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Scenario-based land use estimation: The case of Sakarya

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Abstract
This paper presents scenario-based modelling of urban land use which stem from interactions of the urban functions of Sakarya, one of the most important city for agricultural production and a vulnerable region in terms of natural resources and seismicity in Turkey. The purpose of the paper is to estimate the future land use pattern of Sakarya and discuss the environmental effects of alternative spatial policies. 'Whatif?' approach which allows the users to develop various scenarios, provide a basis to measure the impact of new development areas on natural environment and revise the policies easily in relation to the land use estimation model results and future urban development pattern.

Keywords
Land use, Land use policy, Sustainable development, Urbanization.

1. Introduction

Estimation of future land use pattern are critically important for understanding the effects of alternative planning decision and assessing their impact on the environment in urban planning process. Generally, the techniques of future land use estimation cover spatial and temporal processes. These are the techniques which include uncertainty factor and developed on the basis of the alternative scenarios. Nowadays, urban growth modeling studies witness a change towards building 'what if' scenarios and domination of these scenarios over many modelling efforts (Batty and Torrens, 2005). 'Planning Support Systems' (PSS) constitute an informatics roof which unites all current and future information technologies used for planning with three concepts: information, model and visualization (Klosterman 1999; Geertman and Stillwell, 2004). Considering restraints of the planners about the use of sources and information, an approach of improving alternative 'scenario-based estimations' by using the available database has been introduced, instead of giving a precise forecast about the future (Klosterman, 1998).

This paper presents scenario-based modelling of urban land use which stem from interactions of the urban functions of Sakarya, one of the most important city for agricultural production and a vulnerable region in terms of natural resources and seismicity in Turkey. Modelling the prospective urban growth of Sakarya based on different development scenarios is expected to contribute to the assessment of the future urban development of Sakarya and determination of the strategies regarding the future. Therefore, this paper aims to estimate the future land use pattern of Sakarya and to discuss the environmental effects of alternative spatial policies. In this paper, 'what-if?' model was used, since it allows the users to formulate various scenarios and select the most appropriate one among these and assess its impacts. In addition, this model provides the users with the opportunity to revise their assumptions and policies easily in relation to the model results.

The paper has two objectives: The first objective is to provide an input for the land use planning, and the second one is to develop the alternative local land development strategies in the future. The organization of the paper is as follows: The literature review related to urban spatial modelling have been addressed in the second part. This part is followed by the background information of case study area. In the fourth part consists of methodology and modelling procedure followed by the discussion section. The paper is finalized with concluding remarks and the implications of the research for the future.

2. Literature review: Modelling of urban spatial development

As the human communities have become more dependent on the natural resources, it is progressively becoming an obligation to protect these natural resources, sustain the biological diversity and ensure continuation of the healthy urban mechanism. The urban planning which aims to organize the human actions by protecting the natural resources and ensuring their sustainability faces an increasing uncertainty about the future. The interaction between the human communities and natural systems is of vital importance for the successful functioning of a city (Barredo et.al, 2003; White et.al, 1997), and the land use pattern is emerged as a result of these interactions. However, it is very difficult to understand the nature of these interactions that are tried to be explained by urban systems modelling (Openshaw, 1995). The urban modelling is building and executing the complex mathematical models in order to estimate the urban growth form in the future with the aim of supporting the planners, politicians and other decision-making mechanisms. Role of the models in the planning process is to understand the behaviors of the urban systems and help perform the urban development in compatible with the public policies (Batty, 1976).

It is essential to analyze the land use dynamics in the urban modelling approaches in order to understand the urban functioning. The fact that densely populated cities exhibit urban expansion towards forests, wetlands and agricultural lands results in rapid depletion of the natural resources and degradation of the ecosystems. Therefore, information concerning urban growth rate, spatial development form and concept is necessary for the planning strategies to designate the reserves and capacities of the future natural resources and understand the current and future impacts of the land use changes. Estimating the future environmental results of the urban growth requires to forecast such changes in land use and their effects on the natural resources.

One of the most important challenges to be encountered by the natural and social sciences in the years ahead will be to understand the changes undergone by the cities due to interactions of the humans and natural systems. There are so many complex processes in the interaction of the cities with the natural systems and the change periods. During this periods, urban systems are subject to temporal and spatial changes as a result of the choices and actions of the individuals. These choices and actions are guided by the multiple factors. Households, business circles, real estate developers, managers, etc. are among the important factors of this change. Households and business circles decide about the production, consumption and selection of the location within the city. Real estate developers are in search of the new investments. Managers decide the infrastructure and service investments in consideration of the policies and laws. All these decisions change structures of the ecosystems due to such actions as use of the resources, conversion of the lands into the urban land, generation of emission and wastes. The recent modelling studies conducted to understand the dynamic natures of the urban and natural systems concentrate on the relations of the humans and natural system (Alberti and Waddell, 2000).

Another important challenge in urban land use modelling studies is to understand the interactions between land use and transportation system. Earlier version of travel demand models were based on estimating spatial movements and flows. In mid-twentieth century, classical urban transportation model known as four-step model was widely used, but this modelling techniques were found quite static. Growing understanding of the impact of the interaction between cities and transportation systems on urban growth have led to develop Integrated Land Use Transport (LU-T) Model (Sivakumar, 2007). Earlier version of LU-T model was tried to be explained by gravity type models, first one of which was developed by Lowry in 1964. Later on, such integrated LU-T models as MEPLAN by Echenique, (1985), MUSSA by Martínez (1992), and UrbanSim by Waddell (2002) were developed to better explain the interactions between land use, transportation, the economy, and the environment. Even though such LU-T models were developed and evolved, the 4-step model continues to represent the transport modelling component (Sivakumar, 2007).

Sivakumar (2007) groups the LU-T model in three category. The first group is Travel Demand Models. This type of models divide into five sub categories: Aggregate models, disaggregate trip-based models, tour-based models, activity-based models and modelling freight demand. The second group is operational integrated LU-T models in which models grouped into two sub categories: Static models and dynamic models. Static models are the earliest LU-T models which aim to explain the relationships between the land use and transportation systems. These type of models based on gravity equations or input-output formulations. Since early models approach the matter only from a mathematical perspective, land use spatial strategies and policy analysis remains weak (Sivakumar, 2007). Whereas, dynamic models defined as "…the development of improved modelling methodologies such as entropy-based interaction, random utility theory, bifurcation theory and non-linear optimization, together with significant computational advances has paved the way to the development of dynamic land use-transport model systems" which divided into two categories: General Spatial Equilibrium models and Agent-based Micro-simulation models such as UrbanSim by Waddell

(2002) (Sivakumar, 2007).

Current operational LU-T models contain several shortcomings which are highlighted by Sivakumar (2007). For example, the models highly rely on a) excessive spatial aggregation, b) static equilibrium assumptions and c) four-stage travel demand modelling methods. In addition, the most of LU-T models is operated under the lack of endogenous demographic processes and intricate links between the land-use and travel demand components (Sivakumar, 2007).

Latest LU-T modelling techniques called "Next-Generation Integrated LU-T Models" have been developed in response to the shortcomings of the current LU-T models and they are currently in evolution. According to the Sivakumar (2007), "…these next-generation models build on the strengths and experience of currently operational models, which include generally strong microeconomic formulations of land and housing/floor-space market processes and coherent frameworks for dealing with land use-transport interactions… These 'next-generation' LU-T models are disaggregate, activity-based and strive for greater integration between the various components of the land use-transport system".

Several analytical techniques have been created by using various theories about the urban modelling. Urban form, urban growth and economy of the cities, inter-city relations, social and economic functioning are some of the approaches on which these theories are based. The first examples concerning modelling of the urban systems can be seen in Von Thünen (1966), Christaller (1966), Lösch (1954) and Alonso (1964) (Dökmeci, 2005). In the subsequent years, it became possible to make more complex calculations following the progresses in computer and software technologies and it was endeavored to model the cities considering their complex characteristics. New modelling searches have introduced the dynamic modelling concept. This modelling approach is based on the complex systems theory (Batty, 2005) and has lately become a primary issue in the city and ecology models in terms of the geographic information systems (Meaille and Ward, 1990; Batty and Longley, 1994; Veldkamp and Fresco, 1996; White and Engelen, 1997; Torrens, 2000; Yang and Lo, 2003; Torrens, 2006).

