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Determining the effect of urbanization on flood hazard zones in Kahramanmaras, Turkey, using flood hazard index and multi-criteria decision analysis

Hurem Dutal

Abstract   Floods are the most destructive natural hazard throughout the world. Identifying flood hazard zones is the first step in flood risk management. Land use changes, especially urbanization, is the key factor in the destructiveness of flood events and change in flood risk. Therefore, determining the effect of urbanization on the changes in flood hazard zones presents a valuable data for effective flood risk management and urban development planning. In this context, the aim of this study is to reveal the effect of urbanization on flood hazard zones in Kahramanmaras city. In this study, an index-based approach was used to identify the flood hazard zones. To calculate a flood hazard index, the susceptibility map was multiplied by the land use map by using the raster calculator tool in the ArcGIS. The susceptibility map was generated by combining the maps of flow accumulation, distance to stream, slope, and elevation parameters based on parameter weights obtained from the analytical hierarchy process (AHP) method. Two land use maps for the years 1990 and 2018 were separately overlaid with the susceptibility map to reveal the effects of urbanization on flood hazard zones. According to the results, it was found that very low, low, and moderate hazard zones decreased by 0.01%, 0.09%, and 1.2%, respectively whereas the high and very high zones increased by 3.30% and 0.58%, respectively due to urbanization. It was also determined that the main reason for the increase in the high zone was the expansion of urban areas into agricultural areas in the study area.

Keywords   Urbanization · Flood risk · AHP · GIS

Introduction

The concept of flood briefly expresses high-energy water movement. In a broader expression, it is the uncontrolled flow and spread of large water bodies in stream beds, hills, depression areas, and valleys (Adaji et al., 2019; Doocy et al., 2013; Uddin & Matin, 2021). Floods have beneficial effects on the ecosystem to a certain limit such as providing water and nutrients for riparian zones, removing contaminants from the flood plain, and enhancing soil fertility. But it causes adverse effects on water reservoirs, settlements, lives and properties, ecosystems, and agricultural systems when this threshold is exceeded (Mahato et al., 2021). In terms of endamaging, flood events are placed on the top among natural disasters around the world due to their higher detrimentalness and incidence (Chen et al., 2021; Natarajan & Radhakrishnan, 2021). Every year, 170 million people are affected by flood events in the world (Kazakis et al., 2015). According to the UN Office for Disaster Risk Reduction (UNISDR), 3062 flood events occurred between 1995 and 2015. The number of these flood events corresponds to 43%

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of all-natural disasters that occurred in the same period. As a result of these events, 150,061 people lost their lives (Mahato et al., 2021; Natarajan & Radhakrishnan, 2021). In addition, the flood events that occurred in Germany, Belgium, Luxembourg, the Netherlands, Austria, and China in July 2021 led to the death of hundreds of people and millions of euros in damage.

The most determining factor on the occurrence of flood events which are classified as natural disasters is climatic parameters. These parameters are also the product of a natural process. In addition, lithological and morphological features affecting the occurrence of flood events are also natural factors (Wu et al., 2021). Therefore, flood events are not prevented because of their occurrence process (Roy et al., 2021). Nevertheless, human activities play a decisive role in the severity and magnitude of this natural process (Abuzied et al., 2016). This is the main reason for the devastating effects of flood events. A human-induced phenomenon, urbanization, is the key factor in the destructiveness of flood events (Ekmekcioğlu et al., 2021; Nigussie & Altunkaynak, 2019).

As the result of technological developments, industrialization, and economic policies, urbanization has become the source of many environmental problems in the twenty-first century (Ekren, 2017; Osman et al., 2021). While the number of people living in urban areas constituted approximately 33% of the world's population in 1960, this ratio reached 55% in 2017. It is estimated that this value will reach 68% by 2050 (Quan, 2021; United Nations, 2018). The increase in the urban population and consequently rapid urban development and insufficient urban basic services lead to various problems in urban areas. Due to rapid urbanization, the changes in especially land use and land cover cause adverse effects on hydrological processes of the basins, and thereby give rise to change in the water balance (Aliyu & Amadu, 2017). The short-term and low-intensity rainfalls in urban areas can result in flood events due to increased impervious surfaces (Fang et al., 2018; Yang et al., 2020). Gu (2019) reported that more than one-third of the cities were under high flood risk due to their topographic characteristics, according to 2018 data. In addition, it is projected that the probability of hydrological (flood-torrent, etc.), meteorological (storm-hurricane, etc.), and climatic (drought, etc.) hazards will increase in urban areas due to climate change (Kourtis & Tsihrintzis, 2021).

Different approaches have been adopted to cope with flood events in the historical process. Two different approaches became prominent between the 1950s and 1970s. One of these approaches, the flood defense, focuses on structural measures to mitigate the effects of flood events. The other is the flood control approach based on that floods can be controlled. To emerge in the 1980s and 1990s, the flood management approach adopts that floods can be managed even if they cannot be controlled as a principle. Nowadays, the flood risk management approach has been globally accepted to deal with flood events (FLOODsite, 2009). The aim of flood risk management is to minimize the damages and losses resulting from flood events similar to previous approaches (Chen et al., 2021; Nguyen et al., 2021; Sayers et al., 2013). However, the risk that arises from the situation of people and properties is at the focus of this approach. Therefore, this approach considers not only measures to manage floodwater but also measures to reduce flood susceptibility of the community. According to this approach, flood events do not pose a risk to society in non-vulnerable areas (FLOODsite, 2009). Flood risk management consists of 2 main components: flood risk assessment and flood risk mitigation. This situation reveals that the flood risk should be evaluated before taking measures against flood events, because the extent of the damage resulting from flood events is more important than the magnitude of the flood event. For example, even if a flood occurs in a region, a hazard may not occur. However, the same magnitude of a flood can cause a hazard in another region. This is due to the vulnerability of a region to flooding. In short, the factor that transforms floods into hazards is vulnerability. In order to reduce vulnerability, the first step of management practices is the identification of flood hazard zones in a region (Tehrany et al., 2013; Rahmati et al., 2016). Identifying flood hazard zones not only plays an important role in integrated watershed management but also is the key component of the Flood Directive 2007/60/EC (Feloni et al., 2020). It facilitates decision-makers in flood risk management and sustainable resource management (Bathrellos et al., 2016; Kia et al., 2012; Thirumurugan & Krishnaveni, 2019). In addition, the identification of flood hazard areas becomes even more important with climate change. In this context, identification and monitoring of the flood hazard zones seem to be the first step of a proactive approach in flood risk management.

Determination of flood hazard zones using numerical, hydrological, and hydrodynamic models (suitable for basin scale, not administrative level) is a very difficult task due to limited data and scale of the study area (Kron, 2005). Therefore, the GIS-based index approach that takes various parameters into account has recently become popular. Many studies have shown that the determination of flood hazard zones using this approach is very effective and beneficial (Dash & Sar, 2020; Kazakis et al., 2015; Moazzam et al., 2018). Events or situations that occur as a result of interaction among many factors can be accurately evaluated with multi-criteria decision-making methods. Therefore, these methods are frequently used in flood risk management (Ekmekcioğlu et al., 2021). AHP is one of the multi-criteria decision-making methods. This method provides simplicity and flexibility in the solution of complex processes. The AHP is widely used for the weighting of criteria to solve multi-criteria decision problems (Bayazıt et al., 2021).

In Turkey, flood events are ranked second among natural disasters in the extent of damage to society after earthquakes (Koç et al., 2020). An average of 39 flood events occurs every year in the country. As a result of these events, an annual average of 25 people loses their lives, and the cost of damages exceeds $58 million per year (Gürer & Uçar, 2009; Nigussie & Altunkaynak, 2019). In the most recent flood events in Turkey, people lost their lives, infrastructures were destroyed, and consequently, enormous economic damage occurred in the cities of Rize and Artvin in July 2021. It is well known that urbanization has the potential to trigger these damages and losses. When the change in the urban population of Turkey is evaluated, it is seen that the urban population ratio in Turkey reached 93% in 2020 while this ratio was 32% in 1960 (TSI, 2020). Considering these data, it is of great importance to monitor the flood hazard zones for flood risk management and sustainable urban development, especially in areas where flash floods occur.

Kahramanmaras city center covers both the foothills of the Taurus Mountains and some parts of the Kahramanmaras plain. Since the Taurus Mountains are formed as a result of tectonic movements, they have a folded and fractured topography. This topographic structure has led to the formation of many streams. For this reason, there are many streams originating in these mountains in the city of Kahramanmaras. The flows of these streams suddenly increase during heavy rainfalls and as a result, flood risk increases considerably in the city. The previous flood events also prove this situation. In addition, Kahramanmaras has been significantly affected by the industrialization and migration phenomenon since the 1950s. So, a rapid growth tendency in population and urban settlement areas has been observed. Therefore, monitoring the flood hazard zones is vital for effective flood risk management in the city. In this circumstance, the aims of this study are to (1) determine flood susceptibility, (2) reveal land use change, (3) identify flood hazard zones, and consequently (4) evaluate the effects of urbanization on these zones in the city of Kahramanmaras.

