International Journal of Geography and Geography Education

Research Article/Araştırma Makalesi

To Cite This Article: Tanrıvermiş, Y., Canaz Sevgen, S. & Tanrıvermiş, H. (2022). Land cover monitoring techniques and spatial development: The case of capital of Turkey. *International Journal of Geography and Geography Education (IGGE)*, 45, 437-453.
http://dx.doi.org/10.32003/igge.1007780

LAND COVER MONITORING TECHNIQUES AND SPATIAL DEVELOPMENT: THE CASE OF CAPITAL OF TURKEY

Arazi Örtüsü Değişimi İzleme Teknikleri ve Mekânsal Gelişim: Türkiye'nin Başkenti Örneği

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Abstract

After the declaration of Ankara as the capital city of Turkey in 1923, the size of the city was identified to be insufficient to cope with the developmental and spatial needs of the city. In this study, the analysis and detection of land cover changes were conducted for the last three decades with ten-year time interval by using remotely sensed satellite data in Ankara to monitor the change in land cover, and growth and development of the city. Four classes; manmade area, land area, green area, and water area were created for each year images to assess change in land cover in central neighborhoods of Ankara. Maximum Likelihood Classifier (MLC) and Random Forest (RF) algorithms were performed and classification results were compared. Overall classification accuracy and overall kappa statistics computed as 85%-92% and between 0.78-0.87 for MLC algorithm, respectively. Comparing with MLC algorithm, RF algorithm's performance was unsatisfied. As a second step of this study, administrative data of Ankara such as population, land use types, number of buildings and flats, and spatial development relationships were analyzed in integration with remote sensing data results to analyses land development in Ankara
Keywords: Land Cover, Change Detection, Satellite Image Classification, Urban Growth

Öz

Ankara'nın 1923'te Türkiye'nin başkenti olarak ilan edilmesinden sonra, kentin büyüklüğünün kentin gelişimsel ve mekânsal ihtiyaçlarını karşılamak için yetersiz olduğu tespit edilmiştir. Bu çalışmada, Ankara ilinde uzaktan algıma uydu verileri kullanılarak, kentin büyüme ve gelişiminin izlenmesi amacıyla son otuz yılda on yıllık zaman aralığı ile arazi örtüsü değişimlerinin analizi ve tespiti yapılmıştır. Ankara merkez mahallelerinde arazi örtüsündeki değişimi değerlendirmek için 5 farklı yılda insan yapımı alan, arazi alanı, yeşil alan ve su alanı olarak görüntüler sınıflandırılmıştır. Maksimum Olabilirlik Sınıflandırıcısı (MLC) ve Rastgele Orman (RF) algoritmaları ile sınıflandırma gerçekleştirilmiş ve sınıflandırma sonuçları karşılaştırılmıştır. MLC algoritması için genel sınıflandırma doğruluğu ve genel kappa istatistikleri sırasıyla %85-92 ve 0.78-0,87 arasında hesaplanmıştır. MLC algoritması ile karşılaştırıldığında, RF algoritmasının performansı daha kötü çıktığı görülmüştür. Bu çalışmanın ikinci adımı olarak Ankara'nın nüfus, arazi kullanım tipleri, bina ve daire sayısı ve mekânsal gelişim ilişkileri gibi idari verileri, Ankara'daki arazi gelişimini analiz etmek için uzaktan algılama veri sonuçları ile entegre olarak analiz edilmiştir.
Anahtar Kelimeler: Arazi Örtüsü, Değişim Yakalama, Uydu Görüntüsü Sınıflandırma, Kentsel Büyüme

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Geliş Tarihi/Recieved: 10.10.2021 **Kabul Tarihi /Accepted:** 03.12.2021 **Ç. Yayınlanma Tarihi/Online Published:** 25.01.2022

INTRODUCTION AND LITERATURE REVIEW

Urban areas and their growth have been studied by many researchers in areas of city planning, geomatics engineering, real estate development and so on. Change in urban areas in long term can be easily monitored by processing satellite images. Thereby, it is easy to determine in which direction city is growing by years and to observe the spatial texture and the change of land cover. Thus, land cover change in an area of interest can be monitored in temporally. Moreover, after determining land cover change in cities, relation between change and any other available data that can affect the change can be related. For instance, Shi et al. (2018) argues that change in land use and land cover is correlated with the human activities and its impacts on natural environment. The rapid urbanization and industrialization raise the great change in land use and land cover particularly in metropolitan areas of big cities.

Land cover studies are generally related with socio-economic data to understand factors behind change in urban expansion. For instance, Deng et al. (2008) observed that urban cores of China's cities are positively affected by socio-economic parameters such as income, population, and transportation costs. Yin et al. (2011) conducted a study of Shanghai land cover change and its relationship with policy reform, population growth, and economic development. Abass et al. (2018) examined land use and land cover changes with the effects of peri-urbanisation on arable land use by using Landsat images. Mundia & Aniya (2005) studied Nairobi city of Kenya's urban growth and discovered observed that economic growth and proximity to transportation routes have been the major factors promoting urban expansion. By analyzing Landsat satellite image classification and correlating the results with socio-economic and institutional data, urban growth in Wa, Ghana was discussed by Korah et al. (2018). Many other studies which relate land cover change and other social-economics data can be found in the literature (Canaz et al., 2017; Salvati & Sabbi, 2011; Xiao et al., 2006; Caldas et al., 2015).

Change detection analysis to monitor land cover differences by years in an interested area is conducted by classifying different year's satellite images in any number of classes according to aim of the study and spatial resolution of satellite images. For instance, Yu et al. (2012) monitored land cover changes and urban sprawl dynamics of the years of 1989, 1999, and 2009 of Yantai China by classifying satellite images in five classes. Atlanta, Georgia's land cover changes 1973-1998 were observed by six different classes (Yang & Lo, 2002). Canaz et al. (2017) were classed Istanbul, Turkey, in four different classes to monitor land cover change between the years of 1986-2015. Mialhe et al. (2019) evaluated urban footprints of Phnom Penh from 1973 to 2015 and its main socio-ecological impacts were reviewed by using Landsat images.

