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Regional Variations of Land-Use Development and Land-Use/Cover Change Dynamics: A Case Study of Turkey

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Abstract: Population growth, economic development and rural-urban migration have caused rapid expansion of urban areas and metropolitan regions in Turkey. The structure of urban administration and planning has faced different socio-economic and political challenges, which have hindered the structured and planned development of cities and regions, resulting in an irregular and uneven development of these regions. We conducted detailed comparative analysis on spatio-temporal changes of the identified seven land-use/cover classes across different regions in Turkey with the use of Corine Land Cover (CLC) data of circa 1990, 2000, 2006 and 2012, integrated with Geographic Information System (GIS) techniques. Here we compared spatio-temporal changes of urban and non-urban land uses, which differ across regions and across different hierarchical levels of urban areas. Our findings have shown that peri-urban areas are growing more than rural areas, and even growing more than urban areas in some regions. A deeper look at regions located in different geographical zones pointed to substantial development disparities across western and eastern regions of Turkey. We also employed multiple regression models to explain any possible drivers of land-use change, regarding both urban and non-urban land uses. The results reveal that the three influencing factors-socio-economic characteristics, regional characteristics and location, and development constraints, facilitate land-use change. However, their impacts differ in different geographical locations, as well as with different hierarchical levels.

Keywords: land-use/land-cover change; urban; peri-urban; rural; regression analysis; regional development; Turkey

1. Introduction

Land-use/land cover (LULC) change has become a central component in the literature comprising the topics of global/regional change and sustainable development issues [1]. There is vast literature covering the issues of spatio-temporal dynamics and driving the forces of land-use change worldwide [2–7]. Anthropogenic factors comprising demographic, socio-economic and political processes (Figure 1) are the main forces leading to land-use change at the global scale [8–10]. However, regional inequalities exist, and have become ever larger, due to increasing socio-economic growth and urbanization process [5]. Regional comparative studies covering land-use change and pattern, driving forces, and consequences of land-use change would contribute to international literature on spatio-temporal evolution of land uses [5].

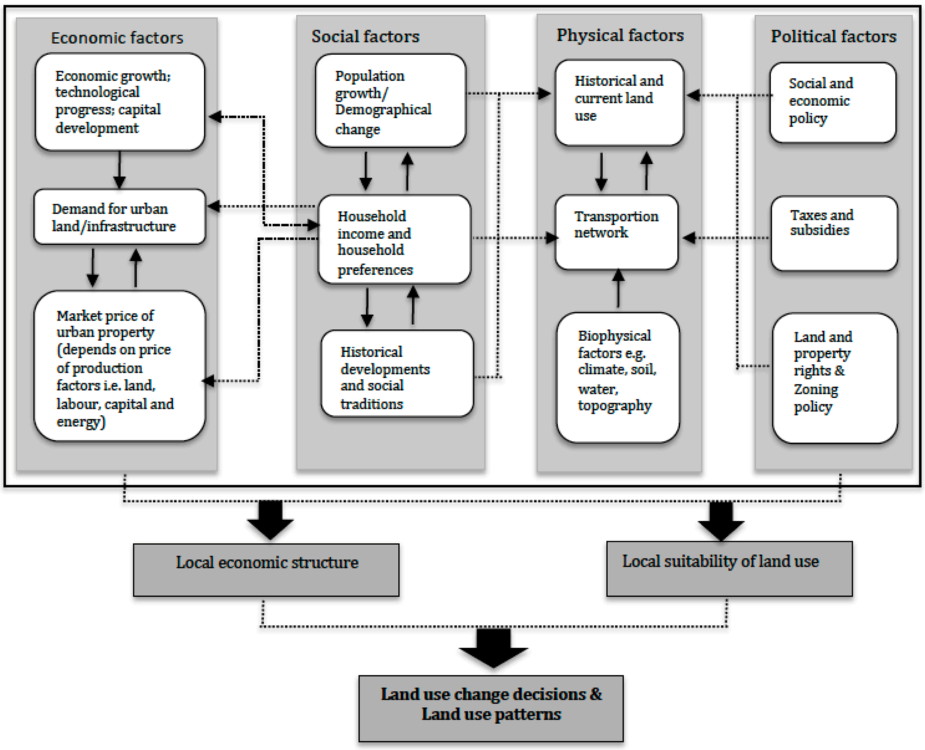


Figure 1. The factors influencing land-use change and pattern.

Land-use/cover change literature demonstrates that the dynamics of land use as a consequence of urban expansion shows variability over time and across space [11–13]. Some regions experience urban growth, while others are characterized with the biggest losses of population [14,15]. Urban growth and decline can be observed in various regions having different socio-economic and physical conditions, as well as different hierarchical levels [16]. Regions with a strong urban core are likely to experience different urban development processes in comparison to peri-urban regions, which may also show diverse characteristics compared to predominantly rural areas, as the latter are weakly connected to central cities and urban regions [17]. In fact, it is difficult to examine urban and rural geographies separately, considering that the boundaries of urban and rural land are intertwined, but instead these can be considered as interrelated geographies, composed of mixed areas ranging from more densely developed, to disperse zones and isolated towns [18,19]. In most countries, urban cores have lost their significance, and there is no longer a clear cut in the administrative structure between the urban core and the countryside. The rural geographies are urbanized through the transformations of production and commodity relations, and rural areas are increasingly based on mass consumption, regardless of the locational differences [19,20]. The peri-urban areas, on the other hand, are dynamic transition zones between the densely populated urban core and the rural hinterland. Peri-urban areas can be characterized by different spatial structure and the density of different urban and rural land-use functions [19]. Because of the differences in spatial development observed in different urban-rural hierarchical levels, in this study, we focus on the analysis of urban and non-urban land-use development trends regarding the urban, peri-urban and rural regions of Turkey.

In order to sustain development for both urban and rural areas and their ecosystems, there is a growing need for sustainable management of resources and the infrastructure needs of urban, peri-urban and rural regions. Therefore, regional and local studies focusing on land-use change [21–23], spatial configuration and pattern [24,25], driving forces and consequences of land-use change [26–29], are increasingly needed in the LULC literature. Most studies related to LULC change patterns have focused on the analysis of urban and/or non-urban land-use changes for the local areas, regions or different countries [16,30,31].

More specifically, the literature on LULC change typologies includes the studies of agricultural land [28,32], urbanization [33,34] and forestland uses [35,36]. Among the few studies that consider the urban-rural interface, there are examples of studies on patterns of land use and land-use change in peri-urban regions [13,37], and studies researching the typologies of LULC change concerning both urban-rural and peri-urban areas at local and regional scales [38,39].

Over the past several decades, Turkey has experienced considerable population growth, as well as rapid economic development, and along with its continuous urbanization and population increase, Turkey has been undergoing an increasingly significant LULC change. Considering the sustainability impacts of rapid urban development upon the environment and society, examination of LULC change dynamics is vital for Turkey. In the literature, the vast majority of studies focusing on LULC change dynamics have been undertaken for Far East countries, particularly China [30,40], for the European countries [17,24], African countries [12,13,41] and the US [42,43]. Unfortunately, much less is known of countries such as Turkey, which is considered to be one of the fastest growing economies in Europe, and internationally. There is wealth of literature focusing on urban expansion dynamics in Turkey, but this literature is either focusing on various cities or regions at the local level, including Adana, Samsun, Kemer and Istanbul [44–47], or examining the urban expansion process from the perspective of legislative and policy frameworks [48,49].

In this study, we quantified and compared the spatio-temporal changes of urban and non-urban land uses in Turkey, disaggregating these changes into a number of specified regions and different hierarchical levels (urban, peri-urban and rural areas), over the past decades covering four periods (i.e., 1990, 2000, 2006, 2012), using spatially high resolution data of Corine Land Cover (CLC) that we had obtained from the European Environment Agency. We note that European Environment Agency (EEA) [50] has recently released the CLC data of 2018, covering all European countries. However, CLC 2018 data for Turkey has not been developed and included in the EEA [50] database yet; and for this reason, we did not conduct analysis for 2018, due to these data availability issues. The objectives of this study were to (i) dynamically map extents of urban land, and analyze current and past trends of land-use change, (ii) quantify spatio-temporal patterns of land-use change at the regional and specified urban-rural hierarchy-related levels comprising 81 regions of Turkey, (iii) then analyze the impact of socio-economic and regional characteristics on urban and non-urban land development across different regions and different hierarchical levels.

2. Case Study

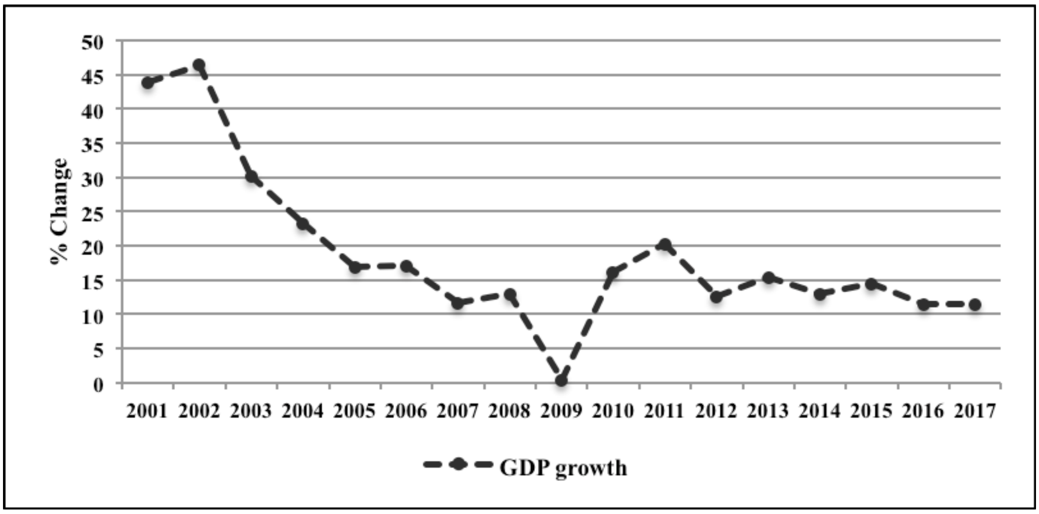
2.1. The Study Area

Turkey is a large country, having a total surface area of 783,356 square kilometers (302,455 sq. mi., the 36th largest in the world). 44% of the Country is covered by agricultural areas whereas forests, mainly covering the coastal and mountainous areas, dominate 15% of the total land area [51]. Total developed land accounts for 1.8% of the total land area of the Country [51]. Around two-thirds of the population lives in the three largest cities and other large and medium-size cities, including Bursa, Adana, Trabzon, Malatya, Gaziantep, Erzurum, Kayseri, Kocaeli, Konya, Mersin, Eskisehir, Diyarbakir, Antalya and Samsun [52]. This is significant in terms of economy, services, infrastructure provision and social welfare, not only of their own residents, but also of the rural residents surrounding these medium-size cities. Over 80% of economic output is produced in these cities, where the north-western region has a share of around 30% of the overall output [52,53]. Contrary to European counterparts, a higher population share (more than 30% of population) lives in rural areas in Turkey. Rising rental price of land and costs of production in the leading cities forced firms to relocate into lower cost alternatives. In addition, connections to external markets contributed to the development of secondary cities, the so-called 'Anatolian Tigers' in Turkey, such as Bursa, Gaziantep, Kocaeli, Samsun, Kayseri and other [54]. These cities became industrial agglomerations during the 1990s, and recorded high rates of economic growth during the period 2004–2011. Medium-sized enterprises of less than 250 employees have pioneered this development. The development of secondary cities also benefited from the growth of construction companies providing construction services abroad.

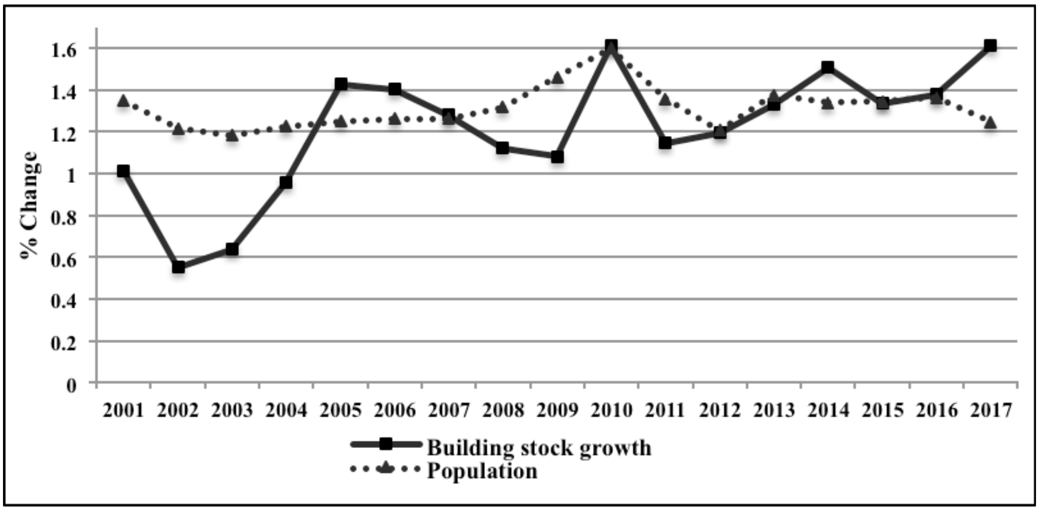
During the period 1990–2012, the population of Turkey increased from 56.4 to 75.6 million, indicating 34% increase [55]. Its urban land cover increased from 855,000 to around 1,130,000 ha (ca. 4,363 sq. mi.), a 32% increase [50]. This implies that urban land cover in Turkey grew as fast as its population during the study period. At these growth rates, the population and urban land cover will more than double in 55 years. In addition to an increasing population and urbanization rate, increased levels of income, growing financial opportunities, changes in accessibility and community structures, have resulted in increasing demand for high quality housing and infrastructure, as well as increasing demand for renewal of urban fabric through transformations of land-uses, densities and the quality of urban functions [56]. Some high quality housing developments have taken place in the periphery of the metropolitan areas, mainly in the form of low-density, automobile-oriented, sprawled developments [57]. The Report published by World Bank [58] demonstrated that the growth rate of metropolitan population in 2011 residing more than 20 km away from the urban centers, is larger than the population observed in the early 2000s. Future expectations regarding increase in land value have induced demand for new developments and increased the development right permissions leading to sprawl-like growth. This has resulted in unsustainable urban development leading to 'low quality of life, high disaster risks, deterioration of unique identities of cities and inadequacies in transport, infrastructure and public spaces' [56].

