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The cover image is a train passes a rail road crossing that is surrounded by flooding caused by rain and melting snow in Nidderau near Frankfurt, Germany, Wednesday, Feb. 3, 2021. (AP Photo/Michael Probst)

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Estimation of the future land cover using Corine Land Cover data

Estimation of the future land cover

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Abstract

In this study, linear and polynomial regression functions were applied to the Corine Land Cover (CLC) data to quantitatively estimate the future land cover for three different cities of Turkey, Ankara, Istanbul and Izmir. For the related cities, the CLC data sets recorded for every 6 years between the years 2000-2018 were individually obtained from satellite images for monitoring changes in land cover for Turkey. These data allow us to have information about artificial surfaces, agricultural areas, natural and semi-natural areas, wetland and water bodies which have been changed accordingly urbanization process in Turkey. Based on CLC data of 2000, 2006, 2012 and 2018 the areas and widths of artificial surfaces spread in these three cities were determined. Mathematical calculations were made by using the linear and polynomial regression models to understand what the future scenarios would be in order to understand what would happen if these changes continued in the same way. To conclude, revealing the possible scenarios in the future will provide important outputs for land cover and will contribute to the development of urban planning and the creation of sustainable cities.

Keywords

Quantitative estimation; Effect of urbanization; Land cover change; Linear and polynomial functions; Corine land cover data.

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1. Introduction

The city has a dynamic structure that is constantly changing, developing and tending to grow. Economic, technological, political and socio-psychological factors with the mentioned situations cause the cities to spread. Because of sudden effects in these factors, the transform from natural areas to artificial surfaces is called urbanization. Urbanization has a great effect on the change in land cover. Urbanization stimulates land cover changes, determining the contraction of agricultural land, the consolidation of forests and semi natural areas and the expansion of artificial surfaces (Paulsen, 2014; Zitti et al., 2015). Other factors affecting the change in land cover are other human-induced activities (migration, agricultural activities, deforestation, etc.) (Hietala-Koivu, 1999; Nagashima et al., 2002; Çakır et al., 2017) and natural factors (insects, natural phenomena, terrain structure etc.) (Çakır et al., 2017). In addition, urbanization, industrialization and intensive agriculture often cause rapid land cover change, loss of ecological capacity, diversity, natural beauty, and damage to the cultural landscape with and historical value (Bastian et al., 2006; Feranec et al., 2010). Urbanization is driven by population growth and migration, which leads to the physical expansion of existing urban centers (Samson, 2009; Alaci 2010; Satı et al., 2017). Migration not only the structure of the community, but also changes the land cover seriously (Cui & Shi, 2012). When the population data were analyzed, according to the data of 1950, the city population was constituting 30% of the total population. In 2018, this rate exceeded 55% and in 2025 it would reach 60% (World urbanization prospects: the 2007 revision, 2007). In addition, the relations of production which have been constantly changing as a result of the rapid technological developments seen after industrialization also affect land cover.

In short, rapid industrialization and unbalanced population growth and unplanned construction are the factors affecting the land covers. Urban ecosystems are adversely affected from this social process, so land cover changes are easily observable. All these factors also cause major local and global problems (Kim &Baik, 2005; Zhao et al., 2006; Cui & Shi, 2012). These are air and water pollution (Liu & Diamond, 2005; Shao et al., 2006; Cui & Shi, 2012), demand for energy and raw materials (Zhou et al., 2004; González et al., 2005; Cui & Shi, 2012), demand for housing and transportation, traffic congestion (Jago-on et al., 2009; Cui &Shi, 2012), and local climate change (Zhou et al., 2004; González et al., 2005; Cui & Shi, 2012).

In Turkey, the rural population until the 1980s constituted the majority of the general population. Therefore, it is classified as a low urbanized country. However, a large majority of the population in Turkey live in urban centers, according to current data. The urban population in Turkey in 1950 was 5 million, this figure has reached 61 million in 2018. As a result of the continuous increase in the urban population and the decline of the rural population in 2050, it is estimated that 82 million people will live in urban centers (The World's Cities in 2018, 2018). Land covers in Turkey after 1980 has been influenced by political decisions. Put into force the "Metropolitan Application" legislation has led to an artificial increase in population in Turkey's urban centers. These artificial population increases in urban have also affected the land cover change. Considering the land cover changes in Turkey, it is seen that there are many factors such as sudden population increases, migration, inadequate planning approaches and ignoring natural processes during the implementation phase. These risks should be evaluated by experts, planners and designers to develop approaches to minimize natural damage. This situation requires an examination of the land cover change. Therefore, urban policy and decision makers are challenged by the complexity of cities as social, ecological, technical systems (Webb et al., 2018).

