Assessing Urban Sprawl Effect of Transportation Investments using Remote Sensing Data and GIS Methods: The case of Ankara Protocol Road

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Abstract. In developing countries such as Turkey, transportation investments maintain their popularity. With these investments, short-term solutions are being sought for urban infrastructure problems that are the result of growth-based model in construction sector. The main purpose of this study is to examine the relationship between transportation investments and urban sprawl. To this end, in the capital of Turkey, Ankara, the results of transportation investment in the protocol road that is the main route which provides transportation service to the north of the city, are evaluated in terms of urban sprawl. In this evaluation, Landsat satellite images of the study area are obtained every four years between 2004 and 2016, and land use is classified by remote sensing and GIS methods. As a result of this classification, it is observed that the built-up areas increased by 164 % and the total population by 33 %. Since the population of Ankara has increased by 27% between 2004 and 2016, it is seen that the study area has improved more rapidly with the contribution of the transportation investment, compared with the general urban area.

1. Introduction

In developing countries such as Turkey, urban population growth and physical development of city are two of the key issues of city and planning authorities [1]. In Turkey, as the new growth dynamics, a construction sector based approach has been followed for the last ten years [2]. This approach is supported by transportation investments such as bridges, highways, tube tunnels and tunnels.

The aim of this study is to investigate whether the transportation investment made in 2006 for the protocol road linking Ankara, Esenboğa Airport and the three districts in the north of the city (Akyurt, Çubuk and Pursaklar) to the city center has caused the urban sprawl in the study area.

The reason for the determination of these three districts as the study area is the recommendation of the development housing area, industrial area and university functions in the 1/100.000 scaled Ankara 2038 Environment Plan approved by Ankara Metropolitan Municipality Council in 2017 [3].

In the north of Ankara which is the study area, the development of urban texture started within the scope of the Law of Urban Transformation Project of North Entrance of Ankara that became legal in 2004 [4], the transformation of the protocol road into a motorway in 2006 and the Law on the Transformation of Areas Under Disaster Risk in 2012 accelerated with supports for urban transformation projects [5]. As one of the parameters affecting the development of urban texture, the protocol road, at the first step, was started to be heated underfloor throughout a 7-kilometer line in order to minimize the risks caused by bad weather conditions in the winter months in 2013 and the route that is provided with this service has been increasing continually every year [6]. This process shows that zoning applications in the study area proceed in parallel with the urban technical infrastructure investments.

Spatial analysis of the urban sprawl is performed in the study area by using remote sensing method with geographic information systems. The purpose of the study that is conducted with satellite images is to determine the land use changings [7], to predict the urban development pattern [8], and to determine the negative effects of spatial growth - population density on the environment [9]. The unique aspect of this study is the use of the remote sensing and the geographic information system techniques in order to measure whether a transportation investment causes the urban sprawl.

In this study, there is a conceptual framework section that explains the definition of the urban sprawl, examines the factors affecting the urban sprawl and the results of the urban sprawl, the methodology section in which the calculation technique used in the study area is conveyed, the limitations and the findings of the research are conveyed and the conclusion section includes the general discussion and suggestions.

2. Conceptual Framework

Urban sprawl can have multiple definitions depending on the level of development and social structure of the countries [10]. The urban sprawl, a concept that depends on time and space, is that the urban areas grow physically towards out of the boundaries of the city, depending on various factors [11]. The European Environment Agency (EEA) describes sprawl as 'the physical pattern of low-density expansion of large urban areas, under market conditions, mainly into the surrounding agricultural areas" [12]. Another definition of urban sprawl is the fragmented and often unplanned development of housing, commercial and industrial areas on urban roads jointed to the city in the city fringes [13].