2.2. Real Property Development Trends

Residential and commercial stock in Turkey has increased considerably between 1990 and 2000, indicating almost 50% and 70% change, respectively [55,59]. In the post-2000 period, the average annual growth rate is about 1.2% for both residential and commercial developments, and the growth rate declined to a minimum of 0.6% in the first three years following the 2001 economic decline [55,59]. Figure 2 compares Gross Domestic Product (GDP) growth with the growth of population and the overall building stock. It is clear that the national real property market moves in line with the economy: Following the recovery period of the 2001 financial crises, building stock increases during periods of economic growth, whereas the opposite occurs during recessions. Real property development is to a certain degree related to the growth of population; however they exhibit diverse trends during the second half of the 2000s that covers the period of the global economic crises of 2007–2008. From 2013 onwards, the growth of building stock is higher than the growth of population. This may have two implications: First, there are low density sprawled patterns of development in the outskirts of cities and metropolitan regions. This trend towards reduced population densities, mainly observed in the last decades, is characteristic for metropolitan regions, as well as some small and medium-sized urban areas. Second, the building stock supply exceeds the demand, considering that the population growth rate declined significantly starting from 2010, and the building stock growth rate exceeds the rate of population growth from 2013 onwards, resulting in oversupply and underuse of urban land.



(**a**)



(**b**)

Figure 2. Comparison of GDP (**a**), building (residential, commercial) stock, and population growth rate in Turkey (**b**), 2001–2017. Source: Turkstat [55,59] Statistical indicators.

2.3. The Land-Use Planning System in Turkey

Within the framework of the adaptation process with the EU's regional policy, the 2000s is a period of transformation of urban management and planning practice in Turkey. Accordingly, new legislative and institutional arrangements have been introduced to comply with EU regional policies. The NUTS classification was introduced in Turkey in 2002, which is followed by the establishment of development agencies aiming at 'promoting regional development, ensuring sustainability, and reducing regional development disparities' [49]. Following these new arrangements, Turkey's land-use planning system is said to be based on four levels consisting of the country, 26 (NUTS2) regions, 81 (NUTS3) provinces, and 1,397 municipalities [49,51]. The central government is responsible for the legislation framework, which defines spatial planning systems at the national level, and the government is also responsible for providing financial sources for major infrastructure investments. The central and local institutional structure and the planning system are summarized in Figure 3. For a full review of the planning and administrative system in Turkey, we refer to Marcou [60]; Ersoy [61]; Orhan [62]; Gürsoy and Edelman [48]; and Turan and Ersoy [49].

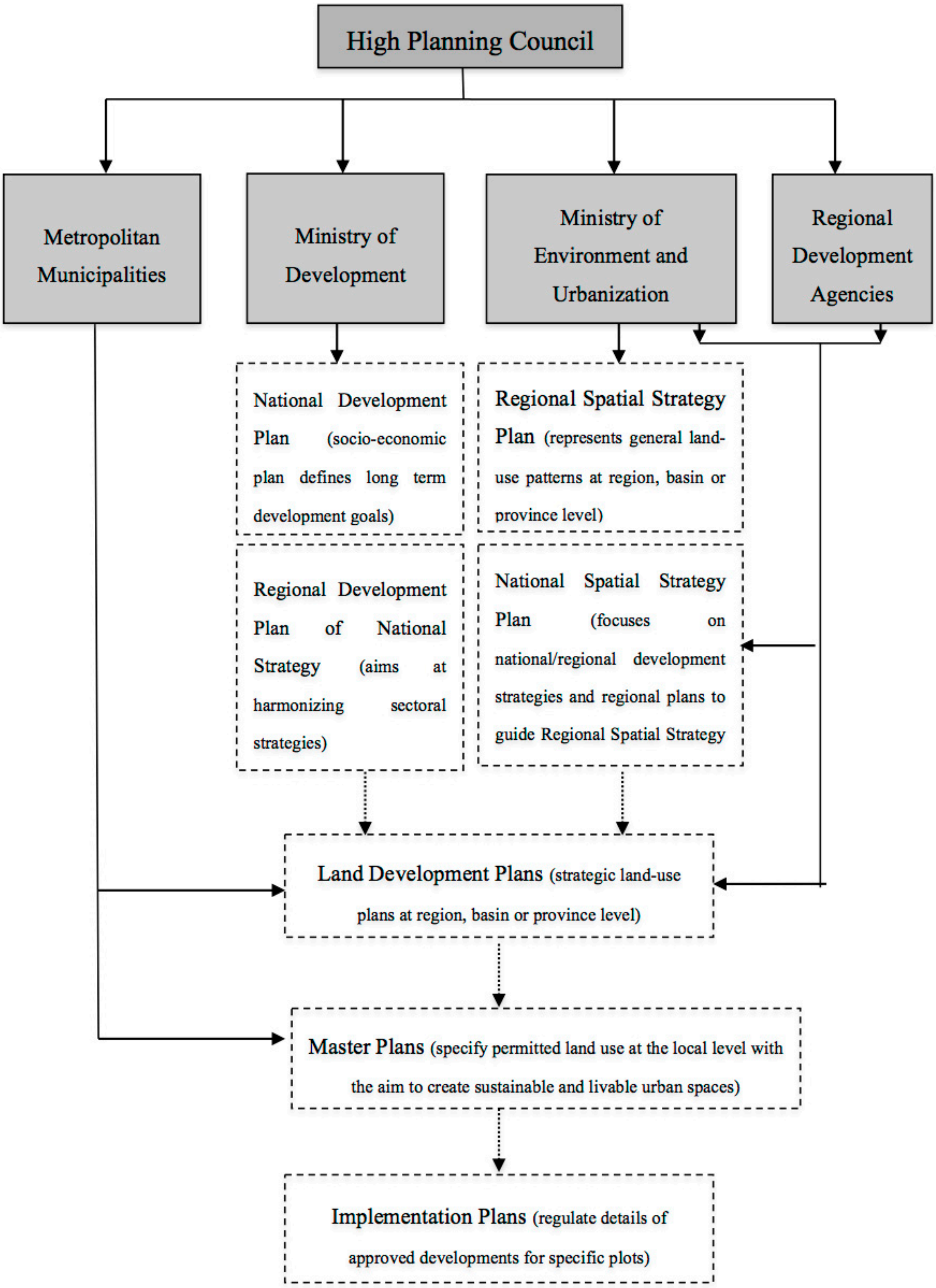


Figure 3. The planning and institutional system of Turkey. Source: Adopted from OECD [51].

Although new institutional and planning structures were introduced to tackle with rapid urban growth and associated urban problems, the literature suggests that the newly introduced plans and planning authorities are not effective, and these have complicated the existing planning system [48,49].

In Gürsoy and Edelman's [48] explanation, the differences and interactions between newly introduced plans are not fully defined, and there is a lack of co-ordination between different planning institutions that do not correspond to the regional/local needs and challenges [49]. Ersoy [61] stated that there are currently almost 20 different public institutions that are authorized to prepare a plan for their corresponding areas, and this results in chaotic and unregulated situations. Further to this, the planning process does not comply with the rules set by the planning legislation, which requires any preparation of plans according to 'scientific data, specifying a program, prioritization of infrastructure needs and involvement of different stakeholders in the planning process' [63]. According to Gürsoy and Edelman [48], a further shortcoming is the lack of any implementation of spatial and economic planning in the regional/local planning context. The monetary sources to finance regional and environmental plans were not defined, and further, there is an insufficient monitoring and evaluation system to control whether the principles and strategies of such plans are implemented or not, after the plan is put into force [48,64,65]. This has increased the vulnerability of the cities and regions to earthquakes and natural disasters, due to malpractices applied in regional and urban policy, land-use and density restrictions, and construction and design processes [62].

3. Data and Methodology

3.1. Data

The data acquisition and examination of the spatial data is significant for the urban spatial analysis explaining the change of land-use and pattern. The existing studies researching the regional development issues in Turkey are mainly based on statistical data sources [66–69]. The use of statistical data is advantageous, reflecting the time continuity during the study period, but such data has the drawback of lacking a spatial component. High-resolution remote sensing data, on the other hand, represent the spatial information for different land uses; and therefore can be effectively used for the analysis of land-use change and examination of the spatial pattern [29]. In this context, to study regional land-use dynamics in Turkey, we used spatially explicit data of land-use/cover change for the period between 1990 and 2012. The Corine land-use/cover (CLC) data with a resolution of 100 m is provided by the European Environment Agency [50]. The CLC data was chosen for this study, considering that Corine is the most recent data source, providing detailed land-use data comprising the whole country for the post-1990 period. Nevertheless, the CLC data has been widely used in the literature in analyzing land-use changes [70,71]; climate and ecology [72,73]; agricultural yield monitoring and forecasting [74]; and the assessment of carbon storage and air pollution [75,76].

In addition to CLC data, population and economic indicators from the Turkish Statistical Institute [55] is used for the same period. The CLC data has an inventory of 44 land cover classes. Overall, we specified seven land-use/cover classes to assess land-use changes in the 1990–2012 period (see Table A1 in the Appendix A). Four classes refer to settlement and urban infrastructure (continuous urban fabric, discontinuous urban fabric, industrial/commercial uses, recreation uses), four sub-classes explain agricultural land (arable land, permanent crops, pastures, heterogeneous agricultural areas), and two classes represent forest and semi-natural vegetation (Figure 4). To map past land-use changes, the official CLC datasets of 1990, 2000, 2006 and 2012 were utilized by using an additional dataset of CLC change between 1990–2000, 2000–2006 and 2006–2012 [50].

The NUTS3 level data that corresponds to the province level in Turkey is used in the analysis, and socio-economic data (e.g., population, economic indicators) were also collected at this level. Following Eurostat's [77] classification, urban-rural typologies are linked to the different urban-hierarchical levels specified in this study. Urban/peri-urban/rural categorization was built on the dataset of Eurostat [77], on urban-rural typologies, including 'predominantly urban', 'intermediate' and 'predominantly rural' classifications for each NUTS3 in Turkey (see Eurostat Urban-Rural Typology [77]).

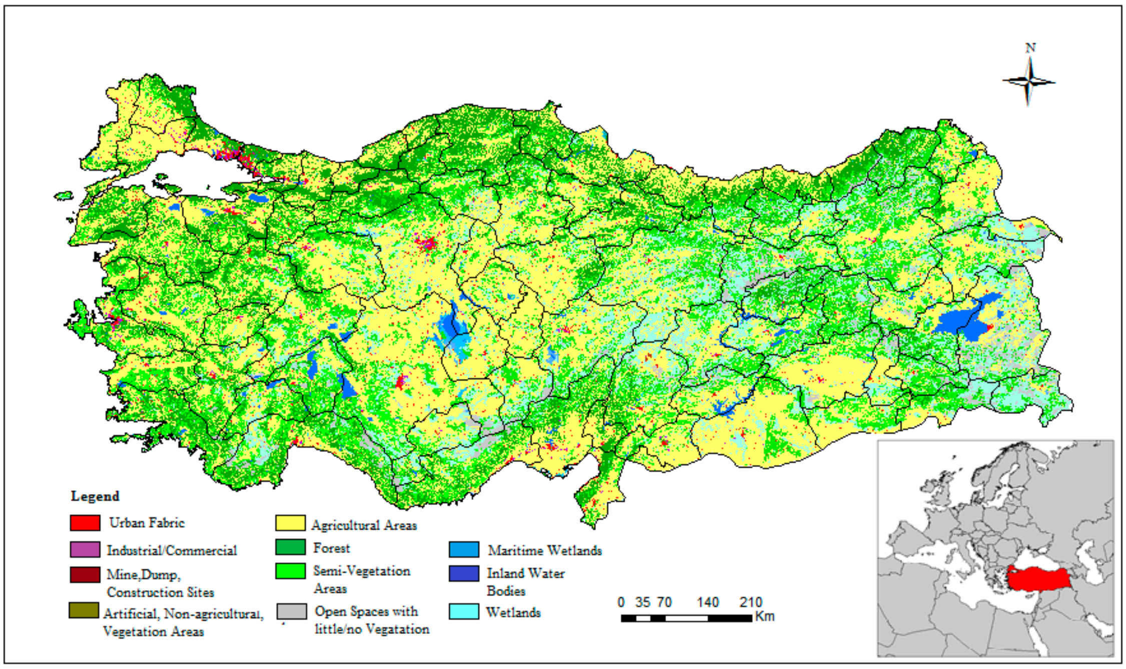


Figure 4. The study area of Turkey. Land use/cover classes visualized with 100 m resolution.

