Land Use Suitability Analysis for Sustainability of Water Resources

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Research Article

Keywords: Urbanization, Land use, Suitability Analysis, Sapanca Basin

Posted Date: August 13th, 2021

DOI: <https://doi.org/10.21203/rs.3.rs-784563/v1>

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Abstract

Cities are developing and spreading in an unplanned way with urbanization and rapid population growth. Natural resources such as forests and agricultural lands and water resources are the primary sources that are changed and consumed due to urbanization. This situation poses serious threats especially on drinking water basins. The aim of this study is to identify the threats of urbanization pressure on the basins, to analyze the changing landscapes and to determine suitable areas for settlement and agricultural areas for the sustainability of the basin. Sapanca Basin, chosen as the study area, is a crucial drinking water basin for Turkey. The reason for choosing this area is that the basin is under the pressure of construction as a result of the increasing population and secondary housing demand in recent years, and this situation shows a visible change in the landscapes of the basin. In this context, suitability analyzes were made for the determination of settlement and agricultural areas in order to ensure the ecological sustainability of the basin and to give a direction of the development of the basin. These analyzes have been made by considering McHarg's suitable land use method in ecological planning. For suitability analysis, ecological data have been synthesized and suitability maps have been formed by overlay method in GIS environment. Land use maps were produced for the basin and these maps were compared with the environmental plan. It has been determined that a large part of the basin is not suitable for settlement. As a result, it has been determined that the residential areas in the basin increased by 200% between the years 2000-2018. This increase was especially on forest areas and agricultural areas. As a result of these changes, the landscape is fragmented and its natural ecosystem is deteriorated. With the study, the current situation of settlement and agricultural areas in the basin was interpreted and suggestions were developed on how these areas should develop in the basin.

1. Introduction

Our planet is changing rapidly with many anthropogenic influences, and this change is expected to increase in the coming years (IPCC, 2007; Fan et al, 2016). Today, more than 50% of the world's population lives in cities. As per the UN 2018 WUP report, the average annual increase of the world's urban population approached from 25 million in 1950–1955 to 57 million between 1990–1995 and to 80 million in 2015–2020. Urban areas of underdeveloped regions accounted for 57 percent of the annual increase in the world's urban population in 1950–1955. Urban areas of underdeveloped regions account for 94 percent by 2015–2020 and are expected to account for 96 percent by 2045–2050. It is estimated that 68 percent of the world's population will live in urban areas by 2050 (UN, 2018). Rapid population growth and urbanization effect in cities cause unhealthy development and construction of urban areas (Kart Aktaş and Yıldız Dönmez, 2019). Unplanned, unsystematic rapid urbanization in the urbanization process causes profound effects on various environmental components, especially the environment and water components (Battista and Vollaro, 2017; Yan et al., 2016; Patra et al., 2018). For instance, the decrease of forest areas in tropical regions, the danger of extinction of many species, and the global warming of rising atmospheric carbon dioxide (Bolstad and Swank, 1997; Geist and Lambin, 2002; Thomas et al., 2004). New urban areas should be created in order to meet the primary needs such as

shelter, food, etc., which are vital for human life with the rapid population growth in the cities. (Akıncı et al., 2013). Especially natural areas are destroyed and wrong use of space and area changes are observed with the transfer of urban growth to rural areas near the city.

In consequences of the rapid population growth in the cities, the destruction in the natural areas located on the city periphery is high with the rapid population growth in the cities. In addition to the purpose of fulfilling the housing need in rapidly developing cities, the destruction is high in the basins that have been built to establish industrial areas for economic activities. It is necessary to create sustainable cities in order to prevent extreme poverty and destruction of nature and to ensure the balance between economy and ecosystem.

In order to ensure sustainability in cities, besides rational planning approaches, land use planning should be performed to prevent ecosystem management and natural destruction. Land use planning has been defined in various ways: Area use planning can be defined as determining future land uses, improving area characteristics and management of the new situation (Lier, 1998). FAO (1993) defines land use planning as a systematic assessment of land and water potential, land use alternatives and economic-social conditions in order to select and adapt the best land use options. The prerequisite for land use planning is land suitability assessment. Land use suitability criteria for urban development are derived from multidisciplinary scientific theories about physical, socio-economic and ecological features. Land suitability analysis is a complex process including ecological, economic and social concepts. The World Environment and Development Commission defined land suitability as a concept related to sustainable development as "development that fulfils today's needs without compromising the ability of future generations to fulfil their own needs" (Marrewijk, 2003).

