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Flood Risk Analysis in Şanlıurfa City Centre

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Abstract

In recent years, Turkey has become a place where loss of life and property due to natural disasters has increased. The rise in losses, particularly from floods, stems from construction in riverbeds and poor planning decisions. One of the most recent examples is the flood that occurred in the city center of Şanlıurfa, one of Turkey's major cities, on March 15, 2023, which resulted in the loss of 17 lives and material losses. The study gained importance because land use decisions in the city center of Şanlıurfa, which was selected as the study area, were made without considering flood risk, increasing the potential for sudden rainfall to turn into floods. To this end, the urban development of Şanlıurfa was examined in terms of flood risk, and the Süleymaniye and Göl neighborhoods, which have the highest potential for impact, were examined in detail. The flood risk analysis map, created using Geographic Information System (GIS) and Analytic Hierarchy Process (AHP) methods, shows that risk increases in areas close to rivers, with high rainfall, and dense construction. According to the risk analysis map, approximately 32% of the study area consists of low-risk areas, 62% of medium-risk areas, and 6% of high-risk areas. In areas where flood risk cannot be prevented, it is recommended that existing structures be evacuated or demolished based on their risk status, and that settlement in safer areas identified in place of risky structures be encouraged.

Keywords: *Land Use, Urban Plans, Geographic Information Systems, Analytic Hierarchy Process, Flood Risk Analysis.*

Introduction

The natural events that started at the beginning of the world's existence started to turn into natural disasters in the history of civilisation (Nasiri et al. 2016). These disasters, which are difficult to avoid, rank among the most significant problems facing the modern world and are often made more destructive by human influence. Rapid urban development linked to population growth and institutional deficiencies lead to improper land use, while geoscientific and climatic factors cause various natural disasters such as earthquakes and floods (Gayen and Saha 2018). Floods are one of the natural disasters that cause the most loss of life and property (Danumah et al. 2016). Research shows that the population living under 100-year flood risk was 1.81 billion in 2020 and will reach 1.93 billion by 2100 (Li et al. 2023).

Due to its geographical location, Turkey has been exposed to many major disasters throughout history; these events have caused serious destruction and loss of life in different regions. 1939 Erzincan earthquake, 1943 Tosya-Ladik earthquake, 1944 Bolu earthquake, 1957 Ankara flood, 1976 Van-Çaldıran earthquake, 1988 Maçka-Çatak landslide, 1990 Rize Çamlıhemşin flood, 1992 avalanche disasters, 1998 Sürmene-Köprübaşı flood and landslides, 1999 Marmara earthquakes are among the most destructive ones (AFAD 2023). In Turkey, the impact of industrialization and the migration to city centers has led to the urbanization process occurring within a very short time frame and an increase in unplanned areas (Usta 2021). One of the most important reasons for the destructive nature of natural disasters is that the importance of pre-disaster work has not been sufficiently addressed in legislation as a result of rapid urbanization. Following the 1999 Marmara earthquakes, which claimed the lives of thousands of people, the concept of “Disaster Resilient Planning” came to the forefront in legislation (Esen 2023). However, Elazığ-Kovancılar earthquake (2010), Van earthquake (2011), Trabzon flood (2019), Elazığ earthquake (2020), İzmir earthquake (2020), Western Black Sea flood (2021), Kahramanmaraş-centred earthquakes (2023) and Şanlıurfa-Adıyaman flood (2023) revealed that disaster risks and planning errors in land use continue. (AFAD 2023). The migrations that have occurred have caused population estimates in the plans to be inaccurate, leading to irregular urbanization, the

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expansion of unplanned areas, and increased vulnerability to natural disasters. Şanlıurfa, one of Turkey's provinces facing significant urbanization and disaster issues, has a high risk of flooding in the event of sudden rainfall due to the presence of the Karakoyun, Cavşak, and Sırrın rivers and numerous tributaries in the city center (AFAD 2021). As a matter of fact, on 15 March 2023, excessive rainfall in the city centre caused floods in Karakoyun, Cavşak and Sırrın creeks. As a result of the floods, 17 people lost their lives and 1,978 houses, 234 workplaces, 19 schools, 8 mosques and 3 underpasses were damaged. (AFAD 2023). One of the most significant causes of these floods is the construction of buildings in riverbeds. The Süleymaniye and Göl neighborhoods in the city center of Şanlıurfa are spread across river and valley beds. The Süleymaniye Neighborhood is home to 19.4% of the population of the city center of Şanlıurfa (TÜİK 2024) and is particularly popular among migrants. The Göl neighborhood is an area with a dense historical and traditional residential fabric, where the trade, service, and tourism sectors have also developed. In this area, where the neighborhood boundaries dating back to the Ottoman period have been largely preserved, residential use has gradually decreased; in contrast, trade, service, and tourism functions have increased (Karacadağ Kalkınma Ajansı 2012). Due to land use decisions in the city center of Şanlıurfa and the location of the neighborhoods, liquid flow occurs from many areas to these neighborhoods during periods of excessive rainfall. This liquid flow, which causes flooding, leads to an increase in loss of life and structural damage in the Süleymaniye and Göl neighborhoods. Recent floods have shown that urban transformation projects have not been effective in reducing risks. This study examines the urban development of Şanlıurfa in terms of flood risk and proposes strategies for the city as a whole to reduce risks in the Süleymaniye and Göl neighborhoods.

The increasing urban expansion caused by the growing population further increases disaster risk, making it crucial to evaluate decisions regarding urban development in terms of disaster risks and to propose solutions accordingly. The main objective of this study is to conduct a natural disaster risk assessment regarding land use sensitivity in the city center and to propose recommendations for urban settlement decisions to reduce risk. In this context, it is evident that quantitative studies are necessary. In the study area, the susceptibility to flooding varies over short distances due to criteria such as slope, rainfall and distance to rivers. Cities are highly sensitive, dynamic and complex systems. Therefore, analytical hierarchy process (AHP), which is one of the multi-criteria decision making methods, was used together with geographical information systems (GIS) in this study. Risk maps are created using this method, based on the criteria obtained from the literature review and the scores obtained from expert opinions. The large number of variables necessitates the use of AHP, while the spatial nature of the data requires the use of GIS. The 1/5000 scale risk map created for Şanlıurfa city centre as a result of AHP and GIS based analyses was evaluated together with urbanisation and planning studies. In addition, considering the effects of the flood that occurred in 2023, the city centre and risky areas were analysed in detail. By overlapping the occupied-unoccupied analysis map of the study area with the risk map, safe unoccupied areas were determined and suggestions were developed for risky areas in line with the findings obtained.

The CBS-AHP technique, widely used around the world, stands out as an important tool for assessing flood risk in different regions. For example, in Tehran, the AHP method was applied to determine the city's resilience to flood hazards (Moghadas et al. 2019). Similarly, in the Pune region of India, CBS and AHP methods were used together to produce a flood risk map; the risk level was determined based on seven criteria, such as rainfall and slope (Jagtap et al. 2023). In Changchun, China, spatial risk maps were produced using the AHP and CBS methods. When compared with previously recorded flood data the model's results were found to provide a reliable and applicable assessment (Duan et al. 2022). Looking at examples from Turkey, sensitivity analyses to flood disasters were conducted in the Uluborlu-Senirkent Basin using the AHP and GIS methods, and the accuracy of the risk maps was supported by the areas affected by floods in previous years (İnce 2023). In the city of Antakya, flood risk analysis was performed using GIS techniques, and resilience-focused scenario recommendations were presented for high-risk areas (Çıldır 2023). Upon reviewing the studies, it is observed that research is generally conducted using the GIS-AHP method, within legal and administrative frameworks, or through the analysis of past natural disasters. The combined application of these methods will help identify risk areas using scientific data and past disasters. On the other hand, identifying deficiencies in legal and administrative processes while developing risk reduction strategies will help propose solutions for existing risk areas and prevent the emergence of new ones. Furthermore, the risk analysis of the entire city center of Şanlıurfa and the implementation of flood risk reduction measures in informal settlements (Süleymaniye Neighborhood) and historical areas (Göl Neighborhood) constitute the original contribution of this study. It is necessary to go down to the neighborhood level to determine risk reduction strategies in the region. Evaluating this study in conjunction with the risks that may arise from the city as a whole is important in terms of accurately analyzing the effects these risks may have on the neighborhood.

1. Materials and methods

Global migration movements, which gained momentum after the 1850s, led to rapid urban growth first in developed countries and shortly afterwards in developing countries (Tekin and Haşimoğlu 2024). While 30 per cent of the world population lived in cities in 1950, this figure increased to 43 per cent in 1990 and 56 per cent in 2020. It is expected to reach 68 per cent in 2050 (UN-DESA 2018). In Turkey, the urbanization rate is expected to reach 86% by 2050 (Karaca et al. 2024). The lack of a gradual urbanization process in Turkey has led to the emergence of unplanned areas such as shantytowns and increased vulnerability of cities to disasters (Usta 2021).

In Turkey, the planning hierarchy is established within a step-by-step system consisting of the development plan, regional plan, environmental planning, master zoning plan, and implementation zoning plan, with higher-level plans guiding lower-level plans throughout this process. Since 1963, the Ministry of Urbanization and Housing, one of the key actors in development planning, has brought regional planning approaches to the forefront within this hierarchy (Keleş 2004). However, the lack of coordination between central and local governments, frequent zoning amnesties, urban rent pressure, and widespread illegal construction have significantly weakened the guiding power of the planning system. With the new Zoning Law No. 3194 enacted in 1985, planning authorities were largely transferred to local governments (Aşık 2019). The Coastal Zone Law No. 3621, which came into force on April 4, 1990, imposed restrictions on construction in coastal areas with a high risk of flooding and aimed to protect natural areas (Yalçınkaya 2021). In 1996, the earthquake zone map was updated using contemporary probability methods. On July 2, 1998, the “Regulation on Structures to be Built in Disaster Zones” was brought into line with contemporary engineering standards. Following the Marmara Earthquake in 1999, fundamental changes were made to disaster management policies in Turkey. Law No. 4452, published on August 27, 1999, defined the measures to be taken against natural disasters and the regulations regarding the compensation of damages (Kalkan 2023). Law No. 5216 on Metropolitan Municipalities, dated July 10, 2004, assigned disaster-focused planning tasks to metropolitan municipalities (Aşık 2019). Law No. 5366, dated June 16, 2005, aimed to protect historical and cultural assets. In the same year, municipalities were granted authority regarding urban transformation applications (SBB 2013). Law No. 5902, published on May 29, 2009, established AFAD as the sole authorized and coordinating institution in the field of disaster management in Turkey. In line with the Sendai Framework for Disaster Risk Reduction adopted in 2015, strategic action plans for risk reduction were developed under the leadership of AFAD, including the development of digital databases, task sharing, and monitoring processes (AFAD 2021). Resilient cities and environmental sustainability targets were addressed in the 10th (2014-2018), 11th (2019-2023), and 12th (2024-2028) Development Plans. These issues were not sufficiently addressed in the plans prior to the 10th Development Plan (SBB 2023).