3.2. Methodology

3.2.1. Land Use Dynamics Model

To specify the quantity of land-use change over the study time period, the land-use dynamics model can be formulated as [5]:

$$\Delta L_l = \frac{L_{lt_2} - L_{lt_1}}{L_{lt_1}} \times 100 \quad (1)$$

where ΔL_l is the variation of a land-use type l over the time period $t_2 - t_1$; L_{t_1} and L_{t_2} represent the area of the land-use type l at time t_1 and t_2, respectively.

3.2.2. The Analysis of Regional Dynamics

The methodology developed by Broitman and Koomen [17] was adopted in the current study in order to examine the land-use dynamics at the regional level. In this respect, urban hierarchical systems (e.g., urban/peri-urban/rural) were specified and were also grouped by geographical proximity (Figure 5). The development of urban hierarchical systems is based on Eurostat's [77] classification of urban-rural typologies. According to the definition, predominantly urban regions have less than 20% rural population, intermediate (peri-urban) regions between 20% and 50%, and predominantly rural regions more than 50% [77]. Using this classification, 5 cities were categorized as urban regions (Figure 5). The 27 cities were categorized as peri-urban areas where these areas correspond to secondary cities defined as non-capital, medium size cities that are economically, culturally and demographically significant [58]. Other cities having more than 50% rural population are referred to as rural areas.

In our analysis, grouping (Figure 5) is based on the locational distribution of a regional development disparity index developed by the Turkish Ministry of Development [78]. In fact, the Country has been officially divided into seven geographical regions designated according to topographical conditions and climatic factors. In this study, we adopted the concept of homogeneous regions [49], which is based on groups of provinces that have similar levels of socio-economic development as defined by the Turkish Ministry of Development [78]. Regions defined with this approach can be used to identify 'priority regions for development', 'incentive regions' and 'regions designated for public sector employment' [78]. The regional development index compiles 61 variables from different socio-economic indicators, including demography, employment, education, health, economic competitiveness and innovation capacity, financial indicators, accessibility indicators and quality of life indicators. The methods used for the computation of the regional development disparity index are out of the scope of this paper. The details on the indicators and development of the indices can be seen in Kalkınma Bakanlığı [78]. Based on the regional development index values and geographical proximity of the regions (NUTS 3 level), Turkey was grouped into 5 main regions comprising its north-west, west, south, north and east regions (Figure 5).

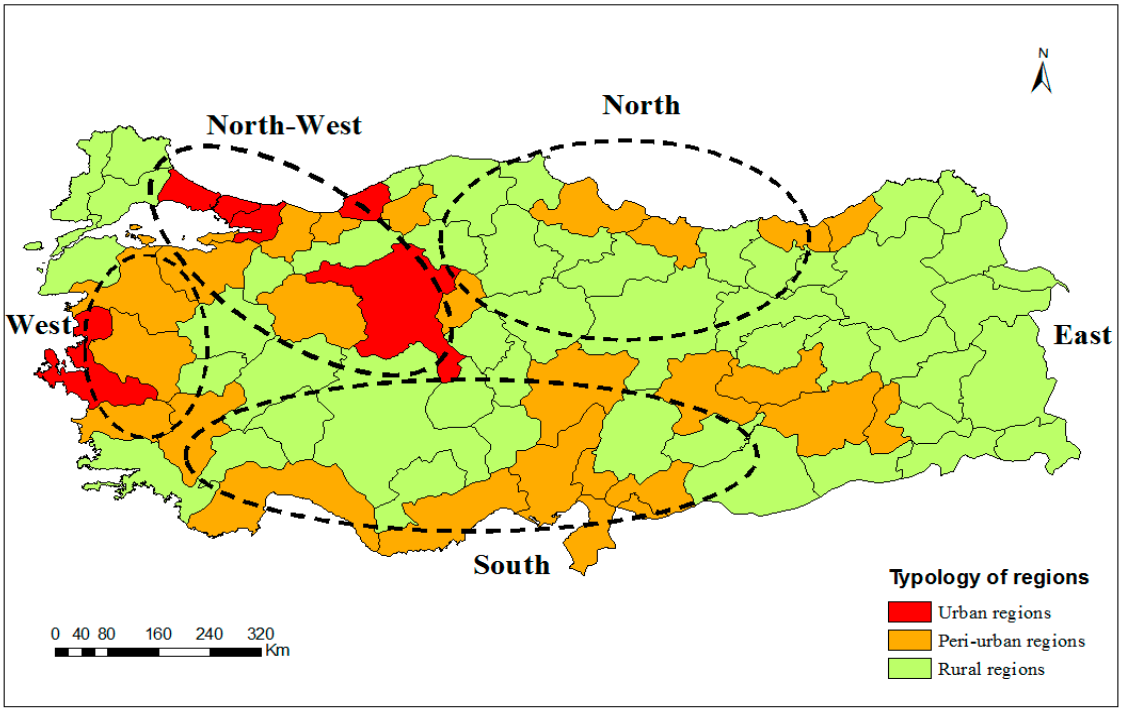


Figure 5. Typology of regions composed of urban, peri-urban and rural areas grouped by geographical zones in Turkey. Source: Figure adopted from Broitman and Koomen [17].

3.2.3. The Analysis on Driving Forces of Land Use Change

The differences in urban development amongst different regions can be explained by three key factors: Urban population, economic income/output and the availability of land for urban expansion. Therefore, urban development is expected to be related, not only to the socio-economic growth performance of the regions, but also to supply restrictions. This is apparent from the empirical literature demonstrating that real estate stock, population and employment are strongly correlated over cities and regions [79–81]. In general, regions with more population living in cities can be expected to have more urban land cover; regions with more economic income can be expected to have more land cover; and the regions with an abundance of arable land can be expected to have more urban land cover [82]. In the first case, the more populated cities require more space to house their urban activities [83]. In the second case, the regions with more per capita income have extensive resources to construct more urban facilities and infrastructure, compared to regions with lower income levels [84,85]. And the more arable land in a region, the cheaper it will be to convert land to urban uses, and much less public and private restrictions are likely to appear in case of converting rural land to urban use [82].

According to the European Environmental Agency's [86] definition, the driving forces of landscape change include: 'social, demographic and economic developments in societies and the corresponding changes in life styles, overall levels of consumption and production patterns'. This definition, however, does not cover biophysical or natural factors. In fact, there is growing body of literature that included these factors implicitly [28,87] (see Figure 1).

To research the impact of socio-economic characteristics on regional land use development, the current research utilizes cross-section data of 2012 comprising population, population density, average household size, GDP, employment (in agriculture, industry and services sectors), and the regional development index, showing the socio-economic development levels of the regions at the NUTS3 level (Figure A1). The cross-section data of 2012 was selected in the analysis, considering that both socio-economic and spatial data at the regional level were readily available for the subject year. Related to economic income and employment, agricultural shares of economic activities are captured by using a percentage share of agricultural employment in total employment, and a percentage share of agricultural GDP in total GDP. It is assumed that the higher the share of agricultural employment and agricultural GDP in total, the less likely is the agricultural land to be converted to urban uses. This implies that agricultural land rent is high enough to sustain agricultural production, and that it is costly to convert agricultural land to urban uses [88]. Total areas of ports and airports are used as proxies to indicate whether or not the regions are well-served by the required infrastructure. Existence of an airport or port in a region, which is linked with surface transport infrastructure, is represented by two different variables indicating the total areas of ports and airports in a region.

Regional area characteristics that are of significance for urban development are geographical location of the NUTS3 regions and the regions either being classified as urban, peri-urban or rural regions. The location and area characteristics are represented by six dummy variables i.e., two dummy variables, each pointing to either peri-urban or rural regions, urban regions being the base category; and four dummy variables for regions located in the north-west, south, west or north of Turkey (Figure 5)—the east of Turkey being the base category. The supply of land in a region depends on factors that may influence an availability of land for urban development [84]. These are natural restrictions, such as water bodies, mountains, and wetlands. The existence of natural protection sites is considered as a development constraint, since urban development is strictly restricted in these areas. Agriculture, natural vegetation and forest land on flat slopes are considered as available land for urban development. Therefore, total areas of natural protection sites and available land in a region were included in the analysis as supply constraints for urban growth. Areas of natural protection sites were obtained from the Ministry of Environment and Urbanization (https://www.says.gov.tr/istatistik), whereas available land in a region was computed using the Corine Land Cover (CLC) data [50]. Besides urban development, our analysis further considers socio-economic and regional factors explaining the growth of agricultural and forest land. In this respect, natural protection sites and urban land uses (residential, industrial and recreation uses) were considered as constraints for agricultural and forest land expansions.

To specify and quantify the key drivers of regional Land use/land cover (LULC) change in Turkey, we apply a regression analysis approach by utilizing socio-economic and location based indicators and development restrictions as key drivers of land use demand and supply. The probability of LULC changes regarding the urban land uses are correlated with the probability of changes of the non-urban land uses. For instance, the increasing rise of services and industrial-based sectors has led to conversion of agricultural land uses to industrial/commercial uses, along with the residential developments. Therefore, change of urban and non-urban land uses can be represented through a set of equations where their disturbances are correlated. Following Zellner [89], a seemingly unrelated regression (SUR) system is provided as:

$$\begin{array}{c} y_{1t} = \beta_1' x_{1t} + \varepsilon_{1t} \\ y_{2t} = \beta_2' x_{2t} + \varepsilon_{2t} \\ \vdots \\ y_{it} = \beta_i' x_{it} + \varepsilon_{it} \end{array} \quad i = 1, \ldots, N;\ t = 1, \ldots, T \tag{2}$$

where y_{it} is a dependent variable, $x_{it} = \left(1, x_{i,t1}, x_{i,t2}, \ldots, x_{i,tk-1}\right)$ is a K_i vector of explanatory variables for unit i, ε_{it} is an unobservable error term where it represents the t^{th} observation of the i^{th} equation in the system.

In the empirical model, there are five different land uses to be considered in the analysis: (a) Residential land, (b) industrial/commercial land, (c) recreational land, (d) agricultural land, (e) forest land. Therefore, the system of Equations in (2) becomes:

$$\begin{aligned}
\log\left(res_land\right)_{i1} &= \alpha_1 + \beta_1 \log(e_{i1}) + \gamma_1 \log(i_{i1}) + \mu_1 r_{i1} + \delta_1 \log(s_{i1}) + \varepsilon_{i1} \\
\log\left(ind_land\right)_{i2} &= \alpha_2 + \beta_2 \log(e_{i2}) + \gamma_2 \log(i_{i2}) + \mu_2 r_{i2} + \delta_2 \log(s_{i2}) + \varepsilon_{i2} \\
\log\left(rec_land\right)_{i3} &= \alpha_3 + \beta_3 \log(e_{i3}) + \gamma_3 \log(i_{i3}) + \mu_3 r_{i3} + \delta_3 \log(s_{i3}) + \varepsilon_{i3} \\
\log\left(agri_land\right)_{i4} &= \alpha_4 + \beta_4 \log(e_{i4}) + \gamma_4 \log(i_{i4}) + \mu_4 r_{i4} + \varphi_4 \log(l_{i4}) + \delta_4 \log(s_{i4}) + \varepsilon_{i4} \\
\log\left(forest_land\right)_{i5} &= \alpha_5 + \beta_5 \log(e_{i5}) + \gamma_5 \log(i_{i5}) + \mu_5 r_{i5} + \varphi_5 \log(l_{i5}) + \delta_5 \log(s_{i5}) + \varepsilon_{i5}
\end{aligned} \tag{3}$$

In Equation (3), we use the following notation: $j = 1, \ldots, 5$ indexes five different land uses e.g., residential, industrial/commercial, recreation, agricultural and forest; i indexes the NUTS3 regions; e is the socio-economic factors; i is the infrastructure; r is the regional characteristics expressed as dummy variables; s is the supply constraint; l is the areas of industrial and residential land uses (only used as explanatory variables in equations of agricultural and forest land) representing the supply constraints for the agricultural and forest land expansions; $\beta, \gamma, \mu, \delta$ are the regression coefficients; α is the constant and ε is the error term.

The dependent variable in the models is the logarithmic value of the total amount of change of the related land use (in hectares) during the 1990–2012 period. These models are expected to explain variations in urban and non-urban land use/cover among different regions, through incorporating a set of relevant factors, and determining the effect of each factor on the corresponding land use/cover change during the study period.

