

Simulation of Urban Growth's Pressure on Urban Blue-Green Space Using the CORINE Database for Kocaeli, Türkiye

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ABSTRACT

Sustainability of resources and combating global climate change are on the agenda at the beginning of the most fundamental problems based on nature worldwide. Although they cover a small area of the world's surface, urban growth and its accompanying effects are the main culprits of these problems. Against these problems, blue-green areas are accepted as a fundamental tool of sustainable urban development in the context of nature-based solutions. The research primarily used CORINE land data; classification was made under five primary headings: land cover, urban areas, industrial and commercial areas, forest areas, agricultural areas, and water surfaces. The 2030-year estimation of the fields was made using the cellular automata-Markov chain modeling method. As a result of the research, it has been determined that blue-green spaces are under severe construction pressure from 2006 to 2030. The suitability of the research model has been proven by the kappa-based method using kappa coefficients (Klocation: 0.9338).

Keywords: Cellular automata, Markov chain, prediction, spatial analysis, urban modeling

Introduction

Since the Second World War, it has been observed that urbanization has expanded significantly on a global scale, especially in developed countries (Aslam et al., 2021; Shrestha et al., 2021; Myers, 2021). Urbanization is a concept related to urban planning that emerges as a result of human activities (Feng and Li, 2021; Zeng et al., 2022) and economic growth (Ahmad et al., 2021; Munir and Ameer, 2022; Ahmed et al., 2022), also considered to be responsible for fundamental problems such as climate change experienced on a global scale (Perez Paris, 2022; Xia et al., 2022). Rapid urbanization has severe challenges in terms of land resource management, especially in developing countries. Mass construction works are carried out to meet the increasing demand for housing. The natural character of the areas where the pressure of urbanization is experienced increases the significance of the research subject.

Rapid urban growth/sprawl increasing impervious surface growth in urban areas directly or indirectly affects the local environment, climate parameters, and other aspects (Patra et al., 2018; Mansour et al., 2020). However, as natural resources are destroyed, blue-green surfaces that reduce harmful gases are also decreasing (Dar et al., 2021; Malyan et al., 2021). The urban blue-green space is the ecosystem most severely disrupted by human social and economic activities. Its condition is directly related to the sustainable development of the urban environment (Alberti et al., 2003; Song et al., 2022). There is no clear definition of the content of the meaning of blue-green space, and its scope has been discussed. According to Taylor & Hochuli (2017), blue-green spaces are classified at the macro and micro levels. The macro-scale includes ecological areas, including forests, coastal areas, croplands, water bodies such as parks and gardens, and vegetation. The microscale refers to the urban open space covered with vegetation, including urban parks, playgrounds, courtyards, urban forests, and urban farms (Song et al., 2021; Song et al., 2022), and land use/land cover change (LULC) in the temporal process, it is inevitable to change due to ecological balance and human intervention.

In the context of land degradation in the process of producing city plans, blue-green areas are an undisputed ecological representation of sustainable development. Monitoring the LULC is essential for natural resource management, sensitive plan decisions, and strategies (Edan et al., 2021; Loukika et al., 2022). Many studies show that land cover change as a critical factor of environmental degradation is followed and modeled as temporal-spatial

Cite this article as:

Işınkaralar, O. (2024). Simulation of urban growth's pressure on urban blue-green space using the CORINE database for Kocaeli, Türkiye. *Forestist*, 74(1), 9-15.

