Theoretical and Applied Climatology (2021) 143:379–388
https://doi.org/10.1007/s00704-020-03439-2

ORIGINAL PAPER

Integrating multicriteria decision-making analysis for a GIS-based settlement area in the district of Atakum, Samsun, Turkey

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Received: 7 July 2020 / Accepted: 14 October 2020 / Published online: 20 October 2020

Abstract

The last century witnessed a boom in the world population, reaching an unprecedented level. In particular, in recent decades, the population has concentrated in cities. Migration from rural areas to urban areas brings many problems to urban areas, necessitating the opening of new settlement areas. These new settlement areas that are needed are mostly determined in line with the initiatives of local authorities based on the situation of infrastructure facilities, not scientific evaluations. If the wrong places are selected, various natural events each year may cause the loss of property and lives, in addition to significant amounts of energy consumption. This study uses various parameters and creates a method for place selection based on multiple criteria. The district of Atakum in the city of Samsun, which has been subject to continuous migration and where new settlement areas have been established, is selected as the study area. Within the scope of this study, in addition to landslide and flood risks, which constitute the most important natural disasters in the region, situations of high voltage electricity transmission lines in places where the establishment of a residential area would be objectionable are evaluated. The situation of biocomfort, which is significantly important, especially with respect to energy efficiency as well as human health, peace, and comfort, is also evaluated. This study is conducted based on these criteria, and as a result, it calculates that only 15.11% of the district of Atakum is appropriate for use as a settlement area. In addition to serving as a reference for the short- and long-term area planning studies that will be conducted in the region, this study also holds significance due to the new perspective it offers regarding urban planning studies.

1 Introduction

In the last century, the world population increased significantly. In the 1900s, it was approximately 1.5 billion, but at present, it is 7.7 billion (Gültekin 2020; Wordometers 2020). Furthermore, developments in industrial areas have changed the communal structure, and migration from rural areas to urban areas has increased. The urban population, which was approximately 9% in the 1900s, has risen to 47% in 2000, and it is predicted to reach 90% in 2030 (Aricak et al. 2020). The population rate of those living in urban areas in Turkey has reached 92.5% (TUIK 2020).

A city is defined in general terms as "the settlement unit which is subject to continuous communal development, where various requirements of community such as working, settlement, sheltering, entertainment, and recruitment are met, where only a few people deal with agriculture or no people deal with it, where population density is higher with respect to villages, and which is constituted of less number of neighborhood units" (Cantürk 2018).

Urban formation, its development stages, and urban growth mainly depend on the means provided by the components that constitute the natural environment. In other words, the positive impacts of natural environmental components such as the topography of the area and the environment where a city is located, appropriate climatic conditions, and water resources on the lives and activities of people play an important role in urban development and growth (Karadağ and Koçman 2007).

Furthermore, urban areas constitute areas where people obtain shelter, which is one of the fundamental requirements of people, and this need must be met in a secure way. Natural disasters are the most important threat to meeting the

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requirement of secure shelter. Situations that, in addition to affecting people, disrupt the normal functioning of natural and cultural resources and that cause them to be interrupted or stopped are designated disasters. Despite the current level of development, disasters cause the loss of hundreds of people and financial losses worth billions of dollars each year (Erkal and Değerliyurt 2009).

The best precaution that can be taken against disasters is related to versatile analysis and planning that is conducted accordingly. In this study, the criteria to be considered when determining areas to be used as settlements are examined based on the example of the district of Atakum. Within the scope of this study, risk maps concerning landslides and floods, which constitute the most common disasters in the region, and electricity transmission lines, which constitute another risk, are evaluated. In addition, areas of biocomfort, which directly affects human lives and comfort and which also have a significant impact on energy consumption, are included in the evaluations. As a result, this study aims to determine the most appropriate potential settlement areas depending on these parameters.

2 Material and method

2.1 Study area

The study was conducted in the region of the district of Atakum, which is one of the most important districts in Samsun, one of the largest cities in Turkey. Due to its location and its features such as its development level, social opportunities, and climatic conditions, Atakum is located in a region that is greatly preferred as a settlement area, and its population increases each year. Hence, it is a region where new settlement areas must continuously be opened. The geographical location of the study area is shown in Fig. 1.

2.2 Method

Within the scope of this study, floods and landslides, which are among the most important disasters throughout the region and cause major losses of property and lives at significant intervals, are analyzed.