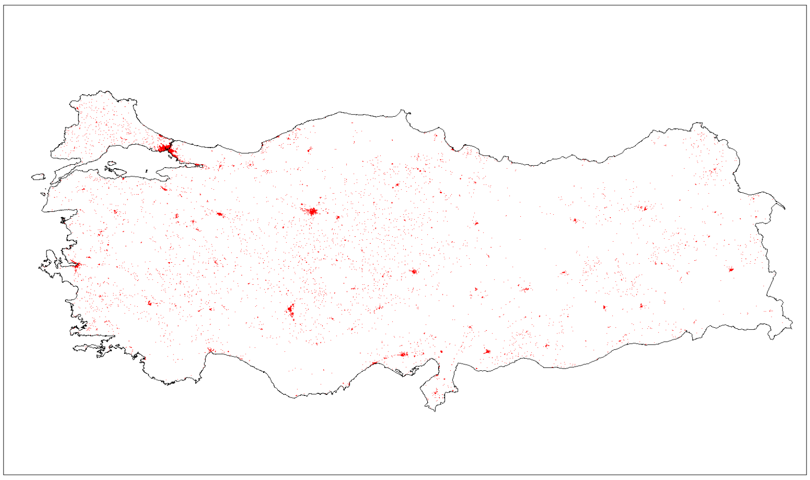
4. Results

4.1. Quantitative and Structural Changes

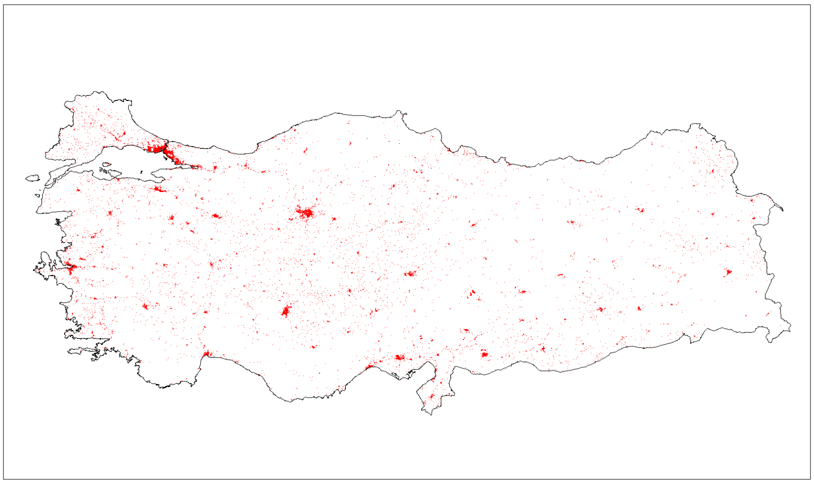
The land-use changes during the study period are presented in Figure 6, and the statistics are summarized in Table 1.

From Table 1, the largest changes are associated with the industrial/commercial land that is followed by recreation and discontinuous urban fabric. The most prominent land use changes are observed for the 1990–2000 period regarding all specified land use classes. During this period, Turkey had experienced a major economic crisis in 1994, and has had to cope with socio-economic and physical influences caused by the devastative Marmara Earthquake in 1999. It is evident from Table 1 that the economic crisis and the earthquake have had minor impacts on the urban land markets, given the high growth rates of urban land use, particularly observed for industrial and commercial developments. By contrast, the 2001 economic crisis had more sound impacts on the land markets, given the lower rates of growth of both residential and industrial/commercial land uses. Following the 2001 economic decline, the annual growth rate reduced from 5.5% in 2002–2007 to 1.9% in the post-2007 period [68].

Table 2 presents general trends for land use, population, employment and Gross Domestic Product (GDP) distribution according to different hierarchical levels in the study period. During the 1990–2012 period, Turkey's population grew by 33.8%, while urban fabric increased by 18.3%. In the same period, population growth rates are higher than the urban fabric growth concerning both urban and peri-urban areas, whereas the urban fabric growth rate is higher than that of population regarding the rural areas. This points to densification of residential land in the former case, and expansion and low-density development in the latter. Increasing densities encourage savings in public service provision costs, such as electricity distribution, school transportation and water/waste water utilities [16,90]. Decreasing densities, on the other hand, result in higher public service provision costs, longer commuting distances, increase in private vehicle use, less access to public transportation, increasing air/water pollution, traffic accidents and overexploitation of natural resources [16,91].



(**a**) Urban land uses, 1990



(**b**) Urban land uses, 2012

Figure 6. Spatial distribution of urban land uses in Turkey (1990; 2012).

Table 1. Land-use changes during the study period.

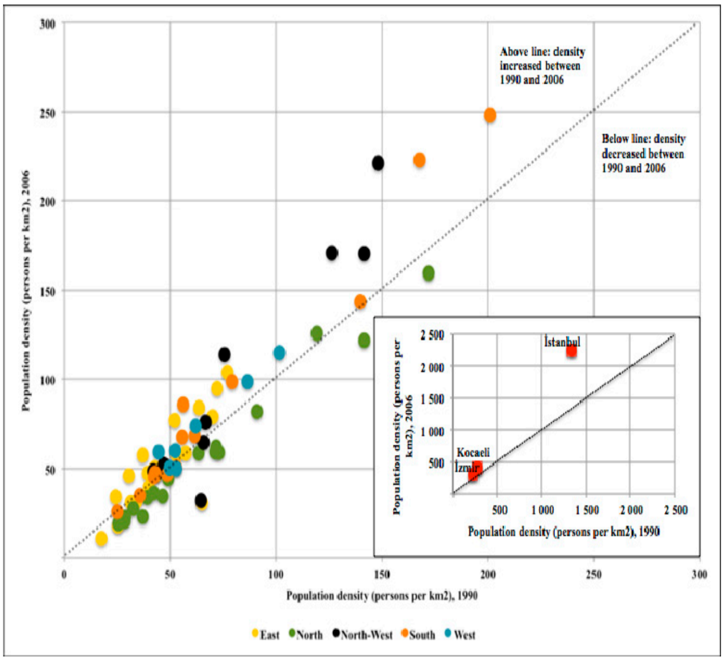
	1990–2000		**2000–2006**		**2006–2012**	
	Change (Ha)	**% Change**	**Change (Ha)**	**% Change**	**Change (Ha)**	**% Change**
Continuous urban fabric	11,530	19.23	98	0.13	4050	3.30
Discontinuous urban fabric	111,443	15.80	10,286	1.25	25,385	3.38
Industrial/commercial land	57,842	98.10	11,703	9.94	24,952	15.19
Recreation	12,578	40.72	2160	4.68	3182	7.07
Agriculture	−251,523	−0.75	−15,749	−0.05	−73,800	−0.28
Forest	219,889	1.88	−45,961	−0.38	−51,106	−0.27
Natural vegetation	−301,795	−1.69	24,024	0.14	9705	0.06

Table 2. Statistics on land-use and socio-economic data in Turkey.

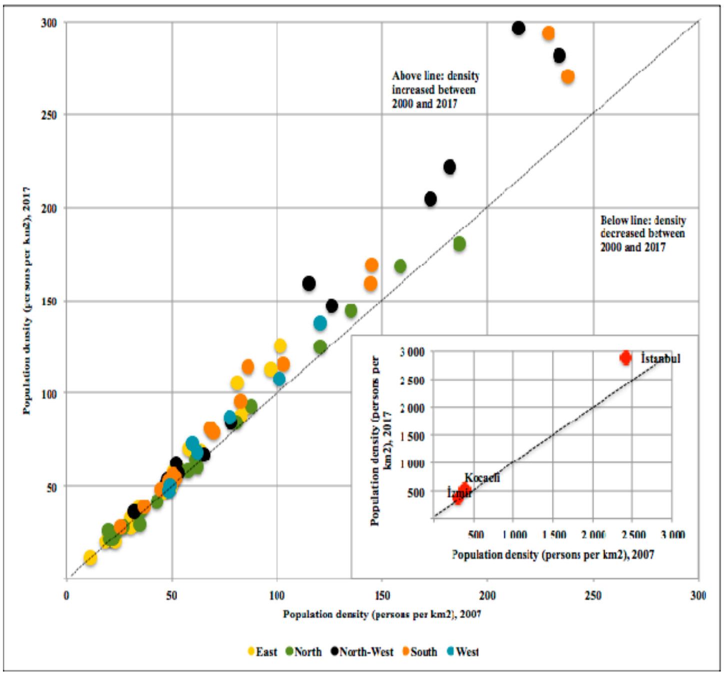
	Urban Areas	Peri-urban Areas	Rural Areas	Total (Country)
Urban fabric [a] (Ha) in 2012	179,117	296,624	429,452	905,193
Industrial/Commercial land [a] (Ha) in 2012	60,870	65,651	60,433	186,954
Recreation uses [a] (Ha) in 2012	13,275	21,090	13,518	47,883
Agricultural land [a] (Ha) in 2012	2,389,865	10,824,310	20,691,279	33,905,454
Forest land [a] (Ha) in 2012	873,040	4,477,990	6,239,125	11,590,155
Natural vegetation [a] (Ha) in 2012	932,487	5,050,186	11,567,087	17,549,760
Share of urban fabric in total (%) in 2012	19.79	32.77	47.44	100.00
Share of industry/commerce in total (%) in 2012	32.56	35.12	32.33	100.00
Share of recreation in total (%) in 2012	27.72	44.04	28.23	100.00
Share of agricultural land in total (%) in 2012	7.05	31.92	61.03	100.00
Share of forest in total (%) in 2012	7.53	38.64	53.83	100.00
Share of natural vegetation in total (%) in 2012	5.31	28.78	65.91	100.00
Urban fabric growth between 1990–2012 (%)	36.29	24.19	47.44	18.30
Industry/commerce growth between 1990–2012 (%)	230.67	265.72	167.37	217.08
Recreation uses growth between 1990–2012 (%)	11.21	59.89	134.52	55.01
Area of ports [a] (Ha) in 2012	1533.1	910.6	461.8	2905.5
Area of airports [a] (Ha) in 2012	5974	12,908.9	10,553	29,435.9
Regional Development Index (average)	2.25	0.25	−0.37	0.00001
Average population density (population/km^2), 2012	834.57	137.99	50.83	105.00
Average household size [b], 2012	3.4	3.8	4.1	3.97
Population [b] in 2012	25,066,959	27,504,602	23,055,823	75,627,384
Population share in 2012 (%)	33.15	36.37	30.49	100
Population growth between 1990–2012 (%)	70.51	31.24	10.63	33.86
GDP [b] (TL) in 2012	639,668,360	439,222,933	490,780,822	1,569,672,115
GDP share in 2012 (%)	40.75	27.98	31.27	100
GDP growth between 2000–2012 (%)	171.00	172.45	173.00	172.03
GDP in agriculture [b] (TL), 2012	9,528,937	52,800,000	59,400,000	122,000,000
GDP in industry and services sectors [b] (TL), 2012	772,000,000	413,000,000	263,000,000	1,450,000,000
Employment in agriculture [b], 2012	342,000	2,645,000	2,807,000	5,794,000
Employment in industry and services sectors [b], 2012	7,845,000	6,084,000	4,599,000	18,500,000

Note: [a] Source: Corine Land Cover (CLC) data obtained from the European Environment Agency (EEA) [50]; [b] Source: Turkstat [55].

Following Angel et al. [82], a picture of density changes for different regions in Turkey to do with the two periods i.e., 1990–2006 and 2007–2017, is provided in Figure 7. Using Angel et al.'s [82] approach, we plot the population density of built-up areas for one period against the density in another period. Figure 7 displays the changes of population densities, where on the diagonal line the density in two periods is equal. From Figure 7a, there are declining densities in the northern, north-western and eastern regions between 1990 and 2006, as urban land area expands faster than the population growth. In the 2007–2017 period, this trend is reversed, as population growth leads to concentration and densification in almost all regions (Figure 7b). In both periods, the highest densities are observed in southern and north-western regions, where Istanbul, Kocaeli and Izmir are the first ranking three cities accounting for the highest densities in the Country. Analysis of land use/cover data shows that the built-up area increased in the period between 1990 and 2012 by 63.6% and 65.8%, pointing to Istanbul and Izmir, respectively. During this period of urban growth, planning and decision making authorities had to cope with physical and social infrastructure problems and also had to deal with the issue of illegal and irregular development, that is a significant problem for both of the cities. Other problems may include price increases for housing, rising infrastructure costs, pollution, environmental degradation and related health problems.



(a)



(b)

Figure 7. Average population density for each NUTS3 region in Turkey (**a**) 1990–2006, (**b**) 2007–2017. **Note:** The small figures on the right lower corner represent development of population densities in the three highest density ranked cities i.e., Istanbul, Kocaeli and Izmir. Source: Data obtained from Turkstat [55], figure adopted from Angel et al. [82].

