



## APPLICATION OF GIS IN FLOOD RISK ANALYSIS AND MITIGATION STRATEGIES: THE CASE OF ULUOVA AND IKITEPE STREAMS

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**Abstract:** In recent years, the frequency and severity of floods have increased significantly due to the effects of global climate change, leading to serious economic and social losses, particularly in agricultural production areas. Floods not only damage cultivated lands but also negatively affect the livelihoods and socio-economic structures of local communities. This situation necessitates accurate identification of flood risk in agricultural areas and timely implementation of appropriate mitigation measures. In this study, flood risk was investigated in agricultural lands surrounding the Uluova Stream located between Doğankuş, Karşıbağ, and the Keban Dam and the İkitepe Stream, which flows through the center of Mollakendi in Elazığ Province, Türkiye. These areas are characterized by intensive agricultural activities. Using Geographic Information Systems (GIS), seven key parameters distance to streams, land use, aspect, slope, soil structure, precipitation, and geological features were analyzed, and corresponding thematic maps were generated. Flood risk levels were determined through spatial analysis and classification of these parameters using ArcGIS software. Based on the results, areas with high flood risk were identified, and both structural and non-structural mitigation measures were proposed for these zones. The findings offer valuable insights to support sustainable agricultural production and rural development by minimizing potential flood damages and reducing associated economic risks in the region.

**Keywords:** ArcGIS, Flood management, Flood mitigation strategies, Flood risk, Geographic information systems (GIS)

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### 1. Introduction

In recent years, climate change has emerged as one of the most significant drivers of the increasing frequency and severity of natural disasters worldwide. Among these disasters, floods stand out as a serious natural hazard that causes loss of life and property, threatens agricultural production, and disrupts sustainable development processes, affecting both rural and urban areas (IPCC, 2022). Floods occurring in agricultural areas not only result in production losses but also lead to decreased soil fertility, increased erosion, and deterioration of the rural economic structure (FAO, 2021). In rural regions, livelihoods are largely dependent on agriculture and agri-food activities. Therefore, accurately analyzing disasters such as erosion, drought, and floods in agricultural areas and developing effective prevention strategies are of great importance for the protection of these lands (FAO, 2021). Due to their geographical locations and topographical characteristics, agricultural areas are often among the regions most exposed to flood risk. In countries like Türkiye, where agriculture plays a major role in the economy, the damages caused by floods affect not only

farmers but also food security and rural development directly (FAO, 2023; Turkish Statistical Institute, 2023). In this context, determining flood risk and developing applicable strategies to minimize this risk are essential for maintaining agricultural sustainability. New approaches to flood risk emphasize multi-dimensional evaluations, considering not only the hydrological aspects but also the broader socio-economic and environmental impacts of floods, including their effects on people, infrastructure, agricultural lands, economic activities, and ecosystems (Mshelia and Belle, 2024).

In many countries, especially those frequently exposed to flooding, integrated flood risk management systems have been developed based on Geographic Information Systems (GIS), hydrological modeling, and remote sensing technologies. For instance, the Netherlands has implemented a comprehensive flood defense strategy through spatial planning and dike reinforcement (Jongman et al., 2012), while the United Kingdom uses risk-based flood mapping supported by LiDAR data and probabilistic models (Bates et al., 2010).

In addition, Kaya and Çelik (2025) demonstrated the effectiveness of integrating GIS with Analytic Hierarchy



Process (AHP) and Fuzzy AHP methods for flood risk assessment in the Upper Tigris Basin, highlighting how such multi-criteria approaches can enhance decision-making under uncertainty and be adapted for global applications.

Disasters can be defined as events caused by human activities or natural factors that result in loss of life and property, environmental damage, and disruptions to daily life (Singh et al., 2021). Among these, floods occupy an important place. Floods occur when water flow exceeds the physical capacity of riverbeds. Chow (1959) and Smith and Ward (1998) define floods as "the overflowing of a water source beyond its capacity, spreading to surrounding land areas." Globally, floods have put millions of lives at risk and resulted in significant fatalities. The possibility of flood recurrence has led to the development of flood frequency analysis methodologies to better understand and manage such events.

Floods are not limited to the physical transport of water but also have severe impacts on human health and infrastructure. Floods are natural phenomena in which excessive water overflows riverbeds, affecting nearby settlements, agricultural lands, and natural environments (Longley et al., 2015; Altın et al., 2024). Beyond their hydrological dimension, floods are also considered as disasters with significant economic, social, and environmental consequences. The frequency, intensity, and impact of floods vary depending on the geographical region, precipitation patterns, and local hydrological and topographical characteristics (Zhou et al., 2021).

It has been demonstrated that changes in land use, such as urbanization and deforestation, intensify water flow and reduce soil infiltration capacity, thereby increasing flood damage. Additionally, land use changes and urbanization within watershed areas directly affect surface runoff and groundwater recharge capacity. Such structural changes disrupt the natural water cycle, increase the frequency and severity of floods, and exacerbate the negative effects of climate change. Furthermore, natural climate variability and extreme weather events, especially severe storms, make flood prediction and management processes more complex and less predictable (Alobid et al., 2024; Dharmarathne et al., 2024).

