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RESEARCH ARTICLE

Determining the suitable settlement areas in Alanya with GIS-based site selection analyses

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Abstract

Urbanization, which is defined as an irreversible global-scale problem nowadays, necessitates the foundation of new settlement areas. In general, no sufficient scientific assessment and analysis were performed during these processes, and thus, various natural disasters cost the loss of many lives and properties every year. Nevertheless, considering the areas that are risky in terms of natural disasters during the selection of settlement areas might prevent a large-scale loss of lives and properties because of natural disasters. Within the scope of this study, it was aimed to determine suitable settlement areas in the Alanya district, which is one of the significant points of interest for tourists in our country and has a large population and new settlement areas because of this increasing population. Within this scope, besides the risks of flood and landslide that are the most important natural disasters in the region, and a forest fire that is among the most significant risks for the region, also the biocomfort zones were included in the assessments. As a result of the study, it was determined that the most important natural disaster risk was flooding in a large portion of the region and that only 6.72% of the study area was suitable for settlement in terms of all the criteria examined in the present study.

Keywords Site selection · Flood · Landslide · Forest fire · Biocomfort · Alanya

Introduction

The world population, which was only 720 million approx. 250 years before, nowadays reached almost 8 billion (Ghoma et al. 2022). In addition, the urbanization rate that was < 10% in the 1900s is approx. 50% nowadays (Isinkaralar et al. 2022) and estimated to reach 90% by the year 2030 (Aricak et al. 2020; Karacocuk et al. 2022). Given the official data, the urbanization rate in Turkey reached 92.5% (Kilicoglu et al. 2021).

Population growth and concentration of population at specific locations made the urbanization problem one of the most difficult problems to resolve throughout the world. Such that it is stated that two irreversible global problems of today were global climate change and urbanization and that urbanization significantly contributed to global climate change (Ucun Ozel et al. 2019; Koc 2021; Varol et al. 2022a,b).

Rapid and unplanned urbanization creates various problems such as infrastructural problems, unhealthy living conditions, traffic jams, and environmental pollution (Kilicoglu 2021; Elsunousi et al. 2021; Cesur et al. 2022; Cetin et al. 2022a,b; Tekin et al. 2022). Besides them, unplanned urbanization and settlement area selection without scientific data and preliminary analyses further increase the problems and urban areas. One of these problems is natural disasters (Liu et al. 2021). Natural disasters, which are among the most important threats to housing safety in urban areas, cause the loss of millions of lives annually, as well as billions of dollars in financial damage (Akinci

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et al. 2011; Rana et al. 2021). The most effective way of minimizing the loss of life and property in natural disasters is the multidimensional analysis and consequent planning studies in order to determine the risky areas and establish the settlement areas in low-risk regions (Kilicoglu et al. 2020).

The present study aimed to determine suitable settlement areas in the Alanya district of Antalya province, which is one of the significant points of interest for tourists in our country and had a large population and new settlement areas because of this increasing population. For such studies, it is recommended to consider the primary risks in the region (Kilicoglu 2022). Thus, within the scope of this study, the risks of flood and landslide, which are the most important natural disasters in the region, and a forest fire, which is one of the most important natural risks, were examined and the bio-comfort zones, which directly influence human life, peace, comfort, and health and play an important role in energy consumption, were included in the study. Thus, considering the case of the Alanya district, it was aimed to determine the most suitable potential settlement areas.

Material and methods

Material

The present study was carried out in the Alanya district, which is one of the most important touristic destinations in Turkey and became an important point of interest in terms of agriculture and industry. Located between 36° 18′ 40.13″–36° 47′ 2.35″ N and 31° 38′ 56.52″–32° 27′ 8.47″ E, the district has the surface area of 1577.38 km^2. The altitude in the district ranges between 0 and 2481.87 m, whereas the slope ranges between 0 and 82.6°. Besides that, the mean altitude is 723.07 m, and the mean slope is 17.69° (Fig. 1).

Given the address-based population registration system of the Turkish Statistical Institution (TURKSTAT), Alanya has a population of 350,636 as of the year 2021. Alanya district is a district that is widely preferred as a settlement area thanks to its advantages, such as developmental level, social opportunities, tourism potential, and geopolitical location, and popularity which gradually increases for this reason.