In the literature, it is easily observed that to determine land cover change in a city, mostly Landsat satellite data, which is freely available, is mostly quoted and used as remotely sensed data on verifying the land cover change (Masek et al., 2000; Yang, 2002; Yuan et al., 2005; Xian et al., 2009; Tan et al., 2010; Heinl & Tappeiner, 2012; Schneider, 2012; Akinyemi & Mashame, 2018). Landsat data have the advantage of long-term digital archive due to its availability and free access options as per other satellite data (Yang et al., 2003). The big disadvantage of the Landsat data is that the medium spatial resolution of data changes 15-60 meters comparing with other satellite data.

In this study, urban growth, and land cover of city of Ankara, was observed using Landsat satellite images of the last three decades with a 10-years' time interval. Within the specialized range years such as 1988, 1998, 2008, 2018 and plus 2020 Landsat satellite images were used for change detection analyses and the results were interpreted. The satellite data for the first year was chosen as 1988 since it was the clearest (cloudless) data that is open access. Four classes; manmade area, land area, green area, and water area were created for each year's images. The classification results were compared and analyzed with secondary social data such as the population, number of flat (detached sections), number of houses and buildings, total area of land data of Ankara and spatial development relationships. Furthermore, spatial change and urban growth direction were monitored and analyzed for the last three decades for Ankara. Consequently, the aim of this study is to monitor the land cover change and observe how fast manmade area of the city growth over the three last decades, and also how the population and other socio economics data correlated with the change.

DESCRIPTION OF THE STUDY AREA

Ankara is the capital city of Turkey, and it is Turkey's second largest and most populous city. According to Turkish Statistics Institute, the population of Ankara has 6.60% of the total population of Turkey. The population of Ankara was 5,503,985 in 2018 and it is and reached to 5,663,332 in the last census 2020 (Figure 1). The official boundary surface area of Ankara is 25,437 km^2. It is in the middle region of Turkey and serves as a bridge between the east west and north south ends of Turkey. The total land and green land per person have been decreased since 1950's due to the population growth. Physical population density in the province is 216 persons per km^2 and average land per person is 0.46 hectare.

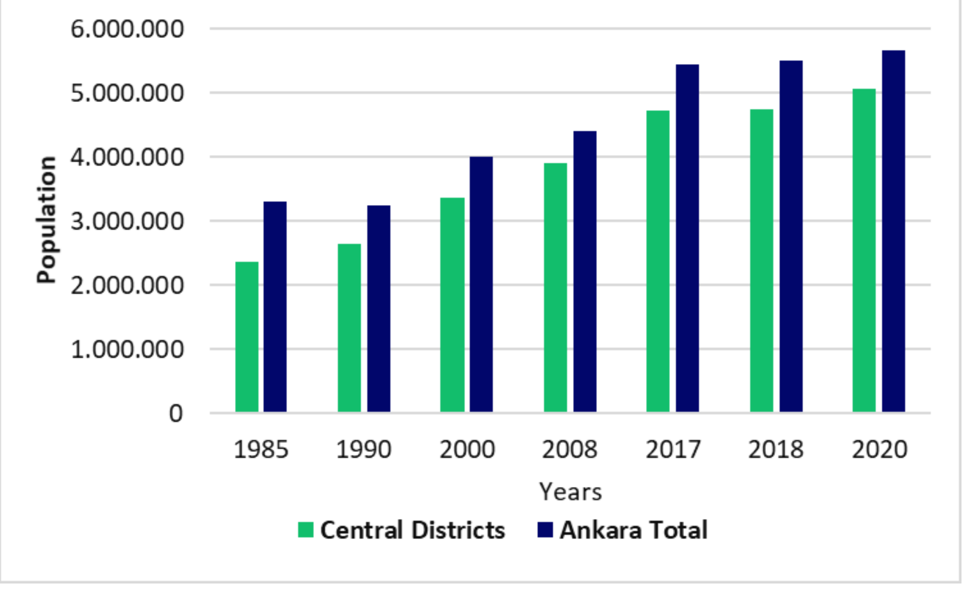


Figure 1: Total and Central District Population of Ankara by Years (Turk Stat 2020)

The study area has chosen as the central district of Ankara province, which includes central neighborhoods of Ankara named as Altındağ, Çankaya, Etimesgut, Gölbaşı, Keçiören, Mamak, Sincan, and Yenimahalle (Figure 2). The selected study area has around 1,036 km^2 surface area. The total population of the 8 districts of the province 4,887,984 and the share of the province total is 89.48 % in 2020. Population growth is around 1.1% in provincial general and more than 1.5% in selected districts. The population density in the selected districts is 21.3 times more than provincial total population.

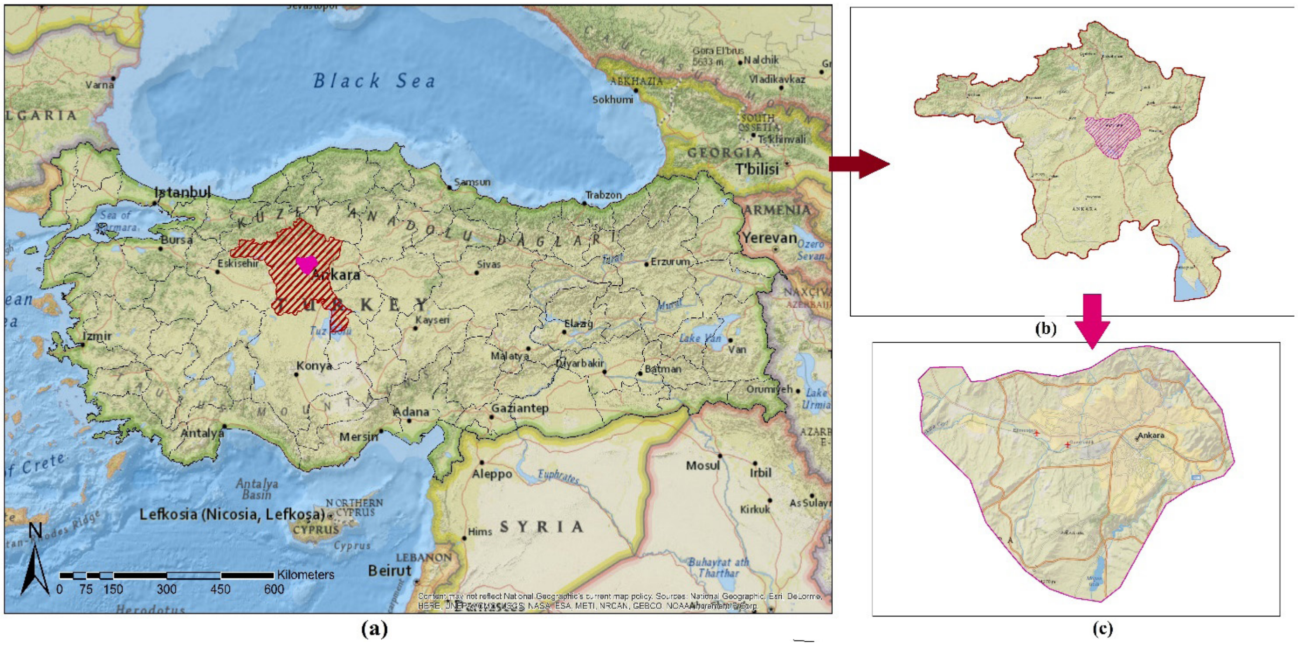


Figure 2: Turkey (a), Official Boundary of Ankara (b), The Selected Study Area (Central Districts of Ankara) (c) (Data Source for Map ESRI Online 2017)