Floods frequently cause significant economic losses, particularly in infrastructure and settlements. It is a natural event in which rivers, lakes, or seas overflow, damaging surrounding areas due to excessively rising water levels (Zhou et al., 2021; Alharbi, 2024). Floods cause considerable economic and social damage, especially in agricultural areas. In Türkiye, after earthquakes, floods are the second most damaging natural disaster in terms of economic losses. Agricultural floods are particularly concentrated along riverbanks, alluvial plains, and areas where water flow paths are located. These regions are intensely used for agricultural production due to their fertile soils. However, floods in these areas cause severe damage not only to crops but also to agricultural infrastructure such as irrigation channels,

drainage systems, and field roads (Republic of Türkiye, Ministry of Agriculture and Forestry, 2017). Agricultural flood disasters can result in:

- Crop losses due to inundated agricultural lands
- Soil erosion and degradation of soil structure
- Damage to agricultural irrigation and drainage infrastructure
- Negative impacts on livestock production (e.g., damage to animal shelters and barns)
- Material damage to agricultural machinery and equipment

If floods occur close to the harvest period, economic losses increase significantly (Republic of Türkiye, Ministry of Agriculture and Forestry, 2017).

## **2. Materials and Methods**

Today, thanks to rapidly developing technologies and information systems, access to accurate and up-to-date data is much easier and faster, and the obtained data can be analyzed and evaluated effectively. These advancements in science and technology form the foundation of the information age and have led to significant transformations, especially in sectors where location-based activities are carried out. Geographic Information Systems (GIS), which have emerged as an essential part of this transformation process, stand out as a powerful technological tool that enables the collection, storage, management, analysis, and visualization of spatial data (Yomralıoğlu, 2003).

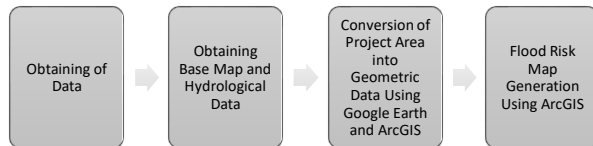
GIS technologies, with their ability to integrate with modern information systems, are widely used in both public institutions and the private sector, contributing significantly to decision-making processes. In this study, GIS infrastructure was utilized to spatially determine and analyze flood risk. The ArcGIS Desktop software used within the scope of the study contains comprehensive tools and modules for the creation, management, visualization, and analysis of GIS data. Developed by ESRI, ArcGIS is widely used around the world in the fields of spatial analysis and mapping (Tanrıverdi, 2019).

The project area selected as the research site includes the region between Doğankuş, Karşıbağ, and Keban Dam, located within the borders of Mollakendi town in Elazığ province, which is known for its high flood risk. The study area also covers the Uluova Stream and the İkitepe Stream, which originates from the downstream of İkitepe district and flows through the center of Mollakendi. Photographs taken in the project area were integrated into the program with the help of Google Earth, and a flow route was created (Figure 1). Based on these generated flow routes, cross-sections of the terrain were systematically created. Within this scope, data were organized using ArcGIS software, and the necessary maps were produced to prepare the flood risk map.



**Figure 1.** General location of the study area and representation of the stream route on Google Earth image.

In this direction, topographic data, hydrological network structure, stream routes, slope, aspect, soil properties, land use, and precipitation data of the study area were obtained. The collected data were integrated holistically in the ArcGIS environment and analyzed. Using GIS infrastructure, spatial analyses were carried out to identify flood risk areas in the region, and flood risk maps were generated. Based on the obtained data and analyses, vulnerable areas in terms of flood risk were identified, and recommendations were developed to mitigate the potential impacts of possible floods. The operational steps of the methodology followed in the study are shown in Figure 2.

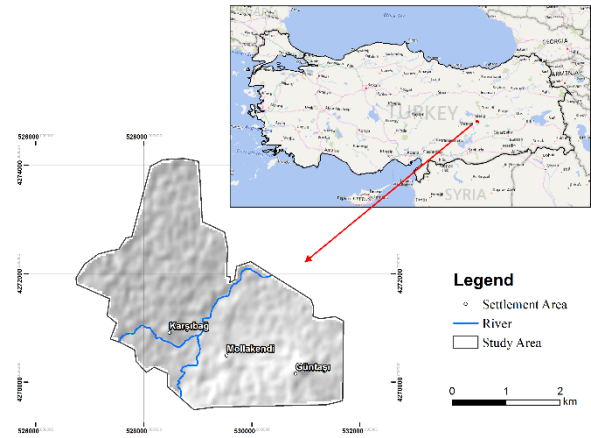


**Figure 2.** Data collection and GIS-based flood risk mapping process.

The GIS-based method used in the study enables both the improvement of spatial accuracy in flood risk analysis and the provision of fast and effective information to decision-makers. Thus, a significant infrastructure has been established for the early identification of flood risk and the implementation of necessary measures.