An in-depth analysis of the economic output for the year 2012 indicates that the highest regional GDP, population (density), industrial employment and the share of industrial employment in total employment, is observed in the north-west region, followed by the south and west regions, both with a GDP of around one forth, and an industrial employment of one third, of the north-west region, followed by the north and finally the east region, with the lowest values (see Table S1). A reverse trend is observed regarding the share of agricultural GDP in total. These findings are in line with the literature pointing to significant differences in terms of socio-economic development levels particularly between eastern and western regions in Turkey [66,67,92]. It is asserted in the literature that the less-developed eastern region is mostly specialized in agricultural production, while west and north-western regions are based on industrial production and services supply [93]. The southern and western regions mostly benefit from service-based tourism activities, as well as other activities in services and finance sectors [68]. In Turkey, 80 percent of high-tech firms are being concentrated in metropolitan regions, in major cities, and additionally in a few important centers, and manufacturing is concentrated mainly in the three largest cities, particularly in Istanbul, which accounts for 40% of total employment [93]. High-tech firms prefer locating in large metropolitan regions in the north-west and west regions where there is an existing concentration of industrial activities. The spatial distribution of industrial activities has enhanced development disparities in the east-west direction. Recent literature on the spatial distribution of manufacturing industries showed that there is persisting spatial heterogeneity in the distribution of industrial enterprises, leaving east regions well behind their western counterparts in the last decades [68,69,94].

4.2. Regional Differences in Urban, Peri-Urban and Rural Ddevelopment

The regional analysis of the land use changes in the 1990–2012 period shows differences among regions and different urban hierarchical levels (see Figure A2). Tables 3–5 show population and land use dynamics across five regions covering the specified seven land use/cover classes. The largest increase in population is observed in the north-west region during the study period. The northern region is the only area that lost population in the 1990–2000 and 2006–2012 periods. During these periods, there is an increase in discontinuous urban fabric, though at moderate levels, most probably pointing to development of low-density sprawl-like settlements under conditions of shrinkage in the northern region. The growth of discontinuous urban fabric ranges between 7.26% and 26.9% in the 1990–2000 period, the north-western region indicating the highest percentage change, while the northern region showed the lowest percentage change (see Figure A3 in Appendix A). In the post-2000 period, a similar trend is observed across all regions. Regarding industrial/commercial land development, the north-west region accounts for the largest increases in the 1990–2000 period. Other regions show much lower rates of industrial/commercial development, in decreasing order the west, south, east and north (Figure A3).

Table 3. Regional dynamics for land-use and population between 1990 and 2000.

	Population		Continuous Urban Fabric		Discontinuous Urban Fabric		Industrial/Commercial		Recreation		Agriculture		Forest		Natural Vegetation	
	Absolute Change (Ha)	Percentage Change (%)	Absolute Change (Ha)	Percentage Change (%)	Absolute Change (Ha)	Percentage Change (%)	Absolute Change (Ha)	Percentage Change (%)	Absolute Change (Ha)	Percentage Change (%)	Absolute Change (Ha)	Percentage Change (%)	Absolute Change (Ha)	Percentage Change (%)	Absolute Change (Ha)	Percentage Change (%)
East	1,048,000	11.19	201	7.16	10,335	8.38	4436	63.83	388	15.80	−52,251	−0.66	15,861	1.63	−32,046	−0.53
North	−1,132,732	−11.56	0	0.00	8945	7.26	3252	54.37	269	18.76	−24,271	−0.35	55,893	1.41	−60,414	−1.74
North-west	5,707,548	32.23	10,037	24.05	44,598	26.90	26,016	109.39	2778	19.51	−85,924	−1.40	131,088	4.49	−161,604	−7.38
South	1,531,775	12.76	273	4.44	29,465	16.36	14,841	98.51	4911	67.24	−55,745	−0.64	5057	0.25	−18,169	−0.48
West	1,101,880	14.51	1019	12.88	18,100	16.04	9297	129.43	4232	77.57	−33,332	−0.88	11,990	0.66	−29,562	−1.28

Table 4. Regional dynamics for land-use and population between 2000 and 2006.

	Population		Continuous Urban Fabric		Discontinuous Urban Fabric		Industrial/Commercial		Recreation		Agriculture		Forest		Natural Vegetation	
	Absolute Change (Ha)	Percentage Change (%)	Absolute Change (Ha)	Percentage Change (%)	Absolute Change (Ha)	Percentage Change (%)	Absolute Change (Ha)	Percentage Change (%)	Absolute Change (Ha)	Percentage Change (%)	Absolute Change (Ha)	Percentage Change (%)	Absolute Change (Ha)	Percentage Change (%)	Absolute Change (Ha)	Percentage Change (%)
East	661883	6.36	0	0.00	707	0.52	995	10.01	55	1.58	1064	0.01	−2	0.00	−2968	−0.05
North	11,473	0.13	0	0.00	536	0.40	758	7.91	44	2.75	−1103	−0.02	−4604	−0.11	2263	0.07
North-west	2,633,629	11.25	69	0.13	5265	2.50	3909	7.70	527	2.92	−11,753	−0.20	4695	0.15	−8269	−0.41
South	1,178,013	8.71	20	0.29	3363	1.58	3625	11.97	1126	8.77	−1739	−0.02	−21,844	−1.11	12255	0.32
West	515,464	5.93	9	0.09	415	0.32	2416	14.14	408	3.99	−2218	−0.06	−24,206	−1.30	20743	0.92

Table 5. Regional dynamics for land-use and population between 2006 and 2012.

	Population		Continuous Urban Fabric		Discontinuous Urban Fabric		Industrial/Commercial		Recreation		Agriculture		Forest		Natural Vegetation	
	Absolute Change (Ha)	Percentage Change (%)	Absolute Change (Ha)	Percentage Change (%)	Absolute Change (Ha)	Percentage Change (%)	Absolute Change (Ha)	Percentage Change (%)	Absolute Change (Ha)	Percentage Change (%)	Absolute Change (Ha)	Percentage Change (%)	Absolute Change (Ha)	Percentage Change (%)	Absolute change (Ha)	Percentage Change (%)
East	866,314	7.82	160	1.66	4828	3.81	2479	15.38	156	9.71	−14,818	−0.23	929	0.03	−4020	−0.07
North	−3787	−0.04	369	4.56	1132	1.05	1950	16.07	3	0.17	−13,271	−0.25	642	0.01	−6653	−0.19
North-west	3,074,982	11.80	2324	3.86	10,445	5.34	10,774	15.29	387	2.22	−22,584	−0.44	9117	0.23	−21,234	−1.03
South	1,392,970	9.47	1194	4.96	6863	3.31	5515	14.35	1259	10.25	−16,068	−0.23	−33,811	−0.92	17,063	0.42
West	566,937	6.15	3	0.01	2117	1.88	4234	15.59	1377	11.51	−7059	−0.24	−27,983	−1.01	24,549	1.02

In the post-2006 period, there are similar changes of industrial/commercial development across all regions. There is loss in agricultural land that is common to all regions, the north-western region indicating the highest percentage of loss that is followed by the west, south and north regions. Conversely, forestland is increasing in the 1990–2000 period, while it is decreasing in south, west and north regions in the post-2000s. Natural vegetation is generally decreasing with the highest percentage change observed in the north-west, while the smallest changes are reported in the south and west regions.

Figure 8 shows residential and industrial development dynamics, together with the population growth rates for the whole country and for the regions. The residential land growth for the period 1990–2000 ranges between 13% and 20% for the peri-urban areas, and between 5% and 13% for the rural areas. In relation to west and north-west regions, in the urban areas, the growth of residential land is more than 37%. In the post-2000s, the growth rate of residential land declines to a minimum of 0.013%, and to a maximum of 7% in the peri-urban areas, where the former is located in west region and the latter in east region. At the national level, urban areas develop faster than peri-urban and rural areas. The disaggregation of the data into regions indicates that this national trend results from the dominance of trends observed in north-west and west regions. The spatial distribution of residential development in north-west and west regions is different from other areas, considering that the three biggest cities of Turkey i.e., Istanbul, Ankara and Izmir, are located in these two regions. These cities are characterized by much stronger urbanization and irregular urban development processes starting from early 1950s. The urban and peri-urban areas in the other regions have experienced much lower rates of urban development, in decreasing order, the south, north and the east region.

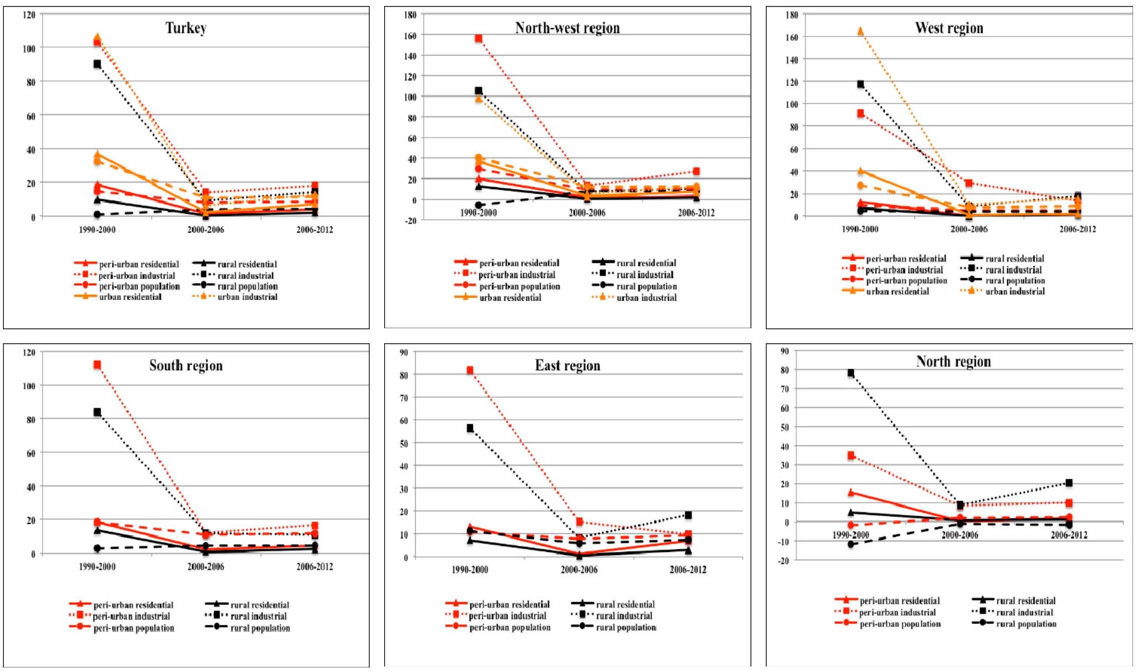


Figure 8. Residential, industrial and population growth (%) at national and regional level for urban, peri-urban and rural regions from the upper left corner: Turkey, North-west region, West region, South region, East region, North region.

The industrial developments are sound in the 1990–2000 period in peri-urban regions, with the highest growth observed in the north-west region of 157%, and the lowest growth is 35% in the north region. In the west and north regions, the industrial growth rates are higher in the rural regions compared to peri-urban areas. The former has a growth rate of 117%, while the latter 78%.

In the 2000–2006 period, the industrial growth rates declined to a minimum of 8% in both north-west and west regions. The reason for declining industrial and residential development in the post-2000 period is the financial outburst of the early 2000s. During the recovery period of 2006–2012, industrial growth rates increased, ranging between 9% in the north and 27% in the north-west.

The population grew in all regions during the study period. In the north, east, and south regions, the peri-urban population grew faster than the rural population. The north-west and west regions had experienced higher growth rates of urban population compared to those observed for peri-urban and rural areas. In these two regions, the peri-urban population has higher growth rates than the rural population. Overall, the urban population growth rate is the highest in the north-west region compared to all other regions. The north region is the only region where its rural population is declining continuously, and the region lost peri-urban population during the period 1990–2000.

4.3. Possible Drivers of Regional Land Development

The details of the socio-economic and land use data that were used in the regression analysis are provided in Table 6. All the variables in Table 6 were used in the regressions except those indicating high correlations with the other variables used in the models. The results in Table 7 present the estimated coefficients of the logarithmic models where the coefficients express elasticities: They indicate the percentage change in land cover of a given percentage change in the independent variable. The R-square values indicate that industrial/commercial land cover dynamics can be relatively explained well by the independent variables.

Table 6. Descriptive statistics of variables.

Variable Name (Abbreviation)	Mean	SD	Max	Min
Socio-economic factors				
Population (pop)	933,671	1,668,005	13,900,000	75,797
Population density (pop_den)	121	303	2725	11
Household size (hh_size)	3.97	1.16	7.9	2.8
Gross Domestic Product (TL) (gdp)	19,400,000	55,500,000	476,000,000	995,449
Gross Domestic Product in agriculture (TL) (gdp_agri)	1,502,381	1,283,725	6,210,693	191,684
Gross Domestic Product in industry and services sectors (TL) (gdp_ind)	1,790,000	5,530,000	475,000,000	690,238
Employment in industrial and services sectors (ind_emp)	228,740	534,411	4,534,000	16,000
Agricultural employment (agri_emp)	71,530	61,257	390,000	8000
Share of agricultural employment in total employment (%) (sh_agri_emp)	33.79	12.73	65.96	0.68
Regional development index (dev_index)	0.00001	1.00003	4.515	−1.733
Supply constraints				
Restricted areas for development (ha) (protect_sites)	25,729	60.288	367,948	0
Available land for development (ha) (avail_land)	778,337	508,614	3,222,689	76,313
Infrastructure				
Area of ports (ha) (port)	35.87	104.03	645	0
Area of airports (ha) (airport)	363.4	499.38	2266	0
Land-use				
Area of recreation land (ha) (recreation_land)	591	1399	7830	0
Area of residential land (ha) (resid_land)	11,175	12,085	68,160	597
Area of industrial/commercial land (ha) (ind_land)	2,308	3,533	20,327	93
Area of agricultural land (ha) (agri_land)	418,585	352,697	2,354,320	24,289
Area of forest land (ha) (forest_land)	143,088	138,411	705,810	0
Regional characteristics				
Dummy for peri-urban regions (peri_urban): base category: urban regions	0.333	0.474	1	0
Dummy for rural regions (rural): base category: urban regions	0.604	0.491	1	0
Dummy for north-west region (north_west): base category: east region	0.185	0.391	1	0
Dummy for west region (west): base category: east region	0.099	0.3	1	0
Dummy for south region (south): base category: east region	0.222	0.418	1	0
Dummy for north region (north): base category: east region	0.259	0.44	1	0

Table 7. Results of the seemingly unrelated regression (SUR) analysis explaining development of urban and non-urban land.