Material and methods

Study area

Kahramanmaras city located in the Mediterranean Region of Turkey is in between 37° 11′ and 38° 36′ N latitudes and 36° 15′ and 37° 42′ E longitudes (Fig. 1). As the twelfth largest city of Turkey in terms of acreage, it has an area of 14,522 km². Kahramanmaras city center including the administrative boundaries of Onikişubat and Dulkadiroğlu districts was chosen as the study area. The study area has an area of 360,530.79 ha. The altitude of the study area varies between 311 and 3020 m. Kahramanmaras plain and its immediate surroundings have Mediterranean climate characteristics. The average monthly temperature is the highest in August (28.4 °C) while the average monthly temperature is the lowest in January (4.7 °C) in Kahramanmaras. When the average monthly precipitation is examined, it is observed that December (130.6 mm) has the highest value whereas August (2.2 mm) has the lowest value. In addition, the maximum precipitation is the highest in December (98.2 mm) whereas it is the lowest in July (11.9) (GDMS, 2020).

Kahramanmaras has a topography covered with a stream network. There are many permanent and temporary streams in the study area. During the urbanization process, some modifications were made in the channels of these streams (Sarigul & Turoglu, 2020). In Kahramanmaras, flood and torrent disasters caused
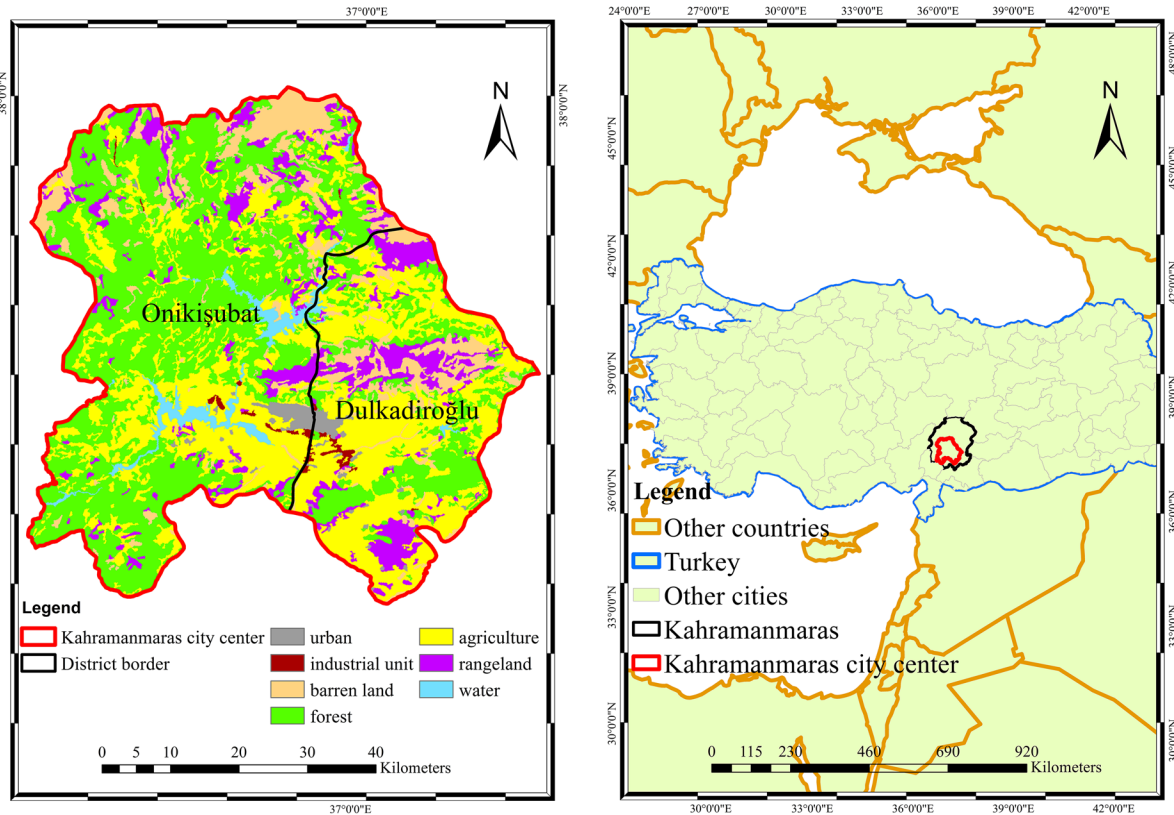
Fig. 1 The location of Kahramanmaras city center

substantial damages in times past. A rainstorm with 31.3 mm lasting 50 min occurred in the study area in 1972 (Sarigul & Turoglu, 2020). As a result of the flood event that occurred in 2010, 118 houses and 83 stores were damaged. This flood event occurred as a result of rainfall with a total of 56.8 mm. In May 2015, many houses and stores were also damaged by the flood event that results from rainfall with a total of 32.8 mm in the study area (Sunkar & Denizdurduran, 2015). A rainfall with a total of 17.8 mm fell, and a catastrophic flood occurred in the city center in June 2018 (Sarigul & Turoglu, 2020).

When the records of daily precipitation amounts are examined, it is seen that there is more amount of daily precipitation than the precipitation that causes flooding in Kahramanmaras. Generally, fall in December, January, and February, these extreme precipitations did not cause floods and torrents in the study area (Sarigul & Turoglu, 2020). This situation reveals that high-intensity rainfalls have the potential to cause flooding in the study area rather than a higher amount of rainfall. As a matter of fact, flash floods are

common in areas located in the Mediterranean region such as the study area. Therefore, green belts have been created since the 1960s due to the flood and erosion potential in the study area. In this context, afforestation activities have been carried out on Ahır Mountain (2301 m), which is one of the upstream in the study area (Dindaroğlu & Çelik, 2019).

Kahramanmaras city center has a constantly increasing population from past to present, thus an expanding urban area. With the increase in industrial investments, the city center started to attract the rural population and showed significant structural changes in terms of demographic, social, and economic conditions. The population which was 34,641 in the 1950s increased to 326,198 in 2000 (Karabörk & Sandal, 2018). In 2020, the population of the city reached 537,766 (TSI, 2020). In the boundaries of Kahramanmaras city center, Menzelet, Sır, Klavuzlu, and Ayvalı dams were built to meet the electricity, flood control, irrigation, and drinking water needs. These reservoirs were completely filled with water after 1990. Among these dams, the Sır has the 20th largest reservoir area

in Turkey while the Menzelet ranks 46th (GDSHW, 2017).

Kahramanmaras is located in the transition zone of the Mediterranean and Irano-Turanian phytogeographic regions. Three vegetation belts are observed in Kahramanmaras city. Shrub formation consists of maquis and pseudomaquis elements while coniferous forest formation also includes broad-leaved trees and shrubs. Alpine grass formation is located above the upper border of the forest in the study area (Palabas Uzun & Koca, 2020).

Method

As it is known, the flood risk (R) varies depending on the hazard (H) and vulnerability (V) parameters and is expressed by formula 1 below (Dash & Sar, 2020).

$$R = H \times V \tag{1}$$

Hazard is about when the flood event will occur, while vulnerability is about where the flood event will occur. Risk, on the other hand, is related to the magnitude of the damage that will occur as a result of the flood event. Hazard constantly changes because it is the result of a natural process (Abuzied et al., 2016). This situation shows that vulnerability must be reduced in order to decrease flood risk in a region. As mentioned earlier, the first step to reducing vulnerability is to determine the flood hazard zones. In this study, an index-based method was used to determine the flood hazard zones (Fig. 2).