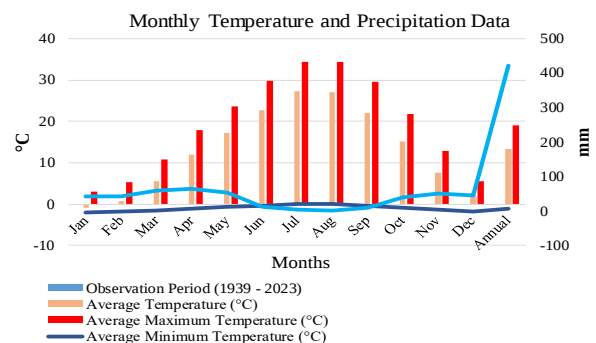
### 2.1. Study Area

The project area is located in Mollakendi, one of the southern towns of Elazığ city center, situated in the Upper Euphrates Section of the Eastern Anatolia Region of Türkiye. The study area, shown in Figure 3, is evaluated within the zoning boundaries of Mollakendi town. The general route of the field survey lies predominantly on flat terrain with a low hydraulic slope. Within the boundaries, the project area includes Uluova Stream (also known as Karingeç Stream), which flows between Doğankuş, Karşıbağ, and Keban Dam, and the İkitepe Stream, which starts its flow from the downstream of İkitepe district and passes through the center of Mollakendi.

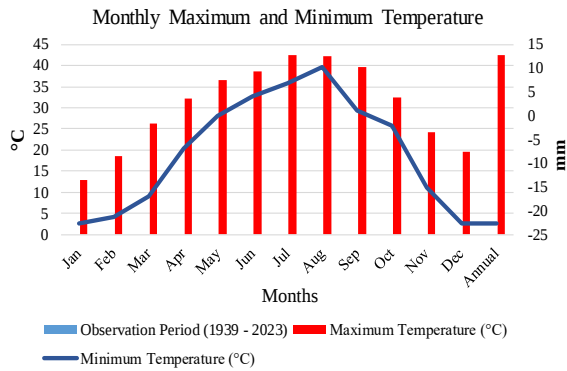


**Figure 3.** Location and route of the study area within the zoning boundaries.

Mollakendi is located in the Eastern Anatolia Region of Türkiye and is characterized by a continental climate. Summers in the region are hot and dry, while winters are cold and snowy. According to the Köppen Climate Classification, the area falls within the Bsk (Semi-Arid Steppe Climate) zone. Based on long-term meteorological data, the annual average temperature of Mollakendi is 13.2°C, and the annual average total precipitation is 420.2 mm (Figure 4). According to the temperature analysis, the highest temperatures are observed in July, with extreme values reaching up to 42.4°C, while the lowest temperatures are recorded in January, with minimum values dropping to -22.6°C. Regarding the precipitation regime, it has been determined that the highest rainfall occurs during the spring months, with April having the highest monthly average precipitation of 63.4 mm. Conversely, August is identified as the driest month of the year, with an average precipitation of only 1.8 mm (Figures 4-5).



**Figure 4.** Meteorological data of Mollakendi district between 1939 and 2023 (MGM, 2024).



**Figure 5.** Monthly maximum and minimum temperature data for Mollakendi district between 1939 and 2023 (MGM, 2024).

## 2.2. Examination of the Stream Course and Current Conditions

The Uluova Stream and the İkitepe Tributary, which are within the project area, generally continue their flow along agricultural lowland areas in the region (Figure 6). Field measurements and analyses reveal that the bed slope of the upstream section of Uluova Stream is approximately 0.00273, while it increases to approximately 0.00366 in the downstream section. The width of the stream channel at the top of the banks varies between 20 and 25.5 meters. For the İkitepe Tributary, the longitudinal bed slope (thalweg slope) is approximately 0.00371, and the stream width reaches up to 10 meters at certain sections.



**Figure 6.** Geographical course of Uluova stream and İkitepe tributary.

It has been determined that, due to floods that occurred in previous years, significant anthropogenic interventions and deformations have been observed along the stream courses (Figure 5). Visual inspections reveal the presence of algae growth in certain parts of the stream banks and bed. Furthermore, the substrate of the area consists largely of sandy and gravelly material, and the natural bed structure has been significantly disrupted due to bed erosion and sediment transport from the upstream areas. This situation is one of the major factors negatively affecting the flow capacity of the stream.

Based on current measurements, it has been calculated

that the discharge capacity of the Uluova Stream along the route varies between 80 and 100 m<sup>3</sup>/s, with a safety capacity of approximately 75 m<sup>3</sup>/s. In contrast, it has been identified that the İkitepe Tributary, particularly in its downstream sections, has a severely limited capacity, with bed capacity varying between 10 and 15 m<sup>3</sup>/s and a safety capacity limited to only 11 m<sup>3</sup>/s, which is insufficient.



**Figure 7.** Overview of Uluova and İkitepe streams.

Observations along the route indicate that sediment transport (gravel, sand, and similar materials) originating from the upstream catchment area occurs partially. The large size of the Uluova Stream's drainage basin suggests that the flood risk may increase in the coming years. Therefore, in addition to immediate mitigation measures to be taken downstream, it is recommended that upstream flood reduction measures also be implemented, depending on budgetary possibilities.

It has been determined that the streambed material along the Uluova Stream route generally consists of sandy and gravelly materials, originating both from the natural characteristics of the floodplain and from sediment transport from the upstream areas. The İkitepe Tributary, on the other hand, has a smaller drainage basin and includes a channel in its upper reaches that collects slope runoff. Therefore, no significant sediment transport issue has been observed along the İkitepe Tributary. However, due to its limited capacity and anthropogenic interventions, the route is exposed to flood risk (Figure 7).