DESCRIPTION OF THE DATA

In this study, Landsat 5 TM and Landsat 8 OLI satellite images, which are freely available (U.S. Geological Survey's Earth Resources Observation and Science (EROS), were used. The selection of data was performed according to cloud coverage of the data, since cloud coverage adversely affects classification results. The clearest (cloudless) and oldest data was found in 1988. Another important part of selecting satellite data in change monitoring studies is that different years' images should be in the same session since comparison of classification results yield to wrong results because of seasonal effects (i.e. snow, tree bloom). Details of satellite data are shown in Table 1. Systematic, radiometric, and geometric corrections of images were made by the National Aeronautics and Space Administration (NASA).

Table 1: Landsat Satellite Images Information Used in This Study

Features / Years	1988	1998	2008	2018	2020
Satellite Name	Landsat 5	Landsat 5	Landsat 5	Landsat 8	Landsat 8
Sensor ID	TM	TM	TM	OIL TIRS	OIL TIRS
Data Acquisition Date	05 Aug. 1988	17 July 1998	28 Aug. 2008	24 Aug. 2018	29 Aug. 2020
Cloud Coverage (%)	0.00	0.00	0.00	0.00	0.00
Pixel size (m)	30	30	30	30	30
Pan-sharpening/final pixel size(m)	No/30	No/30	No/30	Yes/15	Yes/15
Band combination	1-2-3	1-2-3	1-2-3	2-3-4	2-3-4

In this study, socio-economic data of the study area were utilized to observe the relation of change in land cover. Population, number of flats and buildings, and total land area of Ankara were used as secondary data to compare them with the satellite image classification results. However, finding reliable data for some socio-economic data for specific year was difficult, and sometimes some data were not recorded for 1-year period in Turkey. When correlating the satellite data classification results and social data, for some years, there was no available socio-economic data sets, therefore the closest year to the satellite image data acquisition date of the social data were used.

RESEARCH METHODOLOGIES

In this section, image classification was performed to acquire land cover change by years. The images were classified in four classes: manmade area, water area, green area, and land area. Artificial constructions were classified as manmade area; while land area represents soil or rock area. Four classes were decided since these areas can be easily distinguished in low spatial resolution satellite images.

The land cover change detection (classification) process consists of four important steps. The first and important step is to determine integration of bands. Different band combinations were used for different studies. The band combination depends on studies. In this study, real color images were created using Red, Green, and Blue (RGB) bands. With these band combinations, it is easy to select training classes for aimed four classes. As a second step of methodology, Pan Sharpening is shorthand for "Panchromatic sharpening" were applied for appropriate satellite images. The panchromatic sharpening is a process of increasing in multispectral image's spatial resolution using high-resolution panchromatic image (Matsuoka 2012). In other words, the aim of sharpening is to sharpen a coarse spatial resolution image with a greater spatial resolution Panchromatic images (Baraldi et al., 2016). By using the 15-m panchromatic (PAN) band, a PAN-sharpening algorithm is applied to the 30-m band combinations image using ArcGIS 10.1 software, so the new band combination pixel size became 15-m. In this study, pan sharpening was applied to 2018 and 2020 years' data, since these satellite image data had a panchromatic band while the other year's satellite image data do not have a panchromatic band.

Thirdly, after band combinations, a polygon which includes all boundaries of major central districts of Ankara was produced. The polygon was used to clip study area from the whole Landsat data.

The fourth and most important step of the methodology process is the classification section. Supervised classification, which is widely used methodology to class images, was performed for four different years' satellite images. Maximum Likelihood Classifier (MLC) (Bolstad & Lillesand, 1991) and Random Forest (Breiman, 2001) algorithm for the classification process were chosen in this study to compare two different algorithms performance for classifying images.

RF algorithm is often used in remote sensing applications for classification of multi and hyperspectral images, RADAR, LiDAR and thermal data sets. A literature review of these applications was presented in Belgiu & Dragut article (2016). RF algorithm consists of many decision trees (N). In this study, different N were tested and N=200 was chosen for the classification result. RF was performed in the Python Programming Language. There are different studies in the literature that compare MLC and RF algorithm as well. For instance, Jhonneriea et al. (2015) compared ML and RF in land cover mapping using Landsat 5 TM and Alos Palsar imageries, and they observed that two algorithms give similar results though RF performance slightly better than ML algorithm. Otukei & Blaschke (2010) delivered that in general, the Decision Trees (DT, RF) performed better than both MLC and Support Vector Machine (SVM) algorithms. On the other hand, some researchers claim that the MLC algorithm performs better than the other known parametric classifiers (Erdas, 1999). MLC is one of the mostly used supervised classification methods since the computation time of the method is less than any other supervised methods (Chamling & Bera, 2020). MLC assigns each pixel to a class with the highest probability (Ahmad & Quegan, 2012). This classifier has considered not only the mean or average values in assigning classification, but also the variability of brightness values in each class (Banerjee & Srivastava, 2013). In MLC algorithm basically, representative samples for each class in the satellite images were collected which are called as training samples. Using training samples, the algorithm basically assigns each pixel in classes. The accuracy of classification results relied on selection of training classes; therefore, training samples were picked very carefully. Methodology steps were performed using ArcGIS 10.1 software. Finally, results were investigated qualitatively and quantitatively.