Quite a few of the models which have been developed in the last twenty years about the city and ecology modelling (Meaille and Ward, 1990; Batty and Xie, 1994a, 1994b; Landis, 1995; Veldkamp and Fresco, 1996; Pijanowski et al., 1997; White and Engelen, 1997; Clarke and Gaydos, 1998; Li and Yeh, 2000, Yang and Lo, 2003; Torrens, 2006) are cell-based and have been developed as separate software and/or a component of the software of geometric information system. These models have the quality of vector or raster data and generally operated with the aid of software and visualized by integrated with geographic information systems. Such dynamic urban models are qualified as stochastic. BASS II (Bay Area Simulation System) which was developed by Landis (1992) for the San Francisco Bay Area of the USA and used by him for modelling of the urban growth in the related region can be given as an example for the dynamic urban modelling studies. This model aims to perform a realistic simulation of the growth in the related region and explain how the urban growth pattern and density will change in case the urban growth policies are applied on local or regional level (Landis, 1992). In the subsequent studies, Landis (1995) developed CUF (California Urban Futures) model which he applied to Sacramento and San Francisco Bay Area. Advantage of this model in relation to the previous one is that it takes into account the public policies and behaviors of the private entrepreneurs and can evaluate the alternative land use decisions on local-regional scale. Landis improved the CUF model even more and developed the CUF II model (Landis, 1997). In CUF and CUF II models, a modelling technique which was obtained from joint use of the statistical estimation methods and geographic information systems was used.

In the dynamic urban modelling studies, there are also modelling techniques which include uncertainty factor (stochastic) and developed on the basis of the complex systems theory. Recently, modelling efforts which stipulate creation of different scenarios with alternative policies have started to prevail in the urban modelling studies (Batty and Torrens, 2005). Planning Support Systems (PSS) which have come out in recent periods and lay a basis for such modelling studies include various tools supporting geographic information technology and miscellaneous aspects of the planning process (Geertman and Stillwell, 2004).

Conceptual structure of the planning support systems is composed of three components which are information, model and visualization (Klosterman, 1999a). Generally PSSs are broader definitions of the geographic information systems which support many aspects of the planning process (e.g. problem defining, data collection, spatial and process analysis, modelling, visualization, scenario building, prediction, simulation, reporting and decision-making) (Harris and Batty, 1993; Klosterman, 1997; Brail and Klosterman, 2001; Geertman and Stillwell, 2003; Geertman and Stillwell, 2004; Geertman and Stillwell, 2009). Considering limited opportunities of the planners about information and sources, it becomes possible, with the aid of PSS, to develop alternative scenarios and deliver estimations about the future by using the existing data sets (Klosterman, 1998).

PSSs present special support for the specific phases of the planning process by integrating the GIS functions and the computer-aided modelling and visualization tools (Harris and Batty, 1993; Klosterman, 1997; Brail and Klosterman, 2001; Geertman and Stillwell, 2003; Geertman and Stillwell, 2004; Geertman and Stillwell, 2009). Harris and Batty (1993) associate the PSS concept to a system integrated with a set of computer-based models and define three phases of PSS; i.e. definition of the planning phases and problems, designation of the system model and method and conversion of the basic data respectively in a manner to provide input for the model. Brail and Klosterman (2001) mention about four characteristics for a perfect PSS. According to them, a PSS should be a fully integrated, flexible and user friendly system and provide the following opportunities to the users:

"(1) It should enable the user to select and use the most suitable analysis and estimation tools for a specific task/study. (2) To access local, regional or national database with the aid of PSS and make association with the corresponding analytical or prediction model (3) To run the suitable models to determine the alternative policy options about the present situation and future and effects of different assumptions and (4) To view such graph results as graphics, maps, interactive video/sound images."

Consequently, PSS is an integrated framework which is based on planning theories and composed of the data, information, method and model as well as the tools working on a graphical user interface (Geertman and Stillwell, 2003).

Based on the PSS concept, various methodological approaches and applications have been developed to support the planning process (Brail and Klosterman, 2001; Geertman and Stillwell, 2003; Geertman and Stillwell, 2009). Some of the popular applications frequently seen in the literature are as follow: California Urban Futures (CUF) (Landis, 1994), DUEM, (Xie, 1996), SLEUTH (Clarke et al, 1997), TRANUS (De la Barra, 2001), UrbanSim (Waddell, 2000), What if? (Klosterman, 1999a), CommunityViz (Kwartler and Bernard, 2001), INDEX (Allen, 2001), Place3S (Snyder, 2003), Environment Explorer (Engelen et al, 2003), the SPARTACUS (Lautso, 2003), Land Use and Impact Assessment (LEAM) (Deal et al, 2005). In addition to these, there are also micro-simulation models which are developed for planning, design and green space care and help planning processes (Geertman and Stillwell, 2009).

Out of the models stated above, "What if?" software developed by Klosterman (1999b) has been used in this paper. What if? is a strategy-centered planning tool and puts forth possible alternatives regarding prospective spatial development form of a city within the framework of the adopted assumptions and formulated scenarios.

Geertman and Stillwell (2003) emphasize that what if? is flexible and allows the users to specify importance of the factors affecting urban development on various levels. What if? model renders it possible to select a scenario among the alternative scenarios and determine impacts of each scenario. This model also enables the users to easily change the assumptions and policies and reanalyze their results (Klosterman, 2001). What-if?' allows the users to formulate various scenarios based on different spatial strategies, evaluate the each result and assess its impacts. In addition, this model provides the users with the opportunity to measure the effects of the each policy and assumption on the future urban land use. Modelling procedure has been included in the 4rd chapter of the study.

3. Case study: Sakarya

Sakarya province is located in the northeast of the Marmara Region. It is surrounded with Bolu in the east, Kocaeli and Bursa in the west, Bilecik in the south and Black Sea in the north. While it was a village of Kocaeli in 1658, Sakarya became a sub-district in 1742, a district in 1852 and a province in 1954. Today, following the earthquake of 1999, Sakarya gained the status of Metropolitan in 2000. Sakarya has 16 districts in total out of which Adapazarı, Ferizli and Söğütlü are central districts (Governorate of Sakarya, Provincial Directorate of Environment and Forestry, 2008). Population of the city is 888.556 according to 2011 population census (TSI, 2012).

Such macro issues as population increase, economic development and upper scale investment decisions are effective in spatial development of cities. Whereas, spatial development is in close interaction with the natural structure. If spatial growth of the city cannot be kept under control and guided well, then, the natural structure is adversely affected. Non-sustainable development results in weakening of the life-support systems of a city, increasing of the vulnerability against natural disasters and decreasing of the resistance as well as deterioration of the overall life quality. Therefore, it gains importance to describe the basic limiters and guiders arising from natural structure of a city in order to control the future urban development. In this research, each component which constitutes geographical structure of Sakarya has not been analyzed in detail, since such a study was conducted by Provincial Directorate of Environment and Forestry of Sakarya in 2008. Instead, this paper focuses on geographical components, which would limit future urban development of Sakarya, have been examined as main groups and their characteristics which directly provide input for the land use model have been defined.

Sakarya exhibits wide-ranging and very rich location features with its topography, geological conditions, soil structure, water resources and land cover. This richness in natural structure is critically important for biological diversity and sustainability of ecosystems. 6 main groups above have been dealt with, in this study, as control factors of natural structure used in future urban growth modelling of Sakarya.

Land use information is one of the basic data used in modelling of the spatial development of the study area (Figure 1). According to this, land use types and sizes of the study area where 13 land use types are available have been given in Table 1.

4. Data and methodology

What-if? is a kind of bottom-up modelling type and starts the modelling procedure with homogeneous land units or uniform analysis zones (UAZs).Homogeneous land units (UAZ) describe the homogeneous polygons (can be defined as geometrically closed areas or grids) generated by the geographical information systems (Klosterman, 1999; 2001). These units bear information of various parameters regarding the land they represent such as land use type, soil capability and distance to the city center.

The model performs land allocation based on the related units (UAZs) concerning the estimated land use demands which differentiate as per the alternative public policy preferences and puts forth the spatial reflections of the probable regional trends in the future (e.g. growth trends for popula-

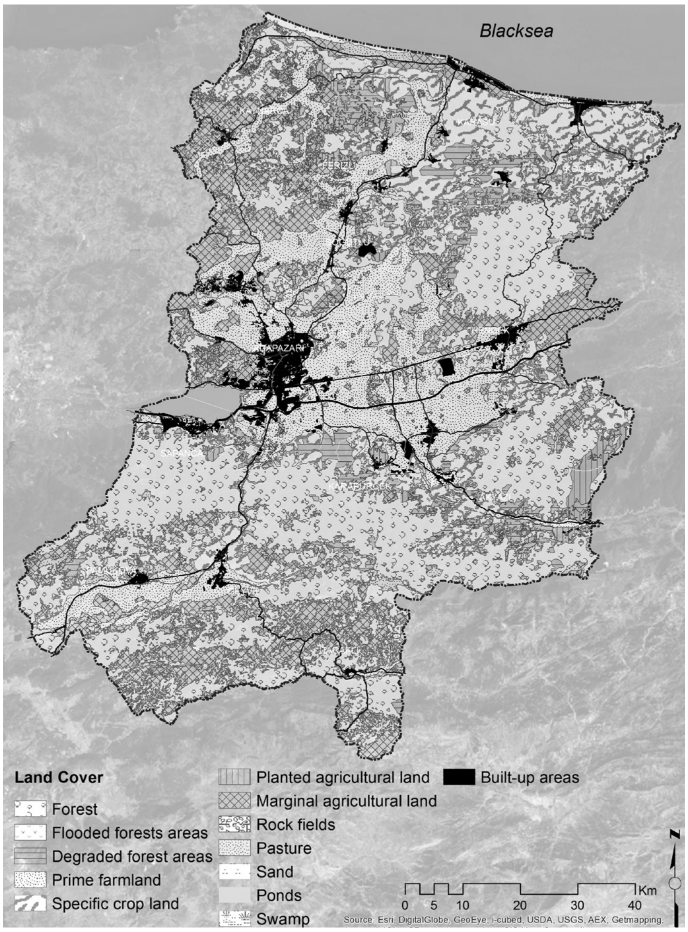

Figure 1. *Land cover of Sakarya (SGM, 2011).*

Table 1. *Land cover classification in Sakarya (Provincial Directorate of Environment and Forestry, 2008).*