Susceptibility and land use were considered the main indicators. It is possible to consider susceptibility as physical and socioeconomic susceptibility. While physical susceptibility indicators are used to identify flood-susceptible areas, socio-economic susceptibility indicators are used to identify flood-susceptible people or societies (Yang et al., 2020). In
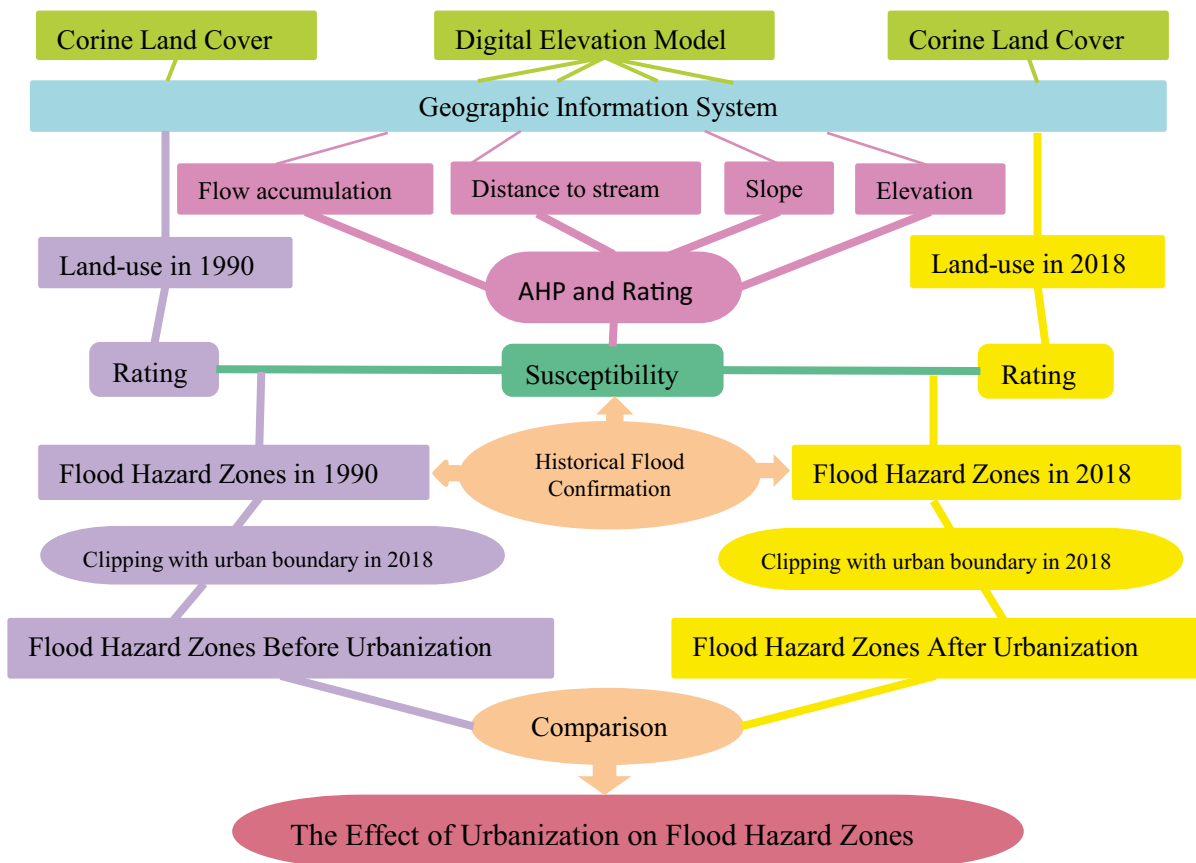

Fig. 2 Flowchart of overall study design

this study, susceptibility was evaluated with physical susceptibility indicators. Both the indicators and the number of indicators used in the determination of physical susceptibility vary in the literature. In this study, elevation, slope, flow accumulation, and distance to stream parameters were used as indicators. Literature was taken into consideration in the selection of parameters (Bigi et al., 2021; Dash & Sar, 2020; Mahato et al., 2021; Roy et al., 2021). The maps of each parameter were generated and converted to raster format in the ArcGIS environment (ESRI, 2015). Elevation, slope, and flow accumulation maps were produced using ASTER DEM (30×30 m) (Bhat et al., 2019). To produce the map of the distance to the stream, a stream network map was firstly generated using DEM and Arc Hydro extension. Then, buffer zones were created around the streams. This process was performed by using the buffer tool in the ArcGIS environment. In the literature, the land use parameter is generally evaluated together with the susceptibility parameters. However, in this study, it is thought that land use is more related to exposure than susceptibility because the effects of land use are different from the susceptibility parameters. It is not possible to talk about the hazard without the land use parameter. In this study, two land use maps for the years 1990 and 2018 were used to reveal the effects of urbanization on flood hazard zones. Land use maps were obtained from the CORINE database (CORINE, 2018). Required arrangements on these maps were made in the ArcGIS environment.

Mapping flood hazard index

In this study, an index-based approach was used to identify the flood hazard zones. To calculate a flood hazard index, the susceptibility map was multiplied by the land use map by using the raster calculator tool in the ArcGIS environment. The susceptibility map was generated by combining the maps of each susceptibility parameter in raster format using formula 2.

$$S = \sum_{i=1}^{n} w_i \cdot s_i \qquad (2)$$

where S is susceptibility, w_i is the weight of each parameter, s_i is the pixel score of each parameter, and n is the number of parameters.

Since each parameter has different effects on susceptibility, the same weight value should not be given to the parameters. In this context, the AHP method was used to determine the weight values of each parameter. The AHP technique, introduced by Thomas Saaty in 1980, is used for decision-making problems. The creation of PCM is the most important step of the AHP method as it directly affects the weight value of the parameters. This matrix is created with expert opinions and the scale of importance developed by Saaty (1980). Experts use the scale of importance to indicate the importance level of each parameter compared to other parameters. The PCM created in this study is shown in Table 1. The importance level between the parameters was determined with the help of expert opinion and similar studies in the literature (Dash & Sar, 2020; Desalegn & Mulu, 2021; Faregh & Benkhaled, 2021; Kazakis et al., 2015; Samanta et al., 2016).

Accumulation of rainwater in a place is a prerequisite for flooding to occur. Therefore, areas, where more water can accumulate, are the regions with the highest probability of flooding. Therefore, the flow accumulation parameter was considered the most decisive parameter in terms of flood susceptibility. Distance to the stream was evaluated as the second important parameter. Because flood events generally occur in areas close to the stream network. This is because the rainwater finally reaches the streams and causes an increase in the amount of water in the stream channels. In the literature, the level of importance between slope and elevation differs in terms of flood susceptibility (Faregh & Benkhaled, 2021; Roy et al., 2021; Samanta et al., 2016). In this study, the approach that slope has a greater effect on susceptibility than elevation was adopted, because the slope is thought to be more decisive on the movement and accumulation of water.

Table 1 Principal component matrix

Parameters	Flow accumulation	Distance to stream	Slope	Elevation
Flow accumulation	1	2	3	5
Distance to stream	1/2	1	2	4
Slope	1/3	1/2	1	2
Elevation	1/5	1/4	1/2	1

Table 2 Normalized component matrix and parameter weights

Parameters	Flow accumulation	Distance to stream	Slope	Elevation	**Weights**
Flow accumulation	0.49	0.53	0.46	0.42	**0.48**
Distance to stream	0.25	0.27	0.31	0.33	**0.29**
Slope	0.16	0.13	0.15	0.17	**0.15**
Elevation	0.10	0.07	0.08	0.08	**0.08**

Then, the values in each column of the PCM were converted to normalized values and the weight of each parameter was determined (Table 2).

To use the determined weight values, the consistency of the PCM must be checked. The aim is to examine the logical and mathematical relation of the pairwise comparison values and to determine the decision makers' misjudgments in pairwise comparisons (Mondal & Maiti, 2013). Saaty (1980) recommends Eq. 3 to check for consistency.

$$CR = \frac{CI}{RI} \qquad (3)$$

where CR is the consistency ratio, CI is the consistency index, and RI is the random index.

The RI is determined by the number of criteria used in the PCM. The RI values corresponding to each criterion number are determined with the help of Table 3.

Since four criteria were used in this study, the RI value was 0.90. Formula 4 is used to calculate the CI value.

$$CI = \frac{\lambda_{max} - n}{n - 1} \qquad (4)$$

where λ_{max} is the maximum eigenvalue of the comparison matrix and n is the number of parameters.

The calculation of the λ_{max} value is comprehensively presented in Saaty (1990). In this study, the λ_{max} value was calculated as 4.02.

In the AHP method, the weight values of the criteria can be used if the CR is less than 0.1 (Desalegn & Mulu, 2021; Faregh & Benkhaled, 2021; Zzaman et al., 2021). Since the CR value was calculated as 0.01 in this study, the weight values could be used to produce the susceptibility map.

In addition to the weight value of each parameter, the change in the pixel values of the parameter maps is also effective on susceptibility. For example, the susceptibility of an area with a low slope value is different from an area with a high slope value. Therefore, subclasses were defined for each parameter to consider this situation. Then, considering the effect of each parameter on the flood susceptibility, scores ranging from 1 to 5 were assigned to the subclasses. While 1 represents the lowest susceptibility, 5 represents the highest susceptibility in terms of flood risk. The natural break technique was used to classify elevation, flow accumulation, and slope parameters. This technique is widely used in MCDA studies. The reason why this technique was preferred is that while minimizing the variance within the class, it keeps the variability between classes at the maximum level (Dash & Sar, 2020). In the classification of the distance to stream parameter, the topographic features of the study area and the literature were taken into account (Faregh & Benkhaled, 2021; Samanta et al., 2016; Zzaman et al., 2021). Land use map has predefined classes. The scores were also assigned to each pixel of the land use map considering the land use classes.