2.2.1 Formation of landslide risk maps

At this stage, 11 different lithological units were surfaced based on a geological map with a scale of 1/100,000 obtained from the MTA General Directorate (Keskin 2011). Rocks were classified based on their formation names and ranked from young to old: recent beach deposits (Qk), alluvium (Qal), old beach deposits (Qek), the Karasamsun member (Tmplsk), the Ilyas member (Tmplsi), Mahmurdağ volcanics (Tmv), the Tekkeköy formation (Tet), the Kusuri formation (Tek), the Atbaşı formation (Tpea), the Akveren formation (Kta), and the Cankurtaran formation (Kc).

Various statistical methods were used during the stage of data collection and processing. The institutions from which the data were obtained at this stage and the subvariables that were derived from the fundamental variables and used in the study are explained in Table 1.

The data were classified for landslide susceptibility analysis. Table 2 presents the classification of the data for landslide susceptibility analysis.

The classification method used in this study is a method that has been used in many studies (Kalantar et al. 2018; Nsengiyumva et al. 2019; Wu et al. 2020). The most important data concerning medium-scale landslide susceptibility studies are "landslide inventory maps" of the site where a study is conducted (Akıncı et al. 2015; Jiao et al. 2019; Yan et al. 2019). In this study, by taking the landslide inventory map with a 1/25,000 scale obtained from the MTA for 2007 as the base, among the 133 examples of landslides in the field, 70% were used for analysis, and the remaining 30% were as controls. In this way, by classifying each factor and using CBS functions, pixel numbers were produced.

In the following stage, by using the normalized frequency rat (NFR), landslide sensitivity maps were created. The NFR is widely used to predict landslides that can occur in the future by referring to the location and attribute information related to landslides that have previously occurred (Yalcin et al. 2011; Shahabi et al. 2015; Thanh et al. 2020). The sensitivity maps, which were created in this study by using 8 different categorical variables that affect landslides, were divided into 5 classes by using a natural break classification to represent areas that have very low (1), low (2), medium (3), high (4), and very high (5) degrees of sensitivity. The conformity of the control landslides with areas having high and very high degrees of sensitivity to landslides was determined to be a total of 82% for the NFR model. The formula used at this stage is as follows:

$$\mathrm{NFR} = \frac{FR - FRmin}{\mathrm{FRmax} - \mathrm{FRmin}}$$

2.2.2 Formation of flood risk maps

Factors such as lithology, topographic maps, the drainage network, and the topographic humidity index, which are widely used in the formation of flood sensitivity models, were analyzed by using the ArcGIS 10 program. Since the drainage network of the study area is predominantly in the form of urban floods, buffer values of 5000 m were used in the analysis. In the sensitivity model, natural break classification was used when determining the boundary weight values of the