	M1 Residential Land	**M2 Industrial Land**	**M3 Recreational Land**	**M4 Agricultural Land**	**M5 Forest Land**
Constant	−4.636 ** (1.71)	−7.095 * (3.89)	−20.596 ** (7.68)	4.529 ** (0.96)	3.387 (4.84)
Log (hh_size)	−0.669 (0.56)	-	-	-	-
Log (pop)	0.358 ** (0.14)	-	−0.083 (0.63)	−0.042 (0.12)	-
Log (pop_den)	-	-	-	-	−1.324 ** (0.57)
Log (ind_emp)	-	0.759 ** (0.16)	-	0.378 * (0.21)	-
Log (sh_agri_emp)	-	−0.023 (022)	-	-	-
Log (agri_emp)	-	-	-	-	1.196 ** (0.53)
Log (gdp)	0.440 ** (0.20)	-	-	-	-
Log (gdp_agri/gdp_ind)	-	−0.433 (2.37)	-	0.488 ** (0.13)	1.334 ** (0.61)
Log (airport)	0.026 * (0.02)	0.009 (0.02)	0.237 ** (0.10)	0.012 (0.01)	−0.147 ** (0.07)
Log (port)	-	−0.086 ** (0.03)	0.184 * (0.11)	−0.066 ** (0.02)	0.229 ** (0.10)
Log (recreation_land)	0.018 (0.02)	-	-	-	-
Log (res_land)	-	-	0.845 (0.66)	0.326 ** (0.11)	−1.417 ** (0.59)
Log (ind_land)	-	-	-	0.209 ** (0.09)	1.268 ** (0.51)
Log (protect_sites)	0.012 (0.02)	0.001 (0.18)	−0.067 (0.09)	0.008 (0.01)	0.018 (0.01)
Log (avail_land)	0.20 * (0.15)	0.431 ** (0.16)	1.161 * (0.66)	-	-
Dev_index	0.517 ** (0.18)	0.025 (0.14)	0.702 * (0.54)	-	-
Peri_urban	−0.75 ** (0.31)	−0.519 * (0.34)	2.141 ** (0.69)	0.024 (0.24)	1.467 (1.34)
Rural	−0.439 (0.36)	−0.502 (0.39)	-	0.192 (0.26)	1.108 (1.54)
Northwest	0.713 ** (0.26)	1.094 ** (0.26)	1.54 (1.43)	−0.232 * (0.16)	1.003 (1.91)
West	0.484 * (0.26)	0.728 ** (0.27)	0.508 (1.35)	−0.419 ** (0.16)	1.716 * (0.94)
North	−0.04 (0.20)	0.094 (0.19)	0.609 (0.94)	0.295 ** (0,12)	1.050 * (0.65)
South	0.601 ** (0.19)	0.693 ** (0.20)	1.814 ** (1.07)	−0.158 * (0.13)	−0.141 (0.56)
Dependent variable	Log (res_land)	Log (ind_land)	Log (recreation_land)	Log (agri_land)	Log (forest_land)
N	81	81	81	81	81
Chi^2 (probability)	323.48 (0.000)	334.75 (0.000)	39.27 (0.000)	326.68 (0.000)	34.59 (0.000)
R-square	0.83	0.88	0.62	0.86	0.51

Note: In parenthesis are the standard errors; * significant at 10%; ** significant at 5%; Industrial land comprises industrial and commercial uses.

The positive coefficient of population in Model 1 (Table 7) indicates that more people living in urban areas can be expected to have large amounts of residential land development. The negative and insignificant coefficient of household size in Model 1 implies that residential land expansion is associated with smaller household sizes.

The coefficient of Log(gdp) is positive and significant, indicating that regions with higher income can be expected to have more residential land cover, compared to regions with lower income. The areas of airport and recreational uses show the expected positive correlations with residential land development. The airport variable is positive in all models except Model 5. According to this finding, the growth of forest land in Model 5 is negatively associated with the size of airport. The port variable, on the other hand, is positively related with recreational and forest land development, while it has an unexpected negative relationship with industrial and agricultural land developments. This finding indicates that industrial land developments take place in inland areas or in the coastal cities which do not have a port. The cities having an airport are positively related to recreational and forest land developments, as can be observed in Table 7.

In contrast to expectations, the area of protected sites is positively related to dependent variables in all models except Model 3. The larger the areas of protected sites in a region, the more likely it is to have an urban/rural expansion. The areas of protected sites are also positively associated with agricultural and forest land expansion. This finding may imply that there is plenty of available land in these regions and the protected sites do not pose a restriction upon urban development. An alternative explanation is the existence of a possible correlation between the areas of protected sites and other explanatory variables included in the regressions. This may be the reason for the insignificant coefficients and unexpected positive signs estimated for the variable Log (protect_sites). The coefficient of Log (avail_land) is positive and significant: Regions with higher amounts of available land are expected to have more residential land development compared to regions with a lower amount of available land. The coefficient of Log (avail_land) in the first three models varies between 0.20 and 1.16. An increase of 10% in available land is associated with a 2% increase in residential land in the former case, and an 11.6% increase in recreational land in the latter. The positive sign of development index related to residential, industrial and recreational development indicates that the higher the development level of a region, the higher the growth of urban land use.

In comparison to urban regions, the cities located in peri-urban and rural regions show negative relationship with residential and industrial land developments. By contrast, these regions show positive relationships regarding recreational, agricultural and forest land developments. The cities in the north-west region are positively related to the growth of residential and industrial land. The south and west regions show positive relationship with the recreational and forest land expansions. The north region is the only region that is positively associated with agricultural land expansion. Except for the south region, there is forest land expansion in all regions, where the west and north regions have the highest elasticities of change regarding their forestland.

In Model 2, the number of industrial and services employment is positively correlated with industrial land development. By contrast, the share of agricultural employment, though insignificant, is negatively correlated with industrial development. The ratio of agricultural to industrial GDP is another explanatory variable in Models 2, 4 and 5, indicating a negative correlation with industrial land development, and a positive correlation with agricultural and forest land developments. This implies that higher returns to agriculture and forest uses may prevent the conversion of agricultural land to industrial uses, and further promote agricultural and forest land expansions. Regarding Models 3, 4 and 5, it can be suggested that population and population density are negatively related to recreational, agricultural and forest land expansions. In other words, the higher the population, the lower the recreational, forest, and agricultural land to be allocated to non-residential and non-industrial uses. This points to consumption of recreational and agricultural land to accommodate increasing population in the growing regions.

In order to assess the correlation of socio-economic parameters and supply restrictions with land use development, region specific regression models were estimated for the residential, industrial and agricultural land uses separately (Tables 8–10). Only the socio-economic factors that do not show collinearity with the other factors and supply constraints were considered as explanatory variables in the regression analysis.

The estimations were also carried out regarding recreational and forest land; however the estimated coefficients were either found insignificant, or had inconsistent signs; therefore results from these regressions are not provided in the current paper. In the regressions explaining residential land development, population, total employment, available land, airport and port variables are correlated with the other explanatory variables (Table A2 in the Appendix A); and therefore these were excluded from the analysis, as these characteristics are captured by household size, population density, GDP and the areas of protected sites. Likewise, correlated variables were excluded from the regressions explaining industrial and agricultural land developments through examining the significant correlations in the correlation coefficient matrices.

Table 8. Results of the regression analysis explaining development of residential land for different regions.

	N	R-square	Log (hh_size)	Log (pop_den)	Log (gdp)	Log (protect_sites)	Constant
South region	18	0.9	2.507 ** (0.94)	−0.357 * (0.21)	0.543 ** (0.11)	0.116 ** (0.03)	−2.088 * (1.53)
West region	8	0.96	3.427 ** (0.98)	0.038 (0.22)	0.391 * (0.19)	0.091 * (0.04)	−1.939 (2.27)
Northwest region	15	0.91	−1.27 (1.29)	−0.203 (1.15)	0.754 ** (0.13)	0.029 (0.06)	−0.999 (1.99)
North region	21	0.53	2.038 (2.46)	−0.175 (0.29)	0.927 ** (0.30)	0.083 * (0.05)	−7.24 * (4.45)
East region	19	0.6	0.770 (0.7)	−0.014 (0.40)	0.757 ** (0.29)	0.054 * (0.030)	4.483 (3.79)
Peri-urban regions	27	0.81	−0.329 (0.59)	−0.26 * (0.19)	1.044 ** (0.13)	−0.043 * (0.03)	−6.092 ** (1.87)
Rural regions	49	0.65	0.593 * (0.35)	0.039 (0.22)	0.962 ** (0.15)	0.047 ** (0.02)	−7.436 ** (2.07)
All regions	81	0.7	0.605 ** (0.28)	−0.293 ** (0.11)	0.877 ** (0.09)	0.029 * (0.02)	−4.824 ** (1.25)

Note: In parenthesis are the standard errors; * significant at 10%; ** significant at 5%.

Table 9. Results of the regression analysis explaining development of industrial land for different regions.

	N	R-square	Log (sh_agri_emp)	Log (gdp)	Log (gdp_agri_ind)	Log (protect_sites)	Constant
South region	18	0.84	−1.273 (0.69) *	0.885 ** (0.19)	−0.785 * (0.49)	0.017 (0.03)	−1.283 (4.13)
West region	8	0.93	−1.522 (1.33)	0.773 * (0.32)	−0.918 (0.64)	−0.116 (0.08)	3.027 (10.39)
Northwest region	15	0.93	−0.212 (0.29)	1.352 ** (0.23)	−0.692 * (0.34)	−0.132 * (0.74)	−11.072 ** (2.77)
North region	21	0.62	−2.066 ** (0.71)	0.781 ** (0.21)	−1.005 ** (0.40)	−0.117 ** (0.04)	4.079 (3.61)
East region	19	0.93	0.311 (0.26)	1.318 ** (0.09)	−0.070 (1.19)	0.051 ** (0.01)	15.051 ** (1.71)
Peri-urban regions	27	0.75	−0.938 ** (0.43)	1.312 ** (0.18)	−0.333 (0.36)	−0.070 * (0.04)	−9.856 ** (3.18)
Rural regions	49	0.79	−0.319 (0.35)	1.258 ** (0.11)	−0.426 * (0.23)	0.039 ** (0.02)	−11.278 ** (2.31)
All regions	81	0.79	−0.410 * (0.24)	1.099 ** (0.09)	−0.507 ** (0.19)	0.009 (0.02)	−8.244 ** (1.79)

Note: In parenthesis are the standard errors; * significant at 10%; ** significant at 5%; Industrial land comprises industrial and commercial uses.

Table 10. Results of the regression analysis explaining development of agricultural land for different regions.

	N	R-square	Log (sh_agri_emp)	Log (pop)	Log (gdp_agri)	Log (protect_sites)	Constant
South region	18	0.62	0.403 (0.43)	0.015 (0.23)	0.363 * (0.23)	0.061 * (0.03)	8.472 ** (3.61)
West region	8	0.53	1.375 (1.31)	1.102 (1.15)	−0.330 (0.83)	−0.024 (0.09)	−1.756 (9.90)
Northwest region	15	0.87	−0.519 ** (0.21)	−0.383 * (0.20)	2.019 ** (0.36)	−0.150 * (0.08)	−7.769 ** (2.92)
North region	21	0.71	0.149 (0.44)	0.325 * (0.21)	0.502 * (0.26)	−0.096 ** (0.03)	1.552 (2.03)
East region	19	0.89	−0.097 (0.29)	−0.042 (0.23)	1.059 ** (0.57)	0.044 ** (0.02)	−1.08 (1.4)
Peri-urban regions	27	0.68	−0.176 (0.34)	0.405 (0.36)	0.527 (0.35)	0.033 (0.03)	0.493 (2.03)
Rural regions	49	0.75	0.331 * (0.20)	0.269 ** (0.03)	0.664 ** (0.14)	0.004 (0.01)	−1.151 (1.32)
All regions	81	0.64	0.167 * (0.12)	0.122 (0.12)	0.680 ** (0.13)	−0.008 (0.01)	−1.066 (1.08)

Note: In parenthesis are the standard errors; * significant at 10%; ** significant at 5%.

From Tables 8 and 9, GDP contributes significantly to the development of residential and industrial land uses across all different regions specified in the study. The contribution of GDP to residential land growth is the highest in peri-urban regions while the lowest contribution is observed in the west region. Peri-urban regions are characterized by high population growth rates that are associated with the growth of residential land. The north region showed considerably high elasticity of change regarding the GDP variable compared to other regions. Considering that the Region has lost population between 2006 and 2012, the high elasticity of GDP to residential land use change confirms that the Region is experiencing low-density developments.