In 1999, a year that witnessed fundamental changes in disaster management policies in Turkey, disaster-focused efforts began to be integrated more into high-level planning by the central government. However, in urban planning efforts transferred to local governments in 1985, this integration could not be successfully implemented in most municipalities due to a lack of technical capacity. Due to all these legal and administrative inconsistencies, the desired success could not be achieved in practice.

Work Area and General Features

Şanlıurfa is located between 30°-36° north latitude and 37°-40° east longitude. This region in the Middle Euphrates section of the Southeastern Anatolia Region (Fig. 1) is 60.4% plateau, 22% mountainous, 16.3% plain, and 1.3% highland (AFAD 2021). The highest temperatures occur in June, July, and August, while the highest rainfall occurs in January, February, and March (MGM 2025).

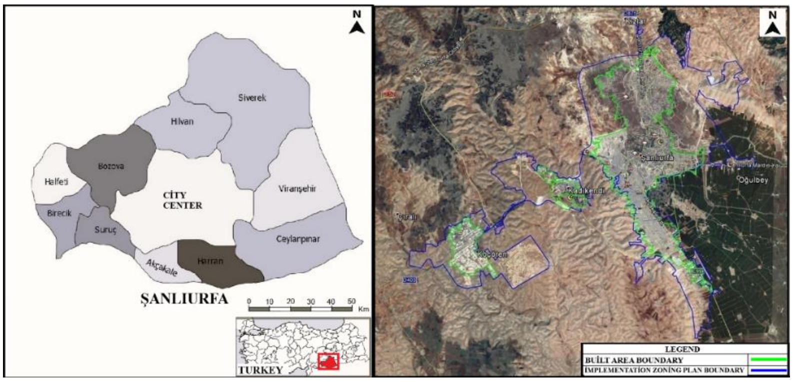

Fig. 1 Location of the study area and boundaries of the application zoning plan (ŞBB 2025).

The city center of Şanlıurfa also has different morphological units and varying elevation levels (Fig. 2). Hill or plateau areas are seen to the north, south, and west of the city, while the Harran Plain plains are seen to the east and southeast (Vural 2022).

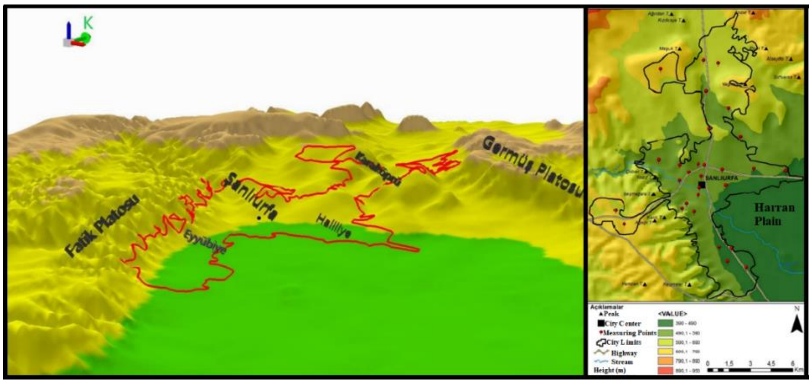

Fig. 2 Topographic map of the city center of Şanlıurfa (Vural 2022).

The city of Şanlıurfa first appeared on the historical stage around 3000 BC with the construction of its city walls. The course of the Karakoyun stream, which flowed through the city walls, was altered in the 500s AD and diverted outside the walls. During these years, construction began on the old riverbed. In 1766, a large part of the settlement area in Urfa was surrounded by walls, and in 1876, the walls surrounding the city center ceased to be a barrier, and new settlements began to form on the new Karakoyun Riverbed in the north (Aydoğdu 2019). It is known that the city mostly expanded within the walls until the 20th century, including the Ottoman period. The first modern urban development movement began in 1903. During this period, the city developed towards the north of the Karakoyun Stream (Şahinalp 2005). In 1923, development towards the west began with the opening of Vali İzzet Bey Street, known as the asphalt road (Fig. 3).

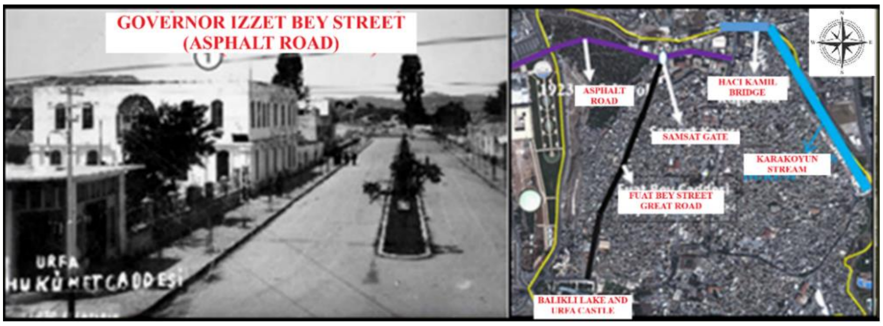

Fig. 3 Vali İzzet Bey Street (Asphalt Road) and the first planning initiatives in Şanlıurfa (ŞBB 2022).

Balıklıgöl, a First-Degree Natural Site, consists of Halil-ür Rahman Lake, Ayn-ı Zeliha Lake, Halilür Rahman Mosque, Rızvaniye Mosque, Hasan Paşa Mosque, Mevlid-i Halil Mosque, Urfa Castle, and the park area surrounding all these structures. There are many examples of monumental and civil architectural structures in the Göl Mahallesi neighborhood where Balıklıgöl is located. In addition, the Karakoyun Creek, which feeds the lake, and many streets pass through the neighborhood (Aydoğdu 2019). In Şanlıurfa, planning efforts were first carried out in the form of road and direction determination (GAP 2004). Vali Fuat Bey Street was opened in 1925 as the main east-west transportation route within the framework of urban planning initiatives carried out in the early years of the Republic. With the opening of the street, the urban fabric, which had previously developed mainly within the city walls and along the eastern axis, began to expand east-west (Fig. 4).

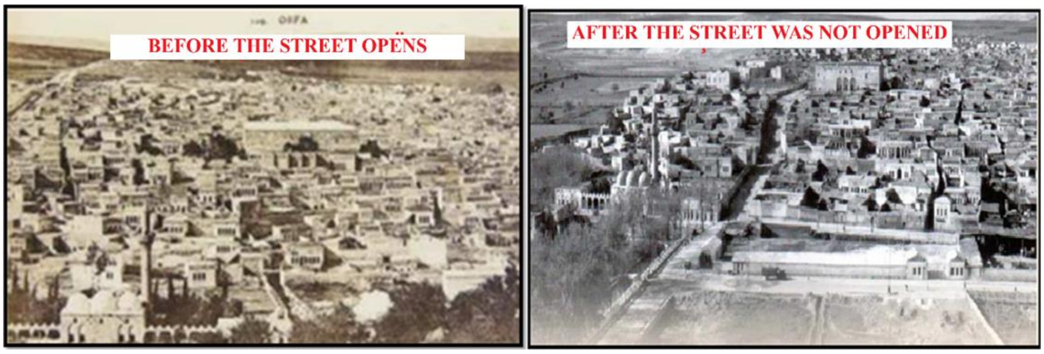

Fig. 4 The impact of Vali Fuat Bey Street on urbanization (ŞBB 2022).

In the 1932 city plan, the first zoning plan of the Republican period drawn in 1937, and the preliminary zoning project prepared in 1940 (Fig. 5), it is seen that the city expanded outside the city walls and to the north of Karakoyun Creek (ŞBB 2023). In addition, the Urfa Reconstruction Preliminary Project states that a dam and canal were constructed in the north of the city to collect water from the mountains (Toksoy 1940).

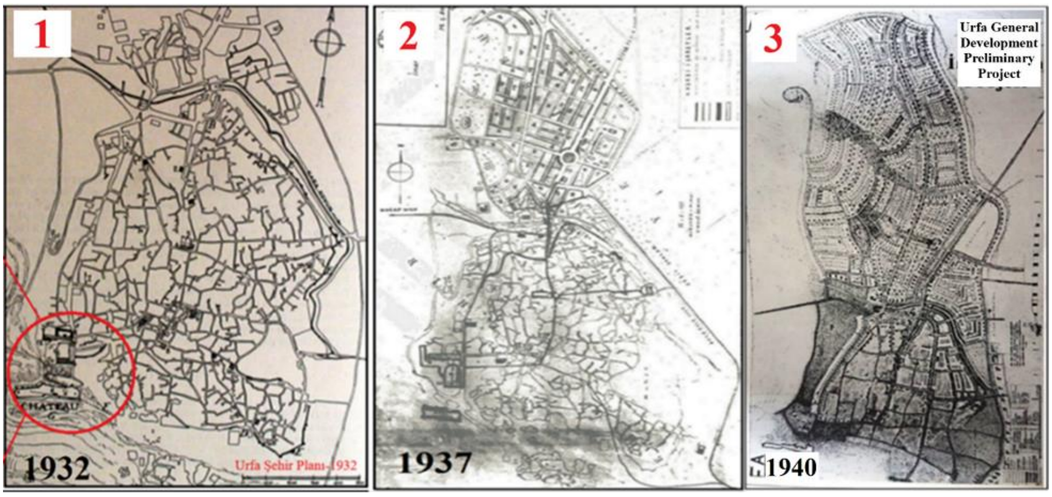

Fig. 5 City plan from 1932, zoning plan from 1937, and preliminary project from 1940 (ŞBB 2023).

In the 1960s, when migration to the city was intense, the population of Şanlıurfa city centre approached 60,000. Due to this unforeseen population growth, 3,639 slums were built in 1967, and efforts were made to demolish these slums, but they were not successful enough (Urfa 1974). In image 1 and 2 in Fig. 6, which are from 1970, it can be observed that the vast majority of these shantytowns were located north and east of the historic city center.

