ANALYSIS OF URBAN LAND USE CHANGE USING REMOTE SENSING AND DIFFERENT CHANGE DETECTION TECHNIQUES: THE CASE OF ANKARA PROVINCE

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ABSTRACT:

This study aims to use remote sensing techniques to map the urban region of Ankara from the past to the present, assessing the nature, magnitude and direction of changes within the area, including the transformation of LULC classes and explaining the driving forces behind these transformations. The study encompasses three stages. Firstly, Landsat 7 ETM+ images from 2000 and Sentinel-2 satellite images from 2020 were obtained for Ankara city and surroundings through the Google Earth Engine (GEE) platform. Image classification was conducted for both 2000 and 2020 using 'Blue', 'Green', 'Red', 'Vegetation Red Edge1', 'Vegetation Red Edge2', 'Vegetation Red Edge3', 'NIR', 'Vegetation Red Edge4', 'Water vapour', ' SWIR1', 'SWIR2' bands, as well as 'NDWI', 'NDVI', 'NDBI' indices on the GEE platform. LULC was classified using the Random Forest (RF) classifier, which included six classes: urban area, forest, water surfaces, open areas, agricultural areas and roads. Secondly, the LULC maps of the 2000 and 2020 images were classified using RF. The study employed the 'Categorical Change, Pixel Value Change and Time Series Change' methods to determine the transformations between LULC categories. Specifically, the urban change within the study area increased by 70% between 2000 and 2020. Over the past 20 years, from 2000 to 2020, the urban areas in Ankara expanded by 170%. Consequently, accurately determining the nature, magnitude and direction of urban development using remote sensing data offers valuable baseline information for various disciplines related to spatial planning at local and national scales.

1. INTRODUCTION

The entire world is changing due to various factors such as climate change, rapid technological advancements, depletion of natural and cultural resources, natural disasters, and deforestation. These changes significantly impact numerous ecosystems (Fadhil and Kurban, 2022). In particular, unplanned urbanization resulting from the uncontrolled and unintended use of the land surrounding cities and haphazard construction leads to continuous changes in land use within urban areas (Şahap, 2015).

It is faster and more up-to-date to derive these data with current technology, these data sets also enabled more effective processing and accurate detection of changes. Considering the recent literature, remote sensing techniques are one of the most common methods. Remote sensing provides a reliable solution in this regard by collecting information about an object or event from the earth's surface without making physical contact with the earth (Ahmed, 2019). Geographic Information Systems (GIS) and Remote Sensing (RS) techniques have made significant advancements in the study of urban development and spatial changes. Remote Sensing serves as an important data source (Donnay et al., 2001; Weng, 2002). Consequently, the combination of GIS technologies and RS plays a crucial role in the identification and monitoring of land cover changes (Stefanow et al., 2001; Wilson et al., 2003; Weng, 2002). Integration of remote sensing and Geographical Information Systems (GIS) also helps to investigate the changing spatial patterns of landscape (Innes and Koch, 1998; Roy and Tomar, 2000).

Until today, with remote sensing methods; There are many studies on the determination of change in urban and regional planning. Multi-temporal analysis based on remotely sensed data has played an important role in landscape analysis especially for detecting the historic change trends of the landscape. Besides, historical change detection can be used to track changes in landscape patterns and helps to quantify the relationships among the complex relationships (Turner and Ruscher, 1988; Henebry and Goodin, 2002).