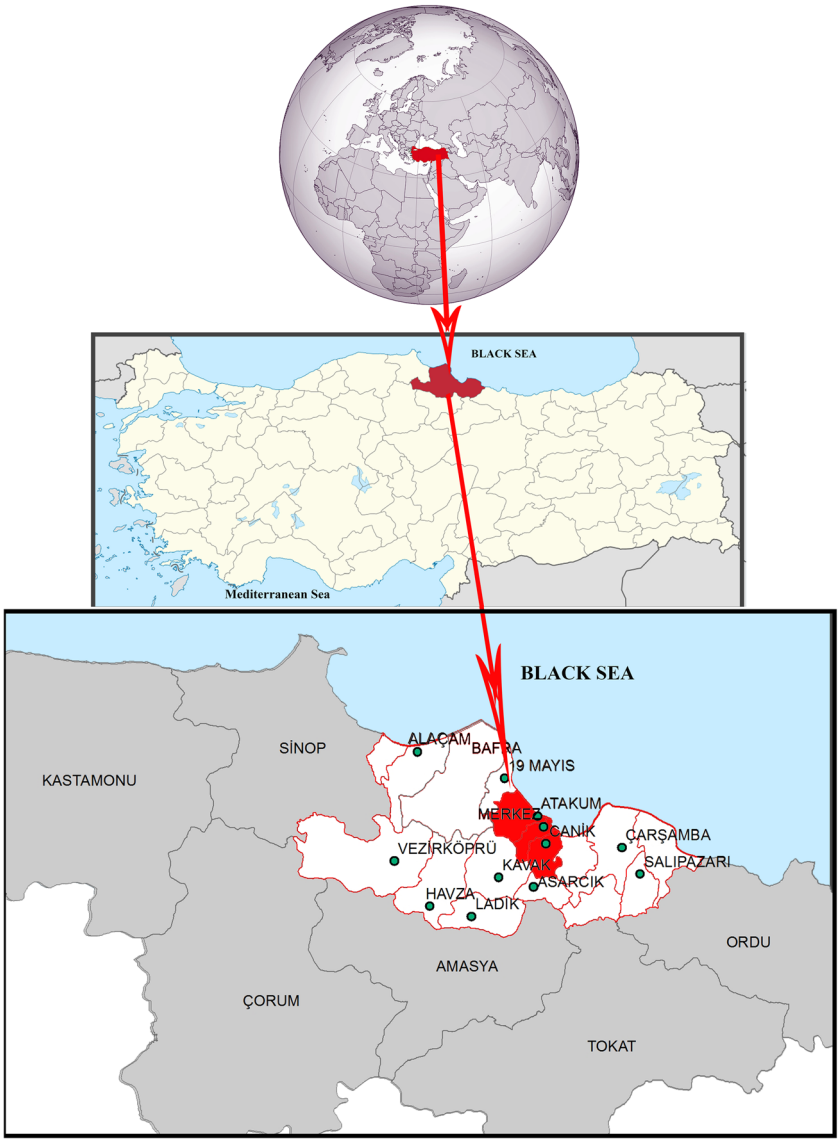

Fig. 1 Geographical location of Atakum

Table 1 Data features

Data layer	Scale	Data source	Data format
Landslide inventory	1/25,000	MTA	Polygon
Lithology	1/25,000	MTA	Polygon
Fault	1/25,000	MTA	Line
Topographical map 10 × 10	1/25,000	HGK	Line
Road network	1/25,000	ArcGIS 10.5	Line
Drainage network	1/25,000	ArcGIS 10.5	Line
Altitude curves	1/25,000	ArcGIS 10.5	Line
Sloping angle	1/25,000	ArcGIS 10.5	Line
Side sloping	1/25,000	ArcGIS 10.5	Line
Planning curve	1/25,000	ArcGIS 10.5	Line
Profile curve	1/25,000	ArcGIS 10.5	Line
Topographical humidity index	1/25,000	ArcGIS 10.5	Line

regions. The study area was divided into 5 classes: very low (1), low (2), medium (3), high (4), and very high (5).

2.2.3 Formation of electricity transmission line maps

High voltage electricity transmission lines result in areas where it is inconvenient for settlements to be established; for areas under and near high voltage electricity transmission lines, settlement permits are not granted. These lines were determined in the study area and were digitized by forming 50 m buffer areas; they were considered within the scope of this study.

2.2.4 Formation of biocomfort conformity maps

Biocomfort maps were created by using the long-term climatic parameters of the region. The physiological equivalent

Table 2 Classification of the data

Factor classification	Altitude	Sloping	Side sloping	Lithology	Profile curve	Curvature	Closeness to rivers	TWİ
	140	4	Flat	Kc	< 0	< 0	350	− 1.76
	260	8	North	Kpa	0	0	700	2.78
	380	12	Northeast	Kta	> 0	> 0	1050	4.95
	500	16	East	Qal			1400	8.48
	620	20	Southeast	Qek			1750	21.45
	740	24	South	Qk			2100	
	860	30	Southwest	Qt			2450	
	980	40	West	Tek			2800	
	1305	50	Northwest	Tet			3150	
		65.30		Tm			4937.94	
				Tmplm				
				Tmplsk				
				Tmplst				
				Tpea				

temperature (PET) index, which takes into account the physiological characteristics of humans, was used when determining bioclimatic comfort zones. In this study, monthly relative humidity, air temperature, global solar radiation, and wind speed data from stations reflecting different terrain textures and for the period 1980–2019 were used. Each station represented a different elevation and land use area. The monthly average PET values were calculated by using GIS software and based on the data obtained from the meteorological stations and made available for use. The GIS could calculate the average radiant temperature and thermophysiological temperature by using the data. Perceptions of thermally determined and calculated PET values included physiological effects on humans based on the years of the bioclimatic comfort maps produced.

2.2.5 General evaluation

In the final stage of this study, by overlapping all of the maps, areas that have a low risk of landslides and floods, that are located at a safe distance from the route of transmission lines, and that are convenient with regard to biocomfort conditions were determined. Hence, the areas that are most suitable for the establishment of settlement areas in accordance with multiple criteria were determined.

3 Results

The risk groups formed in accordance with the situation of landslides within the scope of this study are shown in Fig. 2.

According to the landslide risk group map created at the end of the study, 97.83% of the entire study area was determined to be a landslide-free zone, 0.52% of the region was determined to be an active landslide zone, and 1.65% of the region was determined to be a passive landslide zone. The regions bearing landslide risks had an irregular distribution. The risk group map created based on the situation of floods within the scope of this study is shown in Fig. 3.