Quality control of classification results were conducted by quantitative quality control. Overall accuracy, producer's and user's accuracy, and kappa statistics which popular accuracy measures in image supervised classification (Gómez & Montero, 2011) and widely used parameters for accuracy control were calculated (Cohen, 1960). The selected 210-250 randomly distributed reference points for each year's images were assigned as a one of the four classes using the software of Erdas Imagine™ (version 14) and Google Earth Pro software. The points for each year 1988 and 1998 were collected from the images that used for the classification of a specific year because it is very hard to find another reference image of that specific year. On the other hand, Google Earth Images of the years 2008, 2018, and 2020 were used as reference images for quality control of these years' classification results. For these three years, points are collected from Google Earth Images and projected to classification results to analyses the accuracy. Each class has at least 50 points. The reference points are automatically collected from the satellite images than the samples were labelled. On the other hand, reference points from Google Earth images are manually collected. Error matrices were created using reference point and classification results comparison. Kappa statistic relies on overall accuracy of actual agreement between classification and observation (İsmail & Jusoff, 2008). According to results, the kappa coefficient was calculated between 0.78-0.87 and between 0.61 – 0.70 for MLC and RF algorithms, respectively. The results of the quality control will be shown in detail in the next section.

CITY PLANS OF ANKARA

After 1980, when the states adopted the outward oriented growth model, the urban space became profitable and Turkey adapted to this trend in the 1990s (Töre & Som, 2009). Since the 1990s, the housing supply in the cities through the private sector has been started and the gated communities, which have become a symbol of prestige, have started to grow in Istanbul and Ankara. It is also understood that the urban land for providing this new city experience has grown mainly from the regions close to the rural-urban fringe. Şerefoğlu (2021) made a recent study that analyzes the rural area for the metropolitan city of Ankara in Turkey by developing a rural index and the study showed education is the most important variable for distinguishing rurality.

Considering the city plans in the years when the study was conducted, the most important plan that determined the current urban form of Ankara was the 1990 Master Plan, which was approved on 24.02.1982. This plan draws the basic framework for the most important settlements and working areas of the city, seems to be unsuccessful in the development of urban macroform. The main reasons are the fact that there is no model for transformations of slum areas, and there is no new prediction for the central business area of the city, which is supposed to be decentralized along the western corridor (Ankara Metropolitan Municipality 2006). The green belt prediction, which surrounds the city in the 1990 Master Plan, is an important decision in terms of keeping some regions out of settlement and afforestation, and the reflection of this decision can be seen from the amount of green space in 1988 (Table 2).

Another plan that takes an important place in Ankara's planning history is the 2015 Ankara Structural Plan with a scale of 1/100,000 which was prepared in 1986 with the aim year of 2015. In this plan, the processes such as transportation, location selection, land prices, which affect the macroform of the city were discussed and the western corridor was determined as the main axis where the city was to be decentralized. The principles were defined with this plan in order to solve the air pollution problem of Ankara, repair the damaged work-housing relations, and define macro target and implementation tools for urban transportation. As the effect of the plan, it is seen that the manmade area on the classification map is clustered towards the western axis. It is also possible to see the ring road that surrounds Ankara and the way it serves as an artificial threshold in the 1998 classification results.

The Ankara Metropolitan Development Plan (1/25,000 scale), approved by the Ankara Metropolitan Municipality in 2007, aims to create a holistic plan and an integrated urban macroform. The open-green areas surrounding the urban resident area and the basins are intended to be defined in a unity that can define the green belt. For this purpose, it has stated that every kind of strategy for keeping forest, afforestation areas and agricultural areas out of settlement shall be meticulously implemented.

However, when we look at the change in green area between 2008 and 2018, it is seen that this master plan, which was prepared with the aim of 2023, did not succeed in the macroform target even in 2018 (Figure 3-4).

Table 2: Summary Information on High Scale Plans of Ankara

Name of Plan	Year of Approval	Macroform Orientation
1990 Master Plan (1970-75)	1982	Western Corridor decentralization strategy, growth in the direction of Batıkent, Eryaman, and Sincan, work – settlement relationship, green belt prediction.
2015 Ankara Structural Plan (1985)	Unapproved	Decentralization with green areas in Elmadag – Kirikkale, Kazan and Temelli, radial development prediction along corridors, determination of ring road.
2025 Planning	Unapproved	The effort to guide housing development trends at the border of the contiguous area, extension and expansion in the southwestern corridor.
2023 Capital Ankara Master Plan	2007	Getting rid of the plans and creating an integrated – concentrated urban macroform, development of urban macroform in the direction of radial and green wedges, corridor development with mixed uses.
2038 Ankara Environmental Plan	2018	It has been proposed to give mixed usage decisions to prevent urban spread, to create integrated urban macroform and to be supported by rail system lines.

RESULTS AND DISCUSSION

Classification results of five different years' satellite images were conducted and the visual results of 1988, 1998, 2008, 2018, and 2020 are shown in Figures 3, 4, and 5 respectively. According to visual inspections of results, it is easily observed that manmade area, which includes buildings, roads etc. and shown by red colors, has been increasing by years. In contrast, green area has been decreasing by years in central of Ankara except the last year. The increase of the green area in the last year may occurred because of Covid-19 pandemic, and there was a huge planting campaign in Turkey in 11/11/2019. Likewise, land area that represents the area except manmade, green and water area, has been decreasing, too. Ankara's central area has very small coverage of water area, and according to the results, it is observed that water area remains almost same by years. Finally, most recent summer satellite image (2020) of the Ankara were also processed to show latest growth on manmade area. As it can be seen in Figure 5, Ankara has been growing in every direction in the last year.