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Received: November 27, 2022

Revision Requested: January 06, 2023

Accepted: February 12, 2023

Publication Date: June 16, 2023



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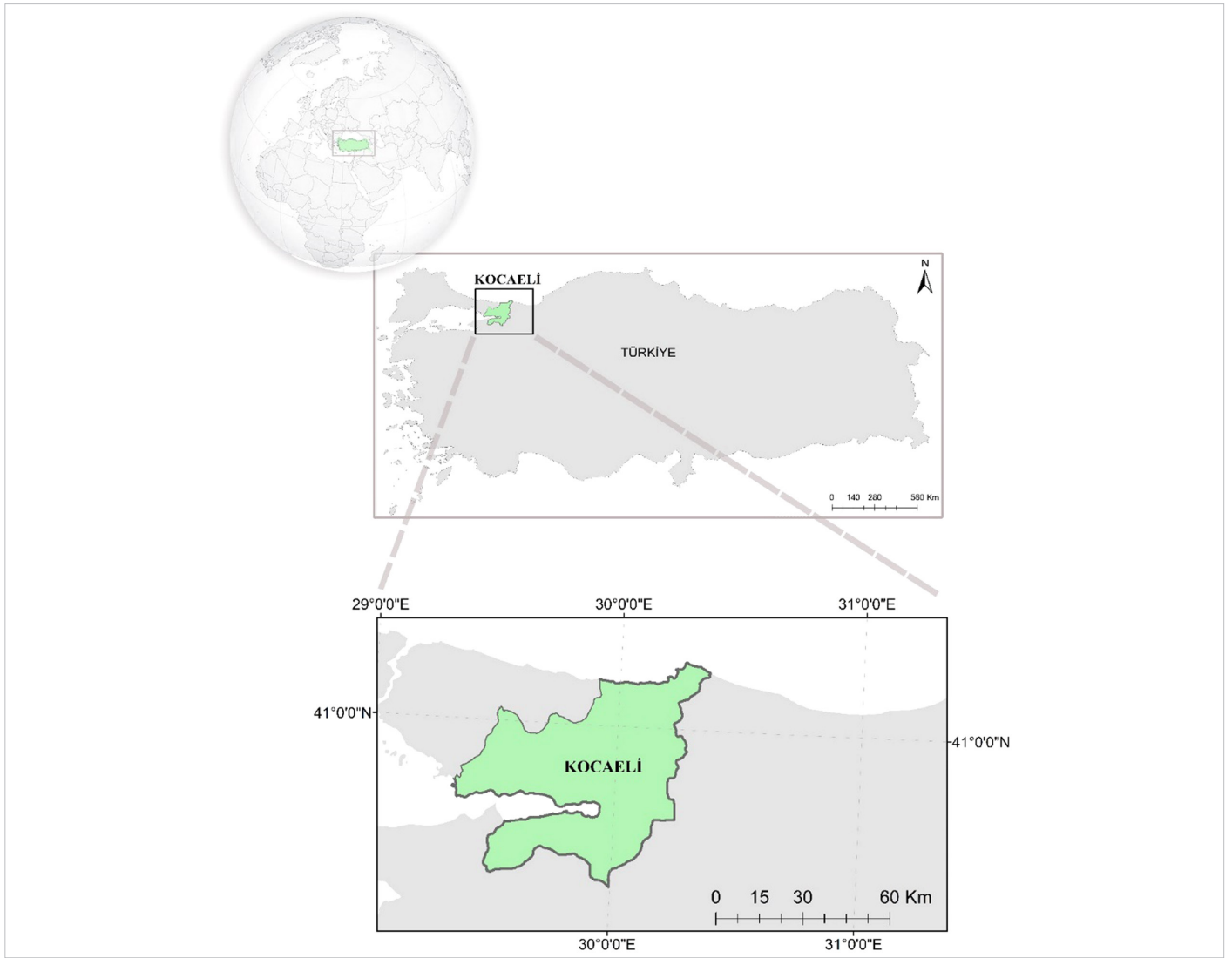


Figure 1.
Study Area Location Map.

(Wang et al., 2021a; Worlanyo and Jiangfeng, 2021). Progress in geospatial techniques, covering geographic information systems and remote sensing methods, facilitates research to reach analytical results using algorithm-based modeling approaches. While these studies present findings that will guide local governments, they also offer spatial reflections on land degradation at the global level (Wang et al., 2021b).

Models produced to understand cities' growth behavior offer ideas about the direction and speed of urban growth of city planners. Thus, it is aimed at managing resources effectively, managing investment decisions, and keeping environmental damage minimal. Many modeling approaches are used today to draw urban growth boundaries (UGB). The cellular automata (CA) model is the first and most widely preferred approach. The CA is based on the logic of future prediction of neighboring cells of a field based on growth rules (Li et al., 2019). The traditional CA model has been developed with integrated techniques such as logistic-CA (Saganeiti et al., 2021), artificial neural network (ANN)-CA (Tong et al., 2020; Xu et al., 2022), and CA-Markov chain (Rahnama, 2021; Isinkaralar et al., 2022), and it provides a realistic spatial reflection of the transition rules in the time-spatial process.