According to the calculations made based on the flood risk group map created as a result of the study, it has been determined that nearly 36.44% of the total study area was composed of first-class lands, 30.42% was composed of second-class lands, 20.99% was composed of third-class lands, 9.96% was composed of fourth-class lands, and 2.19% was composed of fifth-class lands. The fourth- and fifth-class lands are areas where there is a low risk of floods, while the third-class lands are areas with a medium level of risk. These lands can be considered suitable for construction. In this situation, the areas that are suitable for construction with respect to the flood risk are shown in Fig. 4.

As shown in Fig. 4, the areas belonging to the first- and second-class risk groups, which have low or medium levels of flood risk, constitute nearly 66.86% of the total study area. The high voltage electricity transmission lines that are located in the study area and where it is inconvenient for settlement units to be established are shown in Fig. 5.

High voltage electricity transmission lines, which make construction in the areas where such lines are located significantly risky, constitute nearly 2.01% of the study area. The areas in the study area considered to be convenient with respect to biocomfort aspects based on climatic data and topographic data are shown in Fig. 6.

The regions of the study area are classified as comfortable and uncomfortable, and it is seen that the middle sections of Atakum are more comfortable. The calculations determined that nearly 42.87% of the study area was suitable with respect to biocomfort aspects, meaning that they were comfortable,

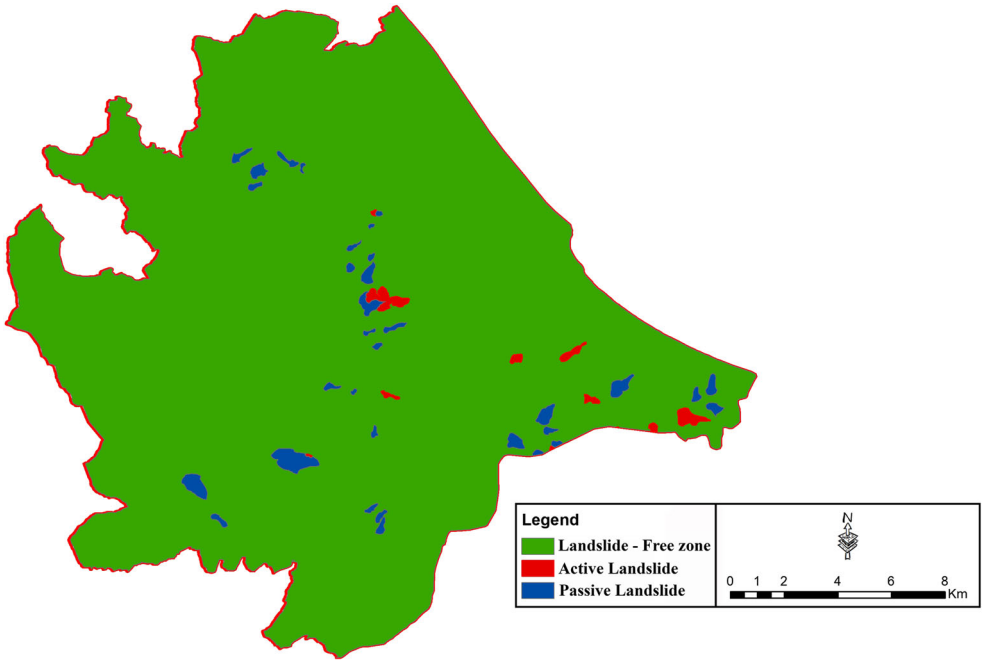

Fig. 2 Map of risk groups based on the situation of landslides

whereas 57.13% of the study area was considered to be unsuitable with respect to biocomfort aspects, meaning that they were composed of uncomfortable areas.

By considering all the risks evaluated within the scope of this study, areas that were located where both landslide and flood risks were at low levels, that were located at a sufficiently far distance from electricity transmission lines, and that were suitable with respect to biocomfort aspects were considered to be the most suitable areas for settlement areas. Therefore, by considering all these criteria, the areas that were most convenient for the establishment of settlement areas were determined, and these areas are shown in Fig. 7.

The areas suitable for the establishment of settlement areas with regard to the criteria considered in this study are examined, and it is observed that these areas are scattered