Macroeconomic, microeconomic and demographic indicators, housing preferences, urban traffic problems, housing costs, transportation infrastructure and limitations in the legal framework are among the factors that encourage urban sprawl [3]. Among these factors, the transportation infrastructure is discussed in more detail within the scope of the study. The sub-criteria such as private vehicle ownership, comfort in transport routes, low fuel prices and the prevalence of public transportation network in transportation systems affect transportation infrastructure as well as affecting indirectly or directly urban sprawl [13].

Transportation investments, one of the parameters accelerating urban sprawl, cause the city center to spread out towards the rural areas depending on the development of the transportation network. The development of the peripheral road surrounding the city center and primary road network linked to the peripheral road, on the one hand, increases the transportation speed of individual users, thereby reduces the traffic congestion in the city center and on the other hand, accelerate the development of alternative living spaces and spreading of the city. This change in the road network usually increases the construction pressure on the agricultural land and removes the favourable conditions for agricultural production by fragmenting agricultural lands [14].

The consequences of urban sprawl include threats to the natural environment, deterioration of the physical health of the community and individuals, declining municipal service quality, leading up to social discrimination through the creation of gated communities, and increasing private vehicle ownership. These consequences, in addition to threatening urban and social construction, do not conform to the understanding of modern urban development based on the principle of sustainability.

The understanding of modern urban planning suggests planned development and opposes the development by the texture of sprawl. With the studies such as urban air quality on a global scale and optimal urban size simulations, solutions are sought for the problems caused by urban sprawl [15-16]. These solutions are used to observe change in land use [7] and urban development pattern [8] with remote sensing and geographic information systems techniques.

3. Methodology

In order to solve the problems caused by urban sprawl and to understand the development tendency of the city, sprawl should be measured by considering multiple variables. The variables used in this measurement can be classified in four main categories [17],

1. Spatial form variables; land use classification, accessibility (transportation structures),
2. Growth variables; population change, spatial change of the built environment,
3. Density variables; labour intensity, population density,
4. The effects of sprawl; losing agricultural areas, diminishing green fields/ forest lands, increasing air pollution.

When environmental and economic factors are taken into consideration, these parameters are influenced by the change in spatial texture over time and affect this change. The spatial texture of urban sprawl can be calculated on the basis of vectorial data. The temporal change is obtained from the satellite images obtained for each year, and these images are converted into a parameter that can be measured vectorial by remote sensing and geographical information systems [13]. These techniques are used to observe change in land use [7, 18] and urban development pattern [9].

3.1. Calculation

Within the scope of this study, the districts of Akyurt, Çubuk and Pursaklar which are located in the north of Ankara and provided access to the city center through the protocol road are examined. The effect of a transport investment, which has been made in the protocol road, on the urban sprawl in these districts is discussed in the period of 2004-2016 by sampling through four year periods. The satellite images for these years are obtained by using the database of Landsat satellite, the selected images are united with the bands in the GIS base (ArcMap 10.1), the land classification is made according to the maximum similarity method and the changing of the built environment is calculated. (Table 1).

Table 1. Data Source

Satellite	Date	Sensor	Resolution	Projection	True Colour Composite
Landsat 7	2004-2008-2012-2016	ETM+	30 m	WGS 84 UTM Zone 36 N	Band 7,5,1

Basically two categories are used during the classification process. The first of these is defined as urbanized area and involves the development areas and areas that is open for urbanization [19]. The category that never falls within the scope of these areas and can be defined as non-urbanized areas, includes agriculture, rural, rocky, forest lands and water resources.

During classification, signature files are assigned to the determined areas in the study area and land distribution texture is obtained from these signature files by making an analogy. The algorithm used in this technique is based on two methods. The first of these techniques, the normal distribution of each cell in the multidimensional area, and the other is Bayes' decision-making theorem [20].

In these districts, after the urban expansion statistics are obtained, the variation of population density in urban areas is also calculated using the populations of the relevant settlements. Census data are obtained from the TUIK database [21]. Since Pursaklar, one of these districts, became a district in 2008, the census data for 2004 is obtained from the census data of the neighbourhoods located in the district center.