In order to understand these systems well, analyzing the past land covers, knowing the future effects of these uses and finally making a decision in the light of these data will significantly contribute to the sustainable planning approach. Also, urban growth generates some opportunities for sustainable planning. There is a need for a true decision-making process in order to shape urban growth with sustainable land use planning. National and international policies with land use provide decision makers the strategic opportunities to get sustainable cities. To the vulnerability of urban areas to the present and future effects of "global warming", non-climatic factors should be also included, whose effects, combined with those of climate change, enhance the final impacts and/or condition the adaptive ability of the population and territory (Zucaro & Morosini, 2018). In the European Union, an average of 117.5 people live in an area of 3 million square kilometers, so the European Union emphasizes the importance of land use planning and management (Environment - land use, 2019). The Association focuses on factors such as air pollution and traffic density that led to greenhouse gases as a result of direct or indirect effects on natural habitats and landscapes, where land covers patterns may have significant effects on environmental conditions.

The European Commission's The ESPON Sustainable Urbanization and land-use Practices in European Regions (SUPER) research project has been set out to create more sustainable land use through a series of qualitative and quantitative surveys based mainly on data processed with analytical and predictive models (Solly et al., 2020). In Turkey, integrated Urban Development Strategy and Action Plan Preparation Project in preliminary studies by the Ministry of Environment and Urbanization was launched (Güler & Turan, 2013). Providing a sustainable spatial development in the settlements and creating an environmentally sensitive living environment in the cities have been within the objectives of the project.

CLC contributes to the knowledge of the land cover and its changes in 24 European countries between 1990 (Feranec et al., 2010) and 2018. In the literature, there are some typical published papers on monitoring land cover changes using Corine land cover data (Yılmaz, 2009; Cieślak et al., 2017). Feranec et al. (2010) did a study on land cover change flows in landscape using CLC data. As land cover is an indivisible part of the landscape, it reflects its states in different stages of changes. Remote Sensing has been an important method for spatial investigations (Yaprak et al., 2017). This is the reason why land cover changes can be considered the correlated information source about processes in the landscape (Feranec et al., 2010).

The purpose of this study is to determine the impact of human effects on future land cover changes in Turkey using CLC data. Considering the current and future urbanization effects, planning studies should be performed take into account Turkeys' three largest cities, which are under pressure in terms of land use with dense population. Therefore, in this study, Ankara, which is capital of Turkey, Istanbul which is one of the world's metropolis city and Izmir which is Turkey's third dense population city were examined. Impacts of human effects on the land cover in the city were evaluated. The future scenarios were obtained as a result of mathematical calculations.

This study proved that the monitor of the impact of human effects on land cover with statistical or mathematical approach gave an opportunity to get the correct planning studies, sustainable land management and predicting the possible harmful human effects on land cover and taking precautions.

2. Location of cities and data collection from maps

2.1 Study area

The studied areas cover the city of Ankara, Istanbul and Izmir in Turkey (see Fig.1). Ankara is located in the Central Anatolia Region of Turkey. The city stretching between 30º 49' - 33º 53' E and 40º 46' - 38º 40' N with a total area of 25,632km² (Province and District Areas, 2020). There are Kirikkale province in the east, Eskisehir province in the west, Bolu and Cankiri provinces in the north and Konya province in the south of Ankara. It is the capital of Turkey and second most populous province with the population of 5639076 (Address Based Population Registration System, 2020). Its altitude is about 890 meters above sea level and it includes 25 districts (Ankara History and Other Information, 2020). In this region, which has a continental climate, winter months are cold and summer months are hot. The hottest month is July-August and the coldest month is January (Cities & Holiday Resorts, 2020). The average annual rainfall is 391.9 mm and temperature is 11.9°C (Cities & Holiday Resorts, 2020). Forest areas constitute 17.1% of the province (Turkey's Forest Assets, 2015). Due to its climate, there are steppe and forest plant communities and 2,389 plant species grow naturally in Ankara (Köroğlu, 2012; Tarıkahya Hacıoğlu et al., 2012).