Determining the effect of urbanization on flood hazard zones

In order to reveal the effect of urbanization on flood hazard zones, 2 hazard maps were produced. While the same elevation, slope, flow accumulation, and distance to stream parameters were used for these 2 maps, land use maps were different from each other. The land use map of 2018 was used for one of these hazard maps while the land

Table 3 RI values

Number of parameter	1	2	3	4	5	6	7	8
Random index (RI)	0	0	0.58	0.90	1.12	1.24	1.32	1.41

use map of 1990 was used for the other. Then, both hazard maps were clipped based on the boundaries of the urban areas in 2018. Finally, the hazard conditions were compared to determine the effect of urbanization.

Results and discussion

Results

This study evaluated the impact of urbanization on flood hazard zones, as well as the change in the hazard zones between 1990 and 2018 in Kahramanmaras city. The hazard zones were determined based on susceptibility and land use components. The main factors such as flow accumulation, distance to stream, slope, and elevation were considered to reveal susceptibility. Consequently, flood hazard maps were generated by overlying susceptibility map with land use maps. The results are presented in detail in the following sections.

Elevation

The elevation values in the study area vary between 311 and 3020 m (Fig. 3). Specifically, the region between the center and southeast of the study area has a lower elevation. Moreover, areas in the lowest elevation class have the highest areal size in the study area. Considering the elevation criterion, these areas have the highest flood susceptibility. According to the elevation criterion, more than half of the study area (approximately 53%) is included in very high and high risk classes in terms of flood susceptibility and major parts of the residential and agricultural areas are located in these areas. So, flood events can cause devastating losses in the study area.

Slope

Another factor affecting flood susceptibility is the slope. The slope values in the study area vary between 0 and 285% (Fig. 4). It is also seen that approximately
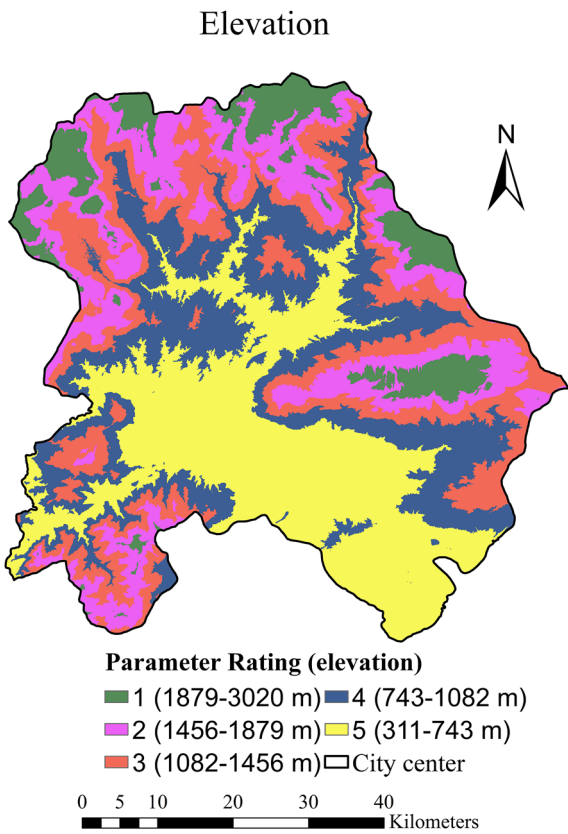

Parameter Rating (elevation)
- 1 (1879-3020 m)
- 4 (743-1082 m)
- 2 (1456-1879 m)
- 5 (311-743 m)
- 3 (1082-1456 m)
- City center

0 5 10 20 30 40 Kilometers

Fig. 3 Elevation map

Parameter Rating (slope)
- 1 (78.9-285.9%)
- 4 (16.9-33.7%)
- 2 (52.6-78.9%)
- 5 (0-16.9%)
- 3 (33.7-52.6%)
- City center
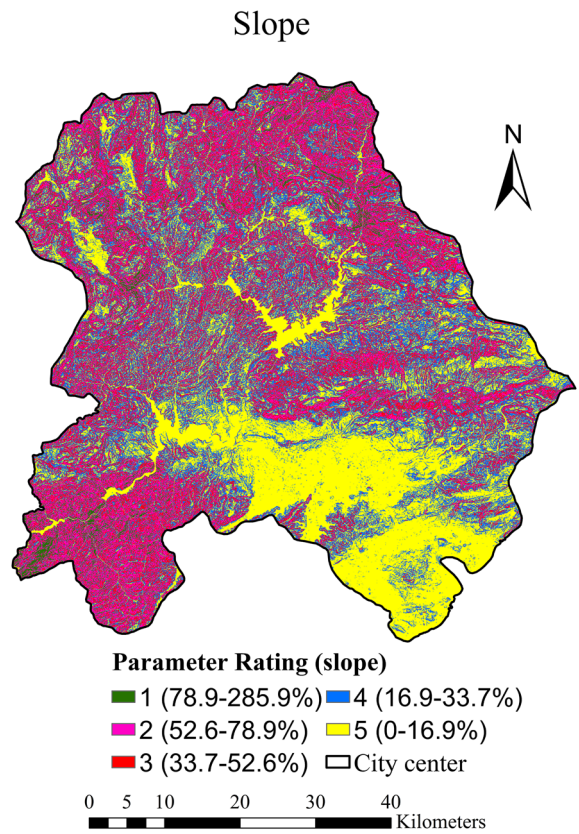
0 5 10 20 30 40 Kilometers

Fig. 4 Slope map

70% of the study area is located on a steep terrain where the slope is greater than 16%. The slope values decrease from the northwest towards the southeast in the study area. Similar to the altitude conditions, the slope values in the region between the center and the southeast of the study area have the lowest values. Considering the slope criterion, areas with the lowest slope covering approximately 29% of the area are in the very high risk class in terms of flood susceptibility.

Flow accumulation

Flow accumulation values in the study area vary between 0 and 3,396,842 (Fig. 5). It increases based on the stream order and reaches the maximum value at the outlet of the study area. Especially at the junction points of the streams, flow accumulation increases suddenly.
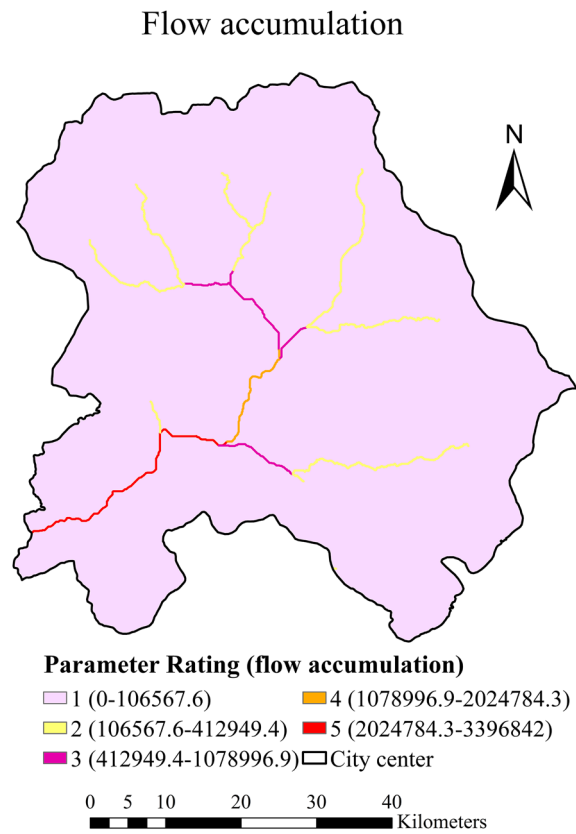
Distance to stream

Parameter Rating (distance to stream)
- 1 (1500-1955.8 m)
- 4 (200-500 m)
- 2 (1000-1500 m)
- 5 (0-200 m)
- 3 (500-1000 m)
- City center

0 5 10   20   30   40
Kilometers

Fig. 6 Distance to stream

Flow accumulation

Parameter Rating (flow accumulation)
- 1 (0-106567.6)
- 4 (1078996.9-2024784.3)
- 2 (106567.6-412949.4)
- 5 (2024784.3-3396842)
- 3 (412949.4-1078996.9)
- City center

0 5 10   20   30   40
Kilometers

Fig. 5 Flow accumulation
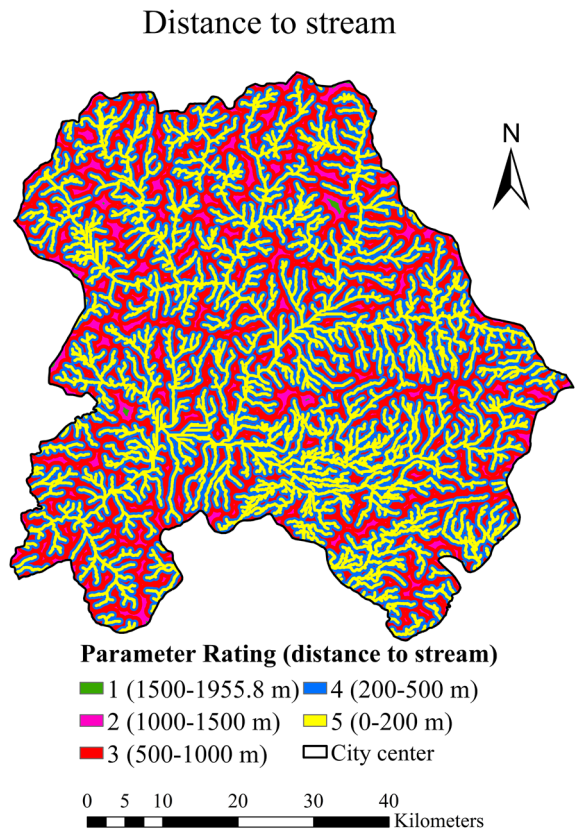
Distance to stream

Considering the distance to stream, approximately 17% of the study area is in the very high and high flood susceptibility classes (Fig. 6). Although 42% of the study area has very low flood susceptibility, a very small portion of the residential areas is located in these areas.