3.2. Limitations of the Study

The built-up areas included in the study are the sprawl stains in the district centers and their surroundings. Existing rural settlements are not included in the study. Depending on this limitation, the population included in this study refers to the population of the district center and the population of the villages is excluded because villages are regarded as rural areas. In addition, the comparison between the province of Ankara and the study area is based only on census data. The calculation of urban sprawl for the Ankara provincial boundaries is among the objectives of the study to be conducted following this study.

3.3. Findings and Discussion

Urban expansion in Akyurt, Çubuk and Pursaklar is defined by area size and expansion rate parameters, using the calculation methodology described in the previous section (Table 2, Table 3). After these values are obtained, the change of the population density is obtained depending on the population change in the district centres in which urban sprawl takes place (Table 4, Table 5). The effect of sprawl, which is the source of the statistics of these districts, is shown separately with the maps of the districts and areas, and causes of the urban sprawl are explained firstly on the basis of the districts and by total evaluation at the end of the section.

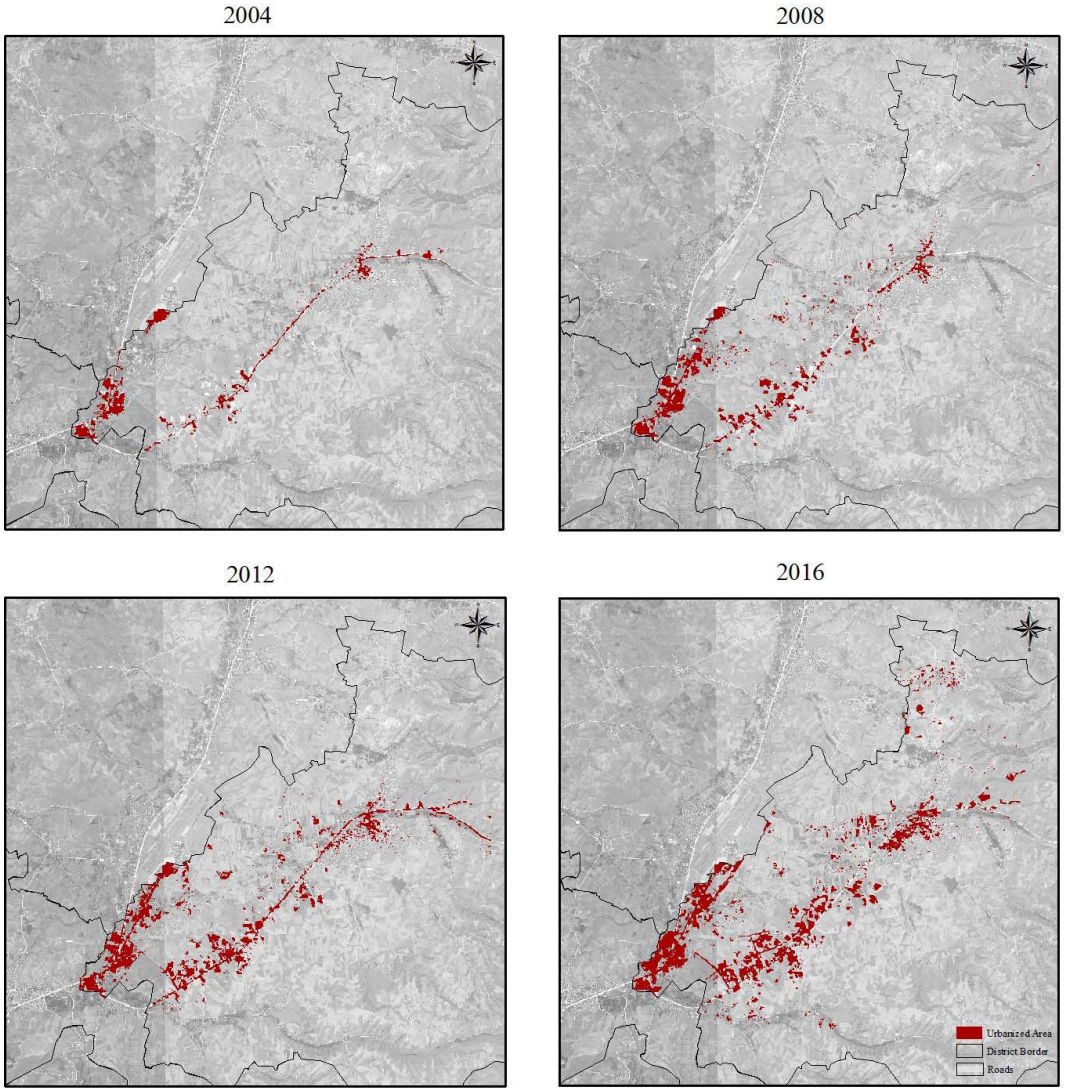

Figure 1. Akyurt District Urbanized Area Development (2004-2016)

The District of Akyurt is located to the east of the protocol road and to the north of the city center. As a result of facilitating access to the city center by means of the transportation investment, the typology of detached houses with garden increases in the district center and the rate of sprawl rises more than double in the period of 2004-2016 (Table 3). Apart from low-density houses, hobby gardening is also increasing in this area and garden houses are being built. Garden houses are the second houses used on weekends and in summers. Another factor contributing the urban sprawl in this area is the increasing investments of industrial enterprises day by day. The location of the district centres offers both the possibility to reach the city center easily with the functions supported by transportation facilities and the possibility to support rural life with urban functions.