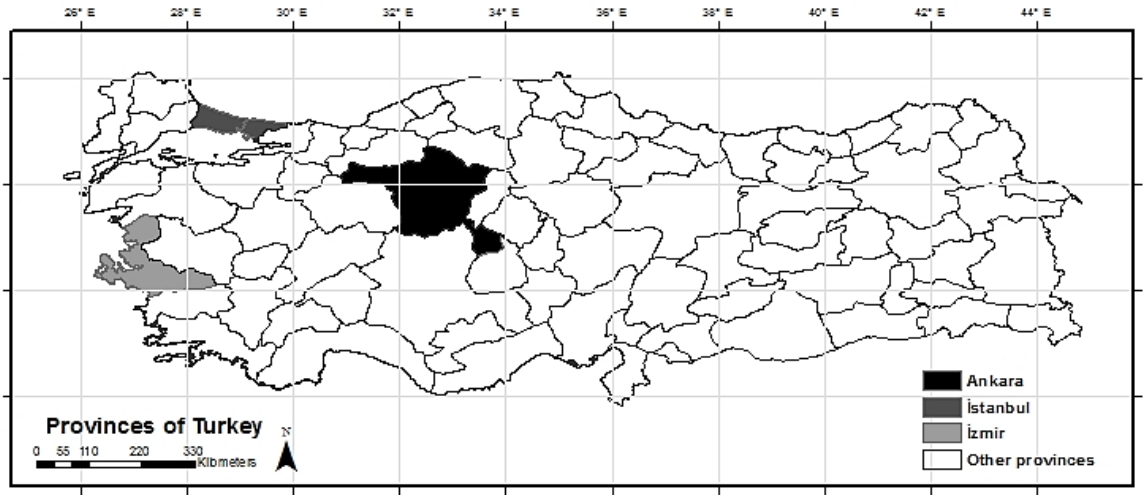

Fig.1 The map of the studied areas

Istanbul located on north-west of Turkey, Istanbul, is a bridge between Asia and European continents. The city stretching between 27º 54' - 29º 55' E and 41º 38' - 40º 48' N with a total area of 5,461km² (Province and District Areas, 2020). There are Kocaeli province in the east, Tekirdag province in the west, Black Sea in the north and Marmara Sea in the south of Istanbul. The lowest altitude in the area is 0, and the highest altitude is 537 m where Aydos hill is located. It includes 39 districts and its total population is 15,519,267 (Address Based Population Registration System, 2020). The area has a temperate climate as it is a transition between the Black Sea and the Mediterranean climate. The average annual precipitation is 677.2mm with the average annual temperature of 14.5°C (Cities & Holiday Resorts, 2020).

Forest areas constitute 43.9% of the province (Turkey's Forest Assets, 2015). In the region, maquis vegetation is dominant. The most important of the forested areas in the region is the Belgrad Forest, 20 km north of the city (Geography, 2020). Izmir is located in the Aegean Region of Turkey. The city stretching between 26º 18' - 28º 30' E and 39º 22' - 37º 51' N with a total area of 11,891km² (Province and District Areas, 2020). There are Manisa province in the east, Aegean Sea in the west, Balikesir province in the north and Aydin province in the south of Izmir. It is the third most populous province with the population of 4367251 (Address Based Population Registration System, 2020). The lowest altitude in the area is 0, and the highest altitude is 2159 m where Bozdaglar Mountain is located (General Information, 2020). It includes 30 districts (General Information, 2020). In Izmir, which is in the Mediterranean climate zone, summers are hot and dry winters are mild and rainy (General Information, 2020).

The average annual rainfall is 711.1 mm and temperature is 17.8°C (Cities & Holiday Resorts, 2020). Forest areas constitute 39.8% of the province (Turkey's Forest Assets, 2015). Izmir is under the influence of the Mediterranean climate in terms of vegetation. There are all types of Mediterranean plants. In areas where forests have disappeared due to overgrazing and fire for centuries, the maqui flora shows itself (About Izmir, 2020).

2.2 Data collection and data analysis

In this research paper, the effect of urbanization on the land cover was studied. In order to estimate the relationship between urbanization and land cover changes. The future information related to land cover change was extracted from actual map information. In preliminary process of the study, the CORINE land cover (CLC) maps at four different years (2000, 2006, 2012 and 2018) were collected from Copernicus land monitoring services. CLC maps are created by using different satellite images. Statistics were produced with the data obtained by interpreting Sentinel-2 and Landsat-8 images. Satellite images have a mid-spatial resolution between 15 and 100 meters, depending on the spectral range. Existing maps were re-created using ArcGis software, as illustrated in Figg. 2, 3 and 4 for Ankara, Istanbul and Izmir, respectively. In the analysis of the effect of urbanization on land cover, CORINE Land cover data were categorized into five different groups, artificial surfaces, agricultural areas, forest and semi-natural areas, wetlands and water bodies.