Land use

Land use was divided into 7 classes based on the CORINE data in the study area. According to the land use map of 1990, 40.7% of the study area comprises forest, while 40.46%, 12.14%, 5.64%, 0.71%, 0.32%, and 0.04% of it comprise agriculture, barren, rangeland, urban, water, and industrial unit, respectively (Fig. 7).

When the land use map of 2018 is examined, forest constitutes 42.66% of the study area, while
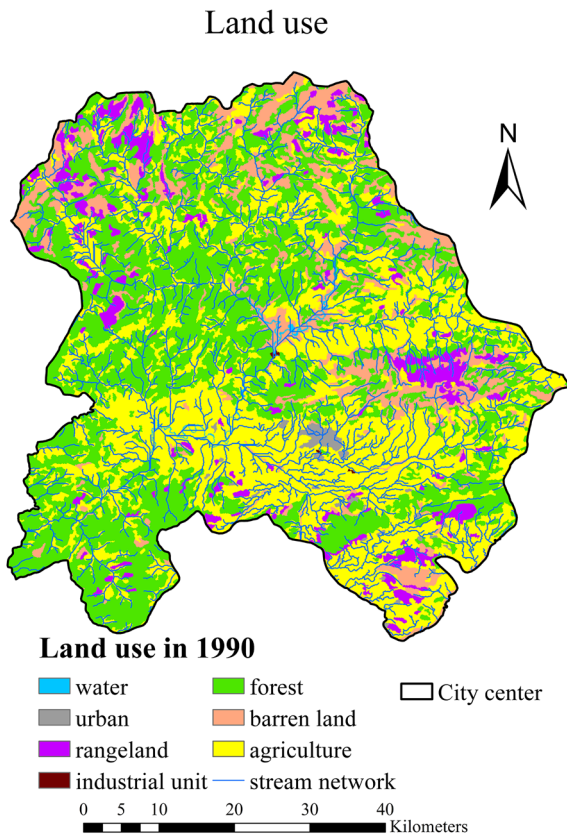
Land use

Land use in 1990
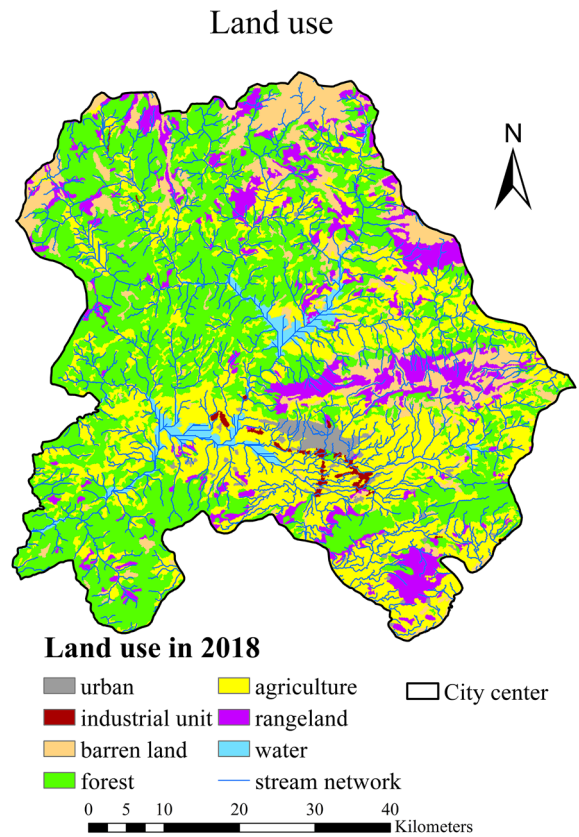
▬ water	▬ forest	☐ City center
▬ urban	▬ barren land	
▬ rangeland	▬ agriculture	
▬ industrial unit	— stream network	

0 5 10   20   30   40
Kilometers

Fig. 7 Land use map of 1990

Land use

Land use in 2018

▬ urban	▬ agriculture	☐ City center
▬ industrial unit	▬ rangeland	
▬ barren land	▬ water	
▬ forest	— stream network	

0 5 10   20   30   40
Kilometers

Fig. 8 Land use map of 2018

agriculture, barren, rangeland, urban, water, and industrial unit constitute 31.97%, 10.95%, 10.04%, 1.32%, 2.47%, and 0.56% of it, respectively (Fig. 8).

Changes in land use between 1990 and 2018 are shown in Table 4. It was determined that there is an increase in urban by 85.88%, industrial unit by 1482.84%, forest by 4.80%, rangeland by 78.51%, and water by 680.63% while a decrease in agriculture by 20.97% and barren by 9.77% in the study area.

Susceptibility

The susceptibility map generated using selected parameters is shown in Fig. 9. According to this map, 0.2% of the study area is in the very high class, while 35.0%, 35.4%, and 20.3% are in the high, moderate, and low classes respectively. The very low class constitutes 9.1% of the study area. In the study area, it was determined that the areas adjacent to stream beds

are in the high risk class. Besides, the city center and major part of the Kahramanmaras Plain are in the high susceptibility class also.

Flood hazard index

In order to reveal the temporal and spatial changes in the flood hazard zones in the study area, the land use maps of 1990 and 2018 were separately overlapped with the susceptibility map. Thus, 2 different flood hazard maps were produced based on hazard index values. In both maps, the study area was divided into five classes as very high, high, moderate, low, and very low. Moreover, the same limit values were used for the separation of hazard index classes in both maps. When the flood hazard map of 1990 is examined, 0.03% of the study area is in the very high flood hazard zone, while 13.21%, 34.46%, 21.42%, and 30.88% are in the high, moderate, low, and very low

Table 4 Changes in land use distribution

Land use	Land use distribution				Change (%)		The general results of the change
	1990		2018				
	Percent	Hectare	Percent	Hectare	Areal	Relative	
Urban	0.71	2567.04	1.32	4770.40	0.61	85.83	Decrease in agriculture
Industrial unit	0.04	126.90	0.56	2008.60	0.52	1482.84	Decrease in agriculture and forest
Barren	12.14	43,751.22	10.95	39,476.62	−1.19	−9.77	Increase in water, rangeland, and forest
Forest	40.70	146,744.19	42.66	153,785.80	1.95	4.80	Decrease in agriculture, rangeland, and barren
Agriculture	40.46	145,860.76	31.97	115,269.28	−8.49	−20.97	Increase in urban, rangeland, water, industrial unit, and forest
Rangeland	5.64	20,338.78	10.07	36,306.05	4.43	78.51	Decrease in barren, agriculture, and forest
Water	0.32	1141.91	2.47	8914.04	2.16	680.63	Decrease in barren and agriculture
Total	100	360,530.79	100	360,530.79			

zones, respectively (Fig. 10). It was noticed that areas next to streams generally lie in the high hazard zone. It was also determined that areas in the moderate hazard zone are generally adjacent to areas in the high hazard zone.