An ecological factor (e.g. Forest value or historical value) usually represents the constraint of development (suitability) through sorted values for a subset of mapping units in a given area. The combined map of ecological factors, protection or protection map is defined as suitability map (McHarg, 1981). The main purpose of the land suitability analysis is to determine the natural capacity of the land unit and to determine and support the land uses that can maintain the natural capacity without deterioration in the long term (Cengiz et al., 2013). The suitability analysis essentially involves identifying opportunities and constraints for anticipated land uses in a city or region or watershed. On the other hand, most physical and socioeconomic factors have permissive and restrictive features for a particular land use, determined by spatial location. For instance, high slope areas are restrictive areas and low slope areas are allowed areas for urbanization movements. The resulting factor maps are used to reflect the degree of opportunity (or suitability) with the values assigned to all mapping units.

2. Material And Method

Sapanca Drinking Water Basin has been chosen as the study area. The fact that the natural areas and water resources of the basin were under threat due to the approximately double increase in the population in the basin from 2000 to 2017 and the uncontrolled urbanization effect in order to fulfil the housing and

social demands of the increasing population, was effective in determining the area as a study area (Yıldız Dönmez, 2019). The Sapanca Basin is located in the Çatalca-Kocaeli plateau in the east of the Marmara Region. It is in the hinterland of İstanbul-Ankara metropolises. The basin is administratively divided between Kocaeli and Sakarya provinces, 26 km of the 39 km lake coastline is within Sakarya and 13 km is within Kocaeli provincial borders (SASKİ, 2013). Sapanca Lake, which gives its name to the basin, is a crucial natural area and water resource for the region (Fig. 1).

As the study area is a crucial drinking water basin, the sustainability of its natural structure and water resources becomes very important. In recent years, serious changes have been detected in land use in the basin. The main factor in the change of landscapes within the basin is the urbanization pressure. The forest areas in the basin have converted into agricultural and residential areas over the years with the effect of urbanization, therefore, suitability analyzes have been carried out to determine settlement and agricultural areas within the scope of the study in order to direct the development of settlement and agricultural areas in the future (Yıldız Dönmez, 2019).

The existing land use map satellite images, aerial photographs, forest stand maps, Kocaeli and Sakarya Metropolitan construction plans and existing maps and area researches related to the study area have been formed by transferring 1/25.000 scale forest stand maps obtained from Sakarya Regional Directorate of Forestry to the GIS environment. All data have been brought to the same coordinate system by georeferencing with the UTM coordinate system in the GIS environment, and overlapped with the basin boundary received from SASKİ and accepted as the study boundary. After the coordinating process of satellite and aerial photographs, controlled classification have been conducted to manual digitizing structures. The basin is divided into 6 classes as forest, agricultural land, degraded forest, pasture, meadow and settlement. On the other hand, residential areas have also been classified as industrial, commercial and residential areas based upon the researches and determinations made in the area and a map of the current area uses has been obtained.

The overlay method developed by McHarg has been used in the suitability analysis. McHarg defines suitability analysis as preparation and interpretation of ecological inventory, forming and mapping an inventory of natural and cultural resources, grouping suitable and unsuitable area uses, synthesizing data for suitability map, overlaying these maps according to the purpose and forming suitability maps (Cengiz et al., 2009). Ecologically based suitability maps have been prepared for residential and agricultural areas in the study area. Criteria and sub-criteria have been created for each area to prepare suitability maps. The studies of Akten (2008), Cengiz et al. (2009), Konaklı (2011) have been used to evaluate these criteria and sub-criteria. For settlement and agriculture suitability analysis, potential erosion risk analysis values, water function analysis values and basin protection zones specified in the Drinking Water Protection Regulation have also taken in addition to ecological criteria such as slope, aspect, land use capability, erosion, geological classes. Sub-criteria for each area are scored from 1 to 4 according to their suitability. In this scoring, 1 represents the lowest, 2 the low, 3 the suitable, and 4 the most suitable (Table 1). The sub criteria for settlement and agriculture are evaluated in terms of potential uses and given values between 1 and 4. For instance, when the criteria of suitable topographic structure are evaluated, the slope

between 0–6% is evaluated as the most suitable with 4 points, 6–12% as suitable for settlement value with 3 points 12–24% less suitable with 2 points and areas larger than 24% as not suitable areas with 1 point. Similar to the slope, 1 and 4 suitability points are given for the landscape, geological structure, erosion, land use capabilities, water function analysis, potential erosion analysis, and synagogue protection zones, which are determined as sub-criteria for settlement. The same method has been used in agricultural areas. For example, 1st and 2nd class lands have been determined as 4 points as the most suitable areas for agriculture in land use capabilities, 3rd class lands have been determined as suitable areas with 3 points, 4th and 5th class students have been determined as less suitable with 2 points and 6th, 7th and 8th class have been determined as unsuitable with 1 point. This scoring system has been calculated in the same way among all criteria determined in the suitability analysis for agriculture.