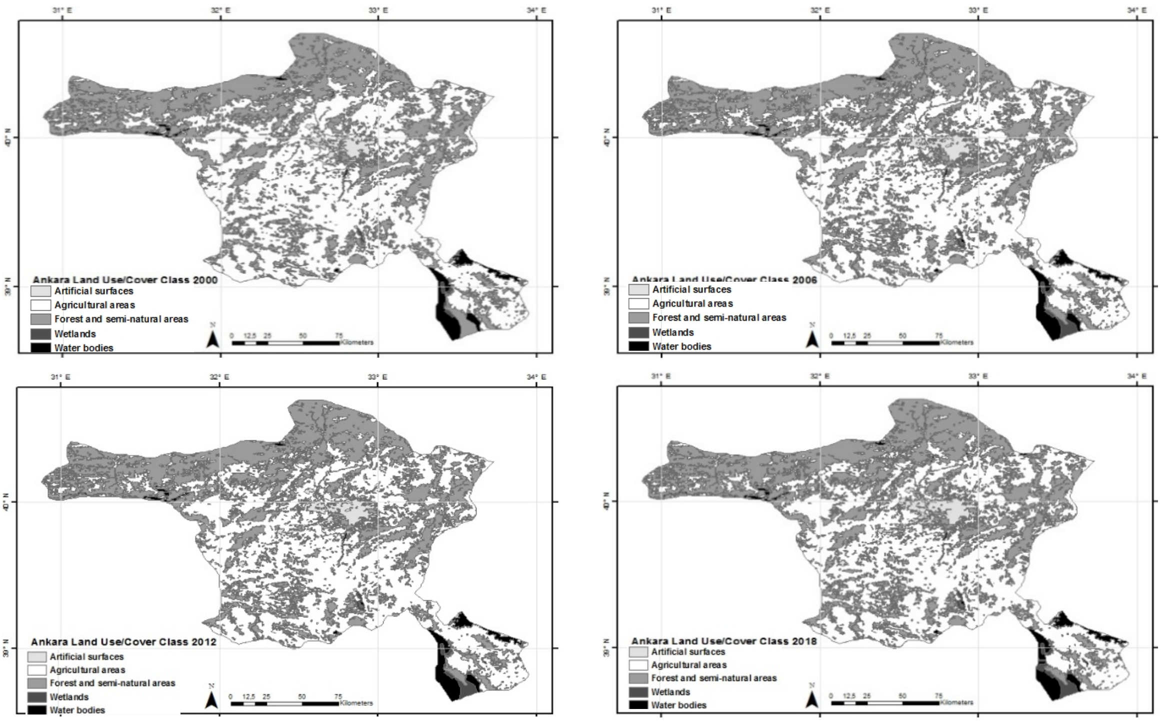

Fig.2 Maps for land cover/ use 2000, 2006, 2012 and 2018 in Ankara

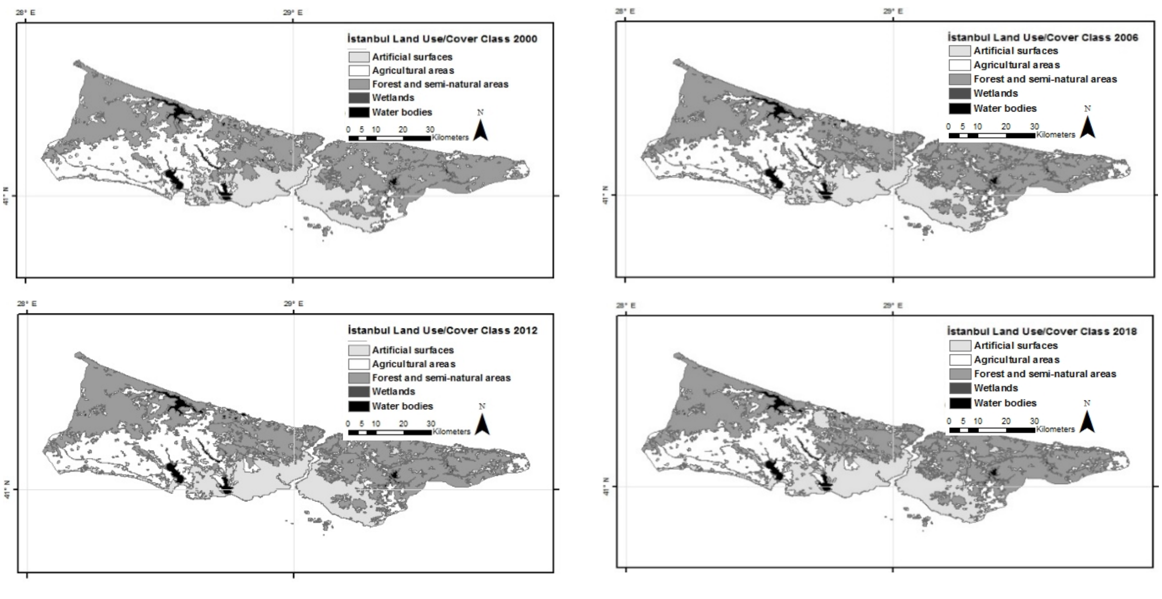

Fig.3 Maps for land cover/ use 2000, 2006, 2008 and 2012 in Istanbul

Then land cover/use areas which correspond to artificial surfaces, agricultural areas, forest and semi natural areas, wetlands and water bodies were computed from maps created for three different cites, Ankara, Istanbul and Izmir. According to the corresponding years, the numerical values of the data for the three cities were listed in Tab.1.