When the flood hazard map of 2018 is examined, 0.07% of the study area is in the very high flood hazard zone, whereas 14.18%, 27.12%, 26.79%, and 31.83% are in the high, moderate, low, and very low zones, respectively (Fig. 11). The flood events that
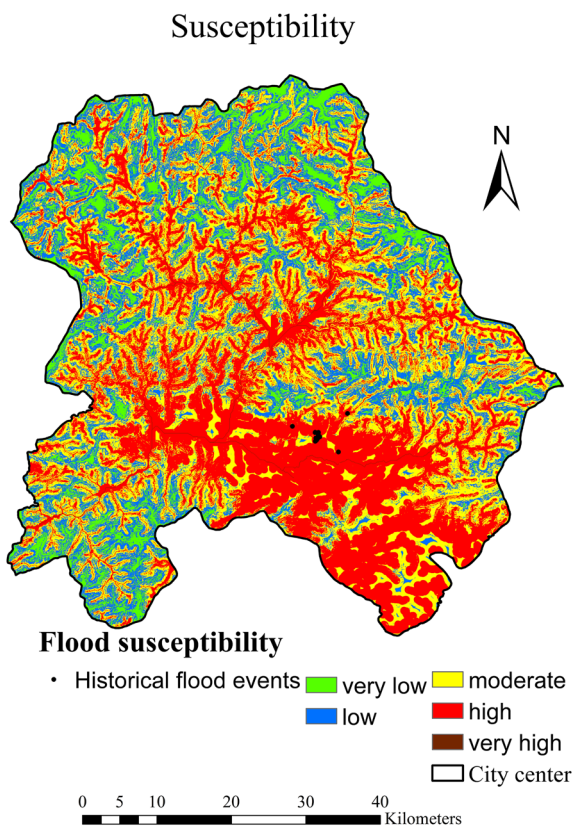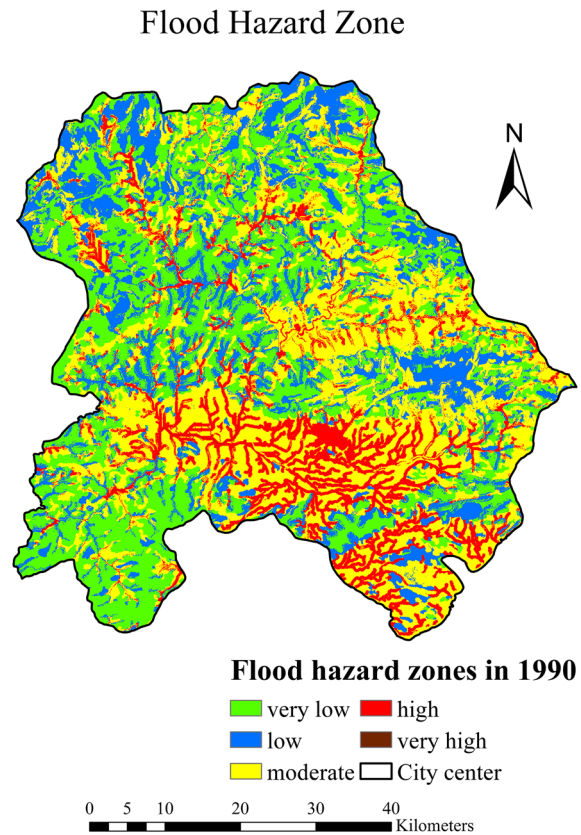

Fig. 9 Susceptibility map

Fig. 10 Flood hazard map of 1990

Flood Hazard Zone

Flood hazard zones in 2018

· Historical flood events

■ very low   ■ moderate
■ low   ■ high
              ■ very high
              □ City center

0 5 10   20   30   40
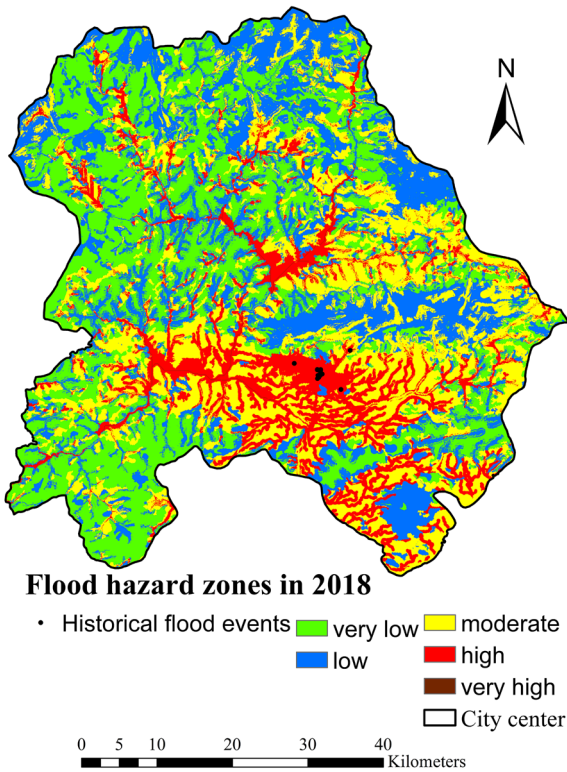   Kilometers

Fig. 11 Flood hazard map of 2018

occurred in the past are involved in the high hazard zone in the study area. In addition, it is seen that the city center and its immediate surroundings are the most hazardous region of the study area.

In 1990, the distribution of land use in each hazard zone is shown in Fig. 12a. Accordingly, there are only 2 land use types in the very low hazard zone. A large part of this class comprises forests (99.7%), while the rest comprises rangelands (0.3%). In the low hazard zone, while the forest (46.2%) is the dominant land use, it is followed by barren (27.9%) and rangeland (25.9%), respectively. Agriculture (0.002%), on the other hand, constitutes a very small portion. While the moderate zone generally consists of agriculture (82.1%) and barren (17.9%), forest (0.032%) and rangeland (0.002%) also cover a very small area. The dominant land use in the high zone is agriculture (92.0%). However, urban (5.4%), water (2.3%), industrial units (0.3%), and barren (0.1%) are also available in this class. In the very high hazard zone, agriculture (66.1%) covers the largest area, followed by water (28.2%). This class also includes industrial units (4.6%) and urban areas (1.2%). When the year 1990 is generally evaluated, it can be said that forest areas are more dominant in very low and low hazard zones. Nonetheless, this dominance shifts to agricultural areas with the transition to the moderate zone. It is also determined that urban areas are generally located in the high hazard zone.
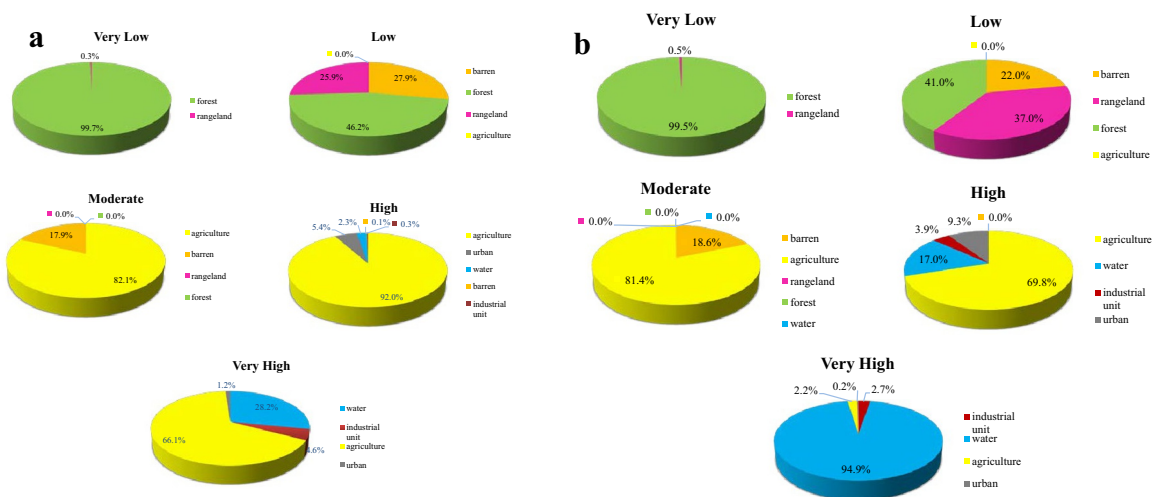

Fig. 12 The distribution of land use in each hazard zone, **a** in 1990 and **b** in 2018

Figure 12b shows the distribution of land uses in flood hazard zones in 2018. Accordingly, while only 2 types of land use consisting of forest (99.5%) and rangeland (0.5%) are available in the very low hazard zone, almost all of this class comprises forest. In the low zone, while the forest (41.0%) is the dominant land use, it is followed by rangeland (37.0%) and barren (22.0%) respectively. The rate of agricultural land (0.002%) in this class is quite low. While agriculture (81.4%) and barren (18.6%) cover a very large part of the moderate zone, there are also forest (0.028%), rangeland (0.007%), and water (0.006%) in this class. While agricultural areas (69.8%) are the dominant land use in the high zone, it is followed by water (17.0%), urban (9.3%), industrial units (3.9%), and barren (0.01%), respectively. Water (94.9%) constitutes the major part of the very high hazard zone while the rest of this class consists of industrial units (2.7%), agriculture (2.2%), and urban (0.2%), respectively. Generally, it can be said that although the dominant land use in the very low and low zones is forest, those in the moderate and high zones are agriculture. In addition, residential areas are generally located in the high flood hazard zone while about 31% of the agricultural lands are located in the high and very high hazard zone.