Land cover class	Size (Ha)	Percent
Prime farmland	87552,37	17,99
Specific crop land	50958,14	10,47
Planted agricultural land	20990,31	4,31
Marginal agricultural land	81466,25	16,74
Degraded forest areas	36030,23	7,40
Flooded forests areas	1447,65	0,30
Forest areas	177198,68	36,41
Grassland/Pasture	9726,13	2,00
Swamp	363,07	0,07
Ponds	6824,47	1,40
Rock fields	170,49	0,04
Sand	1726,71	0,35
Built-up areas	12182,73	2,50
Total	**486637,22**	**100,00%**

tion and employment). UAZs are the main executive units of the model and the estimated land use model is designated on the basis of the information obtained from three main phases: (1) land suitability analysis), (2) growth and (3) land allocation (Klosterman, 2001). Modelling procedure of the model can be seen in Figure 2.

4.1. Land suitability stage

Land suitability analysis is composed of four steps: (1) determination of land suitability factors which help to determine the natural threshold(s), (2) designation of the factor weights, (3) grading of the factor variables and (4) determination of the land use types allowed for land conversion (Klosterman, 2001; Asgary, Klosterman and Razani, 2007).

a. Determination of the land suitability factors: Factors which are suitable or not for development of a certain land use. These factors define the natural thresholds which are limiters and guiders for the future development. These are seismicity, land classification, soil groups, erosion status, hydrography and conservation sites. In addition to these informations of natural environment, the distance variable are also considered as an influential factors on accessibility, urban form, land value and finally urban spatial development. These factors are 'the distance to': railway stations, major road, road junction and city centers (Figure 3).
b. Designation of the factor weights: It aims to specify relative importance of the factors in order to find out relative conformity of each land use type in different locations (Table 2).
c. Grading of the factor attributes/features: During this step, different areas/attributes/features of a certain factor are graded (e.g. There are such qualities as forest, pasture, meadow, heathland in the vegetation factor) (Klosterman, 2001).
d. Determination of the land use types allowed for land conversion: The fourth step includes determination of the current land uses which may be allowed to be converted into another land use (Table 3), if required during the land allocation process (Klosterman, 2001; Asgary, Klosterman and Razani, 2007).

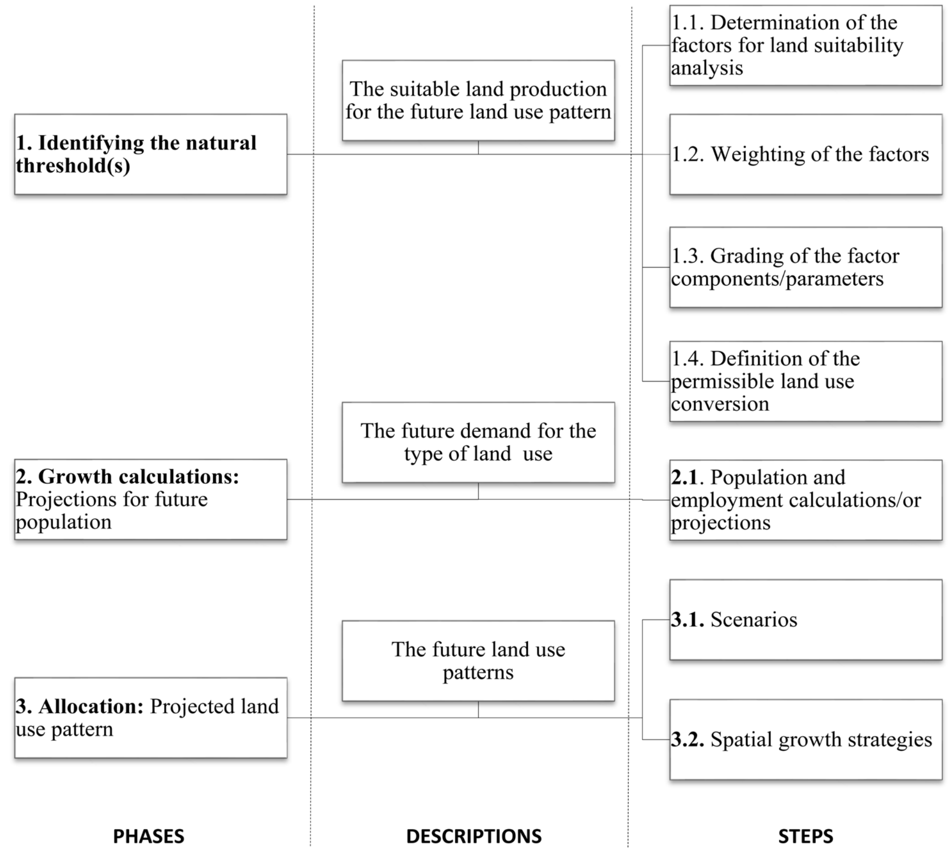

Figure 2. *The flowchart of the model (Derived from Klosterman, 2001).*

Following all steps and after all necessary inputs are provided for the suitability factors, land suitability analysis is obtained for each land use category of the model.

This phase includes determination and weighting of the factors which control, guide and limit the growth in the spatial development modelling. Weighting means determination of the factors influence in the location choice of new settlement areas and designation of the relative importance of the factors in the site selection (Klosterman, 2001). Influence of each factor is graded over 100 points. High points show that the related factor has a high level of impact on the location choice of new settlement areas. During this step, different attributes of a certain factor are graded (Klosterman, 2001). Grading is performed over 100 points and the highest score shows the most preferred situation while 0 (zero) expresses unfavorable region/location (Table 2).

4.2. Growth: Population and density projections

The second phase of the model includes calculation of the future (target year) land use demands. The future land use demands are calculated under the different growth assumptions made for different land use demands. Accordingly, future land use demands are calculated by means of the projection calculations about population and employment within the framework of certain acceptances (Klosterman, 2001).

Population of Sakarya is continuously increasing especially in Adapazarı district. This is mainly resulted from industrialization and inclusion of Kocaeli and then Sakarya into development hinterland of Istanbul. Pursuant to the examination of the population trends on district basis as of 1990, all districts have undergone population increase except for Taraklı district, and only Taraklı constantly has lost population (Figure 4 and Table 4).

Population values of each district were calculated for 2015, 2020 and 2025 (target year) based on the popu-