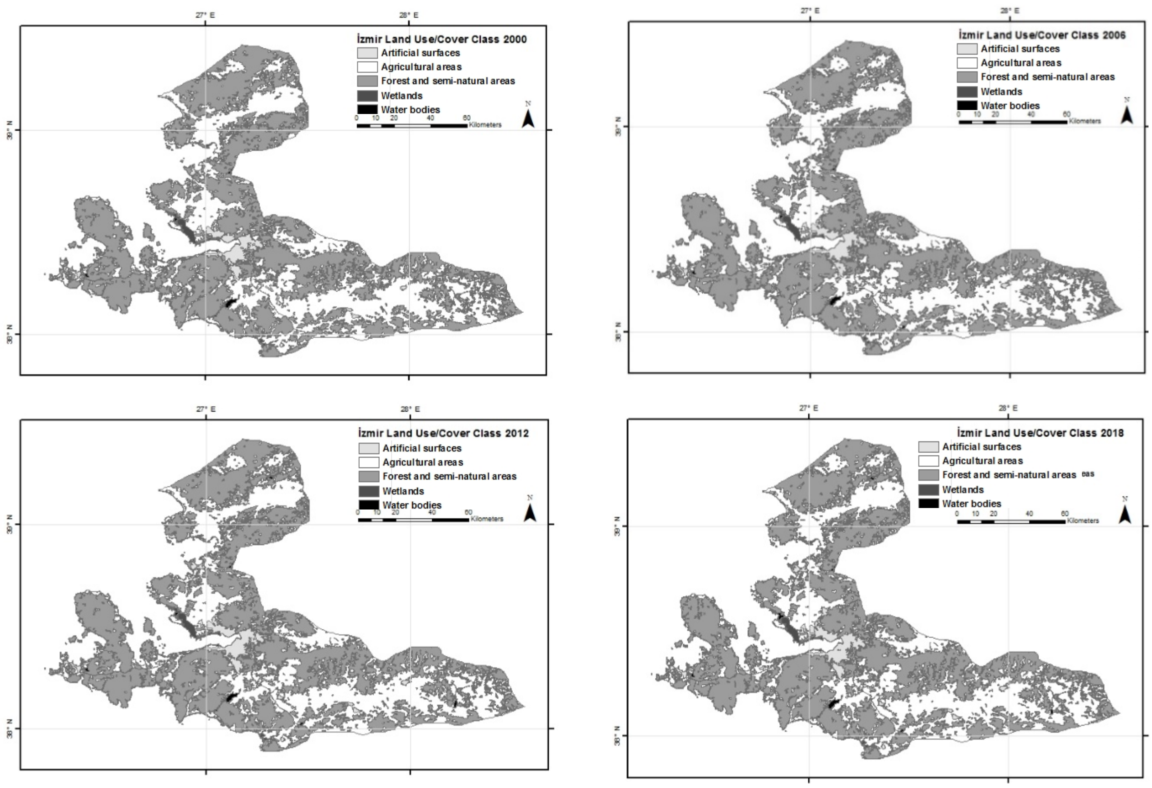

Fig.4 Maps for land cover/ use 2000, 2006, 2008 and 2012 in Izmir

City	Years	Artificial surfaces	Agricultural areas	Forest and semi natural areas	Wetlands	Water bodies
Ankara	2000	75,300	1,492,736	930,602	9,604	64,889
	2006	84,588	1,450,938	949,968	22,674	64,963
	2012	90,818	1,443,932	949,010	22,760	66,612
	2018	102,786	1,432,212	947,207	25,414	65,511
Istanbul	2000	97,505	133,396	231,696	308	13,821
	2006	104,915	139,084	218,160	286	14,280
	2012	108,785	135,578	217,582	286	14,494
	2018	118,690	134,240	209,245	752	13,699
Izmir	2000	52,869	499,659	677,401	6,872	6,655
	2006	61,547	493,232	675,044	6,810	6,822
	2012	64,724	491,537	672,600	6,826	7,768
	2018	67,515	489,875	671,308	6,556	8,199

Tab.1 Computed data of land cover areas in ha for three cities of Turkey

In Tab.1, time (or year) axis (x-axis) and land cover/ use change observation (y-axis) were considered as independent and dependent variables, respectively. From this table, linear and polynomial equations (or functions) for the surfaces of Ankara, Istanbul and Izmir were calculated from the relationship between independent and dependent variables. Linear and polynomial equations and corresponding correlation coefficients for each city were presented in Tab.2. Statistical calculations were performed by using the Microsoft Excel software.