Landsat TM images used image change detection, regression model, Kauth-Thomas transform or Tasselled Cap transform (KT), and Chi-square transform in urban change detection studies (Ridd and Liu, 1998). Overall, many studies showed that there is no single algorithms or band combinations provides an ideal result. Each methods have its own merits and advantages over others (Akın, 2007). Some of the studies have also shown socio-economic impacts on change such as, Bilgili et al. (2018) used 30 m resolution satellite images of Landsat 5 TM (2005) and Landsat 8 OLI (2015) to examine the urbanization in the Harran plain. In order to detect residential areas, a supervised classification method was applied to the NDVI images in combination with the multispectral bands 1,2,3,7 in Landsat 5 TM and 2,3,4,7 in Landsat 8 OLI. It has been reported that there has been a rapid urban growth since the start of irrigation in the Harran plain. This growth has created more concerns about the field of study. As a result, they stated that population growth was accompanied by social welfare, urbanization and industrialization in agricultural areas. In order to accurately determine the land cover change, temporal data are needed at regular intervals. For this reason, time series of remotely sensed satellite images taken at different period over the same area were needed.

The environmental impacts of land cover and land use changes can be significant in many different ways, including climate, hydrology, ecosystem services and surface temperature.

Research on this subject generally includes remote sensing data and modelling approaches. For example, in a study by Owen et al. (1998), the regional-scale climatic effects of urbanization were investigated using land cover and land use parameters derived from satellite images. According to the results of this research, as the surface temperature increased, a decrease in vegetation and moisture was observed. This shows that urbanization is effective on these parameters. Trusilova et al. (2008) investigated the effects of urban land cover on climate using a spatial modelling approach and showed that urban land cover has localized effects on climate variables such as temperature and wind at a local and regional scale. Additionally, emphasizing the impact of current and past land use in the evaluation process of ecosystem services, Ziter and Turner (2018) examined how land-based ecosystem services in an urban landscape are affected by land use. In this study, it is aimed to determine the temporal change of the land cover using remote sensing techniques together with CORINE data of the 2000 and 2020 within the provincial borders of Ankara which is the capital and the second largest city in Turkiye, has an important characteristic structure in the historical process.

2. MATERIAL AND METHOD

2.1. Material

As the study area, a border was determined in the city center of Ankara (39.55'02"N to 32.51'11"E) and its immediate surroundings (Figure 1). Study area Ankara is known as the capital of Turkiye and the second most populated city. While Ankara's population was 3,236,626 in 1990, it reached 4,044 million in 2003. In 2016, the population was announced as 5,346,518. By 2022, this number has reached 5,747,325 people.

The spatial growth of the city of Ankara, which attracts great attention as the capital of Turkiye, has led to an increase in the land cover change especially around the city.
The spatial growth of the city of Ankara, which attracts great attention as the capital of Turkiye, has also led to an increase in the change of land cover especially around the city. Ankara is geographically located close to the center of Turkiye and except for the northern parts in the Western Black Sea Region, most of it is Inner. It is located in the Anatolian Region. With Kırıkkale in the east, Çankırı in the northeast, Bolu in the northwest, Eskisehir in the west, Konya in the south, Kırsehir and Aksaray in the southeast, Ankara has a surface area of 25,632 km2 (Figure 1).

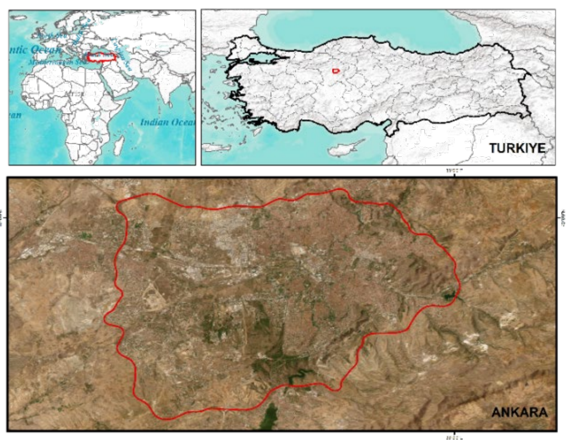

Figure 1. Study area

2.2. Method

The study consists of three stages. In the first stage, Landsat 7 ETM+ images recorded in 2000, Sentinel-2 satellite images recorded in 2020 of Ankara city and its surroundings were obtained via Google Earth Engine (GEE). 6 different spectral indexes that contribute to determining urban areas with the images obtained, NDVI (Normalized Vegetation Index), NDWI (Normalized Difference Water Index), NDBI (Normalized Residential Area Index), NDISI (Normalized Impermeable Surface Index), SVI (Soil and Vegetation Index)), BRBA (band ratio for residential areas) maps were produced and the most appropriate indexes were selected from these indices and included in the classification on the Google Earth Engine (GEE) platform. LULC included 6 classes as urban area, forest, water surfaces, open areas, agricultural areas and roads and classified using Random Forest (RF) classifier.