Fig. 6 Images of Şanlıurfa and its urban area in 1970 (ŞBB 2022; Şahinalp 2005)

Fig. 6 shows that some of the shantytowns were located near the Cavşak and Karakoyun streams on the urbanization map from the 1970s (Image 3). The first comprehensive urban plan for Şanlıurfa was prepared by the Provincial Bank in 1974 (ŞBB 2023). With this plan, the northern and southern parts of the city were opened up for settlement, and the city's population increased significantly during this process. In 1975, the proportion of people living in city centers reached 44%. This plan, which took into account a city center population of 300,000, remained in effect until the new implementation urban plan prepared by the Provincial Bank in 1989 came into force (TÜİK 2024). It is stated that the plan specifically aimed to widen city roads and included various regulations in this direction (Engin 2018). In this context, in 1974, some areas in the north and south were opened for settlement, shaping the spatial development of the city (Akış and Akkuş 2003; Karasu 2016). In 1978, a flood disaster occurred, damaging many homes and workplaces in the historic city and its surrounding neighborhoods (AFAD 2021). In 1980, 47% of the population lived in city centers, and by 1985, this figure had risen to 50% (TÜİK 2024). In addition to the forced migrations that occurred after 1980, the central government pursued policies that encouraged urbanization in the Southeastern Anatolia Region (SBB 2013). During these years, construction began in the Sırrın riverbed. The laws enacted between 1983 and 1985, known to the public as the “Urbanization Amnesty,” provided a legal basis for shantytown development in Şanlıurfa, as in other cities in Turkey. Due to topographical conditions, the city expanded mainly towards the north (Fig. 7). In the south, shantytowns were built on agricultural land (Türkoğlu 1987).

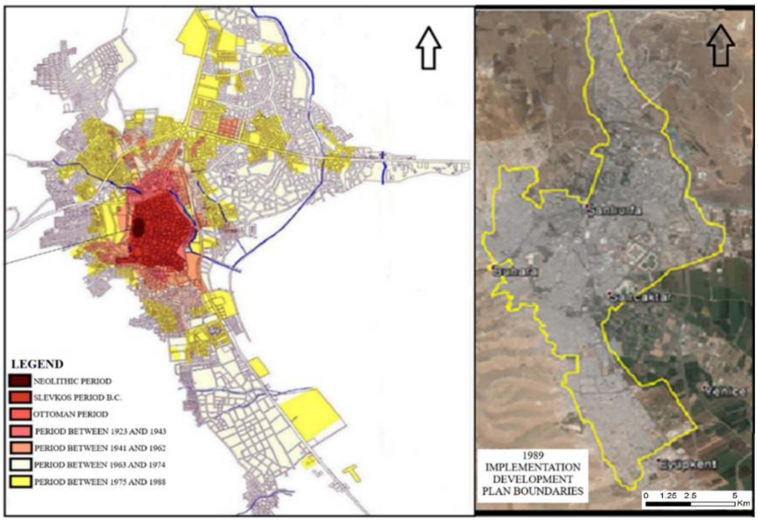

Fig. 7 Urbanization periods of Şanlıurfa and the boundaries of the 1989 implementation zoning plan (Şahinalp 2005)

During the period of the implementation zoning plan approved by the Provincial Bank on October 24, 1989, the city developed around the Harran Plain, located in the south and southeast, where agricultural areas are abundant (Fig. 8) (Türkoğlu 1987). During these years, the city's population exceeded the rural population for the first time (TÜİK 2024).

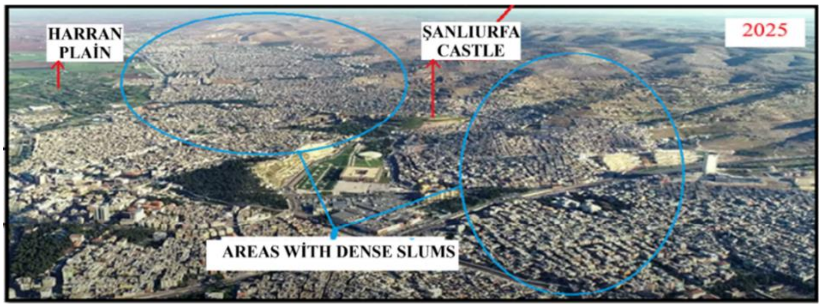

Fig. 8 Areas with a high concentration of shantytowns in the city center of Şanlıurfa (ŞBB 2025).

Şanlıurfa Conservation Implementation Zoning Plan was approved by the Regional Board for the Protection of Cultural and Natural Heritage on 31 July 1992. This plan (Fig. 9), which covers archaeological sites and monumental and civil architecture examples, has been revised several times until 30 November 2017 (ŞBB 2025). Image 1 in Fig.9 shows that the Karakoyun Creek, which passes through the boundaries of the conservation zoning plan, had its course altered in the 500s AD by building a wall to the northwest of the city. With the construction of the wall, the stream bed surrounded the historic city area from the north and northeast. Before the wall was built, the Karakoyun Stream caused numerous floods and torrents within the city walls (Hayes 2002; Şahinalp 2005).

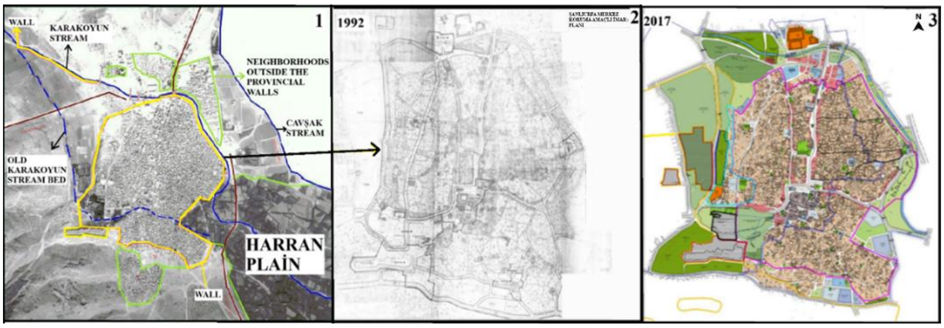

Fig. 9 Conservation-oriented zoning plans (Aydoğdu 2019)

The Halepli Garden Mosaics, located within the urban site area, were first registered as a second-degree archaeological and natural site. After being reclassified as a third-degree site, construction activities were halted when floor mosaics were discovered during construction, and the area was declared a first-degree archaeological site. Furthermore, the western part of the conservation plan boundaries was initially declared a second-degree archaeological site, and later, with the discovery of rock tombs, it was declared an urban archaeological site (ŞBB 2023). Although construction activities were partially halted with these changes, numerous shanties had been built within the boundaries of the conservation zoning plan before the changes were made. Although informal settlement areas spread in all directions until the 1990s, they were more prevalent in the northeast and southeast (Karacadağ Kalkınma Ajansı 2013). In the 1990s, there was a shift towards regular urbanization trends with the GAP and similar development projects. However, informal settlement became widespread due to the inability to meet the housing demand of the growing population (GAP 2004). After the 1990s, construction increased more in the northern direction (TÜİK 2024). The planning studies shown in Fig. 10 also confirm this.

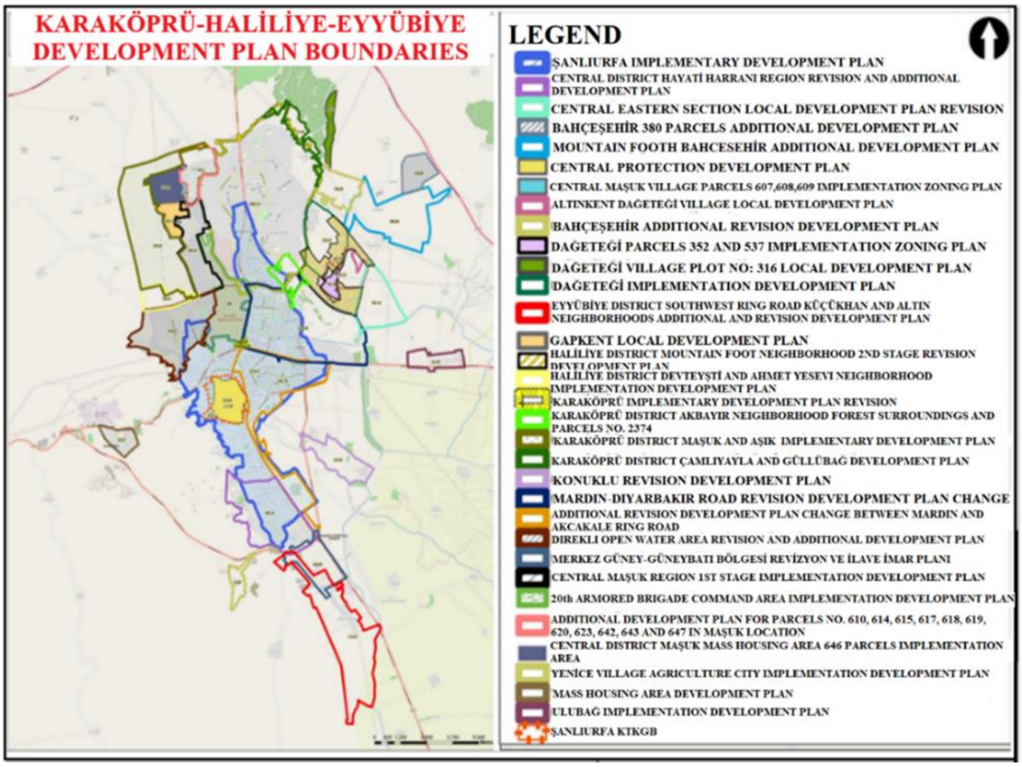

Fig. 10 Zoning plan boundaries covering all central districts of Şanlıurfa (ŞBB 2025)

As shown in Figure 10, urban plans in Şanlıurfa have been prepared with a fragmented approach. These plans, implemented from 1989 to 2025, were subject to the legal regulations of the period in which they were prepared, resulting in a heterogeneous planning approach and physical structure in the city. Urban transformation projects have been initiated in the city to address the spatial problems created by this situation and to adopt a holistic urban planning approach.