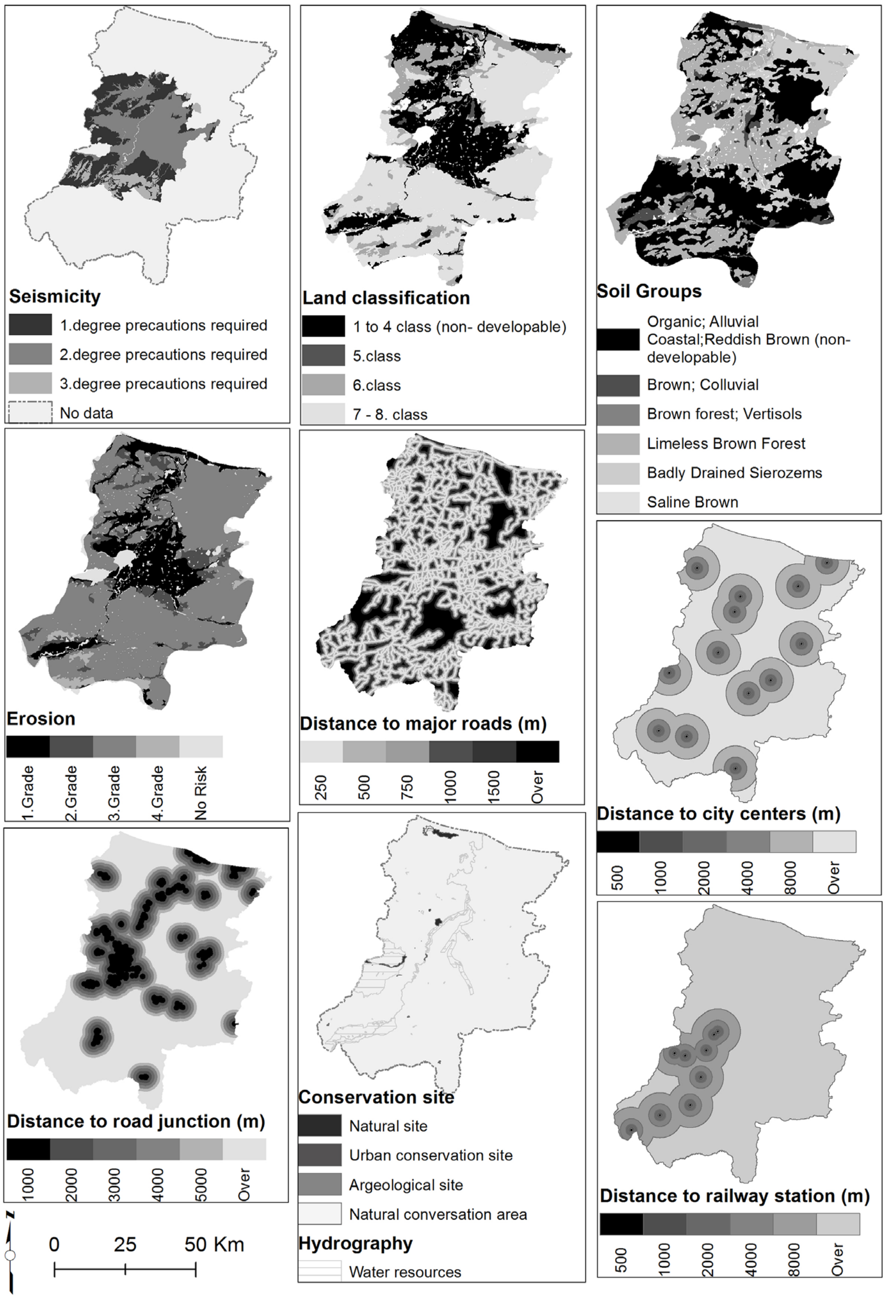

Figure 3. *Suitability factors.*

lation increase trends of the districts. Polynominal equation which presents by far the best predictions about the population trends of each district as of 1990 was used and population values of the next three terms (2015, 2020, 2025) were predicted with the related equation. The predicted populations constituted the population parameters of the target year and taken as basis for the built-up area to be needed in the future (Figure 4 and Table 4).

In Figure 4, graph of Adapazarı shows an almost linear nature in terms of population increase, but gradient of about 45 degree points out that population will increase significantly in the future. As a matter of fact, population of Adapazarı has been calculated to be 605214 in 2025. Besides, Sapanca, Hendek, Karapürçek and Pamukova are other districts with significant population increase. Taraklı is, on the other hand, the only district that loses population.

Size and number of the households and population density are other population-related parameters used in the model (Table 5). Average household size was taken as 3.8 in the study area

Table 2. *The weight of the suitability factors (the number in parenthesis) and theirs attributes on 100 point-scales.*

Land classification (90)	Points	Distance to railway station (60)	Points
1., 2., 3., 4. Class	non-developable	500 m	35
5.class	90	1000 m	70
6.class	95	2000 m	90
7.class	100	4000 m	70
8.class	100	8000 m	35
Seismicity (100)		8001 m over	10
1.degree precautions required	50	**Distance to major road (85)**	
2.degree precautions required	35	250 m	100
3.degree precautions required	15	500 m	90
Soil groups (70)		750 m	80
Organic Soils	non-developable	1000 m	70
Alluvial Coastal Soils	non-developable	1500 m	60
Insufficiently Drained Alluvial Coastal	non-developable	1501 m over	50
Reddish Brown Soils	non-developable	**Distance to road junction (95)**	
Brown Soils	0	500 m	100
Colluvial Soils	0	1000 m	90
Brown Forest Soils	35	2000 m	80
Vertisols	35	4000 m	70
Badly Drained Sierozems	65	8000 m	60
Limeless Brown Forest Soils	75	8001 m over	50
Saline Brown Soils	100	**Distance to city centers (100)**	
Erosion (100)		500 m	100
1.grade	0	1000 m	90
2.grade	25	2000 m	80
3.grade	50	4000 m	70
4.grade	75	8000 m	60
No risk	100	8001 m over	50
Hydrography (50)		**Conservation site (50)**	
Dam, Swamp, Ponds, Lake, Basin, River, Irrigated lands, Flood zone	non-developable	Archaeological site	0
		Natural site	0
		Natural conversation area	0
		Urban conservation area	0

Table 3. Current land uses to be converted to future residential use.

Land cover	Response for new residential areas	Land cover	Response for new residential areas
Prime farmland	0	Pasture/Grassland	1
Specific crop land	0	Swamp	0
Planted agricultural land	1	Ponds	0
Marginal agricultural land	1	Rock fields	1
Degraded forest areas	0	Sand	0
Flooded forests areas	0	Built-up areas	1
Forest areas	0		

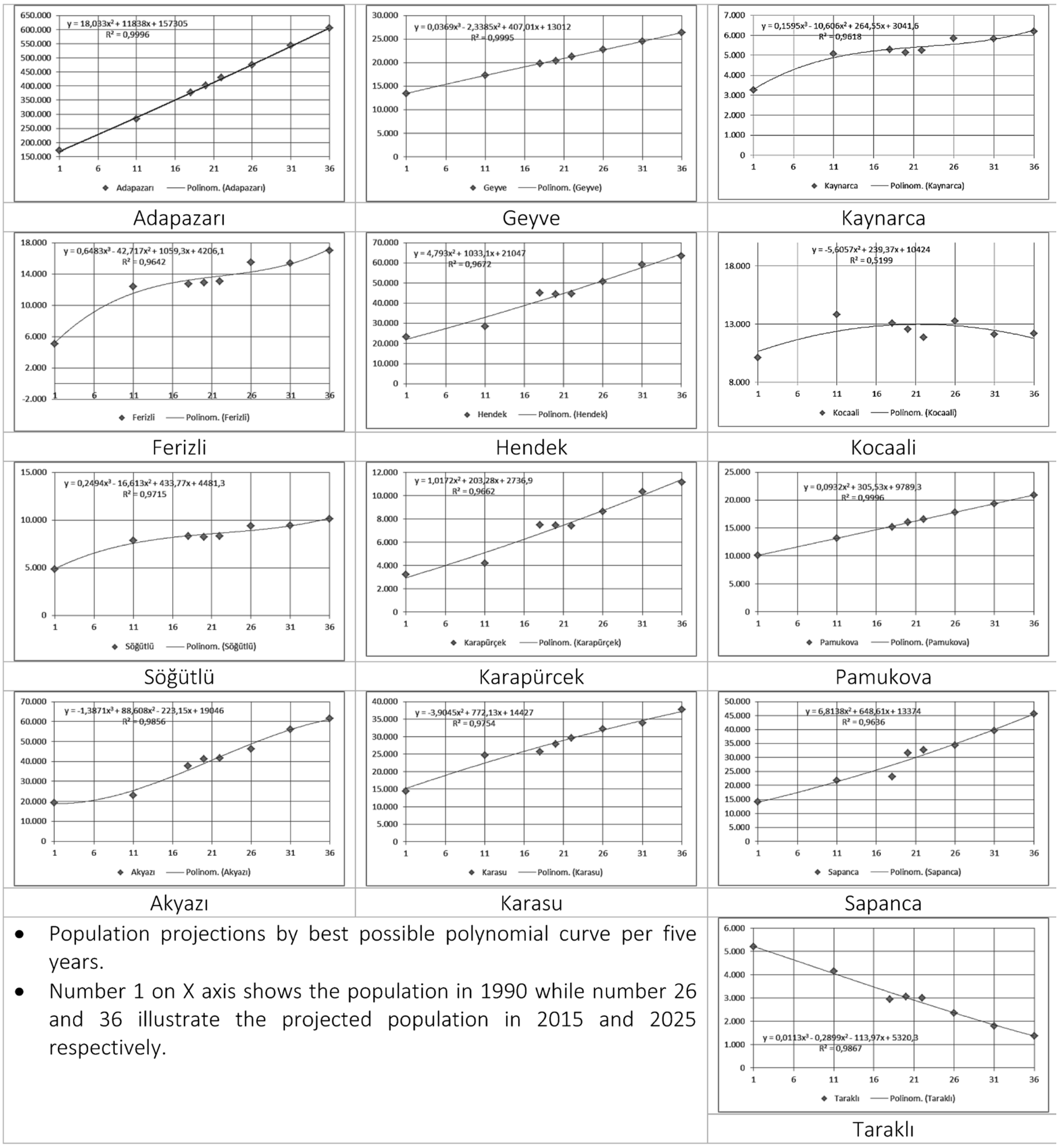

Figure 4. *Population estimations.*

(TSI, 2012).

Amounts of the built-up areas and gross density values can be seen below district by district for Sakarya. The

Table 4. Estimated population of the districts by years.