The generation of multi-source big data has paved the way for new opportunities to explore its impact on LULC change. The detection of LULC in the temporal process was generated using CORINE data for simulation. The CA-Markov model was used to estimate the demand for land growth. The research was conducted in Kocaeli, one of the country's leading cities in terms of industry and a city with a high population growth rate. The Ramsar wetland, the Gulf of Izmit, is located within the provincial borders, and forest areas occupy ample space on the city's periphery. In this context, it is aimed to analyze the pressure on forest areas of the site, which is in the process of rapid construction and migration due to high employment, through modeling.

Material and Methods

Study Area of Modeling the Urban Growth Boundaries

Kocaeli is located in the Çatalca–Kocaeli Section of the Marmara Region, between 29° 22'–30° 21' east longitude and 40° 31'–41° 13' north latitudes (Figure 1), Sakarya in the east and southeast, Bursa in the south, Yalova province, Izmit Gulf, Marmara Sea, Istanbul province in the west, and the Black Sea in the north.

Table 1.
Land Use Classification

Classification	Land Use
Urban areas	Continuous urban fabric
	Discontinuous urban fabric
	Discontinuous rural settlements
	Construction sites
	Sports and entertainment areas
	Mineral extraction sites
Industrial and commercial area	Industrial and commercial units
Forest areas	Broad-leaf forests
	Coniferous forests
	Mixed forests
	Maquis or herbaceous plants
	Areas with little or sparse vegetation
Agricultural areas	Arable fields
	Continuous products
	Pasture
	Mixed agricultural fields
Water surfaces	Waterways
	Bodies of water

It is the tenth most crowded province of Türkiye in terms of population, and according to Turkish Statistical Institute data, its population is 2 033 441 people (TURKSTAT, 2021). Kartepe, also known as Keltepe, is the city's highest point, with an altitude of 1601 m. Approximately 44% of the city's surface area consists of forest areas. The town also has many nature parks and Izmit Bay, a Ramsar wetland within the provincial borders. Rapid analysis studies in Türkiye have been carried out that objectively measure and compare the socio-economic development of provinces and districts in the country called Socio-Economic Development Index of Cities research (SEGE, 2011). According to the analysis conducted, Kocaeli is the most developed city after Istanbul, Ankara, and Izmir.

Land Use Change Forecast

The UGB is determined comprehensively with the land use change estimation carried out in the research area. Estimating land use change consists of three basic steps. First, land use vector data for 2006, 2012, and 2018 were obtained from the CORINE database. Then, the obtained data were transferred to ArcGIS 10.0 software, and land use maps were created. This study divided land use into five groups (built-up areas, industrial and commercial areas, forest areas, agricultural areas, and water surfaces), as described in Table 1.

In the third stage, the obtained maps were converted to raster data and made ready for the model in order to be used in future predictions. Finally, kappa values were calculated to determine the suitability of the model. While calculating the kappa values, the forecast and current situation of 2018 were compared using the land use maps for 2006 and 2012. In the last stage of the study, a land use simulation map for 2030 was made in IDRISI Selva software with the CA-Markov chain model.