Article 73 of the Municipal Law No. 5393, which entered into force on July 3, 2005, granted municipal councils the authority to implement urban transformation and development projects. On November 3, 2006, floods occurred in all rivers in the center, districts, and villages of Şanlıurfa, causing damage to residential areas and agricultural lands in the city center (AFAD 2021). In 2000, Şanlıurfa had a population of 842,129 and a housing shortage of 134,682 units. By 2010, the population had risen to 732,722, and the total need had reached 189,016 units while the rate of unlicensed buildings rose to 80% (Kahya 2015). The 2010 Pre-Regional Development Plan emphasized that rapid and unplanned urbanization threatened environmental sustainability and that infrastructure was inadequate (Karacadağ Kalkınma Ajansı 2010). Law No. 6306 on the Transformation of Areas at Risk of Disaster, which came into force in 2012, was an important legal regulation aimed at accelerating urban transformation projects, especially in risky areas. In the same year, Şanlıurfa became a metropolitan municipality, and the towns of Karaköprü and Eyyübiye gained the status of central districts, along with the old city center (Haliliye), which contains the historic city center, becoming three central districts. These developments further accelerated Şanlıurfa's spatial expansion (Karasu 2016). Starting in the 1900s, structures built in riverbeds gained official status, and planned development areas began to form around unplanned areas (ŞBB 2025). In 2012, flooding caused by excessive rainfall in the city resulted in material damage to homes and workplaces in many areas, particularly in the neighborhoods of Maşuk in the north, Uğurlu in the south, Sırrın in the east, and Direkli in the west (AFAD 2021). The 10th Development Plan, covering the period 2014-2018, included reducing disaster risks and prioritizing urban transformation projects among its main objectives. However, during the spring rains of 2018, some neighborhoods in the north of the city center were flooded, and many structures were damaged. Between 1950 and 2018, more than 80 floods occurred within the borders of Şanlıurfa, and most of these events also affected the city center (ŞBB 2023). The disasters that occurred led to significant changes in the city's planning approach. In particular, various additional and revised zoning plans were prepared and implemented to guide urban development in the city center (Fig. 11).

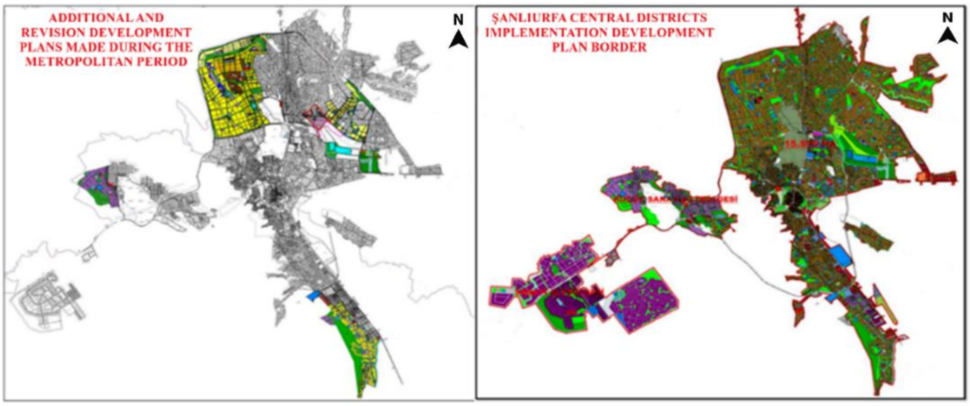

Fig. 11 Additional zoning plans made during the metropolitan period and the 2025 comprehensive implementation zoning plan (ŞBB 2025).

Until 2025, urban development continued in Şanlıurfa city centre with a total of 32 development plans, most of which were approved by the municipal council (ŞBB 2025). The 2004 report of the GAP Administration emphasized the need for a comprehensive planning approach (GAP 2004). By 2025, an integrated urban development plan for Şanlıurfa city centre has been completed and a comprehensive approach to its spatial development has been implemented (Fig. 11). In this context, it is aimed to transform disaster-prone areas in the city into healthy living spaces in accordance with the planning principles (ŞBB 2025). Population projections in plans from the 1980s to 2020 have not been accurate (Usta 2021). In this context, the failure of the estimates in the higher-level plans has resulted in almost all of the adopted zoning plans being inadequate and an increase in substandard construction along riverbanks at risk of flooding (Fig. 12).

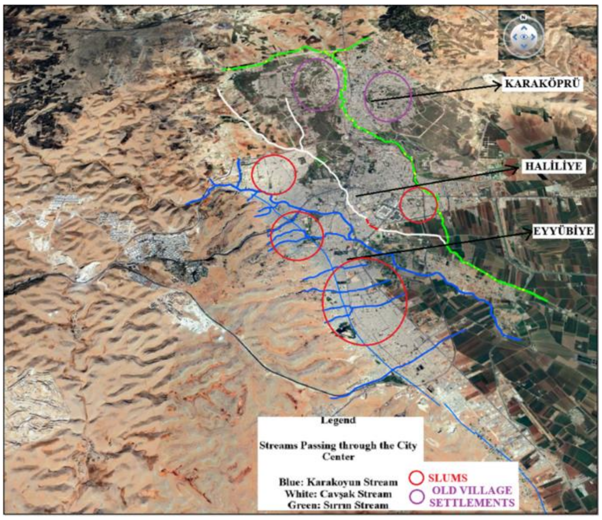

Fig. 12 Streams and unplanned areas passing through the city center of Şanlıurfa (ŞBB 2025).

The construction of shanties in riverbeds and the lack of scientific basis in planning decisions have led to floods almost every year in the Karakoyun, Cavşak, and Sırrın rivers (Fig. 12). According to the Euphrates Sub-Basin Flood Management Plan Report prepared by the General Directorate of Water Management in early 2020, 418 settlements around these riverbeds have been assessed as flood-risk areas (Tarım ve Orman Bakanlığı 2020). Despite the evacuation of some of these settlements (Fig. 13) under the urban transformation program prior to the flood disaster on March 15, 2023 (Bingöl et al. 2023), 17 people lost their lives.

Fig. 13 Structures evacuated from the Karakoyun riverbed and the flood that occurred in 2023 (ŞBB 2025).

Between 2000 and 2012, the development of the eastern slopes of the Fatik Plateau and the Şanlıurfa-Mardin road and the start of construction in some areas in the Harran Plain increased ecological vulnerability and paved the way for the emergence of environmental problems such as drought, runoff and heat islands. While some of these problems affect the entire city center, others pose a threat at the regional level. Due to the complexity of both the disaster phenomenon and the urban structure, it was considered that urban or regional risk reduction strategies alone would not be sufficient, so the two studies were integrated. Based on the studies of Karacadağ Development Agency, the neighbourhoods of Süleymaniye and Göl (Karacadağ Kalkınma Ajansı 2012), which were most affected by flooding in 2023, were selected. The Süleymaniye neighborhood is largely located on the Karakoyun Creek bed and has dense shantytown areas. The Göl neighbourhood, where the old Karakoyun stream bed passes, has a historical texture. The fact that both neighborhoods are located in the lower elevations of the city and have a low-lying topography causes surface runoff resulting from rainfall in the city to flow towards these areas. Therefore, both neighborhoods are among the most flood-prone areas of the city. For this reason, regional and city-wide strategies must be developed to reduce flood risk in the Süleymaniye and Göl neighborhoods.

Part of the flood-prone area within the boundaries of Süleymaniye Neighborhood was developed during the unplanned period, while another part was opened for development during the planned period (ŞBB 2025). Karakoyun Creek (Fig. 14), which runs through the neighborhood and has caused numerous floods in the past, and the streams feeding the creek significantly increase the flood risk in the area. Finally, in the flood that occurred on March 15, 2023, in the Karakoyun Creek bed and its surroundings, 1 person died and 4 people were injured, and 80 houses, 15 workplaces, 1 school, and 1 mosque were seriously damaged (AFAD 2023).

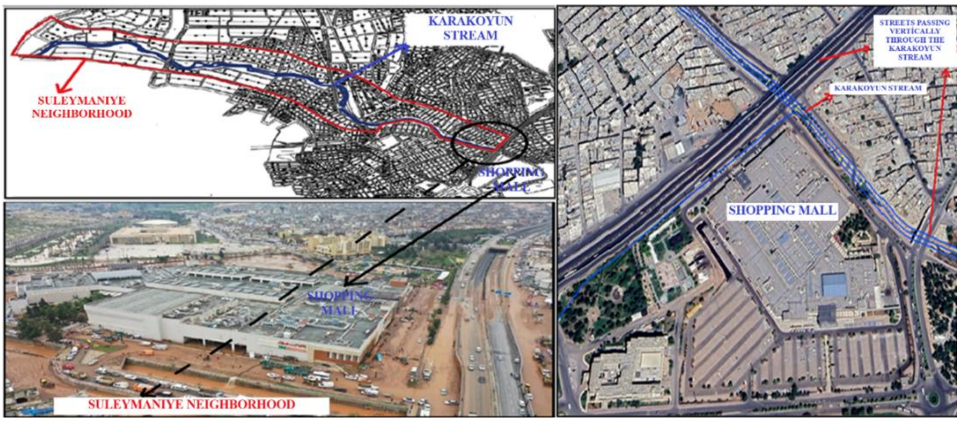

Fig. 14 Street intersecting the stream at a right angle in Süleymaniye Neighborhood (ŞBB 2025).

In Süleymaniye Neighborhood, with a total population of 11,213 (TÜİK 2024), the streets and alleys intersecting Karakoyun Creek at right angles (Fig. 14) partially obstructed the flow of water, resulting in more severe flooding. In this neighborhood, where there are many residential buildings that violate zoning regulations, the stream has been channeled into a U-shaped channel (Fig. 15). The narrowing of the stream bed cross-section and the construction of buildings on the floodplain have further increased the risk of flooding.

Fig. 15 Süleymaniye Neighborhood and riverbed (ŞBB 2025).

Göl Neighborhood, one of the oldest settlements in the study area, is located within the boundaries of the conservation zoning plan (Fig.14). The area, which has a history of 11,000 years, contains structures belonging to many civilizations. The neighborhood, which is located in the bed of the old Karakoyun Creek, is at a lower elevation due to the surrounding plateaus. This causes surface runoff to flow towards the neighborhood (Fig. 16).

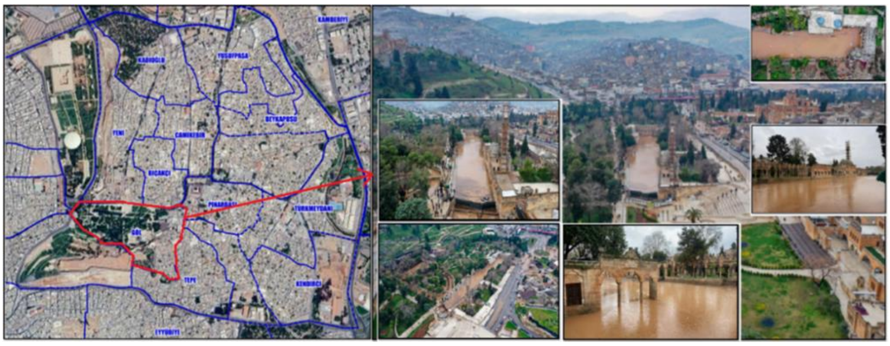

Fig. 16 Göl Neighborhood and its surroundings (ŞBB 2025).

During the flood that occurred on March 15, 2025, the lake's water level rose by approximately 2 meters; this caused damage to the surrounding area and harmed the sacred fish in Balıklıgöl.