## 2.3. Flood Protection Structures and Engineering Structures

There are no dedicated flood protection structures along the Uluova Stream and the İkitepe Tributary within the study area to mitigate flood risk. However, various engineering structures have been constructed along the stream courses to facilitate transportation. In this context, a total of four bridges have been identified along the Uluova Stream, and one bridge along the İkitepe Tributary. Additionally, at the downstream connection point where the İkitepe Tributary joins the Uluova Stream, a culvert with insufficient capacity and significant structural damage has been observed (Figure 8).



**Figure 8.** Culvert structure at the junction of Uluova and İkitpe streams.

Field investigations reveal that many of the existing engineering structures have lost their functionality over time due to various reasons. Significant sediment accumulation has occurred within the streambeds, negatively affecting the natural water flow. Capacity limitations and structural damage to these constructions are among the key factors contributing to increased flood

risk. It has also been reported that floodwaters occasionally exceed the banks, causing damage along the route. In particular, in the curved sections of the streams, floodwaters surpass the banks due to insufficient channel capacity and backwater effects.

In addition to field observations, a basic hydrological evaluation was also conducted to support the assessment of structural adequacy. Considering the contributing catchment area, precipitation data, and average runoff coefficients, the estimated peak discharges for a 10-year and 25-year return period were calculated for both Uluova and İkitpe Streams. It was observed that, particularly in the İkitpe Tributary, the design capacities of existing structures fall below the estimated peak flows, indicating that these structures are insufficient to safely convey floodwaters during significant storm events. This further emphasizes the need for rehabilitation or replacement of under-capacity structures in flood-prone segments.

A detailed assessment of the engineering structures along the Uluova Stream is presented in Table 1.

**Table 1.** General assessment of engineering structures along Uluova stream

| Uluova Stream Hydraulic Structures | Type (Width × Height)                   | Observations                                                                                           |
|------------------------------------|-----------------------------------------|--------------------------------------------------------------------------------------------------------|
| 0+316.33                           | 3-Span<br>12*2m                         | Significant accumulation of bed material. Hydraulic capacity is sufficient.                            |
| 1+531.91                           | 3-Span<br>12*4.5m<br>12*4.5m<br>13*3.5m | Accumulated bed material; one span is partially blocked due to slope gradient. Capacity is sufficient. |
| 2+792.88                           | 3-Span<br>7*4.5 m<br>5.5*4.5m<br>5*3.5m | Spans are relatively functional. Minor material accumulation. One span has an arched structure.        |

### 3. Results and Discussion

In order to prevent flood and inundation disasters, protect against them, and reduce associated damages, it is essential to establish and analyze a comprehensive database that includes the basin's geomorphological, lithological, hydrographic, climatic, soil, vegetation, and land use characteristics (Turoğlu and Özdemir, 2005). Within this scope, parameters affecting flood risk were evaluated using maps prepared in the GIS environment. All data were transferred into ArcGIS software and analyzed accordingly.

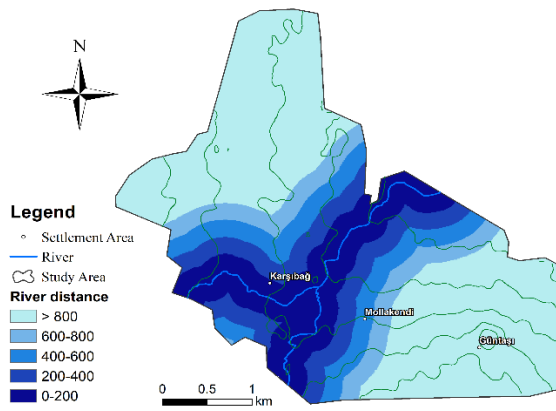
#### 3.1. River Proximity Map

One of the most significant environmental factors to be considered in flood risk analysis is the distance to the nearest watercourse. As highlighted in the literature, flood risk increases as the distance to rivers decreases and diminishes as the distance increases (Şen, 2009). In this context, the River Proximity Map prepared for the study area illustrates different distance zones using a color scale (Figure 9).

Upon examining Figure 9, it is evident that areas within 0–

200 meters are shown in dark blue and represent zones with very high flood risk. Areas between 200–400 meters fall within the moderate-high risk group, while regions 400–600 meters away are classified as low-risk zones. Zones located beyond 800 meters, illustrated in light green tones, represent the safest areas in terms of flood risk.

It was determined that a significant portion of the Mollakendi settlement is located within the 400–600 meter distance range, placing it in the moderate flood risk category. Particularly, the proximity of agricultural areas and residential zones to high-risk areas (0–200 m) increases vulnerability to flooding. It is critically important to prioritize the areas near watercourses in Mollakendi for preventive planning efforts.



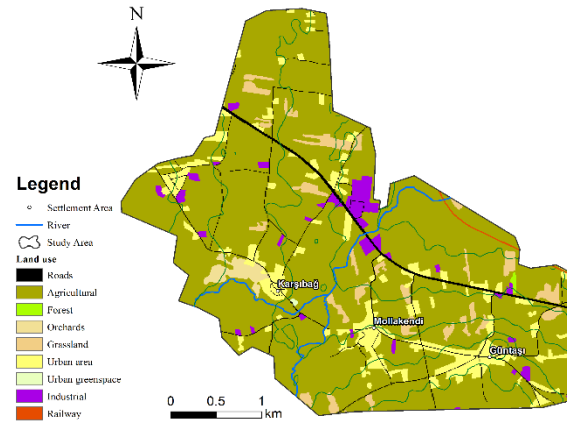
**Figure 9.** River proximity map for flood risk assessment.