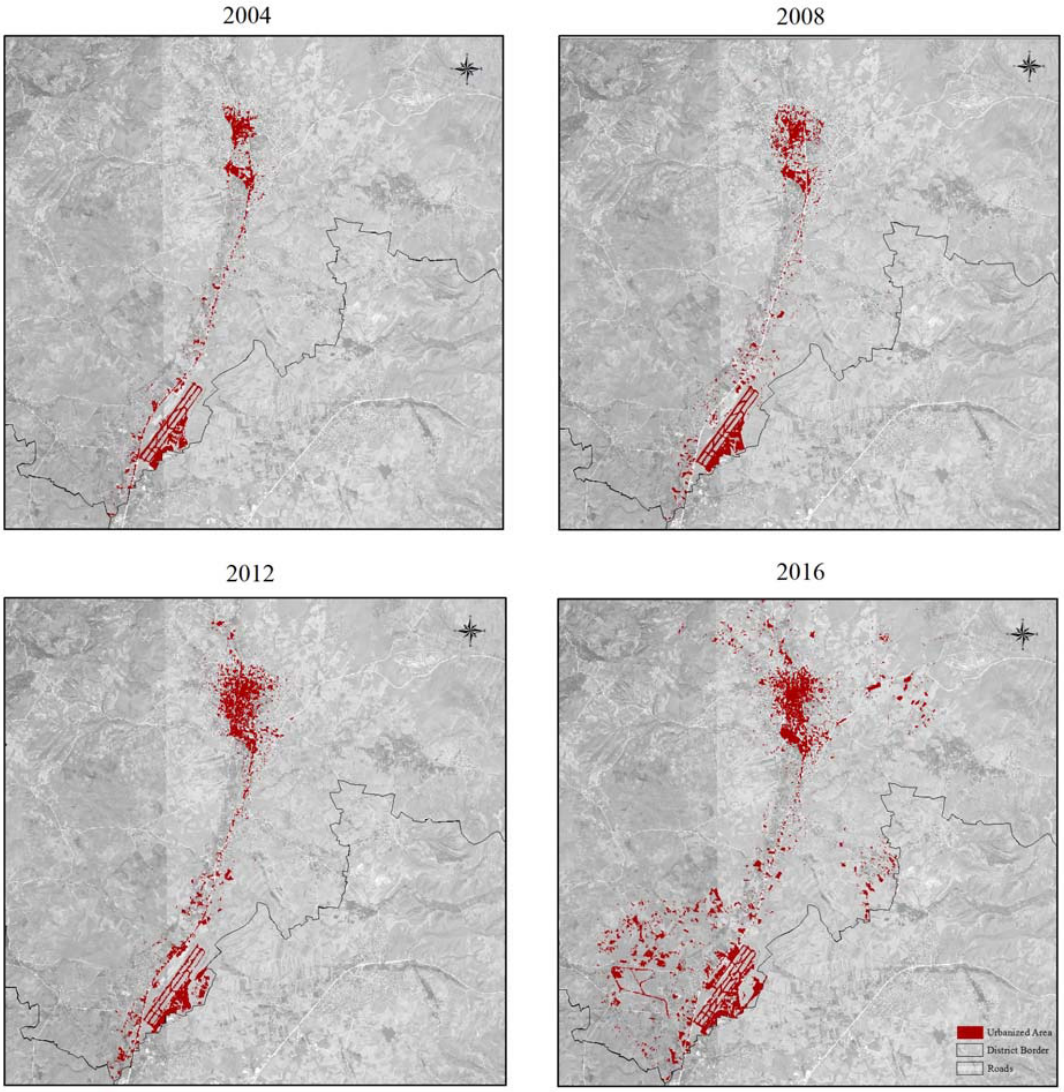

Figure 2. Çubuk District Urbanized Area Development (2004-2016)

The district of Çubuk is located to the north of the protocol road. The fact that Esenboğa Airport is located on the border of this district increases the significance of the district. Investment in the protocol road encourages urban development in the district of Çubuk. On the protocol road, the opening of ÖSYM (Assessment, Selection and Placement Center) e-Testing Center which has 5000-person capacity, Training Center of Ministry of Customs and Trade, Hotel Ibis and Otonomi Automobile Showroom which cost 500 million TL and has 11.000 visitor capacity per day, increases the employment opportunities and therefore the development and growth of the district. In addition, since 2016, the central campus of Yıldırım Beyazıt University is located in the district. During the period of 2004-2016, in the district of Çubuk, the sprawl in urban areas has increased by 181,5 % (Table 3).