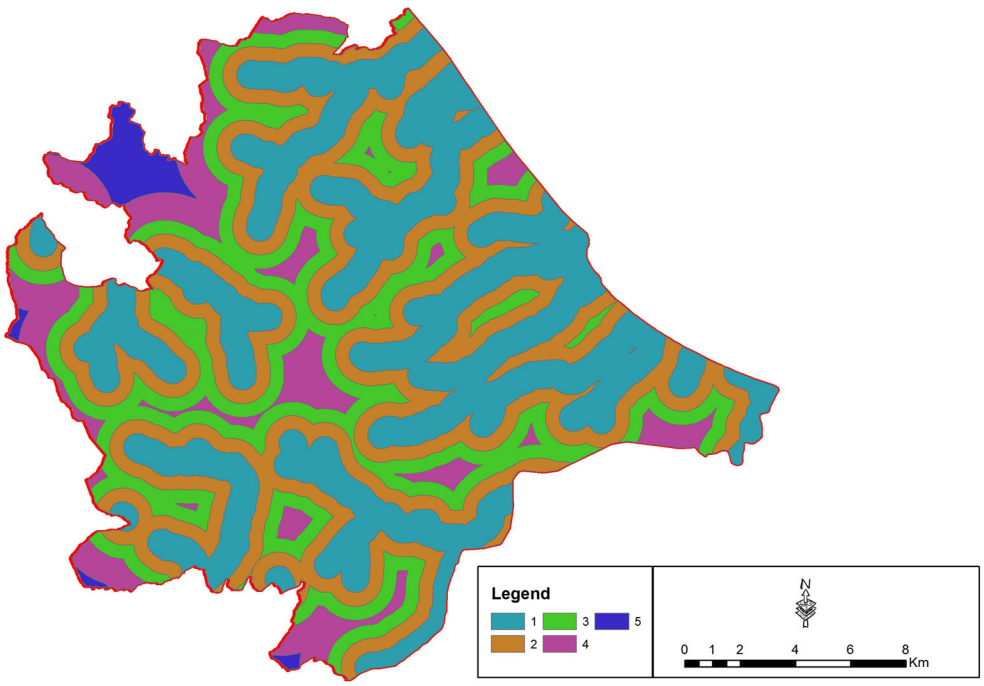

Fig. 3 Risk group map based on the situation of floods

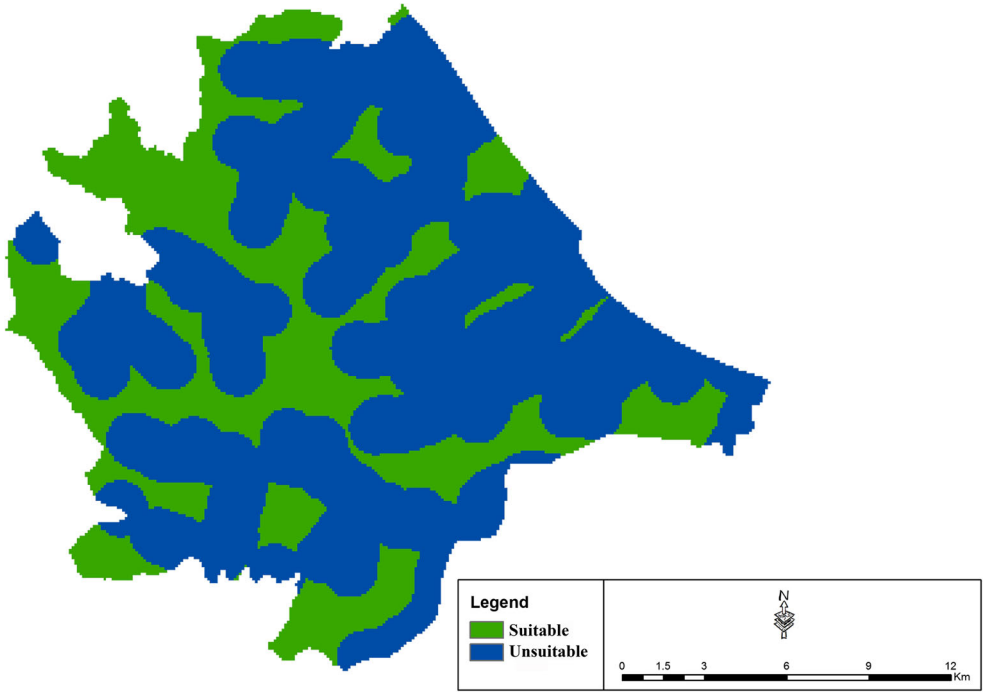

Fig. 4 Areas that are suitable for construction with regard to the flood risk

throughout the district. As a result of this study, the ratio of areas determined to be suitable for the establishment of settlement areas to the total study area was calculated to be only 13.73%. Therefore, nearly 86.27% of the study area is considered to be within the context of areas that are unsuitable for settlement with respect to at least one of the criteria considered in this study.

4 Discussion

As is the case in many countries around the world, the increasing population in Turkey and migration from villages to cities necessitate the opening of new settlement areas. The need for new settlement areas is mostly met in line with the preferences of local managers in accordance with infrastructure facilities.