	1990	2000	2007	2009	2011	2015	2020	2025
Adapazarı	171225	283752	377683	402310	429331	475935	543185	605214
Ferizli	5058	12379	12733	12914	13058	15483	15392	17006
Söğütlü	4839	7858	8306	8233	8306	9391	9443	10112
Akyazı	19331	23192	37729	41179	41738	46313	56038	61539
Geyve	13405	17318	19802	20318	21317	22727	24479	26345
Hendek	23397	28537	45090	44418	44680	50679	59108	63361
Karapürçek	3211	4186	7467	7452	7388	8611	10307	11151
Karasu	14500	24672	25607	27914	29615	32192	33943	37732
Kaynarca	3257	5064	5278	5144	5244	5858	5831	6201
Kocaali	10131	13793	13089	12560	11841	13264	12126	12186
Pamukova	10088	13200	15181	16047	16566	17791	19334	20917
Sapanca	14124	21727	23202	31614	32732	34420	39685	45553
Taraklı	5193	4146	2947	3055	2997	2355	1802	1376
Total	297759	459824	594114	861570	888556	915835	1069378	1145164

built-up areas include houses, trade, industry, public facility areas and all other human-made facilities. Accordingly, the five most densely populated districts are respectively Adapazarı, Pamukova, Akyazı, Geyve and Karapürçek. The least populated districts are Kocaali, Söğütlü and Karasu, starting from the least populated one.

4.3. Land allocation: Future growth pattern

In the last phase of the model, the future land use types are allocated "in the most suitable areas" on the basis of the demands obtained depending on the land suitability analysis results and projection calculations, and change in the natural resources are analyzed. The future land use pattern is obtained following this phase. It is possible to differentiate this pattern according to the alternative scenarios (Klosterman, 2001; Asgary, Klosterman and Razani, 2007). This phase is composed of two steps which are developing scenario and determining the spatial development strategies which would affect the future urban growth. At the end of the land suitability analysis, the following criteria are taken into account in the given order while allocating the future

Table 5. Number of households by the districts (Provincial Directorate of Environment and Forestry, 2008).

Districts	Population	Household size	Number of household	Built-up areas (ha)	Gross density (p/ha)
Adapazarı	429331	3.8	112982	5688.24	75.48
Ferizli	13058	3.8	3436	347.4	37.59
Söğütlü	8306	3.8	2186	457.06	18.17
Akyazı	41738	3.8	10984	807.2	51.71
Geyve	21317	3.8	5610	428.53	49.74
Hendek	44680	3.8	11758	1280.05	34.90
Karapürçek	7388	3.8	1944	151.54	48.75
Karasu	29615	3.8	7793	1074.18	27.57
Kaynarca	5244	3.8	1380	125.95	41.64
Kocaali	11841	3.8	3116	655.59	18.06
Pamukova	16566	3.8	4359	228.05	72.64
Sapanca	32732	3.8	8614	735.08	44.53
Taraklı	2997	3.8	789	77.08	38.88

land use types to the land units (UAZs) obtained for different land use types: land suitability, size of the land, spatial control parameters and randomness. Spatial control parameters are among the remarkable ones of these criteria.

Spatial control parameters describe how future growth of a settlement will be guided and what kind of limitations there will be. Master plan of a city can be given as a proper example. Master plans define spatial location choice of future land use demands. Another spatial control parameter can be transport axis. According to this, linear growth of the city can be induced along the transport axis and it can be defined as a spatial development control parameter. Another spatial development control parameter can be infrastructure investments. It can be foreseen that future urban growth will continue primarily in the areas with completed infrastructure. To sum up, spatial development contl parameters are the factors which determine future growth pattern of a city.

On the basis of the demands obtained from the land suitability analysis results and projection calculations, the future land use types are allocated "in the most suitable areas", and change in the natural resources are analyzed. In the definition of "the most suitable areas" emphasized above, the rules are determined by the user again. The following criteria should be taken into account for the spatial allocation of the future land use: land suitability, size of the land, spatial control parameters and randomization. Spatial control parameters are among the remarkable ones of these criteria. Spatial control parameters describe which fields are prioritized for the future growth of a settlement. As an example, considering that the city will develop along the transport axis, linear growth can be defined as a spatial development control parameter. Thus, the urban growth can be thought to primarily take place on the lands in parallel with the transport axis. Another spatial development control parameter can be infrastructure. It can be foreseen that future urban growth will continue primarily in the areas with completed infrastructure. To sum up, spatial development control parameters are the factors which determine future growth pattern of the city.

After all phases are introduced to the system, the model is run and simulation results of spatial development are obtained for each scenario in the specified target years (e.g. once in every 5 years, 15-year estimation in total). Hence, urban growth form and its impact on the natural resources are found out. Consequently, each scenario shows how the urban growth will take place in the following years and what results it will bring, on condition that the assumptions are accurate and the adopted strategies are implemented.

4.3.1. Scenario-1: Controlled development scenario

According to this scenario, continuation of the distinctive characteristics of development (house type, density, mono-centric development trend, household size) in the future was analyzed and simulation of the future urban growth form was put forward. Leading decisions of the current construction plan were not taken into account in this scenario. It was considered that location choice could also be made outside the development areas projected by the current construction plan for the size of the future built-up area. It was accepted that built-up area demand would be met from planted lands, marginal agricultural lands and grasslands, and all other natural areas would be maintained and excluded from settlement activities. In other words, ecologically sensitive regions would be protected completely and new settlement demands would be directed to the remaining areas. This scenario assumes that new development areas would be concentrated near and around the current district centers. This scenario, in a sense, claims to control the future development which is why it is named as controlled development scenario. Acceptances and spatial development strategies of this scenario have been explained below.

- Built-up areas were considered to develop based on the current density degree of each district.
- It was considered that the future built-up area demand would be met

from planted lands, marginal agricultural lands and grasslands and that forest lands, fertile agricultural lands and ecologically sensitive regions (vineyards, orchards, reeds, stream beds, basins, etc.) would not be opened to settlement.

- While determining the future urban morphology, effect of the city center is decisive. Since the city has a flat topography, development was accepted to take place around district centers in each district.
- Order or precedence is as follows for the location choice of the future built-up areas: 1- Estimated development pattern (around the centers), 2- existence of great lands, 3- land suitability and 4- randomness.

Within the framework of these assumptions, results of the modelling and simulation works conducted for 3 terms until 2025 have been stated below.

4.3.2. Scenario-2: Sprawling development scenario

The main difference between this scenario and the previous one is that this scenario analyzes the situation where the future urban development is 20% less dense than the current status and new settlement demands are met along the transport axis and it puts forth a simulation for the future urban growth form. In some ways, this development form aims to reveal low-density sprawl formation along the transport axis. Leading decisions of the current construction plan was not taken into account in this scenario as well. It was accepted that built-up area demand would be met from planted lands, marginal agricultural lands and grasslands, and all other natural areas would be maintained and excluded from settlement activities. The fact that city centers will not have any influence on the new development areas means that there is not any control parameter in location choice of the new settlement areas. In this scenario, transport network stands out as the most decisive factor in the future urban formation. Acceptances and spatial development strategies of this scenario have been explained below.

- It was considered that market conditions would prevail, to a certain extent, in the future urban formation.
- Built-up areas were considered to be 20% less dense than the current situation in each district.
- It was considered that the future built-up area demand would be met from planted lands, marginal agricultural lands and grasslands and that forest lands, fertile agricultural lands and ecologically sensitive regions (vineyards, orchards, reeds, stream beds, basins, etc.) would not be opened to settlement.
- It was accepted that main axis would be decisive in determination of the future urban morphology and that urban growth would take place physically along the main transport axis in each district.
- Order or precedence is as follows for the location choice of the future built-up areas: 1- Estimated development pattern (along the road networks), 2- existence of great lands, 3- land suitability and 4- randomness

Within the framework of these assumptions, results of the modelling and simulation works conducted for 3 terms until 2025 as well as their impacts on the natural structure have been stated below.

5. Simulation results and discussion

According to results of both scenarios, increase in the amount of built-up areas and decrease in the natural areas (planted land, marginal agriculture and grassland) have been given in Table 6 and Table 7 respectively for the controlled scenario and sprawling development scenario. According to both development scenario, the first three districts with the highest change in the built-up areas are respectively Karapürçek, Akyazı and Adapazarı (Table 6, 7). Two scenarios gave different results in terms of spatial development pattern because of the fact that density value was taken 20% lower in the 2nd scenario and main transport axis were decisive in the urban growth form.

From the perspective of the impacts undergone by the natural areas, the highest loss (the most affected groups of 20% in overall Sakarya) under

Table 6. Changes in built up areas and natural areas in controlled development scenario (% change).