### 3.2. Land Use Map

Land use characteristics are among the most crucial factors influencing flood occurrence. Land use directly affects the surface runoff regime, which can either increase or reduce flood risk (Turoğlu and Özdemir; Özdemir, 2005). As emphasized in the literature, in areas where vegetation cover is sparse, slopes are steep, and land use is inappropriate, rainfall rapidly transforms into surface runoff, accelerating flood formation. Conversely, in regions with dense vegetation and controlled land use, surface runoff decreases, leading to a lower flood risk (Özdemir, 2007; Engman and Schultz, 2000).

The Land Use Map prepared for the study area reveals that the stream beds in Mollakendi and its surroundings predominantly pass through agricultural lands (Figure 10). Agricultural areas are considered the most vulnerable land use class regarding flood risk due to reduced surface permeability and soil disturbance from farming activities. According to reports, between 1975 and 2011, 820 flood events occurred in Türkiye, resulting in the loss of 660 lives, approximately 872 km<sup>2</sup> of agricultural land being affected by floods, and an estimated annual economic loss of 150 million TL (DMİ, 2016). These figures highlight the vulnerability of agricultural areas to flood hazards.

The extensive agricultural lands surrounding streams in the Mollakendi region increase the area's fragility concerning flood risk. Therefore, implementing appropriate protection measures in agricultural areas located within flood zones and relocating settlements and production activities away from high-risk regions is essential.



**Figure 10.** Land use map of the study area.

### 3.3. Aspect Map

Aspect refers to the directional orientation of a slope or terrain, which directly influences hydrological processes, vegetation development, evapotranspiration, and surface runoff. Given Türkiye's geographical location in the Northern Hemisphere, different aspect characteristics are observed on north- and south-facing slopes.

Generally, north-facing slopes receive less sunlight, retain soil moisture for extended periods, and promote vegetation development. In contrast, south-facing slopes are exposed to sunlight at steeper angles, resulting in increased evapotranspiration rates and quicker soil moisture loss. Therefore, vegetation is typically sparse and drought-tolerant on south-facing slopes, while denser, moisture-loving vegetation is common on north-facing slopes (Özdemir, 2007).

The Aspect Map prepared for the study area indicates that the slopes surrounding Uluova Stream predominantly face west, south, and east. This suggests the presence of areas along Uluova Stream, especially on the south-facing slopes, where soil moisture is low, and surface runoff may increase. More balanced conditions are observed on the west- and east-facing slopes. For İkitepe Stream, the slopes generally face northwest, north, southeast, and partially west. North- and northwest-facing slopes are likely to experience reduced surface runoff and prolonged soil moisture retention, leading to relatively lower flood risk in these areas. Conversely, southeast-facing slopes, characterized by lower soil moisture, are prone to increased surface runoff and relatively higher flood risk (Figure 11).

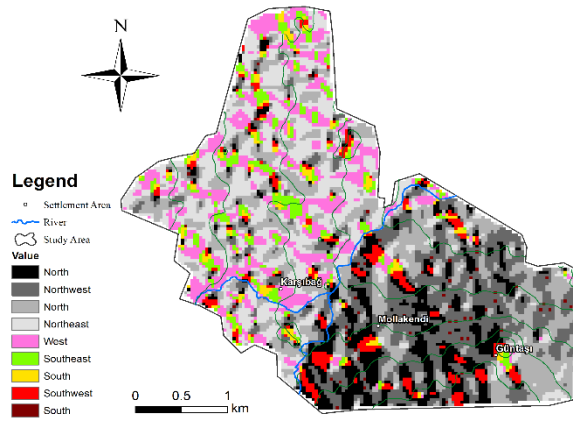


Figure 11. Aspect map of the study area.

### 3.4. Slope Map

Slope is one of the most critical geomorphological factors influencing flood formation. Slope affects surface runoff, soil infiltration capacity, and erosion, playing a vital role in flood risk assessment (Özcan, 2008). According to widely accepted understanding, in steep areas, the retention time of water on the surface decreases, resulting in faster runoff, but the risk of flooding may be relatively lower. Conversely, in areas with gentle slopes, runoff slows down, water accumulates, and the likelihood of flooding increases.

It was determined that the Uluova Stream corridor largely falls within the first slope group, meaning it passes through very gently sloping areas. The İkitepe Stream corridor is predominantly located within the second slope group, corresponding to gently sloping areas (Figure 12). The inverse relationship between slope and flood risk is frequently emphasized in the literature. As slope decreases, water tends to accumulate on the surface, thereby increasing flood risk. In this context, low-slope areas around Uluova and İkitepe Streams are considered more vulnerable to flooding within the study area.

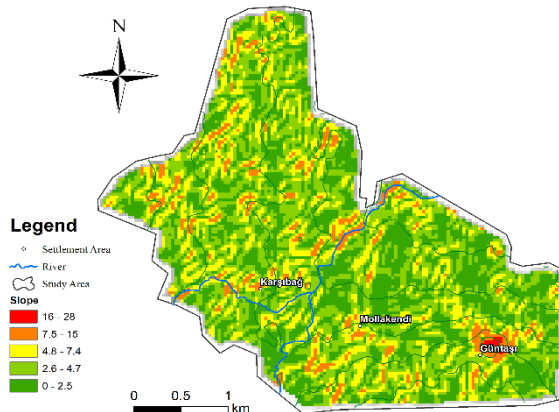


Figure 12. Slope map of the study area.