The change in flood hazard zones in the study area over the 28-year period is shown in Fig. 13. While there is a decrease in the moderate zone, there is an increase in all other hazard zones. The highest increase occurred in the very high zone with approximately 131%. When an overall assessment is carried out, the total increase in the high and very high flood
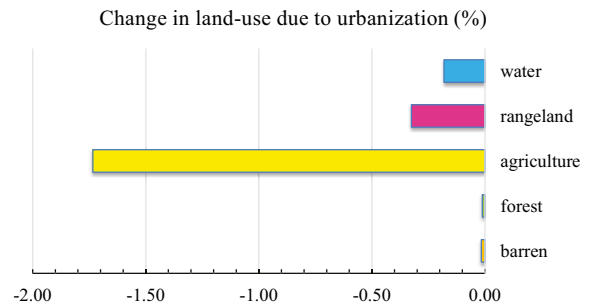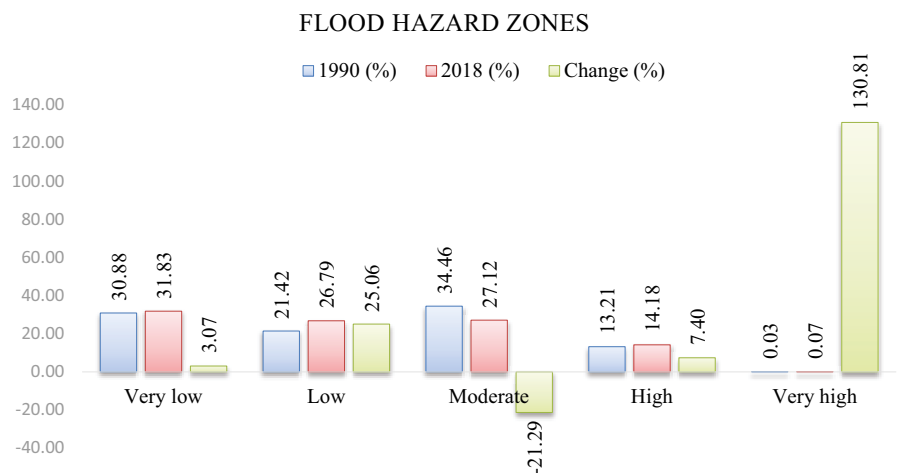

Fig. 14 Land use change due to urbanization

hazard zones is higher than low and very low, which indicates that the probability of exposure to flooding increases in the study area.

The effect of urbanization on the flood hazard zones

While the urban areas covered 0.71% of Kahramanmaras city in 1990, it increased to 1.32% in 2018. In other words, the ratio of the urban area has increased by 86% in a 28-year period. This increase has inherently caused some changes (conversion) in the land uses. While agricultural areas decreased by 1.73%, rangeland, water, barren land, and forest decreased by 0.33%, 0.18%, 0.02%, and 0.01%, respectively due to urbanization (Fig. 14).

Therefore, it is expected that these changes will cause some changes in the flood hazard index. When these changes were examined, it was found that very low, low, and moderate hazard zones reduce by 0.01%, 0.09%, and 1.2%, respectively whereas the
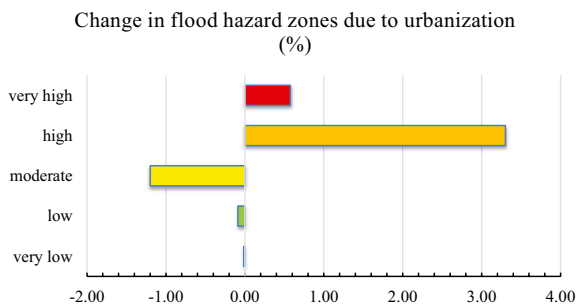
Fig. 13 The change in flood hazard zones

Change in flood hazard zones due to urbanization (%)

Fig. 15 Change in the hazard zones due to urbanization

high and very high zones increased by 3.30% and 0.58%, respectively with urbanization (Fig. 15). It was also determined that approximately 45% of the total change in the high flood hazard zone results from urbanization in the study area.

Discussions

This study explored the effect of urbanization on flood hazard zones for flood risk management and urban planning in Kahramanmaras city center. The flood hazard index approach was used to determine the flood hazard zones. This approach is based on overlying flood susceptibility map with the land use map. In order to reveal the effect of urbanization on flood hazard zones, two flood hazard zone maps were produced by using the susceptibility map and land use maps of 1990 and 2018. Then, the changes within the urban area boundaries of 2018 for 29 years were determined. Results of this study provide a baseline for flood risk management in especially the high-risk areas in Kahramanmaras city center. In addition, the approach used for the determination of the effects of urbanization on flood hazard zones in the present study can be a useful tool for both alleviating flood damages and urban planning. Fang et al. (2018) used the HEC-HMS model to determine the effect of urbanization on floods in the Qinhuai River basin, China. Their study required the data such as daily rainfall and discharge, soil type, land use, and DEM. Feng et al. (2021) also explored urbanization impacts on flood risk in the Don Valley watershed, Canada, by using both hydrologic and hydraulic models together. They selected the Don Valley watershed as a study area because it is a data-rich area that has available hyetograph, soil, DEM, and land use data. In a

study by Zope et al. (2016), impacts of both land use changes and urbanization on flooding were explored by using the rainfall-runoff model in Oshiwara River basin in Mumbai, India. The daily rainfall data, soil properties, DEM, and flood conditioning parameters were used in this study. They found that the highly hazardous zone is raised by 64.29% whereas the less hazardous zone is reduced by 32.14% due to land use changes. Similarly, various hydrodynamic models have also been employed to determine urbanization effects on flood susceptibility in most previous studies (Campbell et al., 2017; Du et al., 2019; Mahmoud & Gan, 2018; Nigussie & Altunkaynak, 2019; Sholichin & Qadri, 2020; Shrestha & Lohpaisankrit, 2017; Suriya & Mudgal, 2012) Although more reliable results can be obtained with such hydrological and hydraulic models, the data required for these models are not available for most places of the world. Thus, the core contribution of the present study is a new approach for revealing simply, quickly, and reliably the effect of urbanization on flood hazard zones in areas with data scarcity for complex models.

The results showed that the susceptibility reaches maximum values at the streambeds and their surroundings, the city center, and the major part of the Kahramanmaras Plain in the study area. Higher susceptibility at the streambeds can be attributed that the areas where water accumulates are vulnerable areas in terms of flood susceptibility. Roy et al. (2021) stated that there is always the potential for a flood to occur in areas where the water accumulates. Therefore, flood susceptibility is naturally maximum in water bodies like streams, lakes, wetlands, and their surroundings. Similarly, Swain et al. (2020) found that areas in the vicinity of the rivers are the most susceptible to floods in their study. They also stated that this is an expected result. This finding is in line with Yang et al. (2018) and Choubin et al. (2019) where the areas around the rivers are the most vulnerable to flooding. A higher flow accumulation value in the water reservoir supports this result in the study area. It is well known that areas with higher flow accumulation values indicate areas where more water accumulates. Hence, these areas have higher flood susceptibility (Kazakis et al., 2015). In addition, the distance to stream is an effective factor causing the higher susceptibility at the streambeds and their surroundings, especially (Yariyan et al., 2020). Since the stream beds are the collecting areas of the water flowing along the slope, the

probability of occurrence of flood events is higher in the areas closer to these areas. As you move away from these areas, the probability of flood exposure reduces (Moazzam et al., 2018; Samanta et al., 2018). On the other hand, higher susceptibility in the city center and Kahramanmaras Plain can be explained by lower elevation and slope conditions as well as the stream network in these areas. This fact has been proven in several studies. Khosravi et al. (2016) stated that the areas with closer to rivers and lower elevations and slopes are more susceptible to flooding. Dash and Sar (2020) reported that elevation is one of the factors affecting flood susceptibility. In the simplest terms, if you are at a higher location on a flood plain, the chance of a flood affecting you is less. Because of gravity, water coming from higher areas will accumulate in lower areas. Therefore, in areas where water moves due to a certain slope, higher regions have less flood susceptibility than lower ones. In short, there is an inverse relationship between flood susceptibility and elevation (Janizadeh et al., 2019; Yariyan et al., 2020). From the watershed point of view, the amount of water rises along the hillslope. The water from higher areas due to surface runoff accumulates in lower areas. The amount of water approaches the maximum level in these areas, especially towards the watershed outlet. Therefore, lower areas in a watershed are more flood susceptible. In addition, the slope naturally affects the flood formation process as it is directly determinant of surface flow and infiltration (Samanta et al., 2018; Yariyan et al., 2020). Since the penetration rate of water is lower in areas with high slopes, the velocity and concentration of surface flow increase (Samanta et al., 2018). The increased surface flow accumulates and rises in areas with low slopes as its movement tends to decrease in these areas (Janizadeh et al., 2019). Therefore, the flood susceptibility increases as the slope decreases (Moazzam et al., 2018).