Adapazarı	**2015**	**2020**	**2025**	**Akyazı**	**2015**	**2020**	**2025**
Planted agricultural land	-1.40	-3.02	-3.97	Planted agricultural land	-0.16	-0.87	-1.35
Marginal agricultural land	-2.75	-6.61	-10.36	Marginal agricultural land	-3.78	-9.04	-11.65
Pasture/Grassland	-10.66	-27.45	-41.45	Pasture/Grassland	0.00	-0.80	-1.76
Built-up areas	10.86	26.52	40.97	Built-up areas	10.99	34.38	47.54
Ferizli	**2015**	**2020**	**2025**	**Geyve**	**2015**	**2020**	**2025**
Planted agricultural land	-0.94	-0.94	-1.30	Planted agricultural land	0.00	0.00	0.00
Marginal agricultural land	-1.58	-1.58	-2.51	Marginal agricultural land	-0.36	-0.60	-0.85
Pasture/Grassland	0.00	0.00	-1.94	Pasture/Grassland	0.00	0.00	0.00
Built-up areas	18.70	18.70	30.37	Built-up areas	6.76	14.91	23.68
Hendek	**2015**	**2020**	**2025**	**Karapürçek**	**2015**	**2020**	**2025**
Planted agricultural land	0.00	0.00	0.00	Planted agricultural land	-5.13	-13.26	-17.73
Marginal agricultural land	-0.69	-1.29	-1.61	Marginal agricultural land	-1.64	-2.04	-2.04
Pasture/Grassland	0.00	0.00	0.00	Pasture/Grassland	0.00	0.00	0.00
Built-up areas	3.61	8.51	11.05	Built-up areas	16.99	39.53	51.41
Karasu	**2015**	**2020**	**2025**	**Kaynarca**	**2015**	**2020**	**2025**
Planted agricultural land	-1.48	-3.71	-8.62	Planted agricultural land	0.00	0.00	-0.02
Marginal agricultural land	-0.55	-0.88	-1.37	Marginal agricultural land	-0.12	-0.12	-0.17
Pasture/Grassland	-2.36	-2.36	-2.62	Pasture/Grassland	0.00	0.00	0.00
Built-up areas	8.71	14.67	27.43	Built-up areas	11.95	11.95	18.29
Kocaali	**2015**	**2020**	**2025**	**Pamukova**	**2015**	**2020**	**2025**
Planted agricultural land	-2.82	-2.82	-2.82	Planted agricultural land	0.00	0.00	0.00
Marginal agricultural land	-0.95	-0.95	-0.95	Marginal agricultural land	-0.02	-0.02	-0.02
Pasture/Grassland	0.00	0.00	0.00	Pasture/Grassland	-0.28	-0.68	-1.00
Built-up areas	12.02	12.02	12.02	Built-up areas	1.95	4.72	6.97
Sapanca	2015	2020	2025	Söğütlü	2015	2020	2025
Planted agricultural land	-4.10	-12.86	-23.74	Planted agricultural land	0.00	0.00	0.00
Marginal agricultural land	-0.32	-17.46	-31.93	Marginal agricultural land	-1.50	-1.55	-2.53
Pasture/Grassland	0.00	-1.26	-1.26	Pasture/Grassland	-14.56	-15.05	-16.08
Built-up areas	5.16	21.32	39.17	Built-up areas	13.12	13.70	21.89

the controlled development scenario is grasslands (decrease of 41%) in Adapazarı, planted lands (decrease of 24%) and grasslands (decrease of 32%) in Sapanca, planted lands (decrease of 18%) in Karapürçek and grasslands (decrease of 16%) in Söğütlü. These rates were calculated as follow for the sprawling development scenario: Planted agricultural land (decrease of 29%) and marginal agriculture (decrease of 16%) in Adapazarı, planted lands (decrease of 32%) and marginal agricultural land (decrease of 28%) in Sapanca and planted lands (decrease of 28) in Karapürçek, planted lands (decrease of 9) in Akyazı and finally planted lands (decrease of 7) in Kocaali.

In the controlled development scenario, three important corridors emerged regarding future development pattern of Sakarya. The first one is Söğütlü and Ferizli axis towards north with Adapazarı in the center. The second axis is Karapürçek – Akyazı with Adapazarı in the center again. Even though development pattern of this axis gives a scattered pattern for 2025, it has the potential of being a strong focus. The third axis is Adapazarı-Sapanca (Figure 5).

Natural limiting factors play a critical role in morphological formation of the built-up area within the study area. What is intriguing in the future modelling of the spatial development

Table 7. Changes in built up areas and natural areas in sprawling development scenario (% change).

Adapazarı	**2015**	**2020**	**2025**		**Akyazı**	**2015**	**2020**	**2025**
Planted agricultural land	-5.08	-16.77	-29.87		Planted agricultural land	-2.33	-6.80	-8.84
Marginal agricultural land	-4.44	-10.57	-15.97		Marginal agricultural land	-1.72	-4.02	-5.97
Pasture/Grassland	-0.61	-0.95	-1.89		Pasture/Grassland	0.00	0.00	0.00
Built-up areas	13.58	33.18	51.25		Built-up areas	13.82	42.92	59.34
Ferizli	**0.20**	**0.45**	**0.70**		**Geyve**	**2015**	**2020**	**2025**
Planted agricultural land	-1.27	-1.27	-1.79		Planted agricultural land	-0.26	-0.50	-0.77
Marginal agricultural land	-1.50	-1.50	-2.81		Marginal agricultural land	0.00	0.00	0.00
Pasture/Grassland	-1.72	-1.72	-2.79		Pasture/Grassland	8.29	18.75	29.55
Built-up areas	23.24	23.24	37.82		Built-up areas	0.20	0.45	0.70
Hendek	**0.20**	**0.45**	**0.70**		**Karapürçek**	**2015**	**2020**	**2025**
Planted agricultural land	0.00	0.00	0.00		Planted agricultural land	-5.73	-5.73	-5.73
Marginal agricultural land	-0.80	-1.56	-1.95		Marginal agricultural land	-9.53	-21.88	-27.74
Pasture/Grassland	0.00	0.00	0.00		Pasture/Grassland	0.00	0.00	0.00
Built-up areas	4.44	10.66	13.79		Built-up areas	20.79	49.84	63.65
Karasu	**0.20**	**0.45**	**0.70**		**Kaynarca**	**2015**	**2020**	**2025**
Planted agricultural land	-2.17	-3.58	-7.06		Planted agricultural land	-0.03	-0.03	-0.03
Marginal agricultural land	-1.88	-3.18	-5.72		Marginal agricultural land	-0.14	-0.14	-0.21
Pasture/Grassland	0.00	0.00	0.00		Pasture/Grassland	0.00	0.00	0.00
Built-up areas	10.97	18.34	34.32		Built-up areas	15.00	15.00	22.94
Kocaali	**0.20**	**0.45**	**0.70**		**Pamukova**	**2015**	**2020**	**2025**
Planted agricultural land	-2.93	-2.93	-2.93		Planted agricultural land	0.00	0.00	0.00
Marginal agricultural land	-7.29	-7.29	-7.29		Marginal agricultural land	-0.15	-0.30	-0.46
Pasture/Grassland	0.00	0.00	0.00		Pasture/Grassland	0.00	0.00	0.00
Built-up areas	15.04	15.04	15.04		Built-up areas	2.63	5.70	8.77
Sapanca	**0.20**	**0.45**	**0.70**		**Söğütlü**	**2015**	**2020**	**2025**
Planted agricultural land	-3.43	-16.81	-32.43		Planted agricultural land	0.00	0.00	-0.47
Marginal agricultural land	-7.32	-18.48	-27.58		Marginal agricultural land	-2.10	-2.21	-3.38
Pasture/Grassland	-1.02	-1.40	-1.40		Pasture/Grassland	-0.46	-0.46	-0.46
Built-up areas	6.46	26.63	48.99		Built-up areas	16.40	17.26	27.15

form of Sakarya is that the new built-up areas can be added to the current structure in some districts while they are separated from one another with natural thresholds due to natural limiters in some others. For instance, in western Adapazarı, Söğütlü and Hendek, the new built-up areas can be added to the existing ones while northern Adapazarı, Akyazı, Sapanca, Karapürçek, Geyve and Karasu present a separated structure as the future urban form. However, this negative disintegration can be turned into an advantage with an integrated planning approach if they are projected as urban areas separated from each other with natural thresholds and having self-integrity and it can consequently create a controlled and compact development form. The most effective control parameter in the development form of this scenario is proximity to the center, i.e., meeting the new settlement demands in the great lands closest to the district centers.