### 3.5. Soil Map

Soil characteristics, particularly infiltration capacity, play a crucial role in the formation of floods and inundations. Factors such as soil surface features, existing soil

moisture, water-holding capacity, temperature, structural properties, and water movement within the soil directly affect infiltration. Soils with good drainage characteristics allow water accumulated on the surface to quickly infiltrate the ground, thereby significantly reducing the risk of floods and inundations (Turoğlu and Özdemir, 2005).

Other critical factors affecting soil drainage capacity include soil texture (proportions of sand, clay, and silt), structure, precipitation amount, environmental seepage, the presence of impermeable layers, salt content and type, groundwater level, and the general physical structure of the soil profile. Additionally, soil type indirectly affects flood and inundation risk by determining vegetation growth conditions. Dense and healthy vegetation reduces surface runoff, limits sediment transport, and increases water infiltration. Conversely, areas lacking vegetation experience increased surface runoff and elevated flood risk.

The Soil Map prepared for the study area reveals that alluvial soils are widespread throughout the region (Figure 13). Alluvial soils are formed by the accumulation of sand, clay, gravel, and similar sediments transported by rivers. These soils are highly permeable but are considered vulnerable to floods and inundations due to their susceptibility to erosion and sediment transport. Alluvial soils are commonly found in plains, riverbeds, and floodplains, where they amplify the impacts of flood events (Oğuz et al., 2022).

The widespread presence of alluvial soils in the region increases the flood vulnerability of the study area and enhances the potential for river overflows.

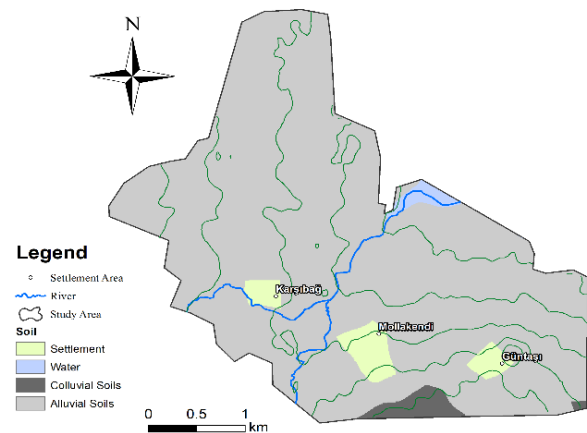


Figure 13. Soil map of the study area.

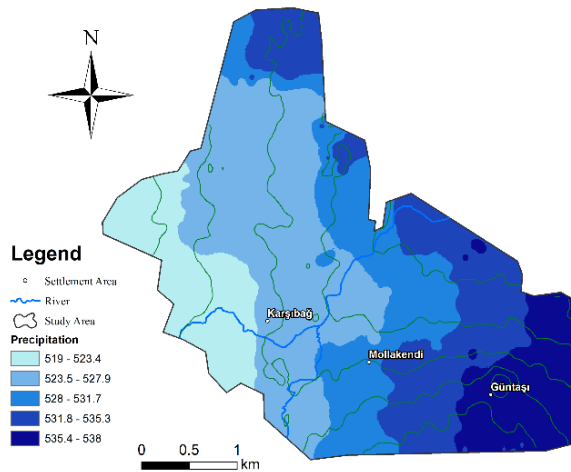
### 3.6. Precipitation Map

Precipitation is among the most influential factors in the formation of floods and inundations. The amount, intensity, and distribution of precipitation directly affect surface runoff, soil infiltration capacity, and groundwater recharge. In regions where precipitation is high or concentrated over short periods, the likelihood of floods and flash floods significantly increases (Turoğlu and Özdemir, 2005).

The Precipitation Map prepared for the study area reveals that annual precipitation ranges between 519 mm and 538 mm (Figure 14). Higher precipitation values are concentrated in the eastern sections of the study area, particularly around the Guntaş settlement, while lower precipitation values are observed towards the west and northwest.

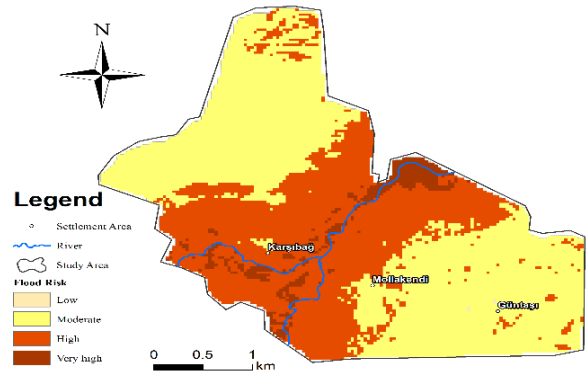
The spatial distribution of precipitation aligns with the region's semi-arid (Bsk) steppe climate, characterized by low overall annual rainfall but significant local variability. Areas receiving more than 535 mm of precipitation annually are considered higher flood risk zones due to the increased likelihood of surface runoff.

The precipitation characteristics of the region, combined with other environmental parameters such as slope, soil type, and land use, must be evaluated holistically to accurately assess flood risk.