City	Surface	Equation	Correlation coefficient (r)
Ankara	Artificial Surfaces	$y = 147.133x - 2.88x10^6$	0.9858
	Agricultural areas	$y = 208.88x^2 + 824403x + 9.00x10^8$	0.9625
	Forest and semi-natural areas	$y=15.03x^3-90733x^2+2.00x10^8x-1.00x10^{11}$	1.0000
	Wetlands	$y=12x^3-72396x^2+1.00x10^8x–1.00x10^{11}$	1.0000
	Water bodies	$y =-3.3372x^3+20105x^2-4.00x10^7x+3.00x10^{10}$	1.0000
Istanbul	Artificial Surfaces	$y = 1123,8x – 2.00x10^6$	0.9867
	Agricultural areas	$y = 8.767x^3-52887x^2+1.00x10^8x - 7.00x10^{10}$	1.0000
	Forest and semi-natural areas	$y = -15.985x^3 + 96380x^2 – 2.00x10^8x + 1.00x10^{11}$	1.0000
	Wetlands	$y = 0.3426x^3-2061.4x^2 + 4.00x10^6x-3.00x10^9$	1.0000
	Water bodies	$y = -0.5895x^3+3544.2x^2-7.00x10^6x+5.00x10^9$	1.0000
Izmir	Artificial Surfaces	$y = 785.25x -1.52x10^6$	0.9578
	Agricultural areas	$y = -3.6258x^3 + 21886x^2 – 4.00x10^7x + 3.00x10^{10}$	1.0000
	Forest and semi-natural areas	$y = -345,32x + 1.00x10^6$	0.9917
	Wetlands	$y = -0.2809x^3+1691.3x^2 \;\; 3.00x10^6x + 2.00x10^9$	1.0000
	Water bodies	$y = 93,004x - 179485$	0.9690

Tab.2 Linear and polynomial equations obtained by the mathematical relationship between independent and dependent variables for Ankara, Izmir and Istanbul

As it can be seen from Tab.2, linear and polynomial (or non-linear) relationships between independent (time or year) and dependent (land cover change) variables with high correlation coefficient was observed. By using the equations illustrated in Tab.2 for the investigated surfaces and for each city, the quantitative prediction of land cover value of artificial surfaces, agricultural areas, forest and semi natural areas, wetlands and water bodies in 2024 for the related cities were obtained by using the extrapolation process. Mathematical results of extrapolation procedure were indicated in Figg. 5, 6 and 7.

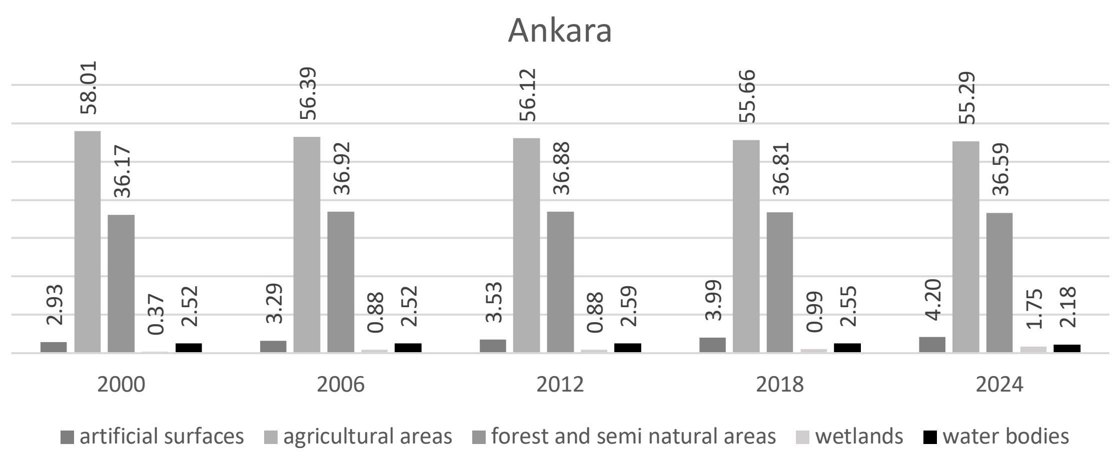

Fig.5 Results related to Ankara obtained from the prediction of land cover percentage changes in 2024 by applying extrapolation process