In the second stage of the study, the LULC maps of 2000 and 2020 images were classified using RF. The 'Categorical Change, Pixel Value Change and Time Series Change' methods and the transformations between LULC were revealed. Spatial autocorrelation of LULC change was determined by Global Moran's I index. Moran's I index determines the degree of spatial autocorrelation between 1 and +1. Positive spatial autocorrelation shows similar values on the change maps, whereas negative spatial autocorrelation shows the large differences. Moran I value of 0, is considered to have a random structure (Figure 2).

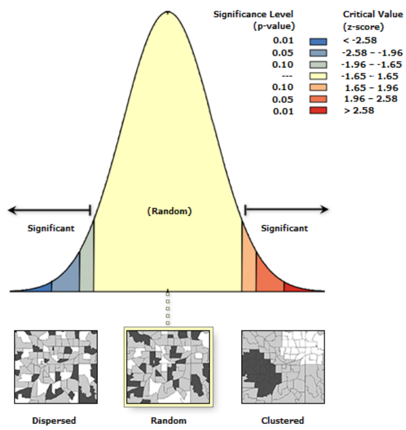

Figure 2. Global Moran's I index

At the final stage of the study, land cover changes derived from Categorical Change, Pixel Value Change and Time Series Change were compared with each other using and Global Moran I Index. The results of the study showed that the Moran I value was statistically significant for 2 different time intervals. In contrast, the Z score derived from spatial autocorrelation showed as 0.8 for 2000 and 2020 indicating that the distribution is strongly clustered and close to 1. The Global Moran index values from 2000 to 2020 are all greater than 0.8, indicating an intensive land cover change.

3. RESULTS

According to CORINE 2000 data; A large part of Ankara, which has a surface area of 25,910 km2, is devoted to agricultural areas. Most of the forest areas are concentrated in the north of Ankara province (Figure 3).

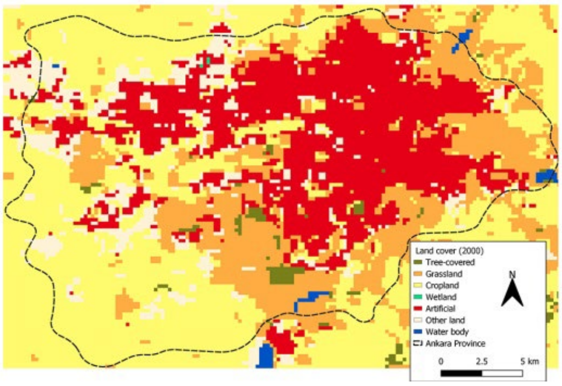

Figure 3. Land cover (2000)

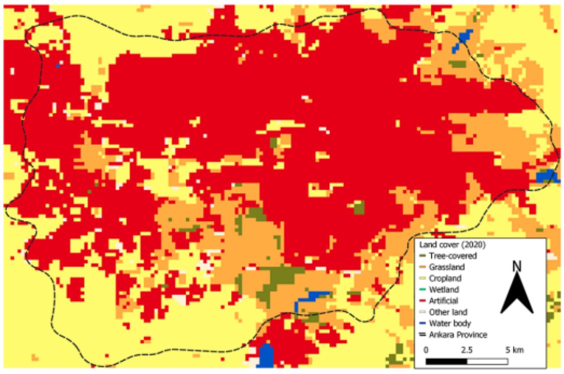

Figure 4. Land cover (2020)