Considering industrial land, west, north-west and east regions have the highest explanatory power, thus each region can explain more than 90% of variation in the industrial land use. The elasticity of GDP to industrial land is the highest in north-west region, and that is followed by the east, south and north regions. This is a promising finding, verifying that economic growth and industrial development in the east region follows the trend of industrial land development of the highly developed north-west region. The former region is characterized by high employment growth, while the latter is characterized by high productivity growth during the last decades. The peripheral regions have created jobs for low-skilled workers outside the agricultural sector [93]. The medium-size enterprises in these regions have increased their employment on average by 5% annually between 2002 and 2010. The regions experiencing particularly strong employment growth in the 2000s are Kocaeli, Kayseri, Van and the surrounding regions (see Figure A1) [93].

From Table 8, household size is negatively related with residential land development both in north-west and peri-urban regions. In other regions, it is positively related to residential development. This points to a correlation of residential development with declining household size in north-west and peri-urban regions, and with increasing household size in other regions. Except west region and rural areas, residential land expansion is negatively related to population density: This implies that the lower the density, the higher the land expansion. Land restrictions may be influential in peri-urban regions, and also in the north, north-west and west regions regarding industrial development. Except the east region, which is characterized by depending on agricultural economy, in all other regions, the share of agricultural employment is negatively correlated with industrial development (Table 9). This finding is also supported by the negative coefficient on the ratio of agricultural GDP to industrial GDP.

In the case of agricultural land development (Table 10), east and north-west regions have the highest explanatory power. The negative coefficient of Log(pop) variable indicates that increasing population in these regions is associated with agricultural land consumption. In east and north-west regions, increasing share of agricultural employment does not result in agricultural land expansion.

This trend is also observed in peri-urban regions which have experienced high growth of industrial employment starting from the 2000s. Increasing share of agricultural employment leads to agricultural land expansion in south, west and north regions, as well as in rural areas where the west region shows the highest elasticity. Higher agricultural GDP contributes to agricultural land expansion in all regions except the west region, showing the lowest elasticity. The results imply that there is possible correlation between share of agricultural employment and agricultural GDP concerning the west and east regions.

5. Discussion and Conclusions

In Turkey, population and urban land use/cover have grown steadily during the last decades, with population growing less than residential land during the 1990–2000 period, and the reverse occurred in the post-2000s, indicating dispersal of residential land uses in the former case, and densification of residential uses in the latter. The overall level of urban expansion in Turkey is characterized by a relatively modest growth in residential and recreational land, and a double growth rate in industrial and commercial land, demonstrating the industrial-oriented development path of the regions. In the 1990–2000 period, urban growth was achieved through conversion of agricultural land and natural vegetation to urban uses. In the following periods, the loss of agricultural land continued with the losses of forests and natural vegetation, though there were small increases of forest and natural vegetation in some specified regions. This result coincides with the findings of the studies of Xiao et al. [21], Dewan and Yamaguchi [22], Araya and Cabral [23], Bieling et al. [24], Broitman and Koomen [17], Rawat and Kumar [41] and Liu et al. [5] which conducted the case studies on China, India, Portugal, Germany, Netherlands and Bangladesh indicated that the changes of agriculture, natural vegetation and forest land is primarily governed by urban expansion. Unlike the findings of Xiao et al. [21] which pointed to a decline in residential land uses in the selected Chinese cities, our results indicated only positive changes with the residential land (as in [5,22,24]) and low-density developments, particularly in the cities of the north region of Turkey, as well as other cities in north-west and south regions. During the study period, there is an increase in residential land and a declining population, pointing to development of low-density dispersed settlements in the northern region as the Region is characterized by having geographical limitations for the development of higher density settlements.

The process of urban dispersal in shrinking cities/regions in the north region of Turkey is also common to the European and US cities of more developed economies, indicating similar development processes with the Turkish case [14,15,95]. For instance, Turok and Mykhnenko [96] showed that many of the Eastern European cities had been facing population decline since the 1990s, and most of these cities had experienced urban sprawl under conditions of urban shrinkage process. Urban sprawl causes direct LULC change at the urban-rural fringe, and impacts indirectly on the rural landscape through fragmentation of agricultural areas and woodlands. This has increased the need for planning tools specifically designed to cope with urban sprawl, and to promote environmentally sustainable urban forms and land saving developments. The impact of declining local economies and job losses, demographic change, sub-urbanization and consequential population loss has resulted in urban shrinkage observed in many urban regions in the World, as well as cities/regions in the north region of Turkey. These cities have been hit by job-related out-migration to the more developed western, north-western and southern regions of the country. As urban shrinkage is influenced by particular governance arrangements operating at different spatial levels and the struggle between public and private interests, it is policy relevant for government and local authorities, infrastructure providers, investors and public associations and other stakeholders representing diverging interests, to develop common strategies of action and cooperation [97].

The results from Liu et al. [5] demonstrated a negative change in industrial land in their study area of Central China, pointing to decline in industrial development considering that industrial land is converted to other land uses. By contrast, in our study, we found that there is considerable industrial expansion during the study period in all regions of Turkey, particularly in the north region that has experienced population decline during the study period.

In the current study, we cannot specify the types of industrial/commercial land that have expanded, or those that have undergone a shrinkage process. Since the industrial/commercial land use class is aggregated in the CLC dataset, it is impossible to disaggregate industrial, commercial and finance sectors that underwent an expansion or decline. With the availability of alternative land use/cover maps disaggregating the industrial/commercial land use classes, it would be possible to identify and quantify the types of economic sectors of expanded and declined land uses. Therefore, we recommend the search of alternative spatial data sources for Turkey as a future research topic to investigate the spatial dynamics of industrial/commercial developments at the regional level. This is important, since persisting pressures of urban growth in Turkey are resulting in conversion of non-urban uses to irreversible urban uses e.g., industrial or commercial development, housing and infrastructure. Nonetheless, urban growth has resulted in major challenges in the growing regions concerning planning and policy making and environmental protection.

The disaggregation of urban and non-urban land uses into regions and different hierarchical levels have shown that population and urban and non-urban land use change rates were diverse and uneven. This coincides with the findings of Broitman and Koomen [17], which focused on the regional diversity in residential development of urban and peri-urban areas in the Netherlands; and Wang et al. [31] investigating spatio-temporal patterns of urban-rural development transformations in China. This points to spatial disparities regarding socio-economic development levels of the regions that are common to both developed and transition economies in Europe and internationally. Our results indicate that the spatial development of regions are deeply influenced by the regional economic level. A deeper comparative analysis reveals that while the north-western region had experienced rapid increase in residential and industrial land in the 1990–2000 period, the less-developed regions, the east and north, witnessed similar changes of residential and industrial land as with the north-west and other regions in the following periods. These land use changes can be attributed to re-location and de-concentration of industrial and commercial activities to peri-urban regions in the north-west, and less developed regions in Anatolia. Though there are similar changes of land use across the regions in the post-2000, the literature has shown that the regional development disparity in Turkey continues in the post-2000 period [66,67,92], as there are considerable differences in the composition of industries and income levels of regions concerning the north-west, the east, and other regions [69,94]. This is also evident from our study, which shows the regional disparities in economic output, population density, and industrial/agricultural employment for the post-2000 period. Since the 1970s, the Government has attempted to promote balanced development of regions in Turkey, and some of the most important measures that were introduced include: The creation of 'Priority Development Areas' and related policy framework, South-East and East Anatolia Development Projects, Regional Development Plan for the Eastern Black Sea Region, the Project on Zonguldak, Bartın and Karabük and others. Since 2006, the recently established Development Agencies have developed new regional plans for their corresponding regions to promote more balanced and sustainable development of the regions. National/Regional Spatial Strategy Plans focusing on national/regional development strategies in a more systematic way have been put into practice more recently. These changes in the planning and institutional system (Figure 3) indicate that regional planning in Turkey is getting more significant and powerful. However, the structure of the planning institutions and regional/national plans needs to be enhanced further to better address regional and sectorial needs, the regional/national growth strategies and sustainable urban development. A critical evaluation of the planning system and its future requirements had already been covered in the literature [48,98].

From our analysis, we note that the cities in north-west and north regions had experienced low-density development patterns in the 1990–2006 period (Figure 7a), while in the post-2006 era, the regions are optimizing their land use structures through higher density and more compact developments (Figure 7b). We found that the northern region lost population between 1990 and 2012. Regarding other regions, population growth rate is relatively higher than residential land growth rate, pointing to higher density developments. An in-depth analysis of land use changes across different regions and hierarchical levels has shown that industrial land use change is concentrated in peri-urban regions, which have experienced considerable economic growth in the last decades.

The residential and recreational land development has spread to rural regions and then to peri-urban regions, where there is abundance of land for development. In north-west, south and east regions, peri-urban and then rural regions recorded the highest changes of industrial land development. In west region, urban and peri-urban regions, and in the north, rural regions are associated with the highest changes of industrial land.

Underlying drivers of LULC change can be evaluated by the standard land use change drivers that were used in other studies. Our regression analysis indicated a combination of underlying drivers i.e., socio-economic, regional and location-based factors and development constraints, influencing urban and non-urban development patterns in the Country and across regions. Regression results of the current study undertaken for Turkey have confirmed the findings of the studies of Dewan and Yamaguchi [22], Wu and Zhang [99], Liu et al. [5], Wang et al. [100] given that combinations of different underlying drivers are responsible for urban expansion and non-urban land use changes in different study areas. Our results have shown that the estimated coefficients are of varying sign and magnitude across different land use developments. This implies that land use change dynamics and drivers of land use change in Turkey are highly diverse, depending on many factors comprising differences in urbanization process, socio-economic differences, differences in locational characteristics, and regional development disparities. In the regressions estimated for all the regions (Table 7), population, industrial employment and economic output are the key factors contributing to the development of residential and industrial/commercial land uses. Urban-related hierarchical levels and the socio-economic development levels of the regions are also prominent in explaining urban land use developments. The presence of land development restrictions was found to be insignificant in the regressions estimated for all the regions, implying that the existence of protected land has not limited the growth of urban and non-urban areas across different regions. However, this is not supported by the region-specific regressions, considering that the areas of protected land show significant coefficients in the regressions estimated for residential, industrial/commercial and agricultural land. From these findings, we conclude that protected sites mostly do not pose a restriction regarding the residential land developments; however protected sites limit industrial, and in some regions agricultural, developments.

Considering the persisting urban growth pressure, the suggested urban development trends may continue in the future. Therefore, land use planning and policy-making authorities will have to deal with increasing development inequalities among regions, urban cores and peri-urban areas. The increasing industrial demand in Turkey seems to be allocated to peri-urban regions, while the residential demand will need to be allocated to rural regions. Therefore, land use plans and policies at both national and regional level pointing to the new areas of development, are increasingly needed. To address this issue, future projections of the selected urban land uses should be performed as a future research focus. The analysis of the future urban land estimations are policy relevant, as it is important for planning and policy-making authorities to formulate well-planned and forward-looking strategies to distribute and allocate scarce land uses efficiently.

The current study provides an empirical evidence for the identification and quantification of urban and non-urban land use change, and the significant drivers of land development at the regional level in Turkey. The study connects with the literature through provision of statistical characteristics, and the key determinants of the land use changes in the 1990–2012 period at the regional level in Turkey [101]. Our findings, combined with national statistics, can contribute to national environmental accounting, as well as provide a base for the studies focusing on drivers of land use change and their policy implications in Turkey. The findings from this study can also be used as a benchmark for the comparison of similar studies undertaken for different countries in Europe and internationally. Based on the availability of future data at the regional level, there is further need for more case studies that assess a broad range of factors (e.g., geological, soil and climatic characteristics, industrial composition, social capital, credit and capital markets), rather than the selected ones used in this study that influence regional land use changes in Turkey.

As a future work, it is also suggested that the current analysis be re-conducted, including the 2018 CLC data for Turkey, that will be provided by the European Environment Agency in the future. In addition, the future change of land use and its links to physical, socio-economic and locational characteristics should be considered for future research.

Supplementary Materials: The following are available online at http://www.mdpi.com/2072-4292/11/7/885/s1, Table S1: Socio-economic indicators for selected regions compared to the national total, 2012

Author Contributions: For research articles with several authors, a short paragraph specifying their individual contributions must be provided. The following statements should be used "conceptualization, E.U. and A.A.; methodology, E.U.; software, E.U.; validation, E.U. and A.A.; formal analysis, E.U.; investigation, E.U.; resources, E.U.; data curation, E.U.; writing—original draft preparation, E.U.; writing—review and editing, E.U.; visualization, E.U.; supervision, A.A.; project administration, E.U.; funding acquisition, A.A.", please turn to the CRediT taxonomy for the term explanation. Authorship must be limited to those who have contributed substantially to the work reported.

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Appendix A

Table A1. Corine Land Cover classification used in the study.