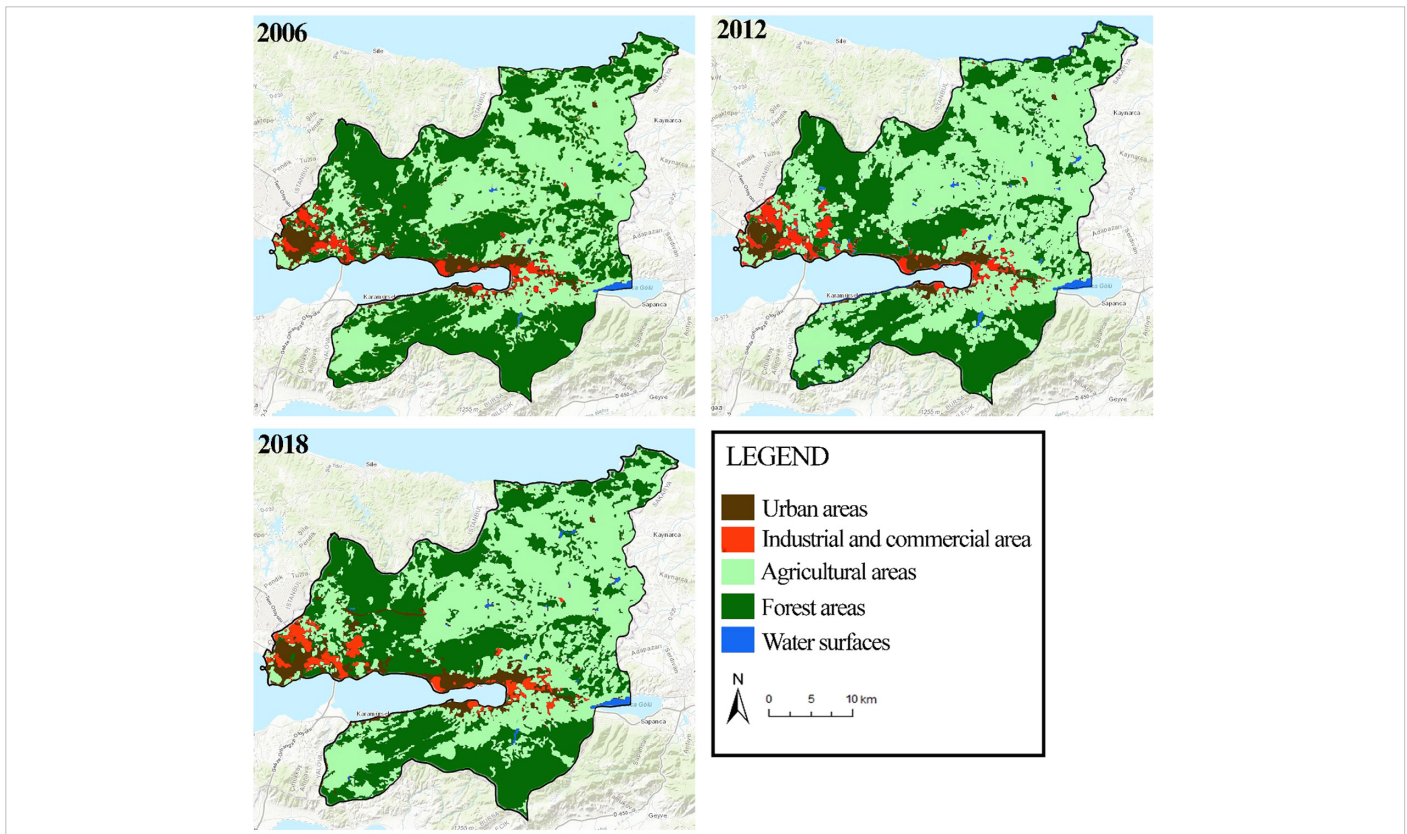


Figure 2.
2006–2018 Land Use Maps.

Table 2.
2006–2018 Land Use Distribution and Change

Land Use Distribution	Land Use Change					
	2006	2012	2018	2006–2012	2012–2018	2006–2018
Urban areas	15 520	16 554	18 030	+1034	+1476	+2510
Industrial and commercial area	8181	9408	10 708	+1227	+1300	+2527
Forest areas	115 015	124 943	123 897	+9928	–1046	+112 393
Agricultural areas	129 282	107 481	108 598	–21 801	+1117	–20 684
Water surfaces	2004	2096	2286	+92	+190	+282

Table 3.
2006–2018 Land Use Transition Matrix

	Urban Areas (ha)	Industrial and Commercial Area (ha)
Urban areas	6656	1207
Industrial and commercial area	2108	1165
Forest areas	22 380	20 336
Agricultural areas	67 280	33 073
Water surfaces	0.56	0.11

Results

Land Use Change of 2006–2018

The land use maps of the study area for the years 2006, 2012, and 2018 are given in Figure 2. The spatiotemporal change of the pressure of the settled industrial-commercial regions and regions in the city of Kocaeli on the forest, agricultural areas, and water surfaces have been evaluated proportionally.