	Initial area (sq. km)	Final area (sq. km)	Change in area (sq. km)	Change in area (percent)
Tree-covered	5,673.85	5,906.31	232.46	4%
Grassland	4,608.14	4,536.82	-71.32	-2%
Cropland	10,723.87	10,520.42	-203.45	-2%
Wetland	41.23	40.24	-0.98	-2%
Artificial	88.80	149.39	60.59	68%
Bare land	471.17	438.57	-32.60	-7%
Water body	243.66	258.95	15.29	6%
Total	21,850.71	21,850.71	1.99	67%

Table 1. Land cover change by cover class

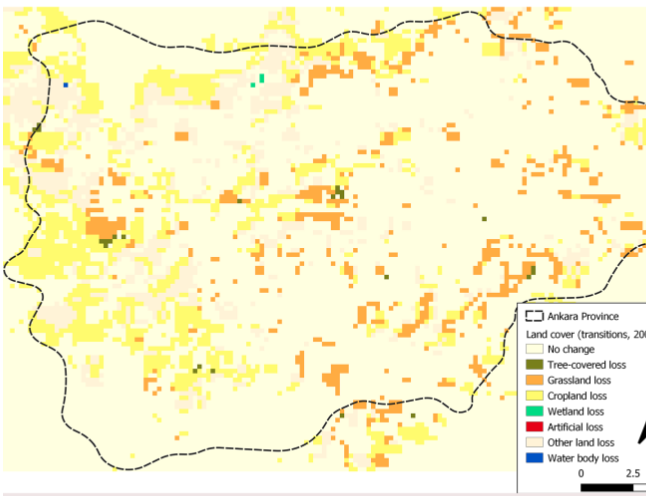

Figure 5. Land cover change (2000-2020)

	Tree-covered	Grassland	Cropland	Wetland	Artificial	Bare land	Water body	*Total:*
Tree-covered	5,636.50	5.25	30.02	0.00	0.49	0.43	1.16	*5,673.85*
Grassland	36.55	4,517.79	47.15	0.00	0.98	1.16	4.51	*4,608.14*
Cropland	228.28	13.04	10,437.23	0.00	32.64	3.27	9.40	*10,723.87*
Wetland	0.74	0.00	0.00	40.06	0.00	0.00	0.42	*41.23*
Artificial	0.00	0.00	0.00	0.00	88.80	0.00	0.00	*88.80*
Bare land	3.57	0.61	5.28	0.00	25.99	433.58	2.14	*471.17*
Water body	0.68	0.12	0.74	0.18	0.49	0.12	241.32	*243.66*
Total	5,906.31	4,536.82	10,520.42	40.24	149.39	438.57	258.95	21,850.71

Table 2. Land area by type of land cover change (sq.km)

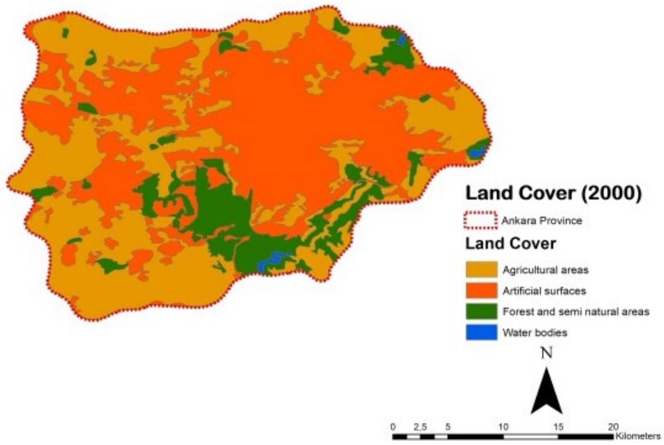

Figure 6. Land cover (2000)

Based on CORINE data, when the land cover change in Ankara province between 2000 and 2020 is examined; It was observed that while agricultural areas decreased, residential areas increased. In this case, it is predicted that agricultural areas will turn into residential areas (Figure 5).