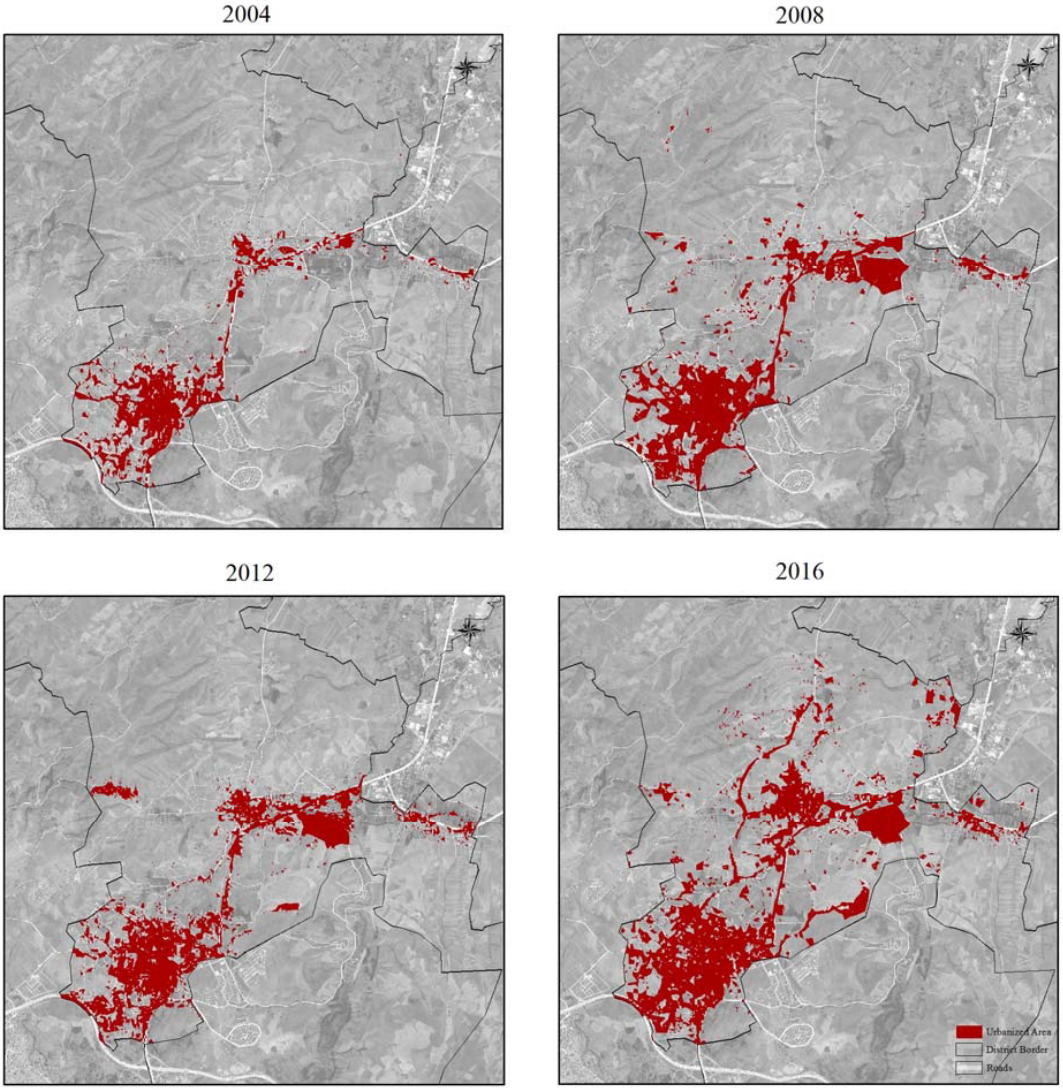

Figure 3. Pursaklar District Urbanized Area Development (2004-2016)

The district of Pursaklar is the closest district to Ankara city center within the study area. This feature, together with the investment in the protocol road and the North Ankara Urban Renewal Project, transform the district into a residential area that develops in terms of mass housing in the urban fringe the North Ankara Urban Renewal Project contains 18.000 house, 470.000 square meters private recreation area, 2 hotels, 2 congress centres, 180.000 square meters pond area, a 3-kilometer road, a tunnel and a viaduct. [22]. With the development of the service sector and the opening of special training facilities in line with the needs of mass housing projects, the area covered by the district grows and the district develops in the west and north directions. Urban sprawl rate in the Pursaklar district between the years 2004 and 2016 is by 132.5% (Table 3).