Method

Due to the presence of numerous criteria affecting flood risks (slope, elevation, land use, etc.), the Analytic Hierarchy Process (AHP) method was chosen; analyses were conducted in a Geographic Information System (GIS) environment, taking into account the spatial nature of the data. The resulting risk maps were examined not only with geographic data but also with planning decisions and the effects of the floods that occurred in Şanlıurfa in 2023, and the risk maps were evaluated comparatively with physical and spatial effects. To determine the proposed settlement areas, flood hazard risk maps were overlaid with the city's full-empty analysis map at the same scale; safe and empty areas that do not carry disaster risk were identified. In this context, both existing risk areas were evaluated with a disaster-focused planning approach and spatially safe areas were proposed for new settlement areas. This methodological integration stands out as the original contribution of the study.

In the literature, the criteria that influence flood risk analysis are divided into two categories: natural and physical variables. Natural variables include environmental elements, while physical variables include elements such as land use that undergo change as a result of both natural processes and human activities (Table 1) (Demir and Altaş 2024). The criteria to be used in flood risk analysis, which are composed of these variables, are explained in Table 1.

Table 1 Variable groups and criteria used in flood risk analysis

NATURAL VARIABLES	
Slope (E)	Flat areas with low slopes are more risky because they accumulate rainwater (Babazadeh 2020).
Drainage Density (DDI)	In areas with high drainage intensity, surface water flows rapidly, increasing the risk of flooding (Zhang et al. 2023).
Elevation (H)	Surface water formed by precipitation in high-altitude areas moves toward low-altitude areas along the topographic gradient. This causes water to accumulate, increasing the risk of flooding (Rahmati et al. 2016).
Precipitation (P)	As rainfall increases, the likelihood of flooding increases (İnce 2023).
Normalised Difference Vegetation Index (NDVI)	Areas with high NDVI values are safer in terms of flood risk because the vegetation cover retains more water (Rahmati et al. 2016).
Hillside Slope (HE)	Positive curvature values indicate convex surfaces, negative values indicate concave surfaces, and zero values indicate flat surfaces. Flood risk is low in convex areas, while it is high in concave areas (Chen et al. 2017).
Distance to Streams (DS)	As proximity to rivers increases, surface and underground water movement increases and flood risk rises (Abd El Aal et al. 2019).
Topographic Moisture Index (TWI)	Areas with high TWI values have a high flood risk as they show more water accumulation (Pourtaghi et al. 2014).
Geomorphology (G)	In hilly and mountainous areas, surface water flow is rapid, so the risk of flooding is low. On the other hand, the opposite is true for valleys and plains (İnce 2023).
Topographic Position Index (TPI)	Flat, sloping, and concave areas pose a high risk of flooding due to their tendency to accumulate surface water; conversely, high and convex areas such as ridges pose a lower risk due to their low surface water accumulation (Rahmati et al. 2016).
Soil Type (S)	Soils with high clay content and low permeability increase flood risk, while permeable soils such as gravel and sand reduce flood risk (Oba 2009). Flood risk is high in settlements due to low permeability (Değerliyurt 2013).
Lithology (L)	Impermeable rocks increase surface runoff, so the risk of flooding is low in porous and soft rocks (Selçuk et al. 2016; Rahmati et al. 2016).
Baku (B)	South-facing areas receive more sunlight, leading to increased evaporation, greater soil dryness, and reduced surface runoff, thereby lowering the risk of flooding. Conversely, the opposite is true for north- and southeast-facing areas (Şengün et al. 2019).
PHYSICAL VARIABLES	
Land Use (LU)	Residential and industrial areas, rainwater quickly turns into surface runoff due to the moisture content of the soil, increasing the risk of flooding. Land use classes exhibit different risks and potentials depending on their water permeability characteristics (Abd El Aal et al. 2019).
Distance to Road (DR)	Areas close to roads increase flood risk due to development and surface hardness (Park and Lee 2019).

In disaster risk analyses, the joint assessment of natural and physical variables contributes to the modeling of disaster scenarios in a more comprehensive, consistent, and realistic manner (Bodur 2018). Once the criteria are determined, the AHP is applied. A scoring (weight values) based on the scored preference scale (1-9) in Table 2 is performed with expert opinions to determine the relative importance of the criteria in the hierarchy in relation to other criteria, and a pairwise comparison matrix is created (Malczewski 2006).

Table 2 AHP importance scale (Saaty 1980)

Importance Scale	Definition	Description

1	Equally important	The two options are of equal importance.
3	Moderately important	Experience and judgement slightly favour one criterion over the other.
5	Strongly significant	Experience and judgement make one criterion highly superior to the other.
7	Very strongly significant	One criterion is considered superior to the other.
9	Definitely important	Evidence that one criterion is superior to another has great reliability.
2,4,6,8,	Intermediate values	A compromise is a value between two consecutive judgements to be used when necessary.

In the study, expert opinion forms were created to determine the weight importance levels of the variables, drawing on different disciplines and perspectives. The expert opinion form used consists of three sections. The first section contains information about the purpose of the form, how to fill it out, and details about the expert. The second section defines the scale (Table 2) used for the pairwise comparison of variables. The third section contains questions designed to determine which variable is more important and how much more important the important variable is compared to the other. The experts consist of four different professional groups: geology engineers, urban planners, architects, and construction engineers.

According to experts' opinions, the weights in Table 3 were created by assigning values between 1 and 9 (both inclusive) to the variables. In this table, the determined criteria attributes and risk score were made according to the literature research in Table 1.

Table 3 Analysis data and explanations

Criterion	First Weight	Attributes	Risk Score	Effect	Explanation
E (Degree)	**7**	0-4	5	The most	Flood potential increases as the slope decreases. Therefore, 5 points are given to areas with low slope and 1 point is given to areas with high slope.
		4-8	4	Very much	
		8-12	3	Centre	
		12-19	2	Less	
		19-47	1	At least	
DDI (Km/Km²)	**8**	0-0.9	1	At least	For flood risk, the class with the highest drainage intensity value was assigned 5 points and the class with the lowest drainage intensity value was assigned 1 point.
		0.91-1.8	2	Less	
		1.9-2.7	3	Centre	
		2.8-3.6	4	Very much	
		3.7-4.5	5	The most	
H (Metre)	**7**	400-500	5	The most	Flood risk potential increases as the elevation decreases. For this reason, 5 points are given to the lowest areas and 1 point to the highest areas.
		500-600	4	Very much	
		600-700	3	Centre	
		700-800	2	Less	
		800-900	1	At least	

P (Mm)	**8**	461.8-505.1	1	At least	The highest risk score of 5 points was assigned to the class with the highest amount of rainfall and 1 point was assigned to the class with the lowest amount of rainfall.
		505.2-541.1	2	Less	
		541.2-572.1	3	Centre	
		572.2-600.7	4	Very much	
		600.8-670.1	5	The most	
NDVI (Classroom)	**4**	-0.14 - 0.086	5	At least	Areas with high density are given the lowest flood risk score and areas with low density are given the highest flood risk score.
		0.087-0.14	4	Less	
		0.15-0.22	3	Centre	
		0.23-0.39	2	Very much	
		0.40-0.61	1	The most	
HE (Radian)	**3**	Concave (Concave)	3	The most	Concave areas are given a high score because more water will be collected, flat areas are given a medium score, and convex areas are given the least score.
		Flat	2	Centre	
		Convex (Convex)	1	At least	
DS (Metre)	**9**	0-100	5	The most	The areas closest to the rivers have the highest flood risk. These areas are given 5 points and the farthest areas are given 1 point.
		100-300	4	Very much	
		300-500	3	Centre	
		500-1000	2	Less	
		1000-1500	1	At least	
		>1500	1	At least	
TWI (Classroom)	**3**	3.4 - 6	1	At least	While 5 points were given to the class with high index value, 1 point was given to the places with low index value since they were less risky.
		6.1- 7.4	2	Less	
		7.5 - 9.4	3	Centre	
		9.5 - 12	4	Very much	
		13 -20	5	The most	
G (Classroom)	**6**	Valley	5	The most	In terms of flooding, 5 points are assigned to the valley, which is the most risky class, and 1 point is assigned to the mountainous areas, which are the least risky class.
		Plain	4	Very much	
		Slope	3	Centre	
		Mountainous Areas	1	At least	
TPI (Classroom)	**3**	Flat Sloping Areas	5	The most	Since the most risky areas in terms of flood risk are flat sloping areas, 5 points were given. The ridge class with
		Low Slope Areas	4	Very much	
		Valley	3	Centre	
		High Slope Areas	2	Less	

		Back	1	At least	the lowest risk is given 1 point.
S (Classroom)	**5**	Basalt	5	The most	Areas with basalt and settlements increase the risk of flooding by increasing surface runoff. Therefore, high scores were given to these areas.
		Settlement	4	Very much	
		Reddish Brown Soil	3	Centre	
		Brown Soil	3	Centre	
		Colluvial Soil	1	At least	
DR (Metre)	**3**	0-50	5	The most	Since the areas close to the roads are considered to be the most risky, 5 points were given, and sİnce the areas at a distance are less risky, 1 point was given.
		50-100	4	Very much	
		100-150	3	Centre	
		150-200	2	Less	
		>200	1	At least	
L (Classroom)	**4**	No Data	5	The most	The lowest score was given to alluvial rocks with high water permeability and the highest score was given to basalt rocks with impermeability.
		Basalt	5	The most	
		Limestone	4	Very much	
		Clayey Limestone	3	Centre	
		Old Alluvium	2	Less	
		Alluvium	1	At least	
B (Degree)	**3**	Flat	5	The most	Areas facing north and south-east have a higher flood risk. For this reason, while high scores were given, south facing areas were given the lowest risk score, i.e. 1 point.
		North (0-22.5)	4	Very much	
		Southeast (112.5-157.5)	4	Very much	
		Northeast (22.5-67.5)	3	Centre	
		East (67.5-112.5)	2	Less	
		South (157.5-202.5)	2	Less	
		Southwest (202.5-247.5)	1	At least	
		West (247.5-292.5)	1	At least	
		Northwest (292.5-337.5)	1	At least	
		North (337.5-360)	1	At least	
LU (Classroom)	**5**	Continuous City Structure	5	The most	Due to the moist soil in agricultural, residential and industrial areas, rainwater quickly turns into surface runoff, which increases the risk of flooding; therefore, these areas were given high risk scores. The land use types assessed include agriculture, forest, pasture, settlement, road,
		Discontinuous City Structure, Continuously Irrigated Areas, Mineral Extraction Sites, Industrial and Commercial Units	4	Very much	
		Agricultural Areas with Natural Vegetation, Found Agricultural Areas, Sparse Plant Areas, Construction Sites, Mixed Agricultural Areas, Pastures, Mixed Agricultural Areas	3	Centre	

		Plant Exchange Areas, Green City Areas, Sports and Recreation Areas, Orchards, Highways	2	Less	airport, industry, construction, mining and sports areas, and each class has been assigned scores based on surface characteristics and factors associated with flood risk.
		Natural grasslands, airfields, coniferous forests, non-irrigated arable land, vineyards, discontinuous urban structure	1	At least	

Based on the weights obtained from the expert opinions in Table 3, 15 dimensional pairwise comparison matrices are presented in Table 4. In the diagonal elements of the matrix, the variables take the value of 1 since they are compared with themselves. The other components are determined according to the degree of importance of the variables relative to each other. For example, when the first variable (distance to the river - AM) is compared with the second variable (drainage density - DY), the first row and second column element of the matrix (AM = 9, DY = 8) will take the value (9/8) 1.12.