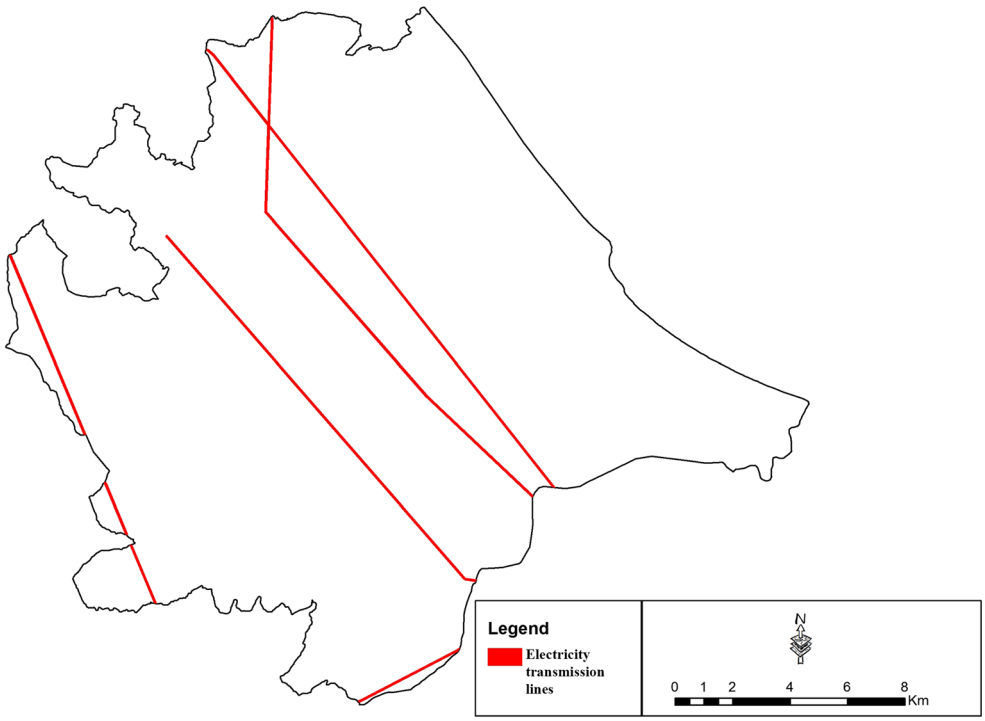

Fig. 5 Electricity transmission lines

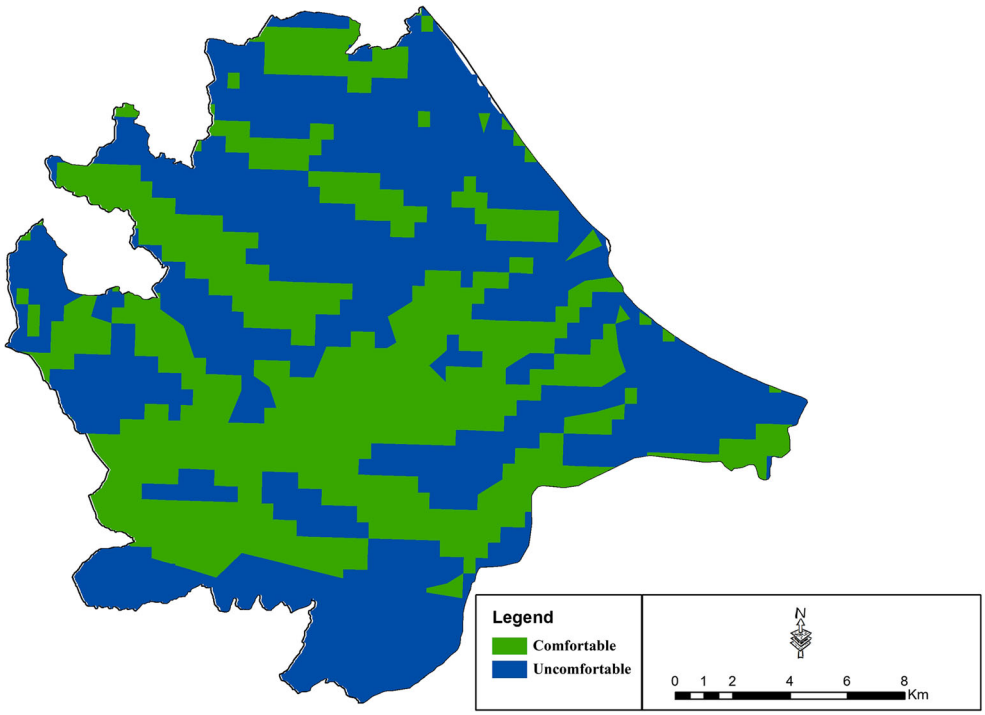

Fig. 6 Areas that are suitable with respect to biocomfort aspects

However, if the wrong places are selected, the lives of thousands of people will be lost, and very significant amounts of financial damage will be incurred each year.