The distributions and rates of change in land use in Kocaeli city in 2006–2018 are given in Table 2. When the distribution of land use is examined, it is seen that forest areas and agricultural areas take up more space. When the changes in land use are concerned, it is seen that the most

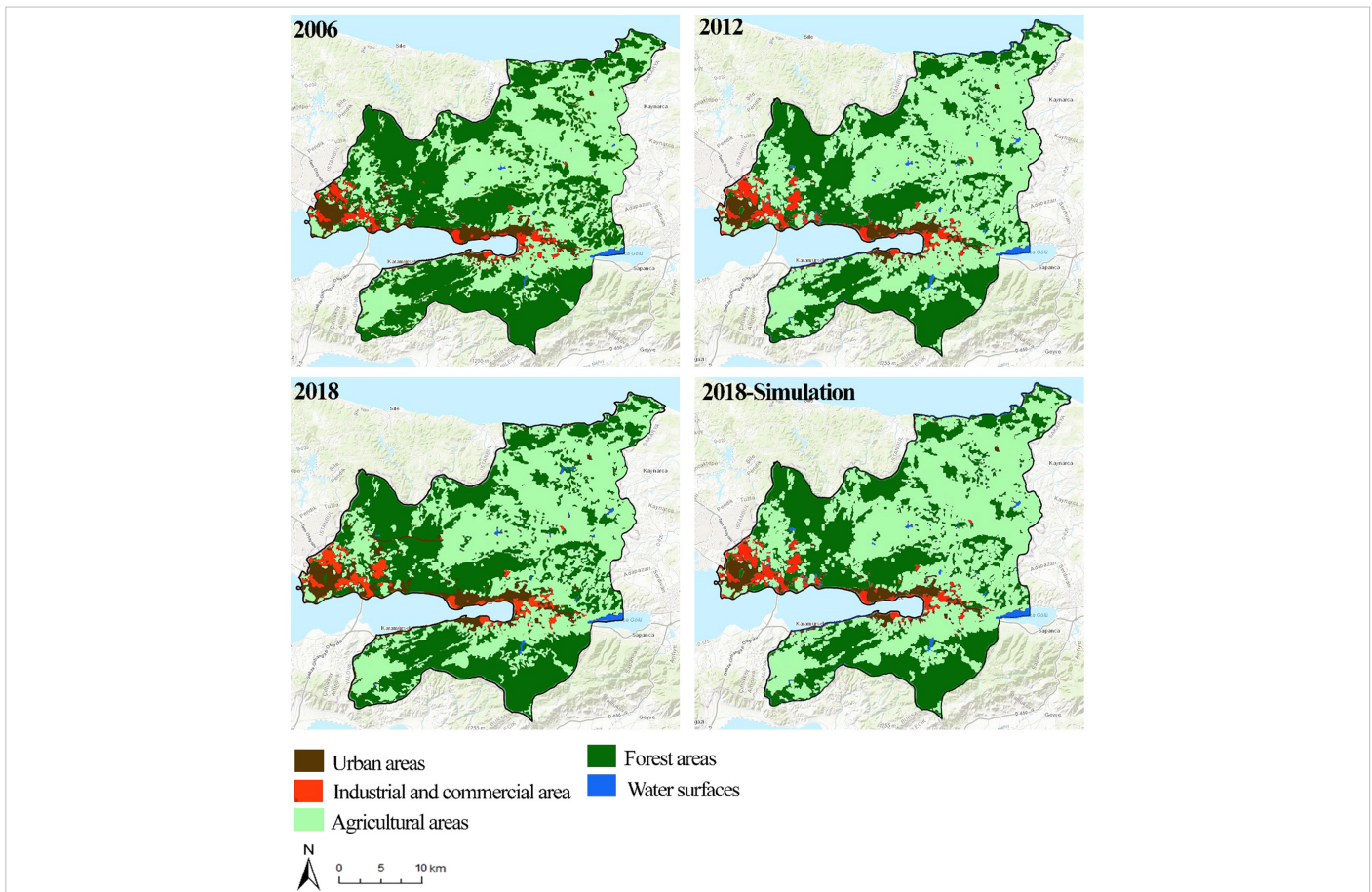


Figure 3.
Comparison of Current Land Use and Forecast Map for 2018.