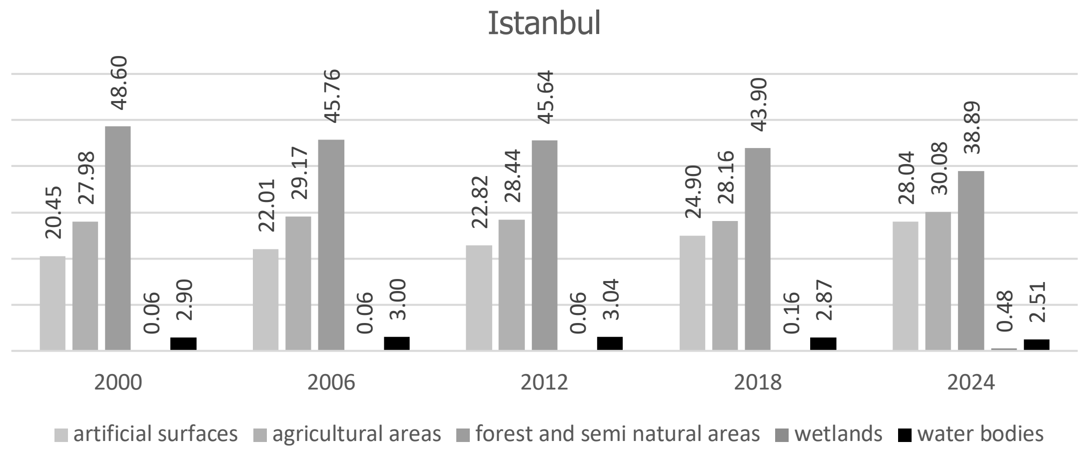

Fig.6 Results related to Istanbul obtained from the prediction of land cover percentage changes in 2024 by applying extrapolation process

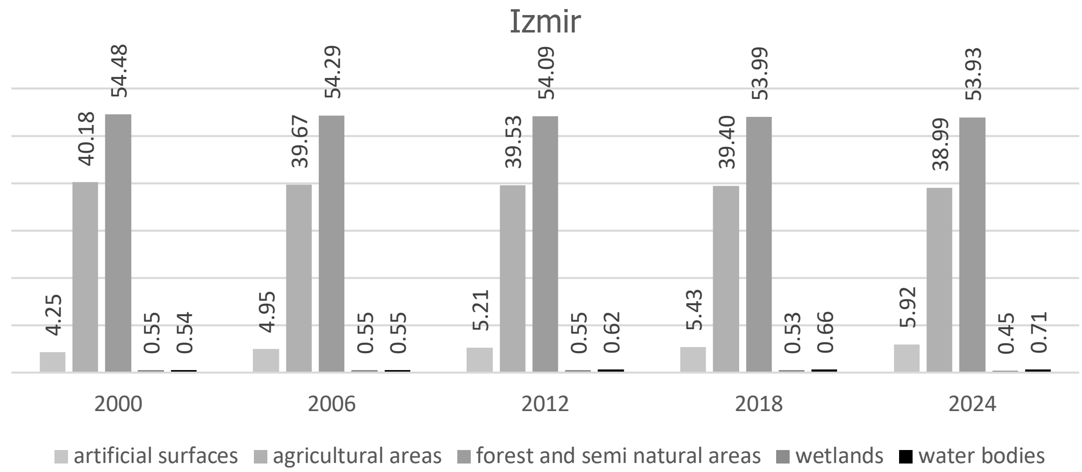

Fig.7 Results related to Izmir obtained from the prediction of land cover percentage changes in 2024 by applying extrapolation process