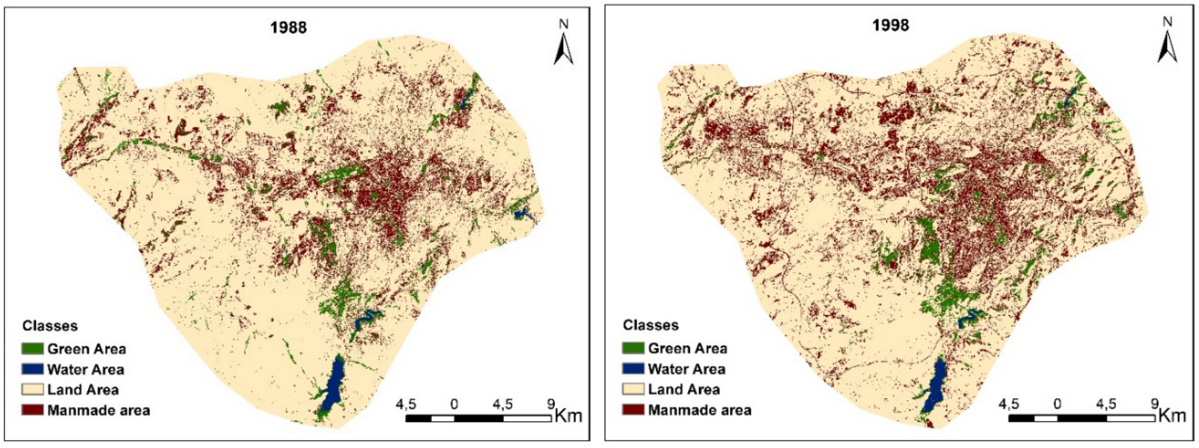
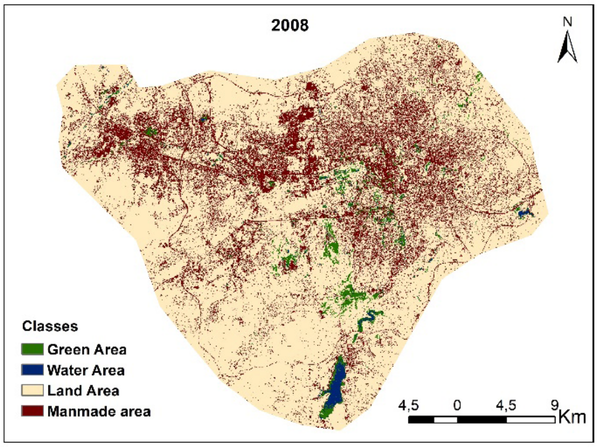


Figure 3: 1988 (Left) and 1998 (Right) Classification Results by MLC Algorithm



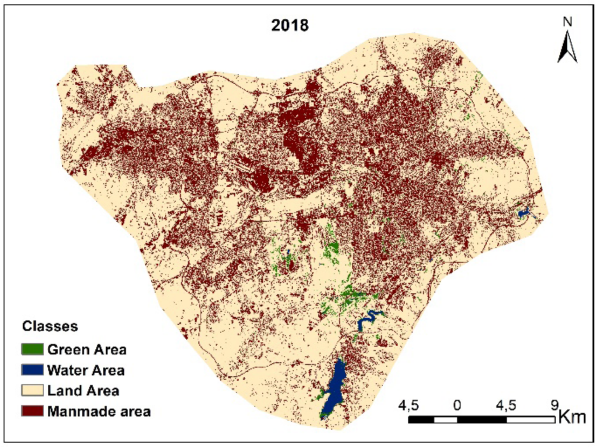


Figure 4: 2008 (Left) and 2018 (Right) Classification Results by MLC Algorithm

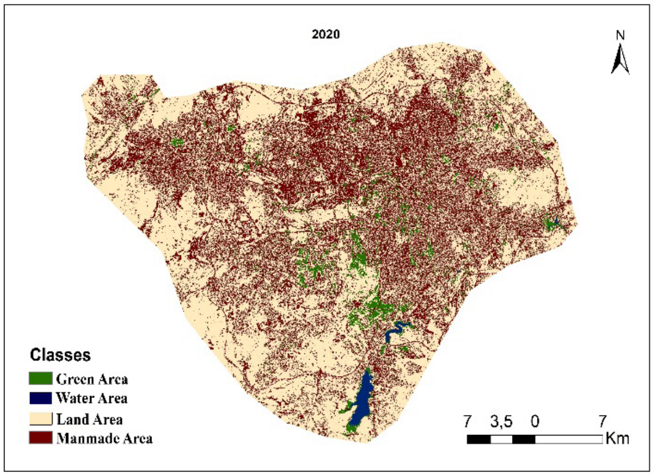


Figure 5: 2020 Classification Results by MLC Algorithm

RF algorithm is one of the most popular algorithms for image classification studies gave worse result than MLC algorithm in this study according to visual and quantitative inspection of the results (Table3-4). Therefore, only two years (1988 and 2018) of the RF algorithms classification results are shown as example results of the RF algorithm in the following figure to show misclassification results of the algorithm. According to the visual inspection of the RF classification results, it is observed that especially manmade areas were misclassified. Moreover, when comparing with the MLC classification results it can be obviously seen that the RF was unsatisfactory for satellite image classification in this study. On the other hand, from both MLC and RF classification results, the expansion of manmade area by years was observed clearly.

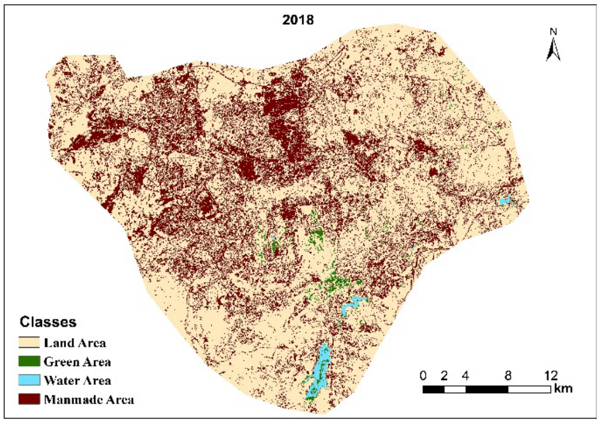


Figure 6: 1988 (Left) and 2018 (Right) Classification Results by RF Algorithm

Quality control of the classification results was conducted by quantitatively and qualitatively. Simply, the results were visually compared with the original Landsat band combinations images for 1988 and 1998 and Google Earth images for 2008, 2018, and 2020. According to visual inspection, it can be said that the results are reliable. For the quantitative quality control, overall accuracy, producer's and user's accuracy, and kappa statistics were computed.

Error matrices were created by comparing reference points and classification results. Overall accuracy, producer's and user's accuracy were computed using error matrices (Table 3). For MLC algorithm, overall classification accuracy found between 85%-92% and overall kappa statistics calculated between 0.78-0.87. The results of each class in 4 different years are presented in Table 3. The results of kappa statistic show that the classification results are in acceptable accuracy range.