CLC Classification (Level 3)	Classification Used in the Study
1.1.1. Continuous urban fabric	Continuous urban fabric
1.1.2. Discontinuous urban fabric	Discontinuous urban fabric
1.2.1. Industrial or commercial units	Industrial and commercial units
1.2.2. Road and rail networks and associated land	Road and rail network
1.2.3. Ports	Port
1.2.4. Airports	Airport
1.3.1. Mineral extraction sites	Mine and dump sites
1.3.2. Dump sites	
1.3.3. Construction sites	
1.4.1. Green urban areas	Recreation uses
1.4.2. Sports and leisure facilities	
2.1.1. Non-irrigated arable land	Agricultural uses
2.1.2. Permanently irrigated land	
2.1.3. Rice fields	
2.2.1. Vineyards	
2.2.2. Fruit trees and berry plantations	
2.2.3. Olive groves	
2.3.1. Pastures	
2.4.1. Annual crops associated with permanent crops	
2.4.2. Complex cultivation pattern	
2.4.3. Land principally occupied by agriculture with significant areas of natural vegetation	
2.4.4. Agro-forestry areas	
3.1.1. Broad leaved forest	Forest
3.1.2. Coniferous forest	
3.1.3. Mixed forest	
3.2.1. Natural grassland	Semi-natural vegetation
3.2.2. Moors and heat land	
3.2.3. Sclerophyllous vegetation	
3.2.4 Transitional woodland shrub	
3.3.1. Beaches, dunes, sands	
3.3.2. Bare rock	
3.3.3. Sparsely vegetated areas	
3.3.4. Burnt areas	

Table A2. Correlation coefficient matrix (variables explaining residential land development).

	Log (pop_den)	Log (hh_size)	Log (protect_sites)	Log (avail_land)	Log (port)	Log (airport)	Log (pop)	Log (gdp)	Log (emp)
Log (pop_den)	1								
Log (hh_size)	−0.001	1							
Log (protect_sites)	0.166	−0.512 *	1						
Log (avail_land)	−0.126	−0.119	0.369 *	1					
Log (port)	0.364 *	−0.304 *	0.355 *	−0.031	1				
Log (airport)	0.365 *	0.126	0.182	0.384 *	0.097	1			
Log (pop)	0.659 *	0.029	0.342 *	0.555 *	0.275 *	0.536 *	1		
Log (gdp)	0.749 *	−0.191	0.425 *	0.502 *	0.394 *	0.561 *	0.881 *	1	
Log (emp)	0.728 *	−0.111	0.417 *	0.561 *	0.397 *	0.576 *	0.919 *	0.974 *	1

Note: * Significant at 5%; correlation coefficient matrices for the other variables used in Table 10 are not provided here, but can be obtained from the authors on request.

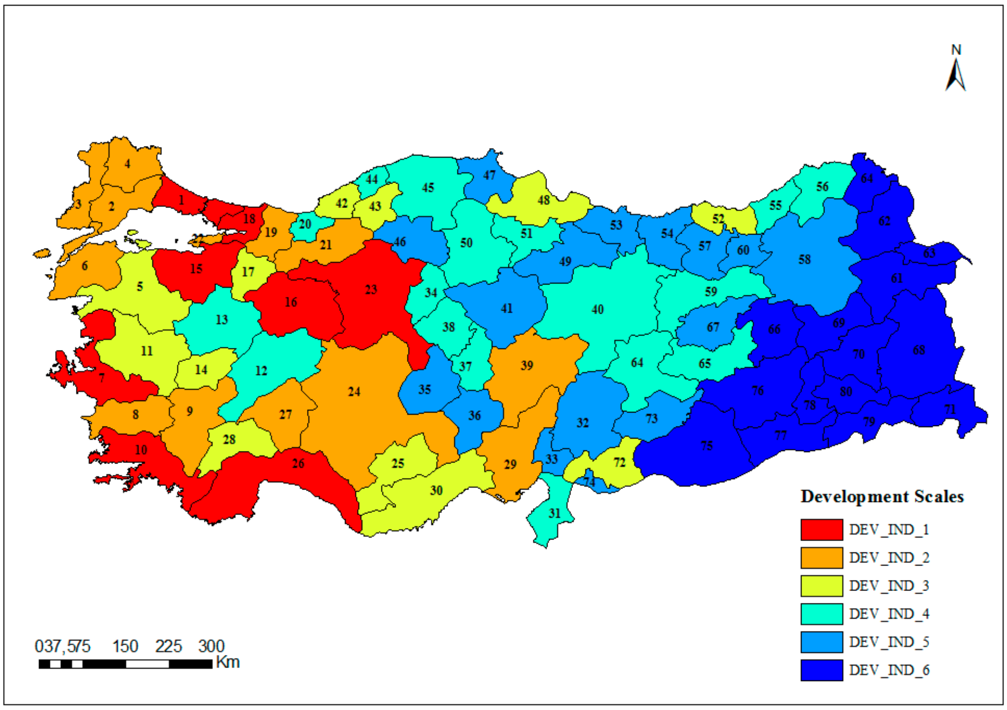
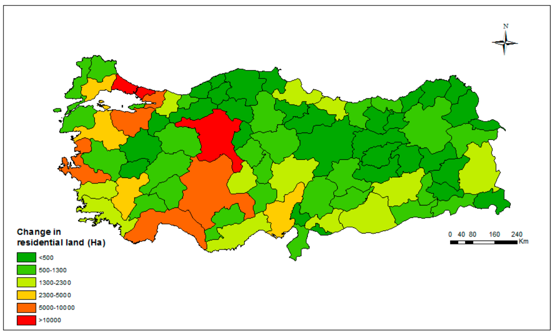
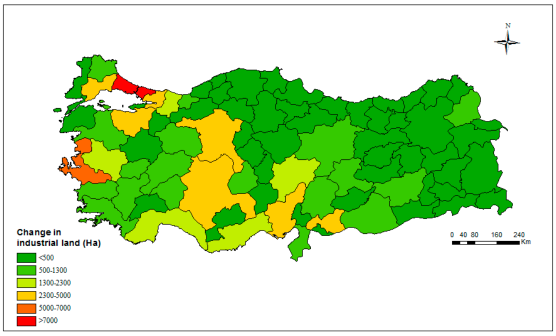


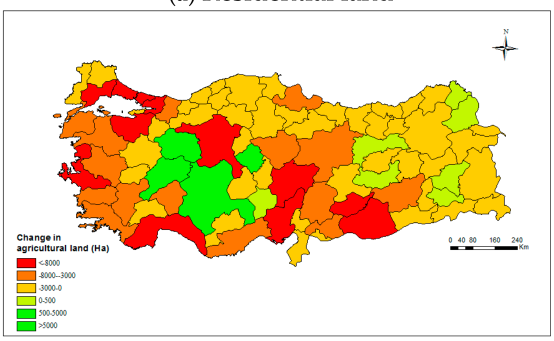
Figure A1. Regional development disparities in Turkey. **Note:** The map displays six separate groups that were identified according to their level of regional development. DEV_IND_1 represents the regions that are in the first place in terms of socio-economic development while DEV_IND_6 indicates the regions in the last place. Selected NUTS 3 Provinces: 1-Istanbul, 2-Tekirdag, 5-Balıkesir, 6-Çanakkale, 7-Izmir, 9-Denizli, 10-Muğla, 15-Bursa, 16-Eskişehir, 18-Kocaeli, 23-Ankara, 24-Konya, 26-Antalya, 29-Adana, 30-Mersin, 39-Kayseri, 48-Samsun, 52-Trabzon, 61-Kars, 63-Van, 64-Malatya, 72-Gaziantep, 76-Diyarbakır. Source: KB [78].



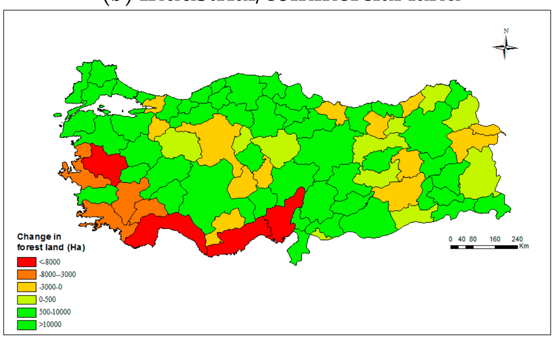
(**a**) Residential land



(**b**) Industrial/commercial land

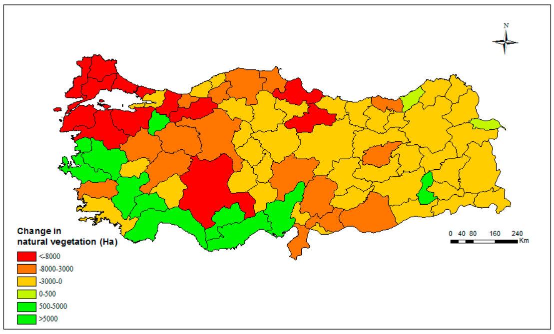


(**c**) Agricultural land



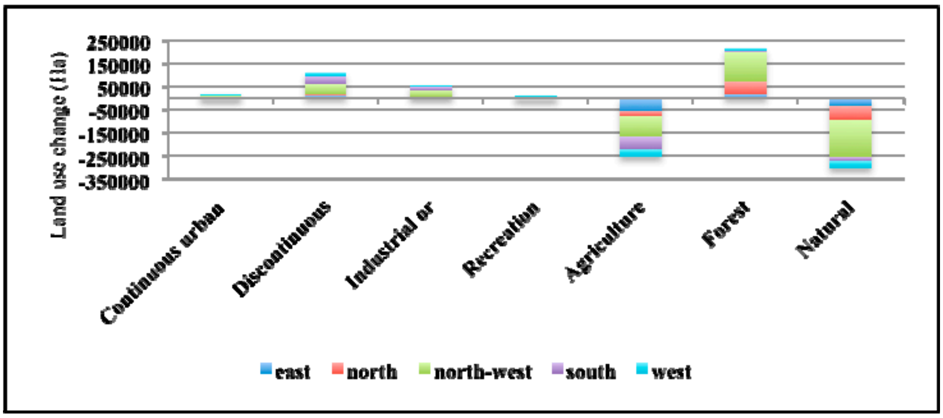
(**d**) Forest land

Figure A2. *Cont.*

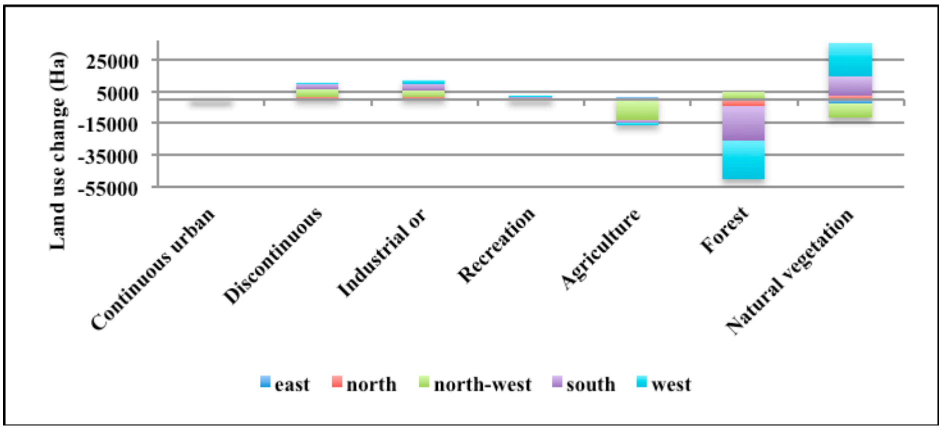


(**e**) Natural vegetation

Figure A2. Change in specified land use types (Ha), Turkey, 1990–2012.

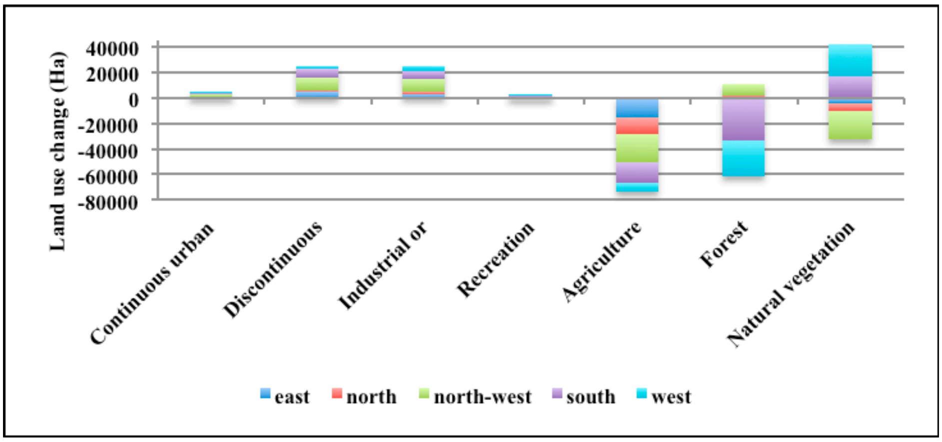


(**a**) Land use/cover change (Ha) between 1990 and 2000 in Turkey



(**b**) Land use/cover change (Ha) between 2000 and 2006 in Turkey

Figure A3. *Cont.*



(**c**) Land use/cover change (Ha) between 2006 and 2012 in Turkey

Figure A3. Land use changes in Turkey, 1990–2012.

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