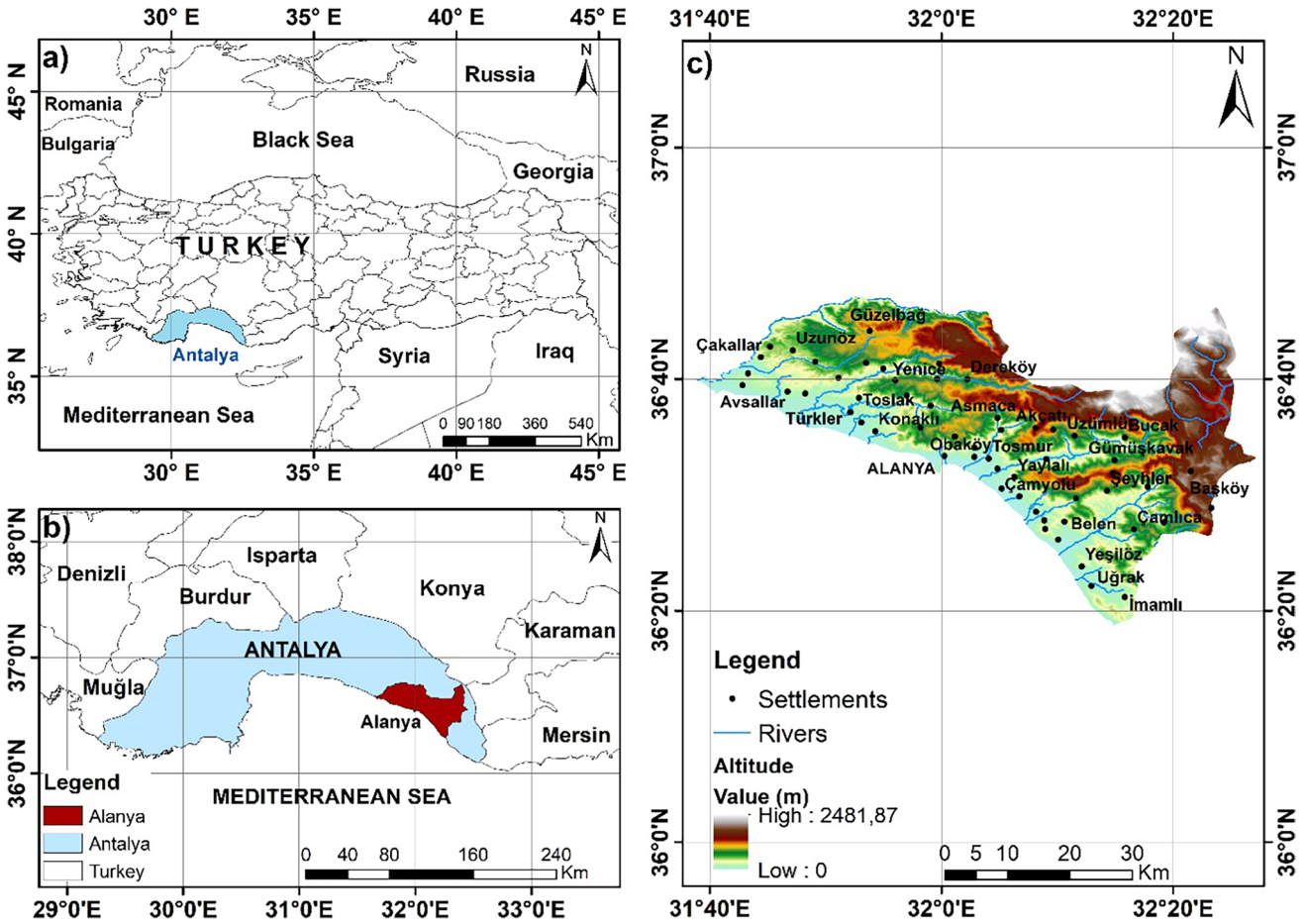

Fig. 1 Location of Alanya district

Figure 2 illustrates the population growth of the district since the year 2007.

Together with the rapid growth of population in the district, it became a necessity to constantly establish new settlement areas. The district is located in a place that bears a very high risk of landslides and floods. In addition, the region is one of the areas having the highest frequency of forest fires, and since the forest areas overlap with settlement areas, the fire risk is at the highest level.

Method

Landslide sensitivity map of the study area

The landslide sensitivity map of the study area was created using the support vector machine (SVM) algorithm. SVM is one of the machine-learning models widely used in mapping landslide sensitivity (Kavzoglu et al. 2014; Colkesen et al. 2016; Ada and San 2018; Vakhshoori et al. 2019; Hu et al. 2020; Akinci and Zeybek 2021; Akinci 2022). The parameters altitude, slope, aspect, plan and profile curvature, topographic wetness index (TWI), lithology, land cover, distance to faults, distance to roads, and distance to drainage networks were used in preparing the landslide sensitivity map of the study area. Used for training the SVM machine learning model in this study, the landslide inventory map was obtained from the General Directorate of MTA (General Directorate of Mineral Research and Exploration). In the present study, the "svmRadial" method of the R 3.6.3 "caret" package (Kuhn 2008) was used in implementing the SVM model. The accuracy and estimation capability of the SVM model were assessed using the area under curve (AUC) of the recipient operation characteristic (ROC) curve. Accordingly, the prediction rate of the SVM model was calculated to be 98.9%.

Forest fire sensitivity map of the study area

Various approaches were developed to prepare forest fire sensitivity maps. The approaches based on machine learning have been widely used in recent years (Kalantar et al. 2020; He et al. 2021; Mohajane et al. 2021; Piao et al. 2022; Trucchia et al. 2022). In the present study, a forest fire sensitivity map was created using the SVM model. During this process, the parameters of altitude, aspect, land cover, forest type, forest density, slope, TWI, distance to residential areas, distance to roads, and distance to power transmission lines were used. As in the landslide sensitivity map studies, the SVM model was verified using the area under the ROC curve. Accordingly, the prediction rate of the SVM model was calculated to be 91.6%.