Landslides, which constitute one of the factors considered in this study, are among the most important natural disasters with regard to loss of life and economic losses. Even though landslides are geomorphological events that occur in almost every region of Turkey because the Black Sea region has a mountainous topography, the region has plenty of rain, and it is located close to the North Anatolian Fault Line, the study area is a region that is more sensitive to landslides (Ercanoglu et al. 2004; Ercanoglu 2005; Yaman 2017).

Landslides are the most important natural disasters that have a direct impact on human lives in various countries. It has been stated that between 1976 and 2015, more than 400 people in Turkey lost their lives during landslides. Landslides are especially important because they are disasters that cause the loss of many lives at the same time. For example, during the landslide that took place in Trabzon Çatak on 23 June 1988, 64 people lost their lives (Yaman 2017).

Floods are another type of disaster evaluated within the scope of this study. Floods are disasters that can affect wide regions and cause more material damage. It has been stated that due to the floods that took place around the world between 1900 and 2008, nearly 2 billion people were affected, and financial losses of nearly 200 billion dollars were incurred. During these floods, nearly 3 million people lost their lives. Forty-nine percent of the 560,000 people who lost their lives in the last 20 years due to natural disasters such as floods, earthquakes, fires, storms, and volcanic eruptions lost their lives as a result of floods and torrents (Dölek 2013).

Floods and torrents are also frequently seen in Turkey, and they cause a significant amount of financial damage in addition to the loss of many lives. For example, among the flood disasters to have taken place in Turkey, during the torrent disaster that occurred in the Western Black Sea region in 1998, 17 people lost their lives, and during the flood disaster that took place in Trakya in 2009, 32 people lost their lives. During the sudden floods that devastated the Aegean coasts in 1995, 61 people lost their lives (Kömüşçü et al. 2011; Tonbul and Sunkar 2011). Between 1975 and 2010, 695 flood events occurred in Turkey, and 634 people died. Additionally, an area of 810,000 ha were inundated with water, causing damage amounting to nearly 3.7 billion dollars (Dölek 2013).

While floods and torrents constitute one of the important problems in Turkey, the risk of floods and torrents are not adequately considered in the establishment of settlement areas, causing a large amount of damage and loss of life.

Electricity transmission lines are another factor considered in this study. Electricity transmission lines are lines that enable electricity to be carried thousands of kilometers, and the interval of high voltage electricity transmission lines is in the range of 154–400 kV. There is a continuous flow of electricity through these conductive wires, and electricity transmission lines can sometimes cause fatal incidents and significant health problems (Apaydın 2019).

Areas where there is a high risk of landslides and floods and areas that are situated close to electricity transmission