Table 4 AHP decision-making matrix

First Weight	Criterion	DS	DDI	P	E	H	G	S	LU	L	NDVI	TWI	HE	TPI	DR	B
9	**DS**	1	1.12	1.12	1.28	1.28	1.5	1.8	1.8	2.25	2.25	3	3	3	3	3
8	**DDI**	0.88	1	1	1.14	1.14	1.33	1.6	1.6	2	2	2.66	2.66	2.66	2.66	2.66
8	**P**	0.88	1	1	1.14	1.14	1.33	1.6	1.6	2	2	2.66	2.66	2.66	2.66	2.66
7	**E**	0.77	0.87	0.87	1	1	1.16	1.4	1.4	1.75	1.75	2.33	2.33	2.33	2.33	2.33
7	**H**	0.77	0.87	0.87	1	1	1.16	1.4	1.4	1.75	1.75	2.33	2.33	2.33	2.33	2.33
6	**G**	0.66	0.75	0.75	0.85	0.85	1	1.2	1.2	1.5	1.5	2	2	2	2	2
5	**S**	0.55	0.62	0.62	0.71	0.71	0.83	1	1	1.25	1.25	1.66	1.66	1.66	1.66	1.66
5	**LU**	0.55	0.62	0.62	0.71	0.71	0.83	1	1	1.25	1.25	1.66	1.66	1.66	1.66	1.66
4	**L**	0.44	0.5	0.5	0.57	0.57	0.66	0.8	0.8	1	1	1.33	1.33	1.33	1.33	1.33
4	**NDVI**	0.44	0.5	0.5	0.57	0.57	0.66	0.8	0.8	1	1	1.33	1.33	1.33	1.33	1.33
3	**TWI**	0.33	0.37	0.37	0.42	0.42	0.5	0.6	0.6	0.75	0.75	1	1	1	1	1
3	**HE**	0.33	0.37	0.37	0.42	0.42	0.5	0.6	0.6	0.75	0.75	1	1	1	1	1
3	**TPI**	0.33	0.37	0.37	0.42	0.42	0.5	0.6	0.6	0.75	0.75	1	1	1	1	1
3	**DR**	0.33	0.37	0.37	0.42	0.42	0.5	0.6	0.6	0.75	0.75	1	1	1	1	1
3	**B**	0.33	0.37	0.37	0.42	0.42	0.5	0.6	0.6	0.75	0.75	1	1	1	1	1
Total		**8.66**	**9.75**	**9.75**	**11.14**	**11.14**	**13**	**15.6**	**15.6**	**19.5**	**19.5**	**26**	**26**	**26**	**26**	**26**

As shown in Table 4, the weights of the criteria in the matrix have been calculated. Subsequently, the normalization process was performed by taking the sum of each column separately and dividing the value in each cell by the total of that column. For example, the value 1 in the first column of the first row was normalized to approximately 0.11 by dividing it by the sum of the first column, which is 8.66. (Table 5).

Table 5 Normalised weight values

Criterion	DS	DDI	P	E	H	G	S	LU	L	NDVI	TWI	HE	TPI	DR	B	W_i
DS	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
DDI	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
P	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
E	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
H	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
G	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
S	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
LU	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
L	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
NDVI	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
TWI	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
HE	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
TPI	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
DR	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
B	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Total	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

After normalization, the W_i value, which indicates the weight of the criterion related to the arithmetic mean of each row among the other criteria, was determined. Following this process, the values in the comparison matrix where each criterion is located were multiplied by the previously obtained criterion weights to calculate the A × W vector. The sum of the products for each row was taken to find the weighted sum vector (AW_i) (Table 6).

Table 6 Weighted total vector values.

Criterion	W_i	AW_i	λ	Criterion	W_i	AW_i	λ
DS	0.115385	3.510165	30,42143	**L**	0.051282	0.664876	12,96508
DDI	0.102564	2.750672	26,81905	**NDVI**	0.051282	0.664876	12,96508
P	0.102564	2.750672	26,81905	**TWI**	0.038462	0.370788	9,640476
E	0.089744	2.088533	23,27222	**HE**	0.038462	0.370788	9,640476
H	0.089744	2.088533	23,27222	**TPI**	0.038462	0.370788	9,640476
G	0.076923	1.521612	19,78095	**DR**	0.038462	0.370788	9,640476
S	0.064103	1.047772	16,34524	**B**	0.038462	0.370788	9,640476
LU	0.064103	1.047772	16,34524				

After this step, λ_{max} its value is calculated.

$\lambda_{max}=\sum\frac{AW_i}{W_i}$=17.1472 (Saaty and Kearns 1985; Babazadeh 2020).

The Consistency Index (CI) is calculated using the λ_{max} obtained for the consistency check. CI is a measure that indicates the degree of consistency of the comparison matrix.

$CI=\frac{\lambda_{max}-n}{n-1}$ = $CI=\frac{17.1472-15}{15-1}$=0.15337 (Saaty and Kearns 1985; Babazadeh 2020).

RI (15 for the criterion):1.59 (Saaty and Kearns 1985).

$CR=\frac{CI}{RI}=\frac{0.15337}{1.59}$=0.09646 (Saaty and Kearns 1985; Babazadeh 2020).

CR = 0.09646< 0.10 → These calculations have been verified for consistency, and the analysis is valid. Thus, the weights have been reliably determined and entered as integer values (Table 7).

Table 7 Conversion of weight values into integers.

Criterion	Weight Values (W_i)	Percent (%)	Criterion	Weight Values (W_i)	Percent (%)
DS	0.115385	%12	**L**	0.051282	%5
DDI	0.102564	%10	**NDVI**	0.051282	%5
P	0.102564	%10	**TWI**	0.038462	%4
E	0.089744	%9	**HE**	0.038462	%4
H	0.089744	%9	**TPI**	0.038462	%4
G	0.076923	%8	**DR**	0.038462	%4
S	0.064103	%6	**B**	0.038462	%4
LU	0.064103	%6			

The Flood Risk Map =(AM×0.12)+(DY×0.10)+...+(Bx0.04) (Saaty and Kearns 1985; Babazadeh 2020). In this process, the flood risk map is created by calculating the weighted sums of all criterion maps. The resulting risk map is divided into classes to make the analysis results more understandable. These classes represent levels such as low, medium, and high risk.

Results and discussion

The study area exhibits significant spatial differences in terms of natural structure, soil characteristics, and land use patterns. These differences directly affect many factors, ranging from agricultural activities to settlement decisions, transportation routes, and urban development dynamics. This diversity has also led to the heterogeneous distribution of flood risks across the area. This situation is more clearly evident when examining the criteria maps produced for flood risk analysis (Table 8).

Table 8 Criteria maps produced for flood risk (produced by the author).