Flood sensitivity map of the study area

The river system in the study area was obtained from the Copernicus land monitoring service (https://land.copernicus.eu/imagery-in-situ/eu-hydro). Then, by using the Euclidean distance function in ArcGIS 10.5 software, the map for the distance to rivers was prepared. The distance map was classified into five groups 0–500 m: very high, 500–1000 m: high, 1000–1500 m: moderate, 1500–2000 m: low, and 2000–5350.82 m: very low. Then, the flood sensitivity map of the study area was obtained.

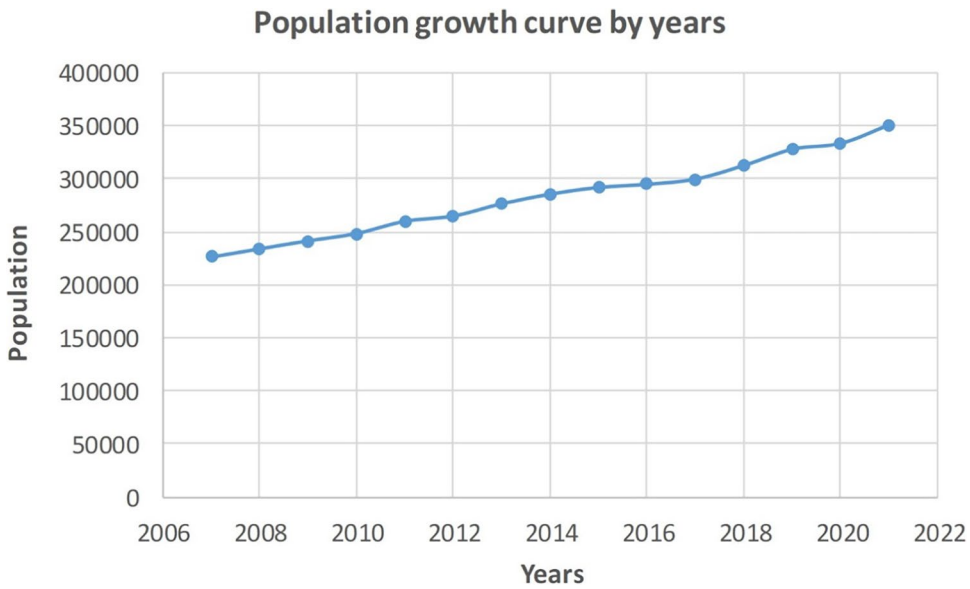

Fig. 2 Population diagram of Alanya district

Biocomfort zone map

Biocomfort is defined as the climatic parameters such as temperature, humidity, and wind being in the range in which humans feel comfortable. Using the long-term climate parameters, the biocomfort zone maps of the region were created. The meteorological parameters used in the calculation of biocomfort are mean daily temperature degraded to sea level, mean daily relative humidity, and wind speed. The spatial distribution of results at the sea level was calculated using the inverse distance weighting (IDW) method. Using DEM data, the altitude-related PET values were obtained, and the bioclimatic comfort maps were created (Zeren Cetin and Sevik 2020; Adiguzel et al. 2020; Kilicoglu 2022; Zeren Cetin et al. 2022).

General assessment

Within the scope of this study, the flood, landslide, and forest fire sensitivity maps created at sensitivity classes between 1 and 5 were reclassified as suitable for settlement and not suitable for settlement. Within this context, for all three types of natural disasters, the areas with sensitivity at very low or low levels were classified as suitable for settlement, and the value "1" was assigned to the pixels. The areas with moderate, high, and very high sensitivity were assigned the value "0" and considered areas that are not suitable for settlement. At the final stage, the flood, landslide, forest fire sensitivity, and biocomfort zone maps were overlapping, and a settlement suitability map was created.

Results

The landslide sensitivity status of the study area was divided into five classes: very low, low, moderate, high, and very high, and the landslide sensitivity map is presented in Fig. 3.

Examining the landslide sensitivity map of the study area, it can be seen that 13.06% of the region was highly sensitive to landslides, and 5.78% was very highly sensitive to landslides. It was determined that the areas suitable in terms of landslide risk the most were located in the shore parts of the district and that the landslide risk was very high in the mountainous region in the southeast-northwest direction was