Table 4. Kappa Values

Kappa Parameters	Value
Kno	0.9844
Klocation	0.9338
KlocationStrata	0.9338
Kstandard	0.9838

Table 5.
2018–2030 Land Use Distribution and Change

	2018	2030	2018–2030
Urban areas	18 030	21 420	+3390
Industrial and commercial area	10 708	13 535	+2827
Forest areas	123 897	120 433	–3464
Agricultural areas	108 598	86 031	–22 597
Water surfaces	2286	2107	–179

Table 6.
2018–2030 Land Use Transition Matrix

2018/2030	Urban Areas (ha)	Industrial and Commercial Area (ha)
Urban areas	9852	1399
Industrial and commercial area	2209	3065
Forest areas	38 420	182 540
Agricultural areas	72 680	20 042
Water surfaces	0.85	0.51

changes are from 2006 through 2018. While the highest increase is seen in the settled area, industrial areas, forest areas, and water surfaces, it is seen that the most decrease is seen in agricultural areas. Considering the change from 2006 to 2018, the pressure of residential and industrial areas on other regions is also clearly seen. It is seen that the most transformation to settled and industrial regions is from the forest and agricultural areas in Table 3.

Model Verification and Calibration

A forecast map for 2018 was produced using the 2006 and 2012 Kocaeli land use maps. When the 2018 reference map and the forecast map are compared, it is seen that the forecast map has a similar spatial pattern to the reference map in Figure 3.

The kappa analysis was calculated to evaluate the accuracy of the estimation results numerically. The kappa coefficient is used to measure the accuracy and reliability of comparisons between two variables. In the study, the maps for the years 2006 and 2012 and the forecast map for 2018 were created. Location analysis for agreement showing Kno as 0.9844, Klocation 0.9338, KlocationStrata 0.9338, and Kstandard 0.9838 is presented in Table 4. The results show that the CA-Markov model is excellent in locating future change in Kocaeli city.

Land Use Simulation

Based on the 2006 and 2018 CORINE land use data, the projected land use situation for the city of Kocaeli in 2030 was estimated by the CA-Markov chain method. While it is seen that there will be a high increase in residential, industrial, and commercial areas in 2030, it is predicted that there will be a decrease in the forest, agricultural areas, and water surfaces in Table 5. When the changes in land use in 2030 are examined, the pressure of residential, industrial, and commercial areas, especially forest and agricultural regions, emerges. The places transformed into residential areas between 2018 and 2030 that belong to these two uses are shown in Table 6. As a result of the estimation made for Kocaeli land use in 2030, it is seen that the highest increase will be

Multiples of Base Resolution (MBR):		1x	1	Information of Quantity	
Information of Location	No[n]	Medium[m]	Perfect[p]		
Perfect[P(x)]	0,4444	0,9981	1,0000		
PerfectStratum[K(x)]	0,4444	0,9981	1,0000		
MediumGrid[M(x)]	0,4327	0,9696	0,9882		
MediumStratum[H(x)]	0,3333	0,8155	0,8145		
No[N(x)]	0,3333	0,8155	0,8145		
AgreeGridcell = 0,1441	DisagreeQuantity = 0,0019	Kstandard = 0,9838			
AgreeStrata = 0,0000	DisagreeStrata = 0,0000	Kno = 0,9844			
AgreeQuantity = 0,4821	DisagreeGridcell = 0,0084	Klocation = 0,9338			
AgreeChance = 0,4333	KlocationStrata = 0,9338				

Figure 4.
Kappa values.