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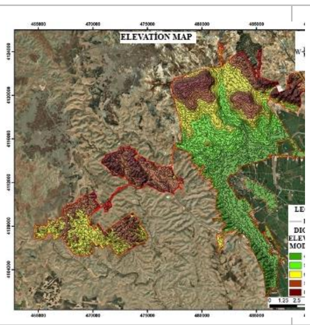
<td>
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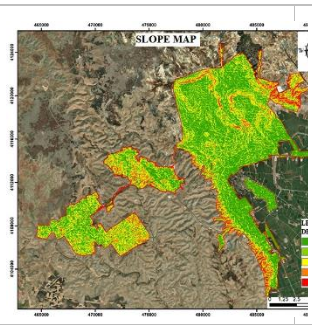
<td>
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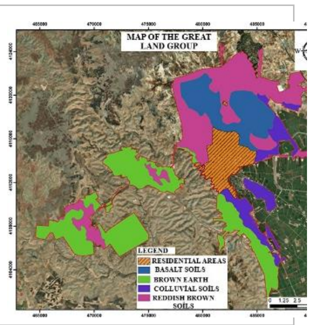
<td>
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<tr>
<td>When examining the elevation map of the city center of Şanlıurfa obtained using the digital elevation model (URL 1), it is observed that the elevation increases towards the north, northeast, and west. Rainwater in these areas flows south and southwest due to the slope, accumulating in low-lying areas. This situation makes these areas more susceptible to flooding.</td>
<td>When examining the slope map of the Şanlıurfa city center obtained using the Digital Elevation Model (URL 1), it is observed that the slope is high in the northeast and southwest directions, while it is quite low in the southeast sections. Due to the high slope in the northern and northeastern regions, surface runoff increases, which in turn raises the risk of flooding in the low-lying and flat areas to the south.</td>
<td>According to the soil group map prepared based on data from the Ministry of Agriculture and Forestry (URL 6), the risk of flooding is high in the north of the city, where basaltic and reddish-brown soils with low liquid permeability are widespread. In the south, however, colluvial and brown soils, which allow water to pass through more easily, reduce the risk. Residential areas are at high risk of flooding.</td>
</tr>
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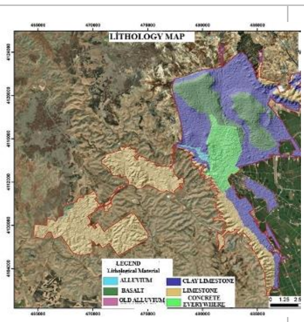
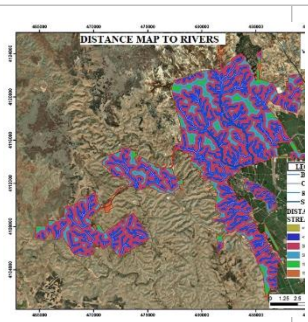
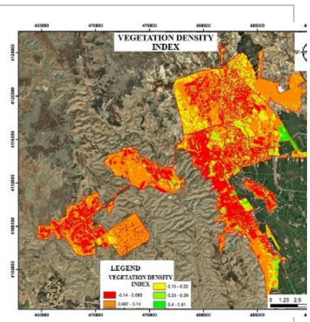
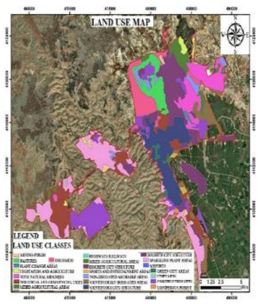
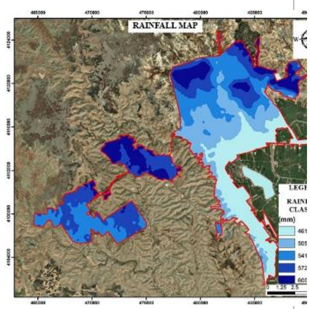
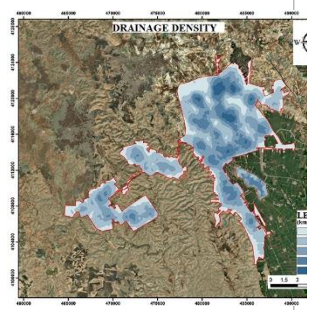
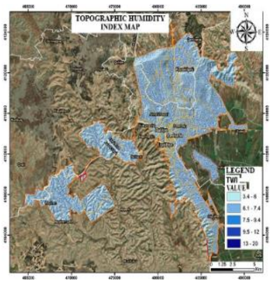
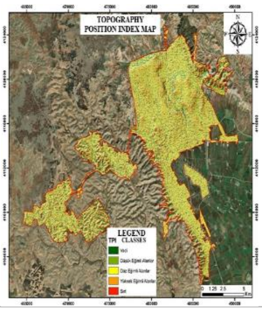
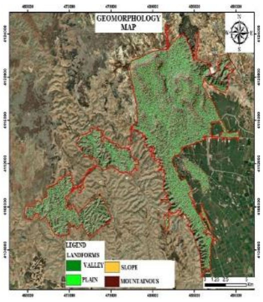
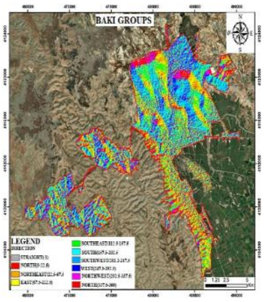
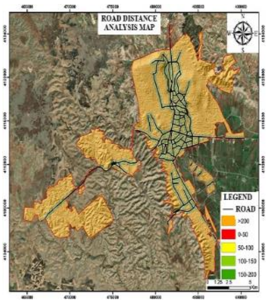
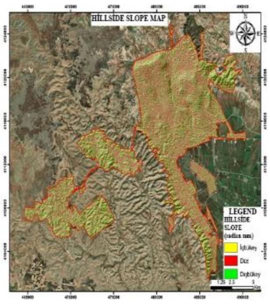
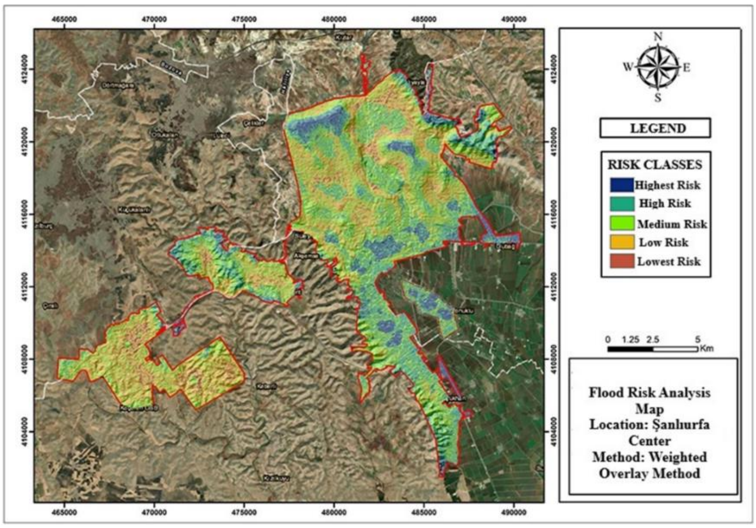
		
According to the lithology map data prepared using data from the General Directorate of Mineral Research and Exploration (URL 7), limestone is prevalent in the west, alluvial deposits in the northwest, basalt in the north, and clayey limestone in a large part of the city center. The northwest region, where alluvial soils are concentrated, has low flood risk due to its high permeability. Clay soils, which are impermeable, have a high flood risk.	When examining the map of distances to rivers in the city center of Şanlıurfa created using the ASF Alaska Module (URL 3), it can be seen that numerous tributaries feeding the Karakoyun, Cavşak, and Sırrın rivers spread across different areas of the city. The concentration of these tributaries, particularly in areas close to the city center, poses a significant threat in terms of flood risk.	Using remote sensing techniques and multispectral satellite imagery (URL 5), the NDVI analysis map revealed that vegetation cover density is high in limited areas in the eastern and southern regions of the city. In contrast, vegetation cover is negligible in other parts of the city. The limited vegetation cover increases flood risks.
		
When examining the land use map prepared using Copernicus Land Monitoring Service data (URL 4), natural vegetation, agricultural areas, and orchards are widespread in the north. These areas facilitate water infiltration into the soil, reducing flood risk. However, the opposite is true in the basaltic soils of the south. In contrast, the agricultural areas in the southeast allow water to mix with the soil, thereby reducing the effects of flooding.	When examining the precipitation map prepared using data from the General Directorate of Meteorology (URL 2), precipitation amounts are higher in the northern and western regions, while they are relatively lower in the southern and eastern regions. In the northern and western regions where precipitation is heavy, surface runoff increases, especially when drainage capacity is insufficient, and this increases the risk of flooding.	When examining the drainage intensity map prepared using the Digital Elevation Model (URL 1), it is observed that drainage intensity is high in the northern parts of the study area. This indicates that surface water flows rapidly and that flood risk is increased in these areas. This particularly increases flood risk in the northern and western regions, where rainfall is also intense.

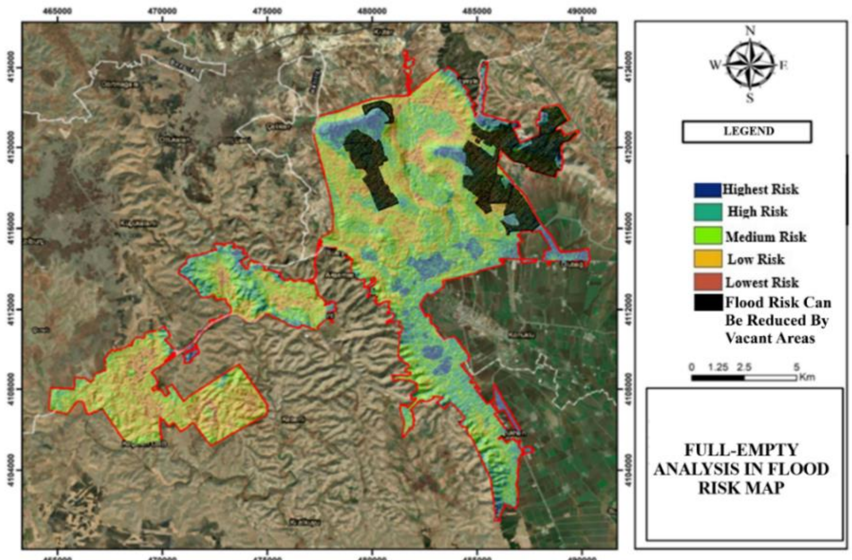
		
When examining the topographic moisture index (TWI) map of the study area prepared using the Digital Elevation Model (URL 1), it is observed that the high topographic slope and drainage density cause water to flow rapidly without accumulating on the surface. In contrast, the flat	When examining the topographic position index (TPI) map generated using the Digital Elevation Model (URL 1), it is observed that valleys and ridges are distinctly present in the northern and northeastern sections of the study area. Throughout the city, flat-sloped and slope-	The geomorphological map created using the Digital Elevation Model (URL 1) shows mountainous areas and deep valleys in the north and west, and wide plains in the south and southeast. Surface water runoff in the mountainous northern and western regions increases
		
When examining the aspect map created with the Digital Elevation Model (URL 1), in the North, north, east, and south-facing surfaces stand out, while in the South, east and southeast-facing areas are more common. Areas facing north and southeast receive less sunlight, resulting in reduced evaporation,	When examining the road distance map of the work area generated using buffer-distance analysis, it is observed that the south, north, east, and southwest regions are closer to the roads, while the distance to the road increases in other areas. The analysis reveals that hard surfaces are concentrated in the south,	When examining the slope gradient map of the study area created using the Digital Elevation Model (URL 1), it is observed that convex surfaces dominate in the northeast and southwest parts of the city, while flatter slopes are more prevalent in other areas. In the northeast and southwest regions, surface runoff

When interpreted separately, some areas identified as high risk on the criteria maps were classified as medium or low risk due to the weighting of other criteria reducing the risk. Therefore, the risk classes presented in Map 1, obtained by overlaying all criteria according to their percentage impact levels in the flood risk analysis, provide a more comprehensive assessment.