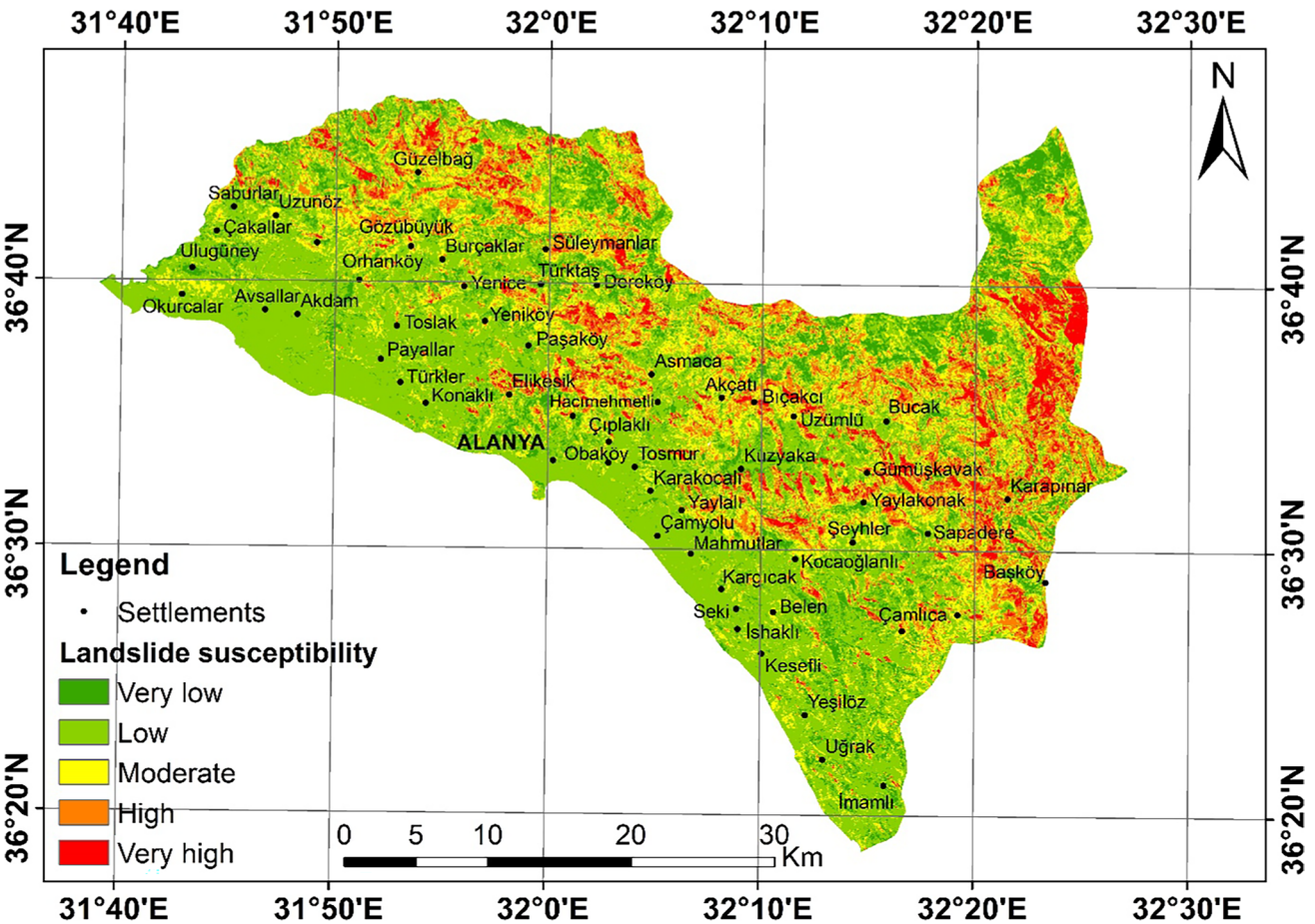

Fig. 3 Landslide sensitivity map of the study area

very high. The forest fire sensitivity map of the study area is presented in Fig. 4.

Examining the forest fire sensitivity map of the study area, it can be seen that the northern portion of the district was highly sensitive to forest fire, whereas the least risky portion was the shore portion and northeastern portion. Given the calculations, the forest fire sensitivity of the district was found to be very low at 20.9% portion, low at 34.52%, moderate at 17.37%, high at 14.21%, and very high at 13%. The flood sensitivity map of the study area is presented in Fig. 5.

Flood sensitivity in the study area was classified into five groups: very high, high, moderate, low, and very low. Given the calculations, the flood sensitivity of the area was found to be very low at 20.44%, low at 15.36%, moderate at 19.08%, high at 21.35%, and very high at 23.77%. Examining the flood sensitivity map, it is very hard to say that flood risk is higher at any specific location. It can be seen that the flood risk is very dispersed in the district. The areas that are suitable in terms of biocomfort were determined and are presented in Fig. 6.

The study area was divided into two groups as suitable and non-suitable in terms of biocomfort. Examining the biocomfort map of the study area, it can be seen that the areas suitable in terms of biocomfort concentrated on the shore portion of the district, whereas there were limited areas in the mountainous portion. Considering the calculations from the aspect of biocomfort, approx. 44% of the study area was found to be suitable and 56% to be non-suitable. At the final step, flood, landslide, forest fire, and biocomfort maps were overlapped, and a settlement suitability map was created, and it is presented in Fig. 7.

Given the map, the areas that are suitable for all the factors were determined to be the potential settlement areas. Accordingly, it was determined that 6.72% of the study area was suitable for settlement, and 93.28% was found to be not suitable. It can be seen that the areas that are suitable for settlement were mainly located nearby the shore portion.