By overlapping the criteria in GIS programs, a cumulative structure has been formed and optimal area uses have been formed by classifying them as "very suitable", "moderately suitable", "less suitable" and "not suitable" according to the FAO classification system (FAO, 1977). Optimal land uses have been compared with the existing land use map and Environmental Plan.

Table 1: Criteria for optimum land-use settlement and agricultural analysis

CRITERIA	Criteria for settlement suitable analyse		Criteria for agricultural suitable analyse	
	Sub-Criteria	Suitable scores	Sub-Criteria	Suitable scores
SLOPE	%0-6	4	%0-6	4
	%6-12	3	%6-12	3
	%12-24	2	%12-24	2
	%24<	1	%24<	1
ASPECT	S, SE, NW	4	S, SE, NW	4
	E, W	3	E, W	3
	NE, NW	2	NE, NW	2
	NE, NW	1	NE, NW	1
GEOLOGICAL STRUCTURE	ALLUVIAL	4	ALLUVIAL SOIL	4
			NON-CALCEROUS BROWN SOIL	3
	OTHER STRUCTURES	1	COLLUVIAL SOIL	2
			OTHER STRUCTURES	1
EROSION	HIGH	1	HIGH	1
	MEDIUM	2	MEDIUM	2
	LOW	3	LOW	3
	NONE	4	NONE	4
LAND USE CAPABILITY	1st, 2nd, 3rd Class	1	1st, 2nd, Class	4
	3rd and 4th class	2	3rd class	3
	6th class	3	4th and 5th class	2
	7th Class	4	6th, 7th and 8th Class	1
WATER FUNCTION	VERY HIGH	1	VERY HIGH	2
	HIGH	2	HIGH	2
	MEDIUM	3	MEDIUM	3
	LOW	4	LOW	4
POTENTIAL EROSION	VERY HIGH	1	VERY HIGH	2
	HIGH	2	HIGH	3
	MEDIUM	3	MEDIUM	4
	LOW	4	LOW	4
BASIN PROTECTION AREAS	STRICT PROTECTION AREA	1	STRICT PROTECTION AREA	2
	SHORT DISTANCE PROTECTION AREA	2	SHORT DISTANCE PROTECTION AREA	3
	MEDIUM RANGE PROTECTION AREA	3	MEDIUM RANGE PROTECTION AREA	4
	LONG DISTANCE PROTECTION AREA	4	LONG DISTANCE PROTECTION AREA	4
1-not suitable;2-Less suitable;3-suitable;4-very suitable				

3. Findings

In the map prepared on the basis of 2018 data, forest, agriculture, meadow, pasture, degraded forest, swamp-reed areas, residential(housing), industrial and commercial areas from urban functions have been identified in the current land use of the basin (Fig. 2). Forest areas are 13608.85 ha within the basin boundaries. Agricultural areas are 7262.83 ha in the basin. Urban areas in the basin are divided into 3 as residential areas, commercial and industrial areas. Residential and commercial land uses are especially

located in the south of the basin around the motorway and railway line, and residential areas represent 2983.75 ha and commercial areas 21 ha. Industrial areas are 89.69ha. Degraded forest areas are 1415.62 ha, meadows are 11.89 ha, pastures are 307.56 ha. The area covered by the lake is 4582.54 ha. Housing areas constitute 12% of the total area in the existing land use, excluding the lake area. The area covered by agricultural(cultivated) land is 28%.

According to the settlement suitability analysis result, the areas suitable for settlement within the basin are very limited (Fig. 3). According to the cumulative scoring made according to the results obtained by overlapping the sub criteria determined for placement, it is determined as:

- Very suitable between 31–34;
- Suitable between 27–30;
- Less suitable between 19–26;
- Unsuitable between 0–18.