Map 1 Flood risk analysis map

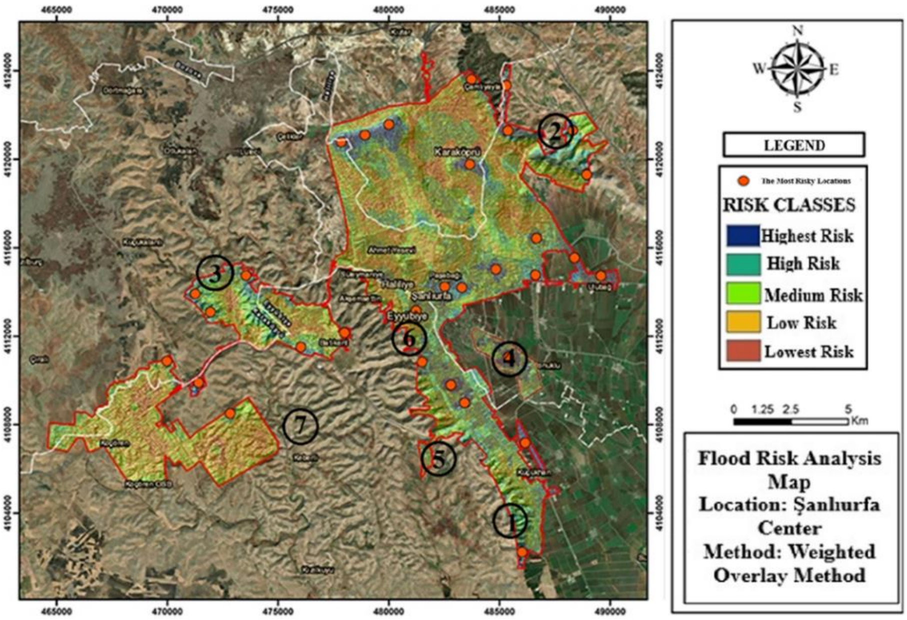
According to the flood risk analysis map, approximately 32% of the study area consists of low-risk areas, 62% consists of medium-risk areas, and 6% consists of high-risk areas. It is observed that low-risk areas are located around the highest-risk areas in the northern part of the analysis map. Although drainage intensity is high in both areas, surface water flow slows down in the high-risk area due to the impermeable soil structure and low slope, causing water to accumulate and increasing the risk of flooding. In contrast, in low-risk areas, the steep slope and permeable soil structure accelerate surface flow, preventing water accumulation and reducing the risk of flooding. In the southern and southeastern parts of the study area, rainfall is low and drainage intensity is high. However, the rocky ground structure in the south and the presence of medium-depth soil groups in the southeast increase the risk of flooding due to the low slope and elevation of the region. In the southwest and northeast sections, despite high rainfall, low drainage intensity, insufficient vegetation cover, and rocky soil structure, as well as low slope despite high elevation, negatively affect surface water flow. Rocky ground prevents water from seeping underground, causing it to accumulate on the surface. When all these factors are considered together, it is seen that the flood risk level in these areas is significantly elevated. High-risk areas on the flood risk analysis map are concentrated in flat areas close to river lines, with high rainfall, dense construction, limited forest areas, and low elevation and slope. The analysis map was overlaid with the full-empty analysis map obtained from the Şanlıurfa Metropolitan Municipality at the same scale; as a result of this overlay, safe empty areas were identified (Map 2).



Map 2 Safe empty zones in the flood risk analysis map

In the city center of Şanlıurfa, institutional and structural inadequacies in planning and management processes play a decisive role in the inability to effectively manage flood risks. Rapid urbanization and population growth since the 1980s have strained the existing planning system; inadequate legislation and implementation capacity have led to the formation of disaster-prone areas. The building amnesty policies implemented during this process have increased the stock of risky structures. Urban transformation projects initiated in the 2000s on the grounds of disaster risk have been insufficient due to the lack of a comprehensive planning approach. Although development plans include objectives such as integrating disaster risks into zoning plans and creating resilient cities, local governments have failed to effectively integrate disaster risks into planning processes.

When the city center of Şanlıurfa is assessed in terms of flood risk, the decision to develop medium and high-risk areas and the intervention in riverbeds complicate disaster management across the city. In this context, the planning of the 540-hectare area (1) prone to flood risk as an urban development area in Map 3 sets a negative example in terms of disaster sensitivity. Similarly, opening up 800 hectares of land (2) adjacent to flood basins for development indicates that risks were not sufficiently considered in the planning process. A similar situation in terms of flood risk arises with the conversion of 274 hectares of land (3) into an urban service area. Opening the boundaries of the Konuklu zoning plan (4), which has medium to high flood risk, to development is a decision that increases risk. Furthermore, changing the function of the green area (5) located south of the city center and close to areas with medium flood risk to open it up for development is a planning decision that could have negative consequences in terms of surface runoff and flood control. Such examples demonstrate that flood risk is not sufficiently considered in spatial planning processes (Map 3). Furthermore, planning decisions made in different periods, differences in the disaster legislation applicable to plans, and illegal urban development occurring periodically have led to varying levels of disaster risk in different parts of the city.



Map 3 Illustration of plan changes in the flood risk analysis map

Some planning decisions have had positive effects in terms of flood and flood risk. For example, the decision to preserve the areas adjacent to archaeological sites (6) within the conservation zoning plan as agricultural land is a positive one, as it allows water to seep into the ground in this area with high flood risk. Similarly, removing approximately 200 hectares of grassland (7) from its function as an urban service area was also a positive planning approach. Although these regulations were adopted in the Şanlıurfa implementation zoning plan to prevent flood risk, these decisions did not have a sufficient impact on the city as a whole.

Conclusion

The rapid population growth and migration across Turkey, coupled with unplanned urbanization, pose a significant obstacle to creating disaster-resilient cities nationwide. Analyses conducted specifically for Şanlıurfa reveal that urbanization has developed without consideration for natural thresholds and risk areas. In particular, the concentration of construction in high-risk plains rather than safer plateau areas has increased the vulnerability of the city as a whole. The diversion of the Karakoyun stream, which flows through the historic city center, to a new stream bed further north has put both areas at risk. The threat to historical and cultural structures in the city center carries not only material and moral risks but also the risk of cultural loss.

The fact that the population forecasts in the plan were mostly inaccurate led to the proliferation of unplanned areas in Şanlıurfa. The inability to produce sub-scale plans consistent with higher-level plans and the disregard for technical criteria have resulted in decisions that undermine the overall plan, increasing the risk of flooding by opening up agricultural land for construction.

Although some measures have been taken in flood-prone areas in Şanlıurfa, it is understood that these interventions are not comprehensive or deep enough to reduce the risk level. There is a need to integrate comprehensive and regional studies with current data. It is recommended that analyses be conducted for the city as a whole to identify disaster-prone areas, develop regional risk reduction strategies, and evacuate people from areas where risk cannot be reduced to safe areas identified through the analysis of the city as a whole. Otherwise, unplanned or inadequate interventions in high-risk areas are likely to cause new environmental and social problems in the long term. Minimizing disaster risks will only be possible through planning techniques, as well as updating legal regulations, strengthening urban transformation practices, and increasing disaster-focused administrative capacity. The preparation and evaluation of flood-focused technical reports should be carried out by science-based expert institutions, independent of political influences. Furthermore, population growth projections in the city should be accurately estimated during planning processes, and the formation of unplanned areas should be prevented.

Data and information infrastructure to be used in spatial planning should be strengthened, criteria and measures supporting disaster-resilient urbanisation should be determined and integrated into zoning decisions. Remote sensing and imaging systems should be used effectively in disaster risk analyses and spatial analysis infrastructure should be harmonised with the national geographical information system. Flood protection and control facilities should be constructed by taking into account seasonal rainfall conditions and the structure of agricultural lands. National and local projects should be developed to control excessive population flow due to migration, rural life should be encouraged and building density in city centres should be reduced. Such policies will play an important role both in alleviating the urbanisation pressure and in reducing the potential damage in case of a disaster. These recommendations will not only reduce existing risks but also make cities more resilient against new threats that may emerge in the future.

The Karakoyun, Cavşak, and Karaköprü basins are topographically located at a lower elevation due to the high plateaus surrounding them. To minimize intervention in the built environment, it is recommended that water collection basins be created outside the urban area. This will reduce the amount of water flowing from the plateaus to the low-lying urban area during heavy rainfall (Fig 17).

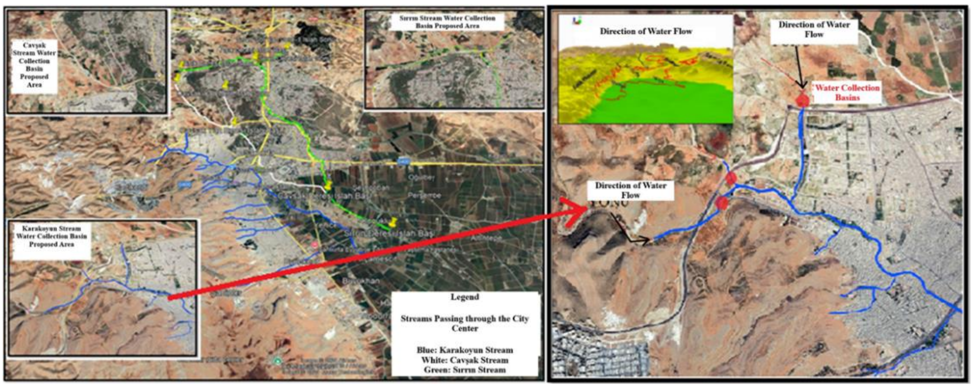


Fig. 17 Proposal for catchment basins at the entry points of the tributaries feeding the streams into the built environment (ŞBB 2025).

Figure 18 shows that urban renewal should be carried out for the slums located in the stream bed of Süleymaniye neighbourhood. With this renewal, the stream bed should be widened, and materials that allow more water to seep under ground should be preferred instead of concrete in hazardous areas and areas close to hazardous areas.

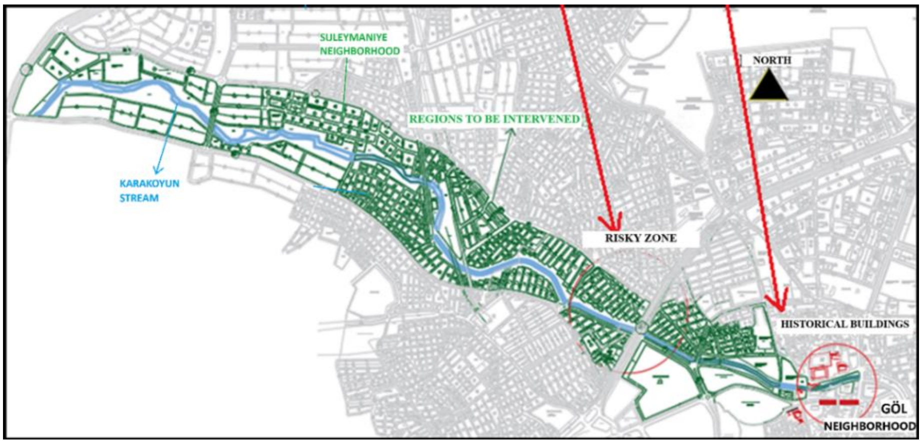


Fig. 18 Süleymaniye and Göl Neighbourhood flood risk mitigation proposal (ŞBB 2025).

To minimize intervention in Göl Neighborhood, which contains historical areas, liquid flow should be reduced through interventions in nearby areas, primarily Süleymaniye Neighborhood. The goal is to reduce surface runoff and ensure local infiltration through the creation of green spaces in the area. This will both reduce the risk of flooding and minimize intervention in built-up areas. Furthermore, in line with flood management plans, transportation and building arrangements should be made parallel to riverbeds to ensure the uninterrupted flow of water in the riverbed. The evacuation of existing structures in areas where the risk cannot be reduced outside the historic city area should be considered; settlement in safe, open areas should be encouraged.

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Author Contribution

Both authors contributed equally to each part of the study.

Competing İnterest

There is no Competing of interest.

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