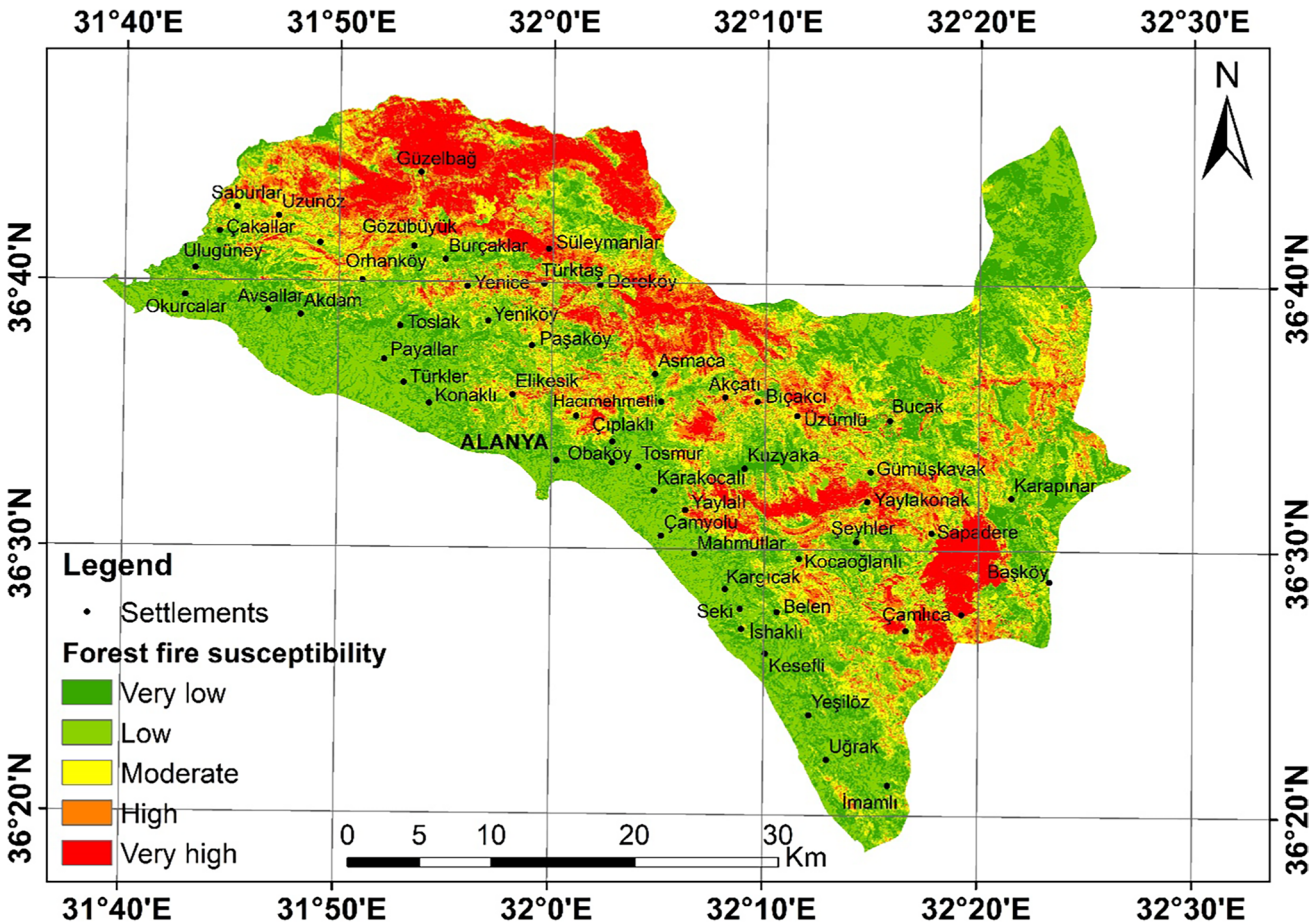

Fig. 4 Forest fire sensitivity map of the study area

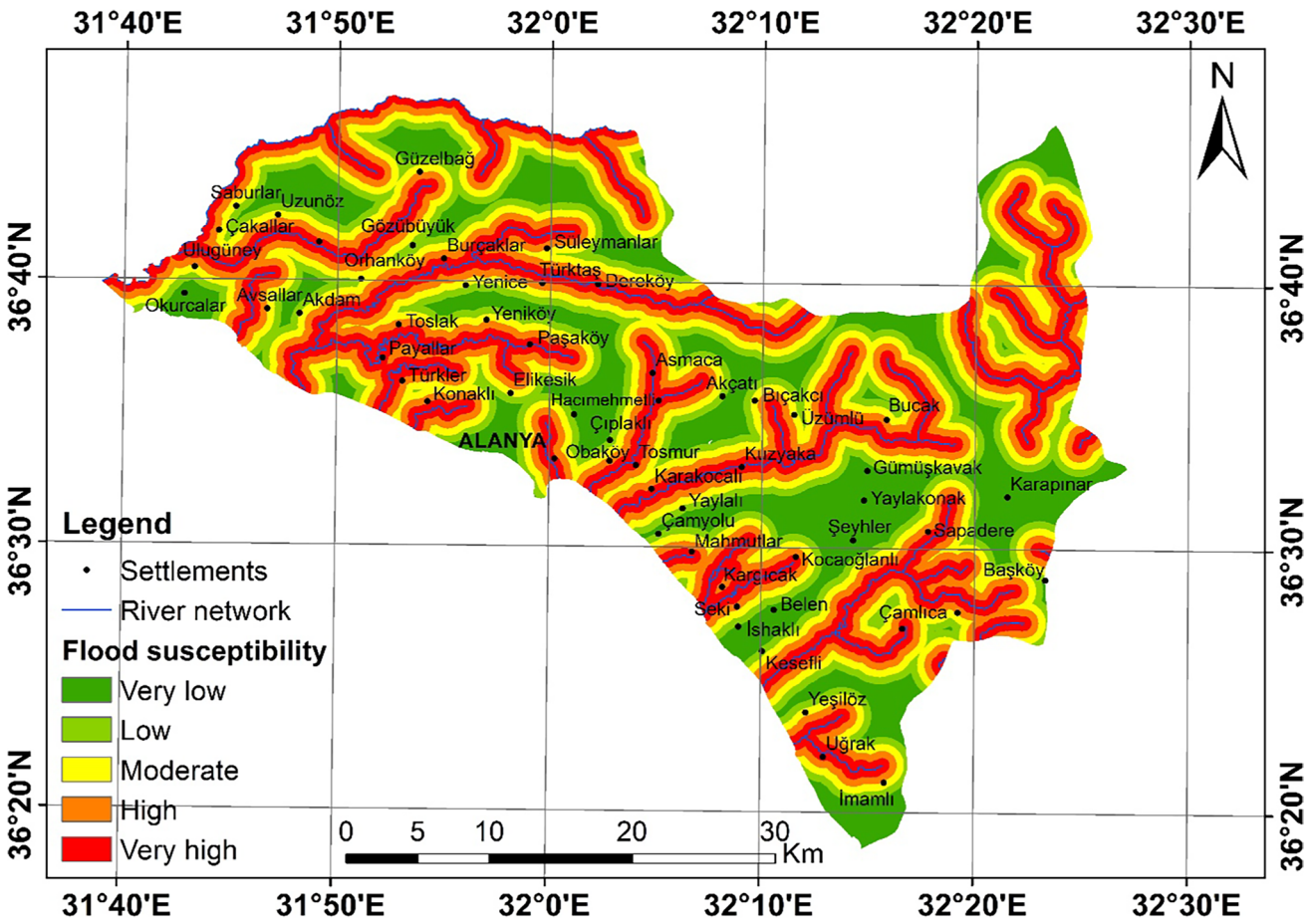

Fig. 5 Flood sensitivity map of the study area

Discussions

Within the scope of this study, the risky areas in terms of natural disasters, which cause significant loss of life and property worldwide, in the Alanya district of Antalya province were determined. The first natural disaster examined in the present study was landslides that causes the loss of lives and properties at a very large level in a short time. Especially 3.7 million km^2 area worldwide is subjected to landslides and approx. 300 million individuals live in these areas. In Turkey, it is known that 13,194 landslides occurred in the last 50 years, and 59,345 individuals were affected (Fidan 2019; Kilicoglu 2022). Alanya district, examined here, is a district where the altitude increases with increasing distance to shore, and landslides are frequently seen because of its mountainous topography.

Another risk factor examined here is a forest fire. Besides damaging the forests, forest fires that are frequently seen in Turkey also cause severe economic and social problems. Forest fire potential is very high, especially in the Aegean and Mediterranean shores of Turkey. For this reason, it is very important to create forest fire sensitivity maps in order to effectively manage forest fires and prevent the damage caused by those fires. Tien Bui et al. (2016) and Trucchia et al. (2022) defined forest fire sensitivity as the probability of forest fire in a specific area depending on the characteristics of that area. Forest fire sensitivity maps are those presenting the potential areas where forest fire might occur in the future, or the areas that are prone to fire (Leuenberger et al. 2018). The district examined here is located in one of the most-risky locations in Turkey in terms of forest fires, and forest fires frequently break out in this region. In addition, it was reported that the Mediterranean region, where the study area is located, would be one of the regions to be affected by global climate change the most (Varol et al. 2021; Canturk and Kulac 2021) and that frequency and risk of a forest fire would increase together with the global climate change (Ertugrul et al. 2021). Thus, a forest fire is one of the most important risk factors possibly to be experienced in the near future (Ertugrul et al. 2019).