It can be seen from the change maps, this change was concentrated in Ankara city center and its surroundings. Ankara continues to grow towards the west due to its location, transportation, infrastructure and locational convenience. As a result, in last 22 years from 2000 to 2022, the urban areas in Ankara have increased by 170% (Figure 6 and Figure 7).

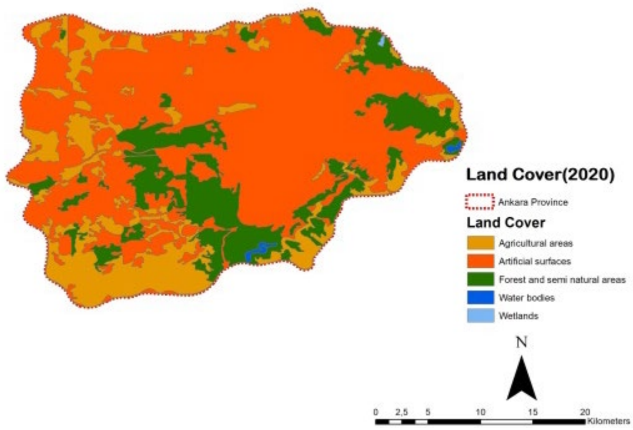

Figure 7. Land cover (2020)

The total population growth between 2009 and 2020 was recorded as 853,183 people. Considering this population increase, the population increase in the western part of the study area was 38,213 people on average. One of the most important reasons for this situation was the implementation of state-supported housing.

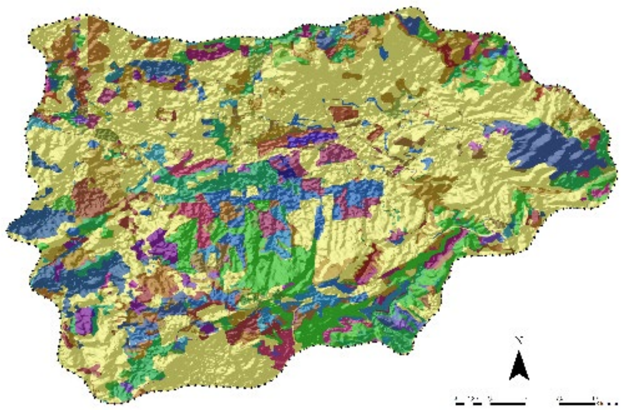

Figure 8. Land cover change (2000-2020)

Considering the annual change rate of land cover types between 2000 and 2020, it has been determined that settlement areas have increased by approximately 1.5% per year (Figure 8)

4. CONCLUSIONS

It was observed that there is a decrease in agricultural areas, as the residential areas increased between the years of 2000-2020 in Ankara and its surroundings based on CORINE data. Urban change is concentrated around the city of Ankara. It is expected that Ankara, which attracts great attention as the capital of Turkiye, will continue to grow rapidly. Particularly, Ankara will continue to grow towards the west due to the physical constraints in its north and east. Therefore, agricultural areas in the west and south will be affected largely from this consequence. For this reason, it will be necessary to take measures to prevent the inappropriate land use of fertile agricultural lands in this direction.

The spatial autocorrelation of LULC change was assessed using the Global Moran's I index. The Moran's I index measures the degree of spatial autocorrelation, ranging between 1 and +1. Positive spatial autocorrelation shows similarity in values on the change maps, whereas negative spatial autocorrelation shows significant differences. A Moran I value of 0 represents a random structure. Lastly, LULC changes derived from 'Categorical Change', 'Pixel Value Change' and 'Time Series Change' methods were compared using Global Moran I Index. The results revealed that Moran's I value was statistically significant for two different time intervals. The Global Moran's I index values from 2000 to 2020 were consistently above 0.8, indicating substantial land cover changes.