In the sprawling development scenario, transport axis became the main decisive for the future formation of Sakarya. Additionally, density value of each district was taken 20% less than the current density values. As a matter of fact, both these acceptances of the scenario are two of the factors effective in low-density and automobile-dependent settlement pattern which are

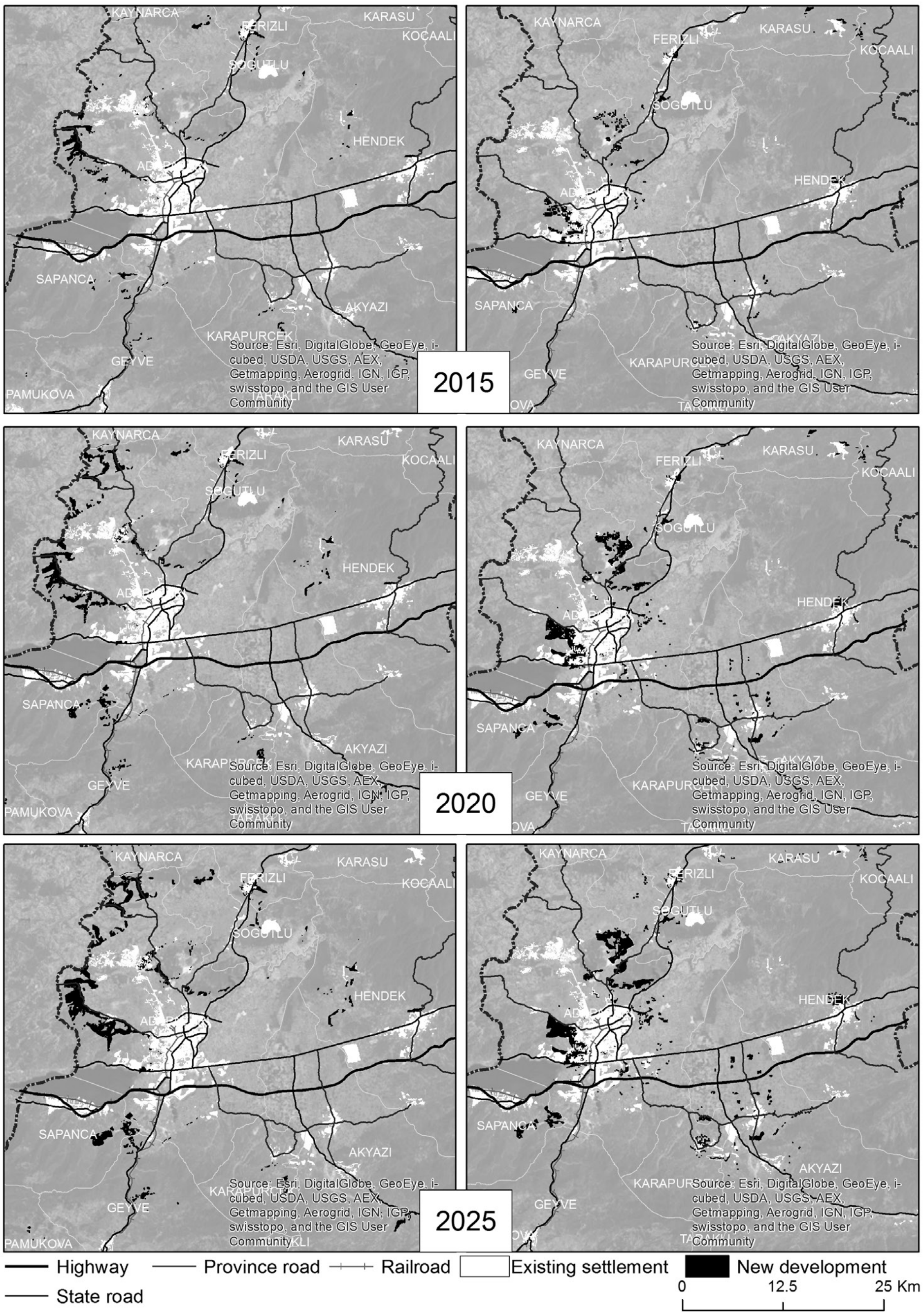

Figure 5. *Simulation results by the years for both scenarios (controlled development on the right, sprawling development on the left).*

defined as urban sprawl in cities of the western countries, especially in the USA. Regarding future settlement form of Sakarya, the simulation results imply a settlement not aggregated around the current city center, but mostly linear and separated from the existing settlement. One of the interesting findings on district level is that new development areas in Adapazarı are located linearly along the highway which extends towards northwest of the city, they are not added to the current settlement unlike the former scenario and in contrary, they developed separately from the existing settlement. One other intriguing finding is that another city shows up in Akyazı, as an alternative to the current settlement. Although the settlement form obtained from this scenario exhibits a pattern irrelevant to the current settlements, it presents an alternative development pattern for the city which faces such destructive natural threat as earthquake. This scenario enables evaluation of the new settlement areas, which come forward in the settlement pattern obtained in 2025, as new satellite cities. What is important here is to plan the new settlement demands expected to come up in 2025 based on the satellite city concept within the plan integrity and coordination.

6. Conclusion

Nowadays, it is becoming a common practice to develop urban development scenarios with 'what if?' type model and perform simulation studies based on these scenarios. 'Planning Support Systems' (PSS) constitute an informatics roof which unites all current and future information technologies used for planning. Considering restraints of the planners about the use of sources and information, PSS has been built to improve the alternative scenario-based estimations by using the available database instead of giving a precise forecast about the future.

This paper presents scenario-based modelling of the complex systems which stem from interactions of the urban functions of Sakarya, which is a vulnerable area in terms of natural resources and seismicity, both among themselves and with one another. Modelling the prospective urban growth of Sakarya based on different development scenarios is expected to contribute to the assessment of the future urban development of Sakarya and determination of the strategies regarding the future.

What if? Model used in this study renders it possible to select a scenario among the alternative scenarios and determine impacts of each scenario. This model also enables the users to easily change the assumptions and policies and reanalyze their results.

Two different scenarios were developed in this study. The first scenario is more controlled, accepts the current development dynamics and tries to predict the new settlement areas by using current density valuesThe second scenario is sprawling development scenario. As can be inferred from its name, this scenario projects development with lower density (density values 20% lower than the current situation were adopted) and takes the main axis as decisive and leading in the urban development.

Both scenarios accept that the future built-up area demand would be met from planted lands, marginal agricultural lands and grasslands and that forest lands, fertile agricultural lands and ecologically sensitive regions (vineyards, orchards, reeds, stream beds, basins, etc.) would not be converted to residential areas.

According to both scenarios, the three districts with the highest change of built-up area are respectively Karapürçek, Akyazı and Adapazarı. Two scenarios gave completely different urban spatial pattern because of the different spatial strategies. In addition, natural limiters play a critical role in morphological formation of the built-up area within the study area.

As can be seen, different development patterns with different assumptions and different scenarios can have the potential to be a suitable development pattern for the city with appropriate planning activities and control mechanisms even though they have different dynamics, planning activities and application tools. This, as a result, ensures that such modelling approaches present the possibilities to see alternative futures for the cities and introduce the possible challenges and opportunities.

What if? allows to work with the GIS data and it has been easy to apply to the any size of cities ranging from neighborhood to the large regions. What-if modelling procedure can be developed by adding a transportation modelling component to estimate future travel demand and pattern which is very much connected to future land use pattern.

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Senaryo tabanlı arazi kullanım tahmini: Sakarya örneği

Arazi kullanım modellemesi çalışmaları, karmaşık kentsel sistemlerin dinamik yapılarının anlaşılması ve çevreye olan etkilerinin değerlendirilmesi açısından büyük önem taşımaktadır. Günümüzde arazi kullanım modellemesi yaklaşımları, mekânsal ve zamansal süreçleri kapsayan ve dinamik modelleme tekniklerini ortaya koymaktadır. Bu teknikler, belirsizlik unsurunu içeren ve karmaşık sistemler teorisine dayanılarak geliştirilen tekniklerdir. Bu nedenle arazi kullanım ve bunun gibi kentsel modelleme çalışmalarının günümüzde karşı karşıya kaldığı en önemli problemlerden birisi 'tahmin edebilirliktir'. Batty (2010), belirli kentsel büyüme biçimlerinin, uygun ölçeklerdeki modellerle kestirilebileceğini ve bu türdeki 'bilinmezliğin' kısmen ortadan kaldırabileceğini söylemektedir.

Günümüzde, arazi kullanım modelleme çalışmaları, 'what if' senaryolarının kurgulanmasına ve bu senaryoların artık çoğu model oluşturma çabalarına hakim olması yönündeki bir değişime tanıklık etmektedir (Batty ve Torrens, 2005). 'Planlama Destek Sistemleri' (PSS), planlama için kullanılan bugünkü ve gelecekteki bütün bilişim teknolojilerini bütünleştiren bir bilişim çatısıdır. PSS, daha önceleri planlama sürecinin farklı yönlerini desteklemek için geliştirilmiş geo-bilgi teknolojisi ile ilgili araçları içermektedir (Geertman ve Stillwell, 2004). PSS, üç kavram ile ifade edilmektedir. Bunlar, 'bilgi', 'model' ve 'görselleştirmedir' (Klosterman 1999). Kaynakların ve bilginin kullanımında, plancıların sınırlamaları göz önüne alındığında, mevcut veri tabanlarının kullanılmasıyla, PSS, geleceği tam olarak tahmin etmek yerine, alternatif senaryo tabanlı tahminleri geliştirmek üzere kurgulanmıştır (Klosterman 1998).