**Figure 14.** Precipitation map of the study area.

Within the scope of this study, the flood risk in Uluova Stream (Karingeç Creek) and İkitepe Stream, located within the borders of Mollakendi Town in Elazığ Province, was comprehensively evaluated. In this context, seven key geographic parameters, including slope, land use, soil, aspect, geology, precipitation, and proximity to watercourses, were analyzed within the Geographic Information Systems (GIS) environment, and a flood risk map was produced (Figure 15).



**Figure 15.** Flood risk map.

The generated flood risk map has clearly revealed the spatial distribution of risk within the study area. The map indicates that areas close to stream beds, low-slope regions, zones with extensive alluvial soils, and agricultural areas are among the most vulnerable zones with a high flood risk. Moreover, considering the region's topographical structure and current land use characteristics, it is evident that flood risk is not only driven by natural factors but also significantly exacerbated by unplanned and uncontrolled human activities.

When the Land Use Map and the Flood Risk Map are examined together, it becomes clear that a significant portion of the high-risk areas overlaps with agricultural lands and settlement zones. In particular, the proximity of extensive agricultural areas to the Uluova and İkitepe Stream beds increases surface runoff and facilitates flood formation. In these areas, characterized by insufficient vegetation cover and soils with low permeability, the water infiltration capacity of the soil is significantly reduced, further aggravating flood risk.

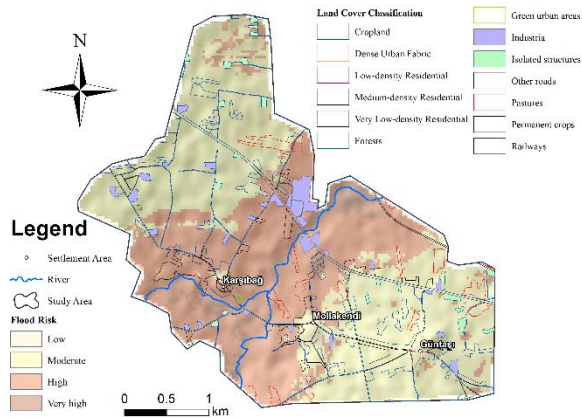
Additionally, industrial zones and residential areas are also observed to be located close to stream beds in the region. This situation poses a serious threat not only to natural areas but also to economic activities and human life.

The literature clearly emphasizes that unplanned land use and improper site selection significantly increase flood risk (Turoğlu and Özdemir, 2005; Özdemir, 2007). The findings obtained from this study concretely demonstrate this situation specifically for the Mollakendi region. It was determined that land use decisions in Mollakendi have largely been made without considering flood risk maps, which increases the potential for future floods to create significant impacts on the local economy and social life.

The Flood Risk Map provides concrete guidance for decision-makers, local administrators, and the local community, enabling the identification of risky areas in advance and the implementation of necessary precautions. Therefore, it is essential that this map is not only regarded as an academic output but also actively utilized in local planning and disaster management processes.

## 5. Conclusion and Recommendations

In this study, the flood risk for Uluova Stream (Karingeç Creek) and İktepe Stream, located within the administrative boundaries of Mollakendi Town in Elazığ Province, was evaluated using Geographic Information Systems (GIS) technologies. Within the scope of the study, seven key geographic parameters—slope, land use, soil, aspect, geology, precipitation, and proximity to the stream—were analyzed through ArcGIS software, and a flood risk map was produced based on these parameters (Figure 16).



**Figure 16.** Flood risk and land use map of Mollakendi region (2018).

The flood risk analysis revealed areas within the study site with varying levels of risk. Particularly, areas close to stream beds, low-slope regions, locations with dominant alluvial soil, agricultural lands, and regions with high precipitation were identified as having the highest flood risk. These vulnerable areas also overlap with residential zones, industrial areas, and fertile agricultural lands, indicating that potential future flood events may cause significant economic, environmental, and social damage. The evaluation clearly shows that land use decisions made in the Mollakendi region to date have largely ignored the realities of flood risk. In particular, the widespread agricultural activities and residential settlements located in proximity to stream beds significantly increase the region's vulnerability to floods.

To reduce the risk of floods and minimize potential losses, the following measures are recommended:

Land use within flood-prone areas should be strictly regulated, and settlements and agricultural activities should be relocated away from high-risk zones.

Natural vegetation cover must be preserved and reinforced to reduce surface runoff and erosion.

Stream beds should be rehabilitated, and flood protection structures such as embankments, culverts, and bridges should be systematically planned and implemented.

Engineering solutions appropriate to soil characteristics, especially in alluvial soil zones, should be developed to enhance flood resilience.

The integration of flood risk maps into local planning

processes should be made mandatory.

Early warning systems should be improved, and public awareness efforts should be increased to enhance preparedness.

Through these measures, the continuity of agricultural production in rural areas where agriculture is the primary livelihood source will be secured, employment opportunities will be preserved, and the risk of income loss to the regional economy will be minimized, creating significant social and economic benefits.

### 5.1. Suggested Academic Warning Statement for Project Planning

The findings of this study clearly reveal that previous land use and development projects within the study area have been implemented without adequate consideration of flood risk. To prevent potential future disasters and economic losses, it is strongly recommended that the integration of flood risk analyses into all zoning, construction, and development projects be made compulsory. Neglecting this obligation will significantly increase the vulnerability of both human settlements and economic activities to flood hazards.