Table 3: Accuracy Assessment MLC Algorithm Results of the Image Classification for Each Year's Images

Years	Accuracy/ Classes	Manmade Areas	Green	Years	Accuracy/ Classes
1988	Producer's Accuracy (%)	62.16	89.69	72.72	74.28
	User's Accuracy (%)	62.16	71.42	76.19	78.78
	Overall Classification Accuracy (%) = 73.02			Overall Kappa Statistics= 0.61	
1998	Producer's Accuracy (%)	63.15	81.63	90.24	81.82
	User's Accuracy (%)	69.23	90.90	82.22	76.59
	Overall Classification Accuracy (%) =78.72			Overall Kappa Statistics= 0.70	
2008	Producer's Accuracy (%)	75.43	72.97	68.96	70.27
	User's Accuracy (%)	72.88	60.00	71.42	80.00
	Overall Classification Accuracy (%) =72.08			Overall Kappa Statistics=0.61	
2018	Producer's Accuracy (%)	69.68	93.03	83.33	72.60
	User's Accuracy (%)	75.14	80.00	83.33	74.64
	Overall Classification Accuracy (%) = 73.61			Overall Kappa Statistics= 0.64	
2020	Producer's Accuracy (%)	68.52	92.01	81.23	73.61
	User's Accuracy (%)	73.24	82.28	82.55	72.94
	Overall Classification Accuracy (%) = 72.65			Overall Kappa Statistics= 0.62	

Finally, error matrices were also created for the RF algorithm result (Table 4). Overall classification accuracy as calculated between 73%-78% and overall kappa statistics discovered between 0.61-0.70. The results of each class in five different years are given in Table 4. The results of kappa statistic for two algorithm shows that the MLC algorithm performed better than the RF algorithm because for the manmade area many apartments roof pixel value very close to some part of the land area and RF is failed to successfully classify this kind of parts. On the other hand, computation time of RF is faster than the MLC algorithm.

Since in this data set, MLC gave better results than RF algorithm, to monitor, discuss, and correlate the change with secondary data set, the MLC algorithm classification results are used here after.

Table 4: Accuracy Assessment RF Algorithm Results of the Image Classification for Each Year's Images

Years	Accuracy/ Classes	Manmade Areas	Green	Years	Accuracy/ Classes
1988	Producer's Accuracy (%)	62.16	89.69	72.72	74.28
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	User's Accuracy (%)	73.24	82.28	82.55	72.94
	Overall Classification Accuracy (%) = 72.65			Overall Kappa Statistics= 0.62	

As it mentioned above, the classification results of the MLC algorithm are more successful than the RF algorithm, the MLC results was determined to correlate spatial change with administrative data from now. To examine classification results quantitatively, number of classified pixels for each class are divided with total number of pixels of the images (Table 5, Figure 7). According to quantitative results, it is obviously seen that manmade area has been growing, while land area has been diminishing.

Table 5: MLC Classification Results by Percentage in Each Image

Years	Manmade Area (%)	Green Area (%)	Water Area (%)	Land Area (%)
1988	13.37	4.38	0.74	81.51
1998	19.24	4.15	0.59	76.02
2008	21.81	2.44	0.96	74.79
2018	29.60	1.16	0.75	68.49
2020	34.10	3.95	0.64	61.30

The analysis of the results is projected to following figure to illsutrate change by years qualitatively. In the figure, manmade area has been growing by years while almost no change in water area was observed by years.

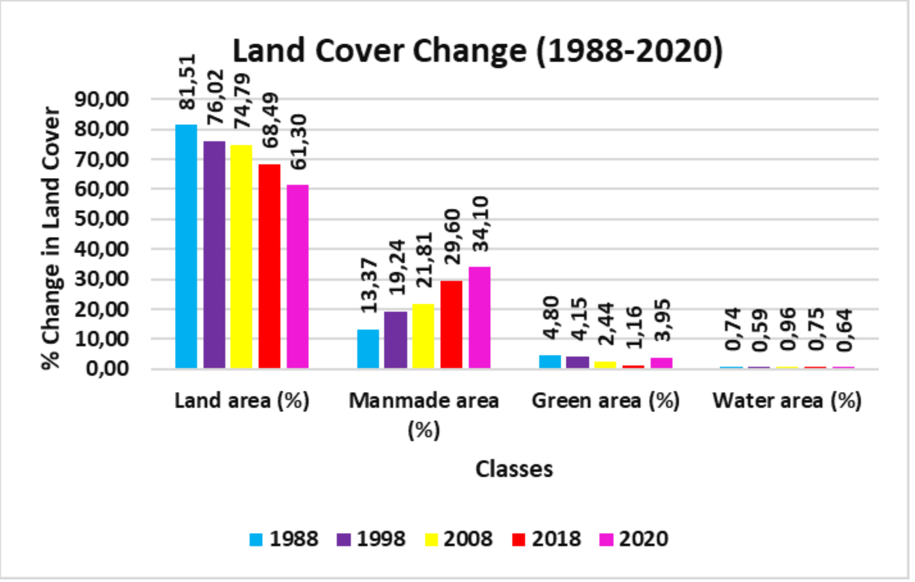

Figure 7: Classification Results Illustration by Graphics for MLC Algorithm

Finally, a figure which show the difference in manmade area for the years 1988-2018 were created to see change in the city, and the growth direction of the city (Figure 9). According to the change analysis in built up area, Ankara city has been growing in every direction for the last 3 decades. A highway road that surrounds Ankara is also clearly seen from the figure. This figure is also very important for the urban planners to see how city has been growing and how they planned during the last 30 years. The officials can act for future plans according to the figure.

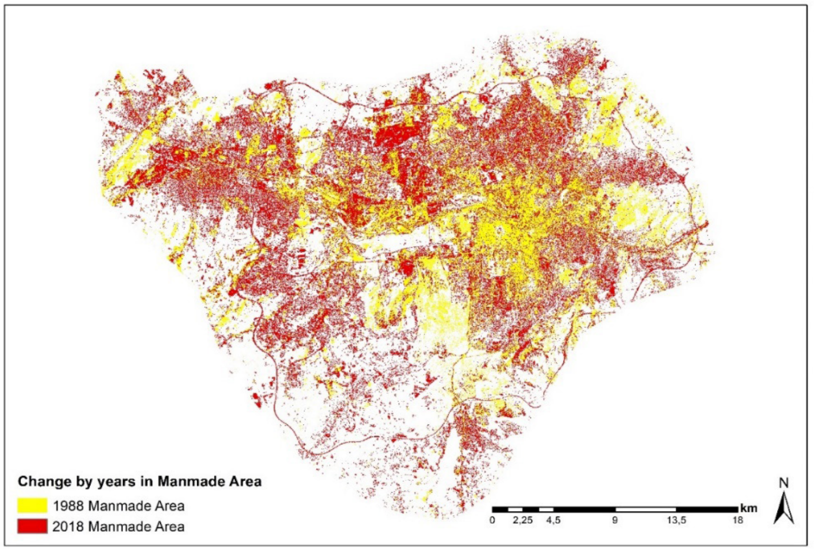

Figure 8: Change in Manmade Area by Years 1988-2018

The classification results were compared with other socio-economic data. Firstly, number of flats in central Ankara (Table 6) and population of Ankara were compared with the change in manmade area percentage by years. It should be noted that after 2018 number of registered flats were not shared by TurkStat.