Bu çalışmada, gerek doğal kaynaklar açısından gerekse depremsellik açısından hassas bir bölge olan Sakarya'nın hem kentsel fonksiyonlarının kendi içinde, hem de bu fonksiyonların birbirleriyle etkileşimleri sonucunda ortaya çıkan karmaşık sistemlerin senaryolara bağlı olarak modellemesine çalışılmıştır. Sakarya'nın arazi kullanımının modellenmesinde What-if? modelleme yaklaşımı benimsenmiştir. Bu yaklaşımın en önemli özelliği, farklı mekansal stratejilere bağlı olarak senaryolar kurgulama ve bu senaryolar çerçevesinde Sakarya'nın gelecekteki arazi kullanımı ve mekansal büyüme biçiminin tahmin edilerek doğal çevreye olan etkilerinin analiz edilmesine olanak sağlamasıdır. Bu model, ayrıca, kullanıcıların model sonuçlarına göre model öncesi varsayımların ve mekansal büyüme stratejilerinin kolaylıkla revize edilerek yeniden modele sokulmasına fırsat vermektedir.

Model iki amaca hizmet etmektedir. Birincisi, arazi kullanım planlamasına girdi vermek, ikincisi ise elde edilen projeksiyonlar çerçevesinde, gelecekte alternatif yerel arazi geliştirme stratejileri oluşturmaktır. What-if? modeli literatürde çokca bahsedilen senaryo tabanlı modelleme türlerinden olan California Urban Futures (CUF)(Landis,1994; Landis, 1995) ve SOAP modeli ile benzerlik göstermektedir (San Diego Assoc. of Governments, 1994).

İlk defa Klosterman (1999; 2001) tarafından geliştirilen What-if modellemesi aşağıdan yukarıya (bottom-up) doğru bir yaklaşım sunar ve 3 aşamadan oluşur:

a. Arazi uygunluk analizi: Bu adımda her bir arazi kullanımı, arazi örtüsü ve doğal kaynakların türleri tanımlanır. Tüm bu türler kentsel gelişmenin yönlendiricileri olan faktörler olarak belirlenir ve bunlar ağırlıklandırılır. Buna ek olarak, mekânsal büyüme sürecinde dönüşüme izin verilen arazi kullanım türleri tanımlanır.
b. Büyüme: İkinci aşamada senaryolara bağlı olarak, gelecekteki (hedef yıl) arazi kullanım talepleri hesaplanmaktadır.
c. Arazi tahsisi: Son aşama ise, arazi uygunluk analizi sonuçlarına ve projeksiyon hesaplarına bağlı olarak, gelecekteki arazi kullanım türlerinin en uygun yerlerde tahsis edilmesi ve doğal kaynaklardaki değişimin analizi aşamasıdır.

Bu çalışmada uygulanan model sonucunda, iki farklı senaryo ile önümüzdeki 15 yıl boyunca arazi kullanımı ve mekansal büyüme biçiminin tahmin edilmesi ve söz konusu kentsel büyümenin doğal kaynaklar üzerindeki etkileri ortaya konmuştur. Birinci senaryo doğal kaynakların korunmasını destekleyici politikalardan oluşan, daha kontrollü büyüme sunan, mevcut gelişme dinamiklerini aynen kabul eden ve yine mevcut yoğunluk değerlerini kullanarak gelecekteki yeni yerleşme alanlarını tahmin etmeye çalışan senaryodur. Bu senaryoya kontrollü gelişme senaryosu adı verilmiştir. İkinci senaryo ise piyasa odaklı gelişme temelleri üzerinde kurgulanmış yayılarak gelişme senaryosudur. Adından da anlaşılacağı üzere bu senaryo, daha düşük yoğunlukla gelişmeyi öngören (mevcut durumdan %20 daha düşük yoğunluk değerleri kabul edilmiştir) ve kentsel gelişmede ana aksları belirleyici ve yönlendirici olarak kabul eden senaryodur. Her iki senaryoya bağlı olarak elde edilen simülasyon sonuçlarından şu sonuçlar çıkarılmıştır:

Kontrollü gelişme senaryosuna göre, yapılaşmış alan miktarında gözlenen artışta ilk üç ilçe sırasıyla, Adapazarı, Hendek ve Karasu ilçeleri olmuştur. Yayılarak gelişme senaryosuna göre ise, Karapürçek, Akyazı ve Sapanca olmuştur. Her iki senaryonun birbirinden tamamen farklı sonuçlar vermesi, hem yoğunluk değerinin 2. Senaryoda 1. Senaryodan %20 daha az kabul edilmesi, hem de şehirsel büyüme biçiminde ana ulaşım akslarının belirleyici olmasından kaynaklanmaktadır.

Kontrollü gelişme senaryosunda, Sakarya'nın gelecekteki gelişme biçiminde üç önemli koridorun öne çıktığı görülmektedir. Bunlardan birincisi, Adapazarı merkez olmak üzere kuzeye doğru Söğütlü ve Ferizli aksıdır. İkinci aks, Adapazarı merkez olmak üzere Karapürçek Akyazı aksıdır. Bu aksın gelişme deseni her ne kadar 2025 yılı için dağınık bir görüntü verse de güçlü bir odak olma potansiyeli taşımaktadır. Üçüncü aks ise, Adapazarı- Sapanca aksıdır.

Araştırma alanında, yapılaşmış alanının morfolojik biçimlenmesinde, doğal sınırlayıcı unsurların büyük rol oynadığı ortaya çıkmıştır. Sakarya'nın mekânsal büyüme biçiminin geleceğe dönük modellenmesinde ortaya çıkan dikkat çekici özellik, yeni yapılaşma alanları bazı ilçelerde mevcut yapıya eklenerek büyüyebilirken, bazı ilçelerde ise doğal sınırlayıcılardan ötürü doğal eşiklerle birbirinden ayrılmış yerleşmeler biçiminde bir gelişme biçimi ortaya çıkmaktadır. Bu ayrışma bir olumsuzluk gibi görünse de, bu alanlar bütüncül bir planlama anlayışı ile ele alınıp, birbirilerinden doğal eşiklerle ayrılmış ve kendi içinde bütünlüğü olan kentsel alanlar gibi planlanırsa bu durum avantaja çevrilerek, kontrollü ve kompakt bir gelişme yapısına çevrilebilir. Bu senaryoda gelişme biçiminde en etkili kontrol parametresi merkeze yakınlık olmuştur. Yani, yeni yerleşme taleplerinin ilçe merkezlerine mümkün olan en kısa mesafelerdeki büyük arazilerde karşılanması olmuştur.

Yayılarak gelişme senaryosunda ise, Sakarya'nın gelecekteki biçimlenmesinde temel belirleyici olarak ulaşım aksları etkili olmuştur. Buna ilave olarak her ilçedeki yoğunluk değeri, mevcut yoğunluk değerlerinden %20 daha düşük alınmıştır. Aslında bu senaryoda yapılan her iki kabul, özellikle Amerika'da şehirsel saçaklanma (urban sprawl) olarak tabir edilen düşük yoğunluklu, otomobil bağımlısı yaygın yerleşme dokularında etkili olan faktörlerden ikisidir. Simülasyon sonuçlarından Sakarya'nın gelecekteki yerleşme biçiminin mevcut kent merkezi etrafında kümelenmeyen, çoğunlukla lineer ve mevcut yerleşmeden kopuk bir yerleşme düzeni ortaya çıkmıştır. İlçeler bazında dikkat çeken bulgulardan birisi, Adapazarı'ndaki yeni gelişme alanlarının kentin kuzeybatısına uzanan karayolu boyunca lineer olarak yer seçtiği, bir önceki senaryodan farklı olarak mevcut yerleşmeye eklenmediği, tersine mevcut yerleşmeden kopuk olarak geliştiği görülmektedir. Bir diğer ilginç bulgu ise, Akyazı'da mevcut yerleşmeye alternatif ikinci bir kentin ortaya çıkmasıdır. Her ne kadar bu senaryoda elde edilen yerleşme düzeni mevcut yerleşmelerden kopuk bir örüntü sergilese, deprem gibi yıkıcı bir doğal tehlike ile karşı karşıya olan kente alternatif bir gelişme deseni sunmaktadır. Bu senaryo, 2025 yılında elde edilen yerleşme deseninde ortaya çıkan yeni yerleşme alanlarının yeni uydu kentler gibi değerlendirilmesine olanak tanımaktadır. Burada önemli olan 2025 yılında ortaya çıkması beklenen yeni yerleşme taleplerinin yine plan bütünlüğü ve koordinasyonu içinde uydu kentler ve çok merkezlilik konsepti ile planlanması gereğidir.

Görüldüğü üzere farklı varsayımlara sahip ve farklı senaryolardan elde edilen farklı gelişme desenleri, farklı dinamiklere, planlama eylemlerine, uygulama araçlarına sahip olsa bile, her iki şehirsel büyüme biçimi uygun planlama eylemleri ve kontrol mekanizmaları ile kent için uygun gelişme deseni olma potansiyeli taşıyabilmektedir. Bu da, bu tür modelleme yaklaşımlarının kentler için alternatif gelecekleri görme olanaklarını, olası sorunları ve fırsatları ortaya koyma becerisini sunmaktadır.