Considering the number of events, the natural disaster that is observed most frequently after landslides and

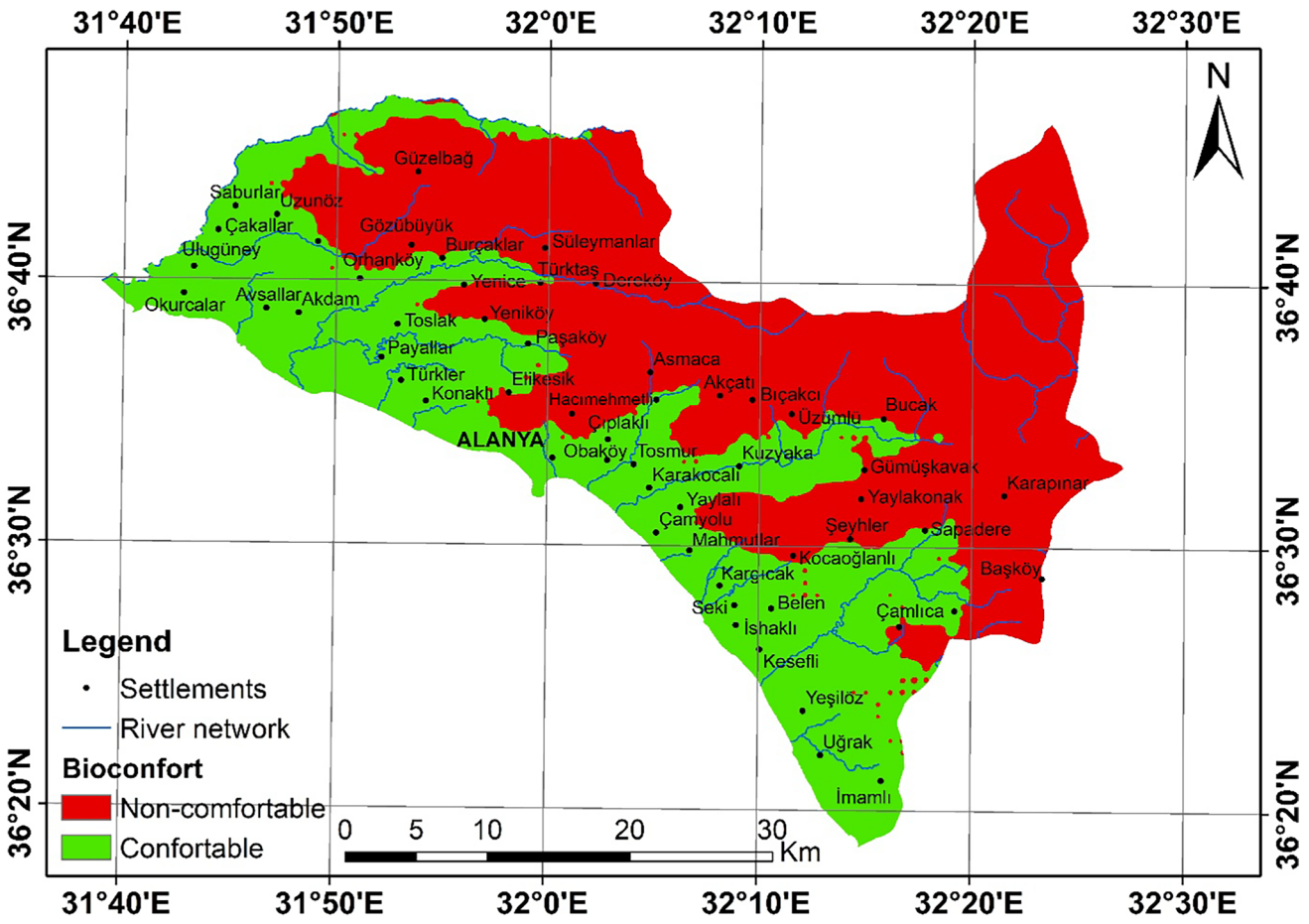

Fig. 6 Biocomfort map of the study area

earthquakes is flooding in Turkey. Floods, which cause the highest level of economic damage after earthquakes, occur in all the provinces of Turkey (ADRC 2019). In Turkey, 428 flood cases, 176 of which resulted in death, were reported in Turkey between the years 2001 and 2011 (Taş et al. 2013). On the other hand, it can be seen that flood disasters significantly increased in Turkey due to heavy rainfalls in recent years (Çanta et al. 2022). Floods damage settlement areas, agricultural lands, transportation, and infrastructure facilities, causing severe economic damages. It was reported that floods caused approx. $100 million in economic damage annually in Turkey (ADRC 2019). For this reason, one of the most important parameters to consider while determining the areas suitable for settlement is the flood sensitivity of the region. Considering the aspect of flood sensitivity, it can be stated that areas far enough from rivers are the areas suitable for settlement the most.

Another factor examined here is biocomfort. Shortly defined as the climatic parameters such as temperature, wind speed, and humidity being within the most suitable range for humans, biocomfort is a factor directly influencing the comfort, peace, health, and performance of individuals (Cetin 2020). In case that the climatic parameters are not within the suitable ranges, anger, disturbance, discomfort, and fatigue might be observed, as well as circulatory and respiratory system problems, burning eyes, and dry throat. In addition, performance might remarkably decrease (Bozdogan Sert et al. 2021). In this case, it is tried to adjust the climatic parameters in the medium to biocomfort levels by making use of various instruments such as heating systems or air-conditioners (Adiguzel et al. 2022). It requires a high amount of energy consumption, and one of today's most important problems is the increasing energy requirement and the damage caused by the production made in order to meet that requirement (Zeren Cetin and Sevik 2020; Adiguzel et al. 2020; Zeren Cetin et al. 2022). Thus, choosing the areas that are suitable in terms of biocomfort is very important for energy efficiency as well as human comfort, ease, performance, and health (Cetin 2019; Gungor et al. 2021).