It has been determined that the north of the basin is more suitable for settlement than the south. The total of areas that are very suitable and suitable for settlement is 2710 ha. When the lake area is excluded in the basin, 10% of the total area is analyzed as an area suitable for settlement. Almost all of the south of the basin has been identified as unsuitable areas for settlement. Due to the fact that this area is covered with dense forests and the water retention function is very high, these areas are unsuitable for settlement.

As a result of the suitability analysis for agriculture in the basin, it is determined as;

- Very suitable between 28–33;
- Suitable between 22–27;
- Less suitable between 16–21;
- Unsuitable between 0–15.

As a result of the analysis, the total of very suitable and suitable areas has been determined as 11,121 ha area (Fig. 4). These areas have been identified as flat lands in the south of the basin, especially near the lake shore edge line, showing the features of alluvial formation rich in soil minerals.

According to the settlement suitability analysis, its share in the total area of the basin corresponds to an area of 10%. In the current land use, residential areas have a share of more than 11% in the total area of the basin. Land suitable for agriculture has a share of approximately 43%. The share of agricultural land in the total area in the current land use is 28%. In the environmental plan, residential areas correspond to an area of 12% in the total basin area, while agricultural areas correspond to an area of 32% (Fig. 5).

When the settlement and agriculture suitability analyses are compared with the environmental plan conducted by the former Ministry of Environment and Forestry for the Sapanca Lake Basin;

- Considering the environmental plan decisions, it has been determined that the residential areas are located in the southern part of the area. It is seen in the environmental plan that settlement decisions are also made within the absolute protection area. However, in the suitability analysis for settlement, the most suitable habitable areas have been determined in the north of the area. Uzunkum neighborhood in the southeast of the area has been determined as a suitable area for settlement.

Table 2

Comparison of current land use and optimum land use for residential and agricultural areas in Sapanca Basin

TYPES OF LAND USE	CURRENT LAND USE (ha)	%	ENVIRONMENTAL PLAN	%	RECOMMENDED OPTIMUM LAND USE (ha)	%
RESIDENTIAL AREA	2.983,75	11,61	3.140,85	12,22	2.710,00	10,54
AGRICULTURAL AREA	7.262,83	28,26	8.220,19	31,98	11.121,00	43,27
AREA OF SAPANCA LAKE (ha)	4.582,54					
TOTAL BASIN AREA (ha)	25.701,19					

- When the agricultural suitability analysis has been compared with the environmental plan, it has been determined that settlements have been made in the Maşukiye-Derbent neighborhoods, which have been determined as suitable areas for agriculture. In a large area of the regions that have been determined as very suitable and suitable areas for agriculture in the suitability analysis, plan decisions have been made for the development of residential areas and industrial areas in the environmental plan.

4. Conclusion

Sapanca Drinking water basin has been determined as the study area. According to the data obtained from TUIK, the population of the basin increased more than 2 times between 2000 and 2017. This situation has also increased the urbanization movements within the basin. Changes in land use are observed with the increase in urban areas in the basin. The destruction of the forest areas in the basin before 2000 to open agricultural areas, the opening of 2B forest areas for settlement after 2000, the shifting of the industrial activities in Istanbul to the periphery of the city, the increase in the interest in the basin by allowing foreigners to construction investments after 2014 increased the land changes in the basin. (Kart Aktaş and Yıldız Dönmez 2019). In consequences of the area change maps measured using aerial photographs and satellite photographs between 2000 and 2018, an increase of more than 200% has been detected in the urban areas of the basin (Yıldız Dönmez, 2019). Drinking water basins are not suitable areas for construction and are areas where there should be zero settlement. However, both

planned political reasons need in developing countries such as Turkey are seen urbanization movement in these areas. Due to the fact that the basin in the Sapanca Drinking Water Basin is located within the borders of two major cities and at the same time, it is attractive for tourists with its natural beauties, the population demand for the basin continues to increase. This increase in lands within the basin often turns into urban settlements without proper planning. These irregular urban spots cause the natural texture of the basin to deteriorate and its destruction to increase. The fact that the basin is evaluated as an urban settlement area with the current policies and planning approach causes the problem to deepen. Current policies need to be changed in order to protect the basin. On the other hand, the existing urbanization policies are not expected to change in the short term as can be seen from the approaches from the past to the present. In order to fulfil the shelter and food needs of the future population, to prevent the destruction and sustainability of the forest areas, which are the main water resources of the basin, suitability analyzes have been carried out to determine the use of the lands within the basin, especially the settlement and agricultural areas.