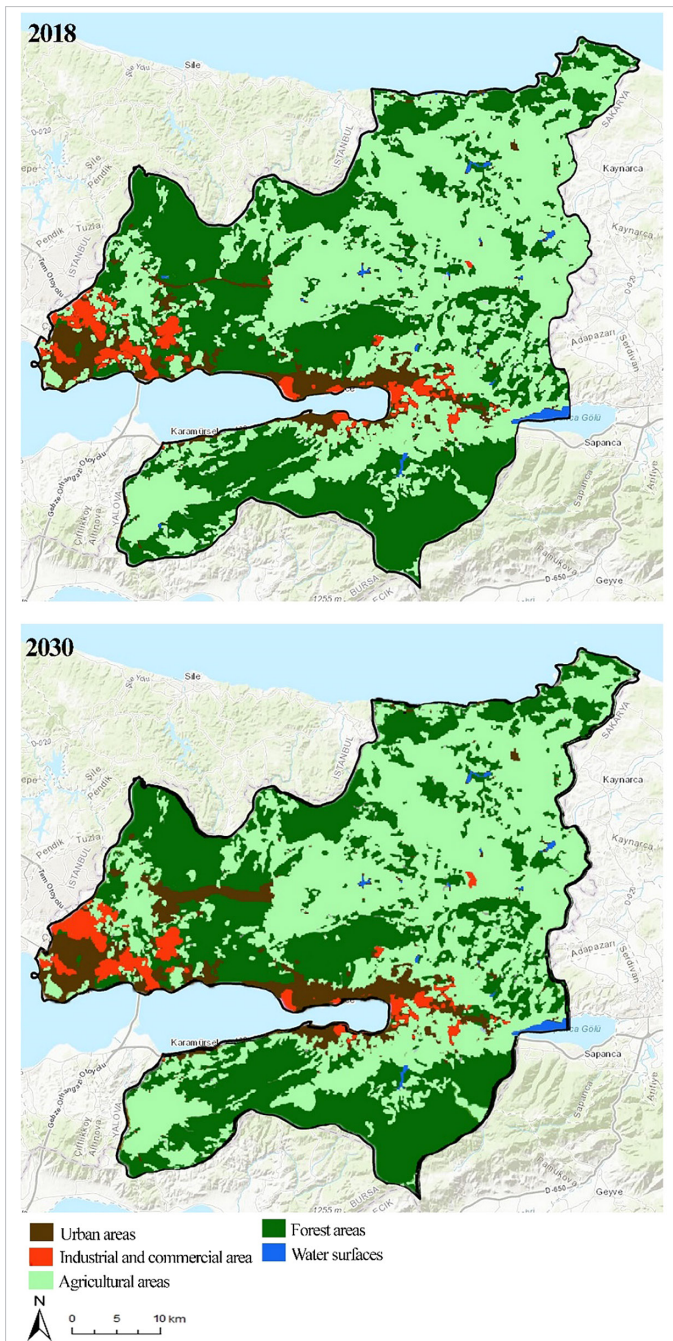


Figure 5.
Kocaeli City Land Use Forecast for 2030.

in residential areas. It is estimated that the settlement areas will develop significantly toward forest and agricultural regions in Figure 4.

Discussion and Conclusion

The research aimed to determine the pressure that the land cover change will create on the blue-green spaces in the temporal process in the city of Kocaeli. While evaluating the change, CORINE data were integrated with the CA-Markov chain method. When the land cover changes in different periods, such as 2006–2012, 2012–2018, and 2006–2018 are compared, it has been determined that the most striking change is between 2006 and 2018. It is necessary to determine to

what extent this situation will affect urban life by establishing a harmonious balance between land use, natural resources, and people, together with the urbanization process and especially the effect of population growth. The impact of urbanization on many issues, such as ecological balance, disaster management, environment and quality of life, and public health, has been revealed by many scientific studies (Gong et al., 2012; Chan and Chan, 2022; Isinkaralar, 2022; Yang and Li, 2023). Therefore, policy and planning strategies that can manage rapid urbanization must be implemented with an approach that significantly reduces urban sprawl, especially in blue-green spaces such as forests and agriculture.

In the study in which land use simulation was made for the year 2030, the most striking result reached as a result of the simulation was that residential areas, industrial and commercial areas will grow toward the forest and agricultural areas. These changes will cause many economic and environmental problems, such as expanding unused land, deforestation, and abandonment of agricultural lands. For this reason, the protection of forest and agricultural areas is of great importance. Simulations with the CA-Markov model are preferred in many empirical studies in modeling land use and land cover change (Huang et al., 2020; Mansour et al., 2020). In addition, many studies have been connected to surface temperature (Tariq and Shu, 2020), temporal and spatial changes in residential areas (Isinkaralar et al., 2022), determination of biocapacity (Wang et al., 2021), and the prediction of carbon sequestration (Babbar et al., 2021). It is preferred in surveys of land use in different frameworks, such as the growth of commercial areas (Isinkaralar and Varol, 2023). Considering that it will contribute to the preparation of large-scale spatial plans and planning strategies, it is possible to use simulation models as a prediction while developing policies that can control urban growth/sprawl and also use in determining UGBs.

In Kocaeli province, an important industrial city in Türkiye that has an intense urbanization effect, it is necessary to make plans compatible with nature in settlements to protect natural areas and increase human-nature harmony. In this context, it is thought that the results obtained in the study will be a reference source for similar studies and future analyzes of the city.

Data Availability: The data supporting this study's findings are available from the corresponding author upon reasonable request.

Peer-review: Externally peer-reviewed.

Declaration of Interests: The author has no conflicts of interest to declare.

Funding: The author declared that this study has received no financial support.

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