultural lands will be disappearing in the near future. This trend of rapid urbanization is consistent with the global trend of urban growth influenced by factors like an increase in population, industrialization, and change in land use types. Rapid urbanization comes with challenges such as intensified resource consumption, environmental degradation, and the social-economic inequalities among the urban dwellers which is a call for well-planned and managed land uses.

Furthermore, the study compared the use of Google Earth imagery (resolution <5 meters) with traditional Landsat imagery for land use analysis. The higher resolution of Google Earth imagery enhances the ability to accurately outline land use areas and detect the changes at different time intervals. This pilot study illustrates the ability of the freely available, high-resolution satellite imagery sources to provide a rapid assessment of changes in land use for a given study area. This may provide valuable information for urban planning and management efforts.

The continued expansion of urban areas in Kemalöz neighborhood aligns with global trends, driven by population growth and industrialization. This underscores the need for better urban planning policies, such as zoning regulations to limit urban sprawl and preserve agricultural and green spaces. Using high-resolution Google Earth imagery also proves valuable for resource-limited areas, providing a cost-effective tool for monitoring land use and informed decision-making.

Future studies could examine the socio-economic factors driving land use changes in the region and evaluate the effectiveness of current land use policies. Further research could also integrate additional remote sensing data or focus on longer-term trends to improve land use classification accuracy. Expanding this analysis to other urbanizing regions would provide comparative insights and enhance the generalizability of the findings.

VI. CONCLUSIONS

The findings of this study could be useful for understanding the land use dynamics of Kemalöz neighborhood, Uşak, Türkiye, for the last two decades. The observed phenomenon of growing built-up areas and decreasing agricultural lands illustrates the extent of the urbanization impact on the landscape of the study area. Thus, sustainable land management practices are key to mitigate the adverse effects of urban development particularly by tackling environmental degradation and social-economic inequalities.

In addition, the application of Google Earth imagery along with GIS techniques provides a quicker and cheaper approach to monitor land use changes, especially in rapidly urbanized areas. This research also adds to the existing body of knowledge on remote sensing technologies that can be used within the field of urban planning and management, highlighting the imperative of using high-resolution satellite imagery in order to acutely and promptly assess land use changes.

In particular, this research has some direct recommendations for the authorities, urban planners, and local communities who should take a proactive attitude towards environmental protection and sustainable land use that will allow cities to develop and survive in the long run in the modern conditions of urbanization. Finally, further investigation is necessary to thoroughly evaluate the land use dynamics throughout Uşak City using the approach developed in this pilot study. This technique will allow for a complete assessment and investigation of the patterns and drivers of land use change across the entire region.

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