Within the scope of the study, the optimum land uses of Sapanca Drinking Water Basin, which is under urbanization pressure, have been determined and compared with the existing land use and 1/25000 scale environmental plan. In consequences of the study carried out in the basin;

- It has been determined that the existing residential areas are above the capacity according to the optimum land use data and that the environmental plan is planned in a more area than the land uses suitable for the basin. It has been observed that the residential areas planned in the environmental plan is planned in the 1st and 2nd degree protection zones of the basin, and in areas with high water function. It has been observed that the degree protection zones are also planned in areas with high water function.
- It has been determined that the existing agricultural lands and the environmental plan in the basin cover less area in terms of area than the optimum land use for the planned agriculture. On the other hand, the plan decisions do not contain information to protect the natural structure of the basin for agriculture. At the same time, most of the areas identified as existing agricultural areas are used as ornamental planting growing areas. Using too many chemical pesticides for the rapid growth of the plant during the growth period of the plant in these areas poses a danger to the basin. Agricultural activities in the basin should be followed by good agricultural practices. No substances that pollute groundwater or soil should be used in agricultural activities in the 1st and 2nd degree protection zone of the basin.

As long as the urbanization pressure in the basin continues to increase and there is no change in the current planning policies and plan decisions, the deterioration of the natural structure of the basin will not be prevented. Ecological decisions should be taken for the settlement structure in order to protect the natural balance of the basin and the ecosystem, and a settlement typology specific to the Sapanca basin should be developed (Kart Aktaş and Yıldız Dönmez 2019). In areas that can settle in the entire basin, settlement typologies should be developed by examining examples of eco-villages that do not have dwelling density, which do not produce much waste, that can generate its own energy (Yıldız Dönmez,

2019). Regardless of ecological balances in natural areas, urbanization movements made with fast, wrong planning policies damage ecosystems and negatively affect sustainable urban development by negatively affecting critical environmental components such as groundwater, temperature and precipitation. In order to create healthy cities and sustainable cities, systematic and comprehensive planning approaches should be established by protecting natural resources (Patra et al., 2018). Water catchment areas are areas that are not suitable for settlement and should not be settled unless obliged (McHarg, 1969). However, with the growth dynamism of the cities in developing countries such as Turkey, there are structuring and misuse of areas in these areas as in the Sapanca Basin. The plans prepared for these areas should be made by taking ecological data into consideration and determined as a result of the necessary analysis. In order to prevent unsystematic urban growth that threatens natural areas of the state, the state should make deterrent laws and regulations.

Declarations

Declarations

Funding

No funding was received.

Conflicts of interest/Competing interests (include appropriate disclosures)

We have no conflicts of interest to disclose.

Availability of data and material (data transparency)

The data that support the findings of this study are available from the first author, [N.Y.D.], upon reasonable request.

Code availability (software application or custom code)

Not applicable

Authors' contributions (optional: please review the submission guidelines from the journal whether statements are mandatory)

The first author especially analyzed the data. The second author worked during the literature research, design of the subject, and interpretation of the data.

Additional declarations for articles in life science journals that report the results of studies involving humans and/or animals

Not applicable

Ethics approval (include appropriate approvals or waivers)

Not applicable

Consent to participate (include appropriate statements)

Not applicable

Consent for publication (include appropriate statements)

We, give our consent for the publication of identifiable details, which can include photograph(s) and/or videos and/or case history and/or details within the text ("Material") to be published in the above Journal and Article.

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Figures

Figure 1

Figure 2

Sapanca Lake Basin land-use plan

SAPANCA LAKE BASIN SUITABLE AREAS FOR SETTLEMENT

Figure 3

Sapanca Lake Basin suitable areas plan for settlement

SAPANCA LAKE BASIN SUITABLE AREAS FOR AGRICULTURAL

Figure 4

Sapanca Lake Basin suitable areas for agricultural

COMPARISON OF SAPANCA BASIN ENVIRONMENTAL PLAN AND SETTLEMENT SUITABILITY ANALYSIS

Figure 5

Comparison Sapanca Basin Environmental Plan and suitable plan for settlement areas

COMPARISON OF SAPANCA BASIN ENVIRONMENTAL PLAN AND AGRICULTURAL SUITABILITY ANALYSIS

Figure 6

Comparison Sapanca Basin Environmental Plan and suitable plan for agricultural areas