Table 6: Registered Flats in the Central Districts of Ankara by Years

Years	Altındağ	Çankaya	Etimesgut	Gölbaşı	Keçiören	Mamak	Sincan	Yenimahalle	Total
2006	69,469	66,049	92,638	5,290	221,609	96,313	118,867	132,179	802,414
2007	74,625	78,724	111,764	7,694	237,852	109,158	128,091	140,545	888,453
2008	81,629	92,158	129,046	9,869	248,794	119,292	134,457	151,871	967,116
2009	88,207	102,189	139,888	11,317	257,609	129,699	141,107	165,255	103,271
2010	94,008	112,407	151,359	16,922	267,266	142,192	148,439	185,921	1,118,514
2011	102,225	119,222	167,331	19,373	281,782	156,438	155,767	199,205	1,201,343
2012	110,202	125,026	183,020	20,734	296,032	170,380	165,001	214,498	1,284,893
2013	118,031	132,530	197,915	22,724	311,009	186,554	171,105	231,493	1,371,361
2014	129,627	144,920	209,031	26,293	332,603	203,404	176,950	243,944	1,466,772
2015	138,972	157,644	220,219	28,160	349,396	219,993	183,365	254,452	1,552,201
2016	148,612	179,116	228,752	31,960	362,546	231,804	191,508	265,365	1,639,663
2017	150,539	449,509	228,422	39,946	349,614	228,757	186,423	260,461	1,893,671
2018	160,123	464,099	233,442	42,540	357,817	239,589	192,220	266,424	1,956,254

According to comparison between flats and population in Ankara and change in manmade areas, as it expected high correlation between population and change in manmade area classification results and number of flats and change in manmade area were observed found as 0.99 and 0.99, respectively (Table 7). Especially, in the last two decades the population of Ankara grow rapidly. Before the year of 2000, population census in Turkey was done with five years' interval, therefore 1990's population is used for 1998, and 2000 population was used for 1998 for correlation between population and change in manmade areas. In this and the following comparisons, only 10 years' intervals classification results were conducted.

Table 7: Comparison Between Flats, Population, and Manmade Change

Years	Flats	Change in manmade area (%)	Population of study area
1988	No Data	13.37	2,650,401 (1990 year)
1998	No Data	19.24	3,356,877 (2000 year)
2008	967,116	21.81	3.896.713
2018	1.956.254	29.60	5,503, 985
Correlation	0.98		0.99

Figure 9 shows another secondary data that were employed in this study to show the number of houses and buildings in Ankara by years and it shows that the housing stock is increasing gradually (after 2018 the data is not reachable). This figure also proves that Ankara has been growing in vertically therefore, the number of houses growing faster than buildings. Every apartment in Ankara has more than four flats in it.

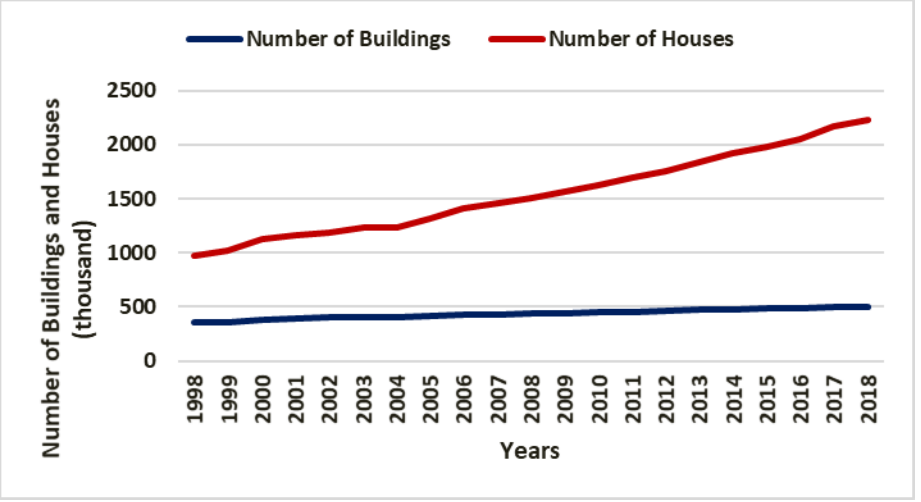

Figure 9: Graphical Illustration of Number of Houses and Buildings in Ankara by Years

Finally, correlation between change in land cover (%) based upon the satellite image analysis results and total agricultural (land) area based on the administrative data of Ankara was examined. Total agricultural area also includes of meadows and pasture lands as land class in the satellite images. The correlation was found as 0.94 (Table 8). Land cover ratio and total agricultural area has been decreasing and residential areas has been growing since 1988.

Table 8: Correlation Between Change in Land Cover (%) and Total Land Data of Ankara

Years	Land Change (%)	Agricultural Land (hectare)	Years*
1988	81.51	No data	-
1998	76.02	1,291,034	2000
2008	74.79	1,196,074	2010
2018	68.49	1,091,007	2019

Source: TURKSTAT (2019) & General Directorate of Cadastre and Land Registration (2019).

•Since the exactly same years of the satellite images is not available for agricultural land data, the closest years were chosen.

The Ankara Environmental Plan of 2038, which was approved by the Ankara Metropolitan Municipality in 2017, shows that several number of upper scale decisions have been taken in the research area. Considering the population, labor force, and employment balances in the planning regions, it has seen as important decision to protect the urban macroform by developing projects that will prevent the scattering of residential areas. Since the plan is very new, it is difficult to see its reflections, however, it can be said that there are important macroform targets to prevent the spread of the city.

Finally, using simple linear regression method, future prediction of Ankara was performed. According to results (Figure 10), it is expected that manmade area will be increased almost a half of the study area in 2055 according to the Simple Linear Regression (SLR) prediction. This means that manmade built up area continue to grow, and to make a future plan of the city, this growth needs to be considered formally.