Considering the annual rate of change, the 1.5% growth of the residential areas will continue, and the residential area of Ankara will grow 1.33 times in 2030.

As a result, determining the direction, speed and type of urban development areas with high accuracy using remotely sensed data will provide an important baseline data for various physical planning disciplines, local and central decision makers at local and country scale. Negative effects such as unplanned urbanization, destruction of natural vegetation and open green areas, especially due to population growth, should be determined and followed up as soon as possible.

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REFERENCES

Ahmed, S. H., 2019: Determination of urban expansion and loss of agricultural lands in Sulaymaniyah using remote sensing and geographic information systems (GIS) [PhD Thesis]. Harran University.

Akın, A., 2007: Evaluation of Different Extending Detection Methods in Determining Land Cover Changes in the Cukurova Delta Coastal Area. *CU Graduate School of Natural and Applied Sciences*.

Aydın, O., Özgür, E.M., 2009: Measuring Ankara's urban development with remote sensing and geographic information systems, *New World Sciences Academy (NWSA), e-Journal of New World Sciences Academy Nature Sciences,* 4A0014, 4(4), 215-242

Baysal, D., 2007: Evaluation of the physical change of Eskişehir urban settlement area for different years by remote sensing method [PhD Thesis]. Anadolu University.

Dereli, M. A., 2019: Determination of short-term land cover change for Giresun city center with Sentinel-2 satellite images. *Afyon Kocatepe University Journal of Science and Engineering*, 19(2), 361-368.

Fadhıl, A., Kurban, T., 2022: Modeling of urban sprawl with cellular automata Markov chain method: The case of Kirkuk province. *Geomatics,* 7(1), 58-70.

Henebry, G.M., Goodin, D.G., 2002: Landscape trajectory analysis: toward spatiotemporal models of biogeochemical fields for ecological forecasting. In: Paper Presented at Workshop on *Spatio-temporal Data Models for Biogeophysical Fields*.

Innes, J.L., Koch, B., 1998: Forest biodiversity and its assessment by remote sensing. *Global Ecology Biogeography journal.* 7, 397–419.

Lillesand, T. M. , Kiefer, R. W., 2000: Remote Sensing and Image Interpretation Land Use/Land Cover Mapping. New York: Wiley and Sons. Inc. *Balikesir University Journal of Social Sciences Institute,* 16(30). dergipark.org.tr/tr/download/article-file/112023

Mishra, S., Shrivastava, P., Dhurvey, P., 2017: "Change detection techniques in remote sensing: A review. *International Journal of Wireless and Mobile Communication for Industrial Systems*", 4(1), 1-8.

Owen, T., Carlson, T., Gillies, R., 1998: An Assessment Of Satellite Remotely-sensed Land Cover Parameters In Quantitatively Describing the Climatic Effect Of Urbanization. *International Journal of Remote Sensing*, 9(19), 1663-1681. doi.org/10.1080/014311698215171.

Roy, P.S., Tomar, S., 2000: Biodiversity characterization at landscape level using geospatial modelling technique. *Biological Conservation.* 95, 95–109.

Şahap, A., 2015: The effects of urban development on land use by means of remote sensing and geographic information system: A case study in Şanlıurfa city [PhD Thesis].

Trusilova, K., Jung, M., Churkina, G., Karstens, U., Heimann, M., Claussen, M., 2008: Urbanization Impacts On the Climate In Europe: Numerical Experiments By The Psu–ncar Mesoscale Model (Mm5). *Journal of Applied Meteorology and Climatology,* 5(47), 1442-1455. doi.org/10.1175/2007jamc1624.1

Turner, M.G, Ruscher, C.L, 1988: Changes in the spatial patterns of lands use in Georgia. *Landscape Ecology,* 1, 241-251.

Ziter, C., Turner, M.G., 2018: Current and Historical Land Use Influence Soil-based Ecosystem Services In An Urban Landscape. *Ecol Appl,* 3(28), 643-654. doi.org/10.1002/eap.1689

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