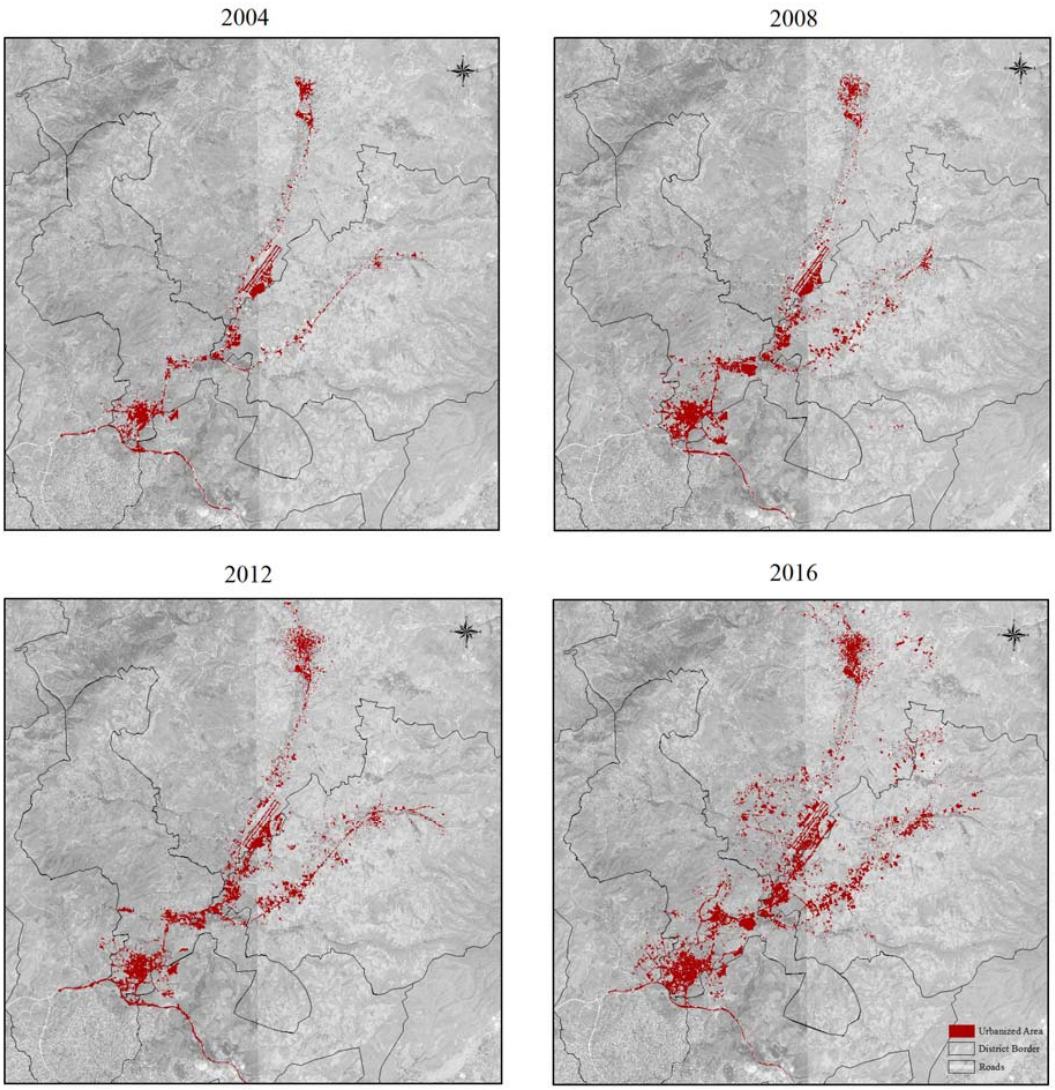

Figure 4. All Districts Urbanized Area Development (2004-2016)

The study area is located in the northeast of Ankara (40 ° 0'17 "N, 33 ° 0'9" E). This area is highly important for the development of urban texture since it has transport connections such as Esenboğa Airport and the protocol road. The transportation investments linking this region to the city center create the effect of sprawl in urban areas. When the tables and maps are examined, it is seen that the period in which the urban sprawl rate is highest is 2012-2016 period. This date range refers to the time after the construction of transportation and housing investments.