3. Results and discussion

As it can be seen in Tab.2, in Ankara, Istanbul and Izmir, a linear increase was observed for the values of artificial surfaces against the years 2000, 2006, 2012 and 2018. In the same way, forest and semi-natural areas and water bodies have showed a linear change in Izmir. On the contrary, the polynomial (or non-linear) relationship between the independent variables, years and the dependent variables agricultural areas, forest and semi-natural areas, wetlands and water bodies for Ankara and Istanbul were reported from the related equations in Tab.2. In Izmir, agricultural areas and wetlands showed a polynomial change (see Tab.2). From the linear and polynomial equations given in Tab.2, the numerical values of the investigated surfaces in 2024 were predicted by using the extrapolation process. The results of the landscape change predictions were given in Figg. 5, 6 and 7 as seen in Fig.5 artificial surfaces are expected to increase in Ankara, Izmir and Istanbul in 2024. It has been calculated that artificial surfaces in Ankara will increase by 1.9% compared to 2000. This figure reveals that there was a rapid construction within the specified dates in Ankara. It is estimated that there will be a 2.72% decrease in agricultural areas in the specified date range in Ankara. The increase in artificial surfaces in Ankara will cause a significant decrease in agricultural areas. In parallel with the results of this study, Bayar and Karabacak (2017) state that there is a relationship between the decrease in agricultural areas and the increase in residential areas in Ankara. The disappearance of natural and semi-natural areas in Istanbul reveals that the natural structure has been damaged significantly and measures should be taken against this risk in the future. It is estimated that the natural and semi-natural areas of Istanbul will decrease by 9.91% from 2000 to 2024. Algancı (2018) states that when the land cover change characteristics of Istanbul are examined, the large-scale artificial surface increase especially in the last five years are important. It is stated that a large part of the change in artificial surfaces in Istanbul is caused by the 3rd Airport, Yavuz Sultan Selim Bridge and the connection roads that provide access to these areas (Algancı, 2018). Karaali (2020), in her study examining the changes of land cover, states that between 1990 and 2019, artificial surfaces in Izmir have undergone a visible change. There is an increase in artificial surfaces with the increase of the population due to reasons such as industrial activities, education and migration (Karaali, 2020). In this study, it has been observed that there will be a 1.67% areal increase in artificial surfaces from 2000 to 2024 in Izmir. On the other hand, it was revealed as a result of calculations that there will be a decrease in forests and semi-natural areas in Istanbul and Izmir in 2024. Another situation in our predictions, while artificial surfaces increased in Istanbul and Izmir in 2024, forests and semi-natural areas decreased. In addition, a series of important land cover changes are expected to occur in 2024. For example, wetlands in Istanbul are expected to increase rapidly from 752 hectares in 2018 to 2128 hectares in 2024. This means a 0.08% surface increase in wetlands. As described above, mathematically or statistically monitoring the CORINE Land cover data obtained in a certain period using linear and polynomial models provided the opportunity to visualize the effect of urbanization on the land cover. In practice, the quantitative prediction of artificial surfaces, agricultural areas, forest and semi-natural areas, wetlands and water body for the analyzed cites, Istanbul, Ankara and Izmir enabled to take measures against the major changes or to prevent the destruction of natural and semi-natural areas. From the results obtained, it would be possible to modify a healthy direction of wrong planning decisions for urban sprawl in the future.

Exploring the rules and relations which are effective in changing lands into urban area and also the estimating the trend of city development in the future through credible and efficient methods have received significant attention in urban researches (Soltani & Karimzadeh, 2013). There are many studies in the literature that make predictions for medium-term physical growth based on past trends. Such models remain an essential part of efforts to determine the global consequences of human activities; untested predictions, based on the best science available, are still better than proceeding blindly (Rastetter, 1996; Miller et al., 2021). In order to include economic, demographic and political decisions in extrapolation models, the importance of these studies needs to be emphasized and developed. The greater availability of data in recent years also allows for models that incorporate shorter transition periods, potentially leading to more accurate estimation (Iacono et al., 2015). In addition, extrapolation models may also have value in identifying data needs and knowledge gaps and in describing the potential consequences of alternative management actions (He & Mladenoff, 1999). In many cases, the products of extrapolation are amenable to testing, and there is much to be gained by doing so (Miller et al., 2021).

4. Conclusions

Urban planning is the most relevant decision-making process affecting urban land covers. To support planners in enhancing sustainable urban land use planning, there is a need to understand how human impacts may affect urban land cover. In this paper, the mathematical extrapolation procedures based on linear and polynomial regression models obtained from the relationship between the related dependent and independent variables revealed the effect of human on land covers in the analyzed provinces in Turkey. Another contribution of this applied methodology is that it provides strong evidence regarding the future effects of past land cover changes.

Within the studied areas, possible land cover changes in 2024 have been presented. Evaluating these data combined with national population data and policies can have a complementary effect in terms of environmental monitoring. Moreover, information on changes in landscapes will makes an invaluable contribution to appropriate decision-making, which is essential to wise use of the resources and sustainable development (Alphan, 2003). This study showed that agricultural areas, forests and semi-natural areas were at risk with the creation of artificial surfaces for the investigated cities, Istanbul, Ankara and Izmir. In this context, observing the land cover under risk is of great importance in terms of establishing a correct urbanization understanding, protecting the natural structure and not losing biodiversity. In the coming years, we concluded that observing the landscape changes in Ankara, Istanbul, Izmir, and putting forward a controlled urbanization policy and planning approach would be effective in preventing natural areas and biological destruction and sustainable land management.

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Image Sources

Figg.1, 2, 3, 4, 5, 6, 7: Made by the authors;

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