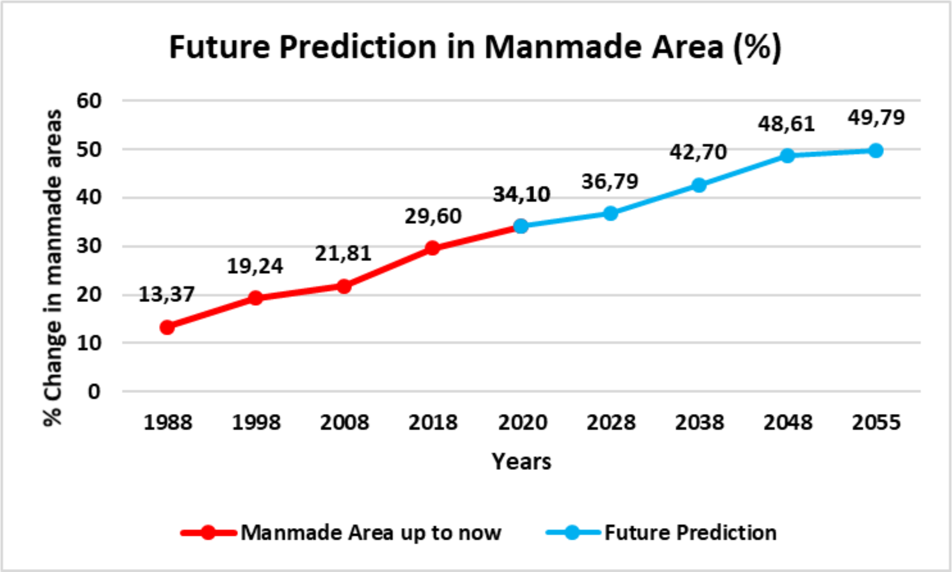

Figure 10: Ankara Predicted Man-Made Area Percentage in the Future Years by SLR

According to official data, there has been an increase of 4.6 times in the population, 6.5 times in the number of houses and 4.5 times in the number of buildings in Ankara in the period of 1960-2018 (TurkStat 2019). It was observed that the number of buildings in the city has increased at similar rates, and the city's spread and the city's growth has been balanced with the population growth. The number of high-rise buildings has increased rapidly over time, depending on the concept of prestige projects in cities, along with an increase in technological development, high unit cost of land acquisition for residential areas in the city center, landscaping, reduction of roof and ground costs. From all the data mentioned above show that the city has been increasing in manmade area and it expands in all direction of the city, which was observed from the classification results of the remotely sensed data.

Urbanization and urban development are observed in different districts within the Ankara Province and other districts are mostly taken place in rural settlements, and these households living in these livelihoods mainly depend on agricultural activities for their income and living. In the districts where urbanization and population growth are high, the rapid transformation of lands into zoning parcels, infrastructure investments, and residential and non-residential building construction works are also progressing at a rapid pace.

The number of newly constructed buildings in Ankara and the total of their area and distribution by districts also confirmed this assessment. The land allocated for uses such as total agricultural land, forests and pasture lands in the province is significantly decreasing, and it is observed that these lands are rapidly transformed into human structure uses such as residential, commercial real estates, industrial and infrastructure investments. In the 2000-2019 period, the amount of agricultural land decreased in the 8 districts included in the scope of the survey by 32.35% and 15.49% across the province, and the agricultural lands were either transformed into other uses or left idle.

While the pastureland in the analyzed districts decreased by 17.73% between 2000 and 2019, the presence of pastureland in the province increased by 11.37% due to the lack of livestock activities in the neighborhoods close to the settlements within the periphery of the metropolitan municipality, and the destruction and use of the pasture lands due to the increasing urban use thereby the pasture land became unprotected as a natural cultural asset. Similarly, while the presence of forest land decreased by 49.59% in eight districts, the presence of forest land in the province increased by 21.59%. Other lands consisting of residential areas, military areas, water surfaces, and other communal land resources were increased both in eight districts

(56.56%) and throughout the province (15.65%). The analysis results of administrative data and satellite images are consistent in general perspective.

CONCLUSIONS

In this study, the analysis of satellite images shows that expansion of the Ankara on the all axis increased in the amount of manmade area. According to change detection results, urban growth of Ankara was observed in every direction, especially in the west. This also shows that the development plans of Ankara since the 1980s shape urban growth directly. Speculative movements occurred on the axes defined in the master plans and that the city started to spread. Studies on monitoring and forecasting urban growth need to be increased to keep the city macroform under control. Furthermore, the change of land cover and the compliance of this change with the plan should be determined to prevent the mistakes of the previous master plan.

The analysis of this study allows us to quantify the manmade area and the amount of green space quantitatively, and thus, the success rate of the plans in the study was also analyzed. In addition, because the manmade area allowed seeing the direction of development, a qualitative comparison could be made between the macroform projections of the plan and the current map. For the future oriented studies required detail for classifications of structures, it has been increased importance to proper design of land use strategies.

The findings of the study indicate that manmade structure or built up areas increased while vegetation areas mostly decreased by years due to rapid urbanization. High correlation between population, change in manmade structures, and number of flats in Ankara was observed. In eight central districts, which represent centre city of Ankara, forest, meadows, and agricultural area has been decreased due to the urban growth and therefore the existing zoning plans did not serve to protect natural resources due to weak conservation works. Both the land use data and satellite image analysis results represent that the increase in manmade structure or built up area cause the decrease of green land and thus, land cover change is correlated human activities and socio-economic development. In order to protect the green areas within the urban sprawl and surroundings the city, master plan of the Ankara province and land use strategies should be based on the proper analysis and develop proper land use strategies based on ecological dimension of land use.

There is a requirement for optimizing decisions on land use strategies and the redefinition the of the real estate specialist in land use planning process is required based on the multiple use of land resources and suitable land use strategies development under the framework of social, economic, and ecological benefits and long run sustainability of land management in both urban, semi-urban and rural area of each province as well as national level. There is need of enhancement of the protection of green areas due to dwindling of life support system or vegetation as biological assets particularly surrounding of the cities and coastal zone areas. On the other hand, it is necessary to setup assessment and monitoring system related to land use and land cover change in all levels such as local, regional, and national level considered as satellite images analysis and relevant socio-economic data integrations.

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