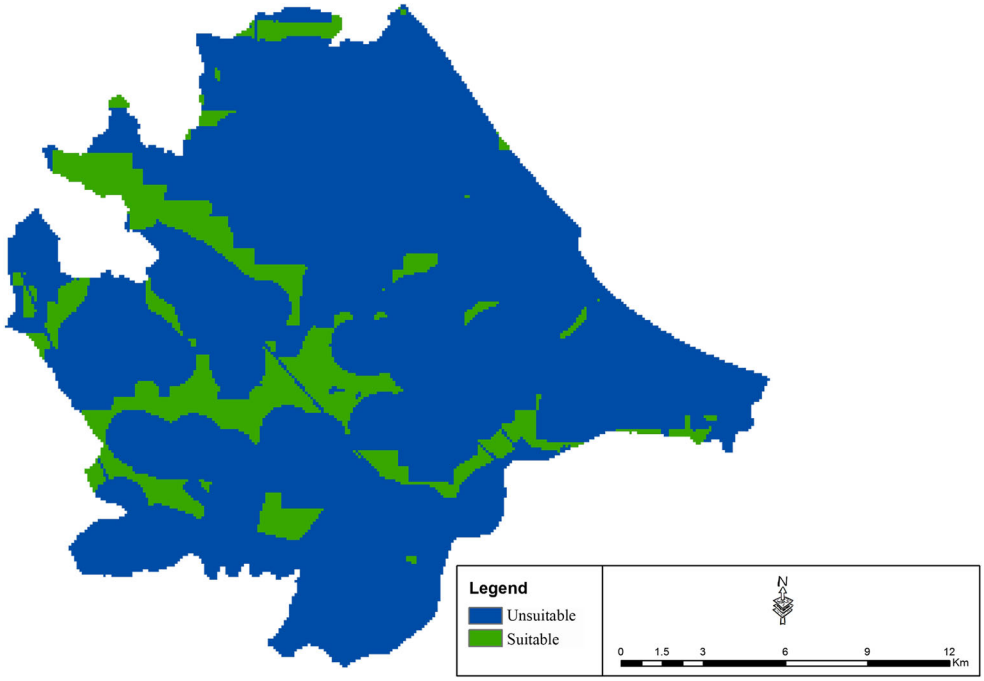

Fig. 7 Areas suitable for settlement area planning

lines are areas where settlement areas should absolutely not be established. One of the criteria evaluated is related to areas that are suitable with respect to biocomfort aspects. The situation where temperature, wind speed, and humidity are within appropriate intervals for people to feel comfortable is defined as "bioclimatic comfort" or "biocomfort" (Cetin 2016, 2019, 2020).

Biocomfort is a factor that has a direct impact on the comfort, peace, health, and performance of people. A situation where the biocomfort values of the environment fall outside the range of values considered to be comfortable can cause symptoms such as nervousness and feeling of fatigue, and it can also cause various problems related to the circulatory and respiratory systems and ailments such as burning eyes and dry throat. For this reason, people try to bring environmental conditions to within intervals that are convenient for them by means of their clothing as well as heating and cooling systems (Cetin 2015; Cetin et al. 2018, 2019; Adiguzel et al. 2020; Elhadar 2020).

Bringing the biocomfort conditions of an environment where there are people to the range of appropriate values can cause a significant amount of energy consumption. It is anticipated that global energy consumption in 2030 will be 60% more than the current level of consumption and that the energy consumption of Turkey in 2030 will be nearly two times the current level of national consumption. Given that forecasts project that the population will increase by a rate of only 1% during this period, it is easy to understand how large the increase in energy consumption will be. The amount spent on heating and cooling constitutes a significant share of energy consumption (Cetin et al. 2018; Zeren Cetin et al. 2020; Elhadar 2020; Zeren Cetin and Sevik 2020).

For this reason, the establishment of settlement areas in regions that are suitable with respect to biocomfort aspects holds great significance with respect to both human comfort and energy efficiency. Due to the awareness of the impact of biocomfort on human health and energy efficiency, many studies have been conducted in different regions with the aim of determining areas of biocomfort (Lodi et al. 2017; Potchter et al. 2018; Xiong et al. 2019). However, the number of studies being conducted to determine areas that are suitable with respect to biocomfort aspects is still quite limited.

5 Conclusions

The increasing population and migration to urban areas necessitate the opening of new settlement areas in many regions. However, the selection of these areas, meaning the determination of new settlement areas, is carried out mainly by considering short-term costs, based on the personal decisions of managers or settlers, and with little to no recourse to scientific studies. Wrong place selection can cause the loss of property and lives due to the occurrence of various natural disasters in subsequent years. However, conducting risk analysis before the establishment of new settlement areas and establishing settlement areas in regions with low risk levels can help avoid major disasters and the impact of natural disasters.

In fact, when performing place selection, certain criteria can be considered. However, these criteria are generally shaped in accordance with the conditions at the time. For

example, after the occurrence of destructive floods or torrents, areas bearing the risk of floods and torrents will be placed on the agenda for a certain period of time; afterwards, however, these problems will be forgotten, and these risks will no longer be the primary evaluation criteria when settlement areas are established. History has witnessed thousands of natural disasters causing the loss of millions of lives. Perhaps it may not be possible to be completely protected from such disasters, but by taking simple precautions, the loss of property and life can be reduced to a minimum.

Determining the regions that are suitable with respect to biocomfort aspects in addition to natural disasters and establishing settlement areas in these regions can enable a significant amount of energy savings in addition to saving the lives of thousands of people. However, to select the most convenient places, it is necessary to determine the levels of disaster risk with regard to all possible disasters, such as earthquakes, fires, floods, torrents, and avalanches, in a region. Afterwards, areas such as those that are close to electricity transmission lines or industrial plants, areas with a high level of pollution, and garbage collection areas, which can be risky for human health, should be determined. Additionally, by determining the areas that are suitable with respect to biocomfort aspects, by conducting detailed feasibility studies, and by considering all the factors in the selection of settlement areas, place selection should be carried out. Pre-evaluation studies conducted before the establishment of settlement areas incur very low costs, and in the long term, they can prevent significant losses of life and financial damage.

Authors' contributions CK, HS, BA, and MC designed the study and performed the experiments; HS, BA, and MC performed the experiments, analyzed the data, and wrote the manuscript.

Data availability Not applicable.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Code availability Not applicable.

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