Table 2. Urbanized Area

	Urbanized Area (Ha)			
District	2004	2008	2012	2016
Pursaklar	838.3	989.5	1200.8	1948.7
Çubuk	481.3	697.5	718.3	1355.0
Akyurt	437.1	799.0	814.6	1348.2
Total	1756.7	2486.1	2733.7	4651.9

Table 3. Urban Sprawl Rate

	Urban Sprawl Rate (%)			
District	2004-2008	2008-2012	2012-2016	2004-2016
Pursaklar	18.0	21.4	62.3	132.5
Çubuk	44.9	3.0	88.6	181.5
Akyurt	82.8	2.0	65.5	208.5
Total	145.8	26.3	216.4	164.8

The district of Pursaklar in terms of urbanized area size (1948.7 ha) and the district of Akyurt in terms of sprawl rate (208.5%) have the highest values (Table 2). In the period of 2008-2012, the fact that urban transformation projects were carried out, especially the North Ankara Project, and the proximity to the city center accelerated the spread in Pursaklar, and during the current period following this period, a substantial increase has been observed in the other two districts for some reasons such as the increase in transportation facilities and involvement of Pursaklar in the urban texture (Table 3).

Table 4. Population [21]

	Population			
District	2004	2008	2012	2016
Pursaklar	86792	91742	119593	137808
Çubuk	84381	80123	82408	87503
Akyurt	21456	24312	26572	31541
Total	192629	196177	228573	256852

Table 5. Population Density

	Population Density (Per/Ha)			
District	2004	2008	2012	2016
Pursaklar	103.5	92.7	99.6	70.7
Çubuk	175.3	114.9	114.7	64.6
Akyurt	49.1	30.4	32.6	23.4
Total	109.7	78.9	83.6	55.2

When the population data is evaluated, it is seen that the district of Pursaklar is the district where the largest number of people live thanks to the advantages offered by being the closest district to the city center (Table 4). The continuation of the urban transformation projects in this district and the domination of the high-density housing typology in this area show that the district also has the highest density of population (70,7%) (Table 5). The cause of Akyurt District's having the lowest population density is that the low-density housing typology is preferred in the area and that the area had a rural characteristic before the investments. (Table 5).

Table 6. Population Increase and Population Density Decrease Rate

	Population Increase Rate (%)	Population Density Decrease Rate (%)
District	2004-2016	2004-2016
Pursaklar	59	32
Çubuk	4	63
Akyurt	47	52
Total	33	50

When population densities are considered, although the rate of urban sprawl increases, the density of population decreases in all areas due to the fact that low-density housing typologies are preferred in the use of related area. The rate of decrease in population density is the highest in the district of Çubuk

(63%), while it is the lowest in the district of Pursaklar (%32) (table 6). The main reason for this result is that the typology of mass housing is preferred in the district of Pursaklar while the typology of much lower-density housing with high utilization of space is preferred in the other areas. Thus, the district of Pursaklar has the lowest rate of sprawl in terms of area, however, it is the densest area in population.

When the study area is evaluated as a whole, in the period of 2004-2016, sprawl in urban areas was by 164% (Table 3) and population density increased by 33% (Table 6). As the sprawl rate in the study areas increased faster than the population, the population density decreased by 50% in the related period (table 6).

4. Conclusions

Urban sprawl is one of the fundamental problems of sustainable planning in terms of efficient use of resources and management of urban population. Remote sensing and GIS techniques are frequently used to follow and model a dynamic process such as urbanization and to predict the outcome of possible interventions. Measuring the change and development in urban areas with these dynamic methods is critical in terms of analysing the current situation of cities and developing future projects. In addition, the use of these methods is also used for optimal planning of natural resources within the scope of sustainability principle. In the study area, the results of a transportation investment that is legal and regulatory compliant were determined between 2004 and 2016 by using remote sensing and GIS techniques. Following this investment, mass housing projects were developed in areas that are close to the district centers and the development of detached houses with garden was accelerated on the fringes of the district centers. This transport investment, which is specific to the protocol road, not only encourages population growth and growth in urban areas, but also causes some urban functions to shift towards the area. Although the urban development of the study area is an economically favourable impression, it also causes environmental, infrastructural and unplanned urbanization problems in the long run. Therefore, the transportation investments planned for the continuation of the economic activities in the cities should be formed by considering of the sustainability of natural resources within the frame of comprehensive transportation and construction plans instead of fragmented projects.

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