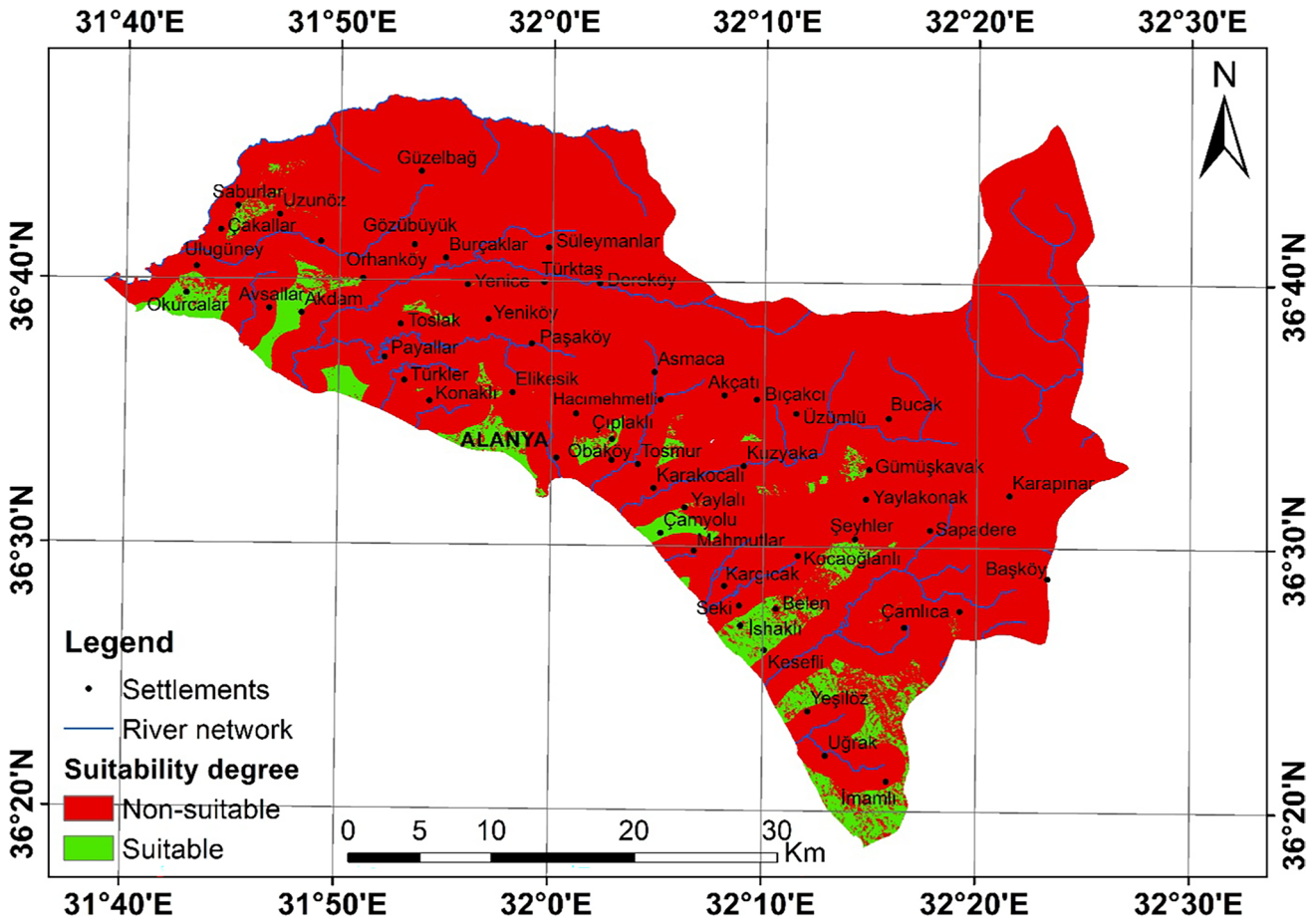

Fig. 7 Settlement suitability map

Conclusions

Within the scope of this study, the areas that are suitable for settlement in Alanya district, in which the population constantly grows and consequently the need for founding new settlement areas constantly increases, were determined considering the most important risk factors for the region. It is recommended to carry out studies on settlement area selection by considering the primary risks for the regions. For this reason, the present study was carried out by considering the landslide, forest fire, flood, and biocomfort factors, which are the most important risk factors for the region. As a result, it was determined that 6.71% of the study area was suitable for settlement and 93.28% was not. The low percentage of suitable areas was thought to be because the area has a relatively dense river system, and thus, 64% of the study area was not suitable for settlement in terms of the flood risk.

Author contribution Original idea: SD, CK, HA, HS, and MC. Experiment design: SD and CM. Measurement: HA and MC. Data analysis: HA, SD, and MC. Manuscript preparation and revisions: HA, HS, SD, CK, and MC.

Data availability The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Code availability Not applicable.

Declarations

Ethics approval and consent to participate Not applicable.

Consent for publication Not applicable.

Conflict of interest The authors declare no competing interests.

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