Land use change analysis suggested that urban increased by 85.83% while industrial units, water, and forests increased by 1482.84%, 680.63%, and 4.80% respectively in the study area. These changes in urban and industrial units reveal rapid urbanization in the study area. On the other hand, the increase in water is due to the dams built in the study area. The relatively small increase in forest areas can be also attributed to the afforestation practices and regrowth of forests in abandoned rural areas due to migration. Land use is a crucial factor in terms of flood risk (Janizadeh

et al., 2019) as it influences hydrological processes such as infiltration, evaporation, runoff, and interception (Dash & Sar, 2020). Agriculture, water, and residential areas have an increasing effect on flood risk, whereas forest areas have a reducing effect on it (Samanta et al., 2016). Therefore, these changes in land use naturally caused the flood hazard zones to change. This result is in agreement with the results of the study by Tehrany et al. (2017). In the present study, an increase in water areas leads to a significant increase in the very high zone. On the other hand, it can be said that the decrease in the moderate zone is due to urbanization as well as an increase in forest and pasture areas while the increase in the high hazard zone is generally caused by urbanization in the study area.

It was found that historical flood events occurred in the high hazard zone in the study area. This supports the accuracy of the flood hazard map. In addition, flat areas and areas adjacent to streams are in the high zone similar to previous studies (Borzi et al., 2021; Samanta et al., 2018; Wang et al., 2011; Zzaman et al., 2021). This study also showed that the city center and its immediate surroundings are located in the most hazardous region of the study area. This can be attributed to the high susceptibility of this region as well as the concentration of residential and agricultural lands in this region. Considering the effects of residential and agricultural areas on flood vulnerability (Janizadeh et al., 2019; Yariyan et al., 2020), this is not an unexpected result. Similarly, residential areas located at lower elevation and slopes were found to be most hazardous in the studies by Toriman et al. (2009) and Tehrany et al. (2017) also.

In this study, it was found that approximately 31% of the agricultural lands are located in the high and very high hazard zone whereas almost the whole forest area is located in the low and very low zones. This shows that floods can pose a serious threat to agricultural production. Therefore, flood risk must be always considered as agriculture is one of the main livelihoods of the people in the study area. In this context, crop insurance can be a sensible option in terms of flood risk management. On the other hand, the concentration of forest areas in the low and very low hazard zones can be attributed to the effect of forests on runoff. Forest restrains the effect of raindrops on soil and consequently prevents decreasing infiltration capacity in a short time. The root system in forests has

functions that increase infiltration, macro-porosity, drainage, and organic matter also. Moreover, the litter layer under the forests provides more time for infiltration. It was revealed that the litter layer reduces the runoff by 31.3% compared to the barren land (Li et al., 2014). Forest soils have a relatively higher water holding capacity as organic matter in forest soils is higher than the soils under other land use such as agriculture, rangeland, barren, etc. (Dutal & Reis, 2020). Considering that organic matter can hold up to 20 times its weight in water (Reicosky & Forcella, 1998), it is

clear that it can significantly reduce runoff. Thus, this is an expected result.

It was determined that agricultural areas are more affected by urbanization compared to other land uses in the study area. This is because urban areas are surrounded by agricultural areas. As the urban areas expanded, it naturally caused the surrounding agricultural areas to lose. This result is in line with the studies by Du et al. (2014), Van Vliet et al. (2017), Lambin and Meyfroidt (2011), Jiang et al. (2020), and D'Amour et al. (2017). The same trend has been

Fig. 16 Urban expansion into agricultural areas in the study area

observed in western European and China (Beckers et al., 2020; Deng et al., 2020). In recent times, the expansion of the urban areas in these regions has led to the loss of fertile arable lands. In addition, especially in developing countries, agricultural lands are sold for the sake of earning a high income in a short time and turned into concrete structures (Balasubramanian & Choi, 2010). In this context, it is a necessity to urgently take measures that reduce the pressure on agricultural areas in the study area. Conversion of these productive areas to residential areas will not only increase the flood vulnerability but will also trigger many problems (Beckers et al., 2020; Lambin et al., 2001). For example, after the conversion of agricultural lands to urban areas, great pressure on forest and pasture areas emerges. Because the first option to meet the increasing demand for agricultural products with urbanization is usually the destruction of forest and rangeland areas (Zhang et al., 2008).

The present study showed that while urbanization causes a decrease in the moderate hazard zone, it leads to an increase in the high zone. This situation can be attributed to the transition of agricultural areas in the moderate zone to the high zone because of urbanization in the study area. In general, the expansion of urban areas into agricultural areas also supports this opinion (Fig. 16).

Similarly, Natarajan and Radhakrishnan (2020) found that there is an increase in the severity of flood hazards due to urbanization. Duran et al. (2012) found that especially agricultural areas have been lost due to urbanization in Mersin city of Turkey. They stated that flood events have increased in Mersin city, as a result of this land use change. The increase in impermeable surfaces due to urbanization causes to reduce infiltration capacity considerably (Fang et al., 2018; Gregory, 2006). This situation leads to an increase in the runoff and consequently increases the chance of flooding. Reis and Dutal (2019) reported that when the forest is converted to urban, the increase in runoff is 66.71% and 12.24% during 10 mm/day and 20 mm/day rainfall events, respectively.

Future studies may focus on providing a more detailed inventory of flood risk using high-resolution satellite images such as IKONOS and QuickBird in high and very high hazard zones. In this study, the effect of urbanization on flood hazard zones was determined based on two years in the past. In future studies, urbanization projections can be made with

methods such as SLUET, and the possible effects of urbanization on flood hazard zones in the future can be revealed for more sustainable urban planning.

The present study includes some limitations. Although the approach used in the study is simple, useful, and reliable, it contains uncertainties due to the nature of the AHP method. Therefore, in areas where there is no data shortage, parameter weights can be determined with a statistical index model. The low data resolution used in the present study prevents obtaining of more precise outputs also. Thus, future studies can be carried out by using higher-resolution data.

Conclusions

In this study, the change in flood hazard zones and the effect of urbanization on this change were revealed. Flood hazard zones were determined using the flood hazard index approach. Susceptibility parameters such as flow accumulation, distance to stream, slope, and elevation, and land use parameter were used to calculate the index values. A susceptibility map was generated by superimposing susceptibility parameters in ArcGIS based on the weight of the parameters obtained at the result of AHP. Finally, flood hazard zone maps of 1990 and 2018 were produced by overlapping the susceptibility map with the land use maps of 1990 and 2018, respectively. In order to reveal the effect of urbanization on flood zones, the changes that occurred within the urban area boundaries of 2018 were determined.

According to the results, it was found that 0.02% of the study area has a very high susceptibility, while 35.0%, 35.4%, 20.3%, and 9.1% have high, moderate, low, and very low susceptibility, respectively in the study area. It was understood that the effect of elevation on susceptibility in flat terrains is more than those in steep terrains.

It was determined that while urban increased by 85.88%, industrial unit, forest, rangeland, and water increased by 1482.84%, 4.80%, 78.51%, and 680.63%, respectively between the years of 1990 and 2018. In addition, agriculture decreased by 20.97% while barren decreased by 9.77% in the study area. These changes in land use lead to a decrease in the moderate zone and an increase in all other hazard zones in the study area. This situation indicates that

the probability of exposure to flooding increases in the study area. So, it is necessary to take more precautions to reduce the flood risk in the study area. Otherwise, flood disasters in these areas will be inevitable due to increased flood risk.

In the study area, the ratio of the urban area increased by 86% in 28 years. As a result of this urbanization process, it was determined that very low, low, and moderate hazard zones reduce by 0.01%, 0.09%, and 1.2%, respectively whereas the high and very high zones increase by 3.30% and 0.58%, respectively. This situation shows that existing measures against flood risk in urban areas should be revised first. Moreover, effective flood risk management seems to be necessary to avoid flood disasters in urban areas generally located in the high hazard zone. In this context, streams converted into closed conduits during urbanization should be consistently checked and their necessary maintenance must be carried out. In addition, depending on the flood risk in the study area, decision-makers should adopt a renaturalization approach in urban areas and protect and develop the existing ecosystem in suburban areas, which will reduce the flood risk. In this context, the protection of forest areas, permeable pavements, water harvesting, and the expansion of urban green spaces are among the measures that can be taken.

It was also found that approximately 45% of the total change in the high flood hazard zone is due to urbanization in the study area. This situation was attributed to the conversion of agricultural areas in the moderate zone into urban areas. In these areas, therefore, necessary measures should be taken to restrain the increase in flood risk. Conversion of these productive areas into urban areas in the future should be also prevented with legal arrangements and urban development plans. In addition, it should never be forgotten that agricultural production will reduce due to the decrease in agricultural areas and this will trigger various sociological, economic, and ecological problems.

In general, forest areas are more dominant in very low and low hazard zones while agricultural and urban areas are generally located in the moderate and high hazard zones in the study area. This reveals that afforestation can be used as an effective flood mitigation measure in high and very high flood hazard zones.

Consequently, this study is expected to be a guide for urban planning and flood risk management in the study area. In addition, it is thought that the approach in this study can be used for effective flood risk management in different regions of the world by making the necessary adaptations.

Declarations

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