### Author Contribution

The percentages of the authors' contributions are presented below. All authors reviewed and approved the final version of the manuscript.

|     | M.U. | M.K. |
|-----|------|------|
| K   | 50   | 50   |
| T   | 50   | 50   |
| Y   | 50   | 50   |
| VTI | 50   | 50   |
| VAY | 50   | 50   |
| KT  | 50   | 50   |
| YZ  | 50   | 50   |
| KI  | 50   | 50   |
| GR  | 50   | 50   |
| PY  | 50   | 50   |
| FA  | 50   | 50   |

C= Concept, D= Design, S= Supervision, DCP= Data Collection and/or Processing, DAI= Data Analysis and/or Interpretation, LR= Literature Review, W= Writing, CR= Critical Review, SR= Submission and Revision, PA= Project Administration, FA= Funding Acquisition

### Conflict of Interest

The authors declare that there is no conflict of interest regarding this study.

### Ethical Consideration

Since this study did not involve research on humans or animals, ethical committee approval was not required.

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## References

- Alharbi T. 2024. A weighted overlay analysis for assessing urban flood risks in arid lands: a case study of Riyadh, Saudi Arabia. *Water*, 16(3): 397.
- Alobid M, Chellai F, Szűcs I. 2024. Trends and drivers of flood occurrence in Germany: a time series analysis of temperature, precipitation, and river discharge. *Water*, 16(18): 2589.
- Altın G, Taşkın S, Yurtal R, Aköz MS. 2024. Kuru derelerde taşkın risk analizi; Kebendibi deresi örneği. *Çukurova Üniv Müh Fak Derg*, 39(1): 221-229.
- Bates PD, Horritt MS, Fewtrell TJ. 2010. A simple inertial formulation of the shallow water equations for efficient two-dimensional flood inundation modelling. *J Hydrol*, 387(1-2): 33-45.
- Chow VT. 1959. Determination of hydrologic frequency factor. *J Hydraul Div*, 85(7): 93-98.
- Dharmarathne G, Waduge AO, Bogahawaththa M, Rathnayake U, Meddage DPP. 2024. Adapting cities to the surge: A comprehensive review of climate-induced urban flooding. *Results Eng*, 102123.
- DMİ. 2016a. Doğal afetler. devlet meteoroloji işleri genel müdürlüğü. URL: <http://www.mgm.gov.tr/arastirma/dogal-afetler.aspx?s=taskinlar> (accessed date: December 9, 2016).
- Engman ET, Schultz GA. 2000. Future perspectives. In: *Remote sensing in hydrology and water management*. Springer Berlin Heidelberg, Berlin, Germany, pp: 445-457.
- FAO. 2021. The state of food and agriculture 2021: Making agrifood systems more resilient to shocks and stresses. Food and Agriculture Organization of the United Nations.
- FAO. 2023. The impact of disasters on agriculture and food security 2023: Avoiding and reducing losses through investment in resilience. Food and Agriculture Organization of the United Nations.
- IPCC. 2022. Climate Change 2022: Impacts, adaptation and vulnerability. Intergovernmental Panel on Climate Change.
- Jongman B, Ward PJ, Aerts JC. 2012. Global exposure to river and coastal flooding: Long term trends and changes. *Glob Environ Change*, 22(4): 823-835.
- Kaya B, Çelik R. 2025. Dynamic and scalable flood risk assessment using GIS, AHP, and novel fuzzy AHP: A case study of the upper tigris basin. Preprint, Research Square, <https://doi.org/10.21203/rs.3.rs-5776107/v1>
- Longley PA, Goodchild MF, Maguire DJ, Rhind DW. 2015. *Geographic information science and systems*. John Wiley and Sons, New York, US, pp: 517.
- Meteoroloji Genel Müdürlüğü Resmi Veri Sayfası. 2024. <https://mgm.gov.tr> (accessed date: July 2024).
- Mshelia ZH, Belle JA. 2024. A systematic flood risk assessment of Bloemfontein Watershed, South Africa. *Geom Nat Hazards Risk*, 15(1): 2423739.
- Oğuz E, Oğuz K, Öztürk K. 2022. Düzce bölgesi taşkın duyarlılık alanlarının belirlenmesi. *Geomatik*, 7(3): 220-234.
- Özcan O. 2008. Evaluation of flood risk analysis in Sakarya sub basin by using remote sensing and GIS. MSc Thesis, İstanbul Technical University, Institute of Information, İstanbul, Türkiye, pp: 72.
- Özdemir H. 2007. SCS CN Yağış-akış modelinin CBS ve uzaktan algılama yöntemleriyle uygulanması: Havran Çayı Havzası örneği (Balıkesir). *Coğrafi Bil Derg*, 5(2): 1-12.
- Republic of Türkiye, Ministry of agriculture and forestry, general directorate of water management. 2017. *Flood Management Book*, Ankara, Türkiye, pp:1-160.
- Singh S, Dhote PR, Thakur PK, Chouksey A, Aggarwal SP. 2021. Identification of flash-floods-prone river reaches in Beas river basin using GIS-based multi-criteria technique: validation using field and satellite observations. *Nat Hazards*, 105: 2431-2453.
- Smith K, Ward R. 1998. *Floods: Physical processes and human impacts*. John Wiley & Sons, Chichester, UK, pp: 12-382.
- Solin L, Skubincan P. 2013. Flood risk assessment and management: review of concepts, definitions and methods. *Geogr J*, 65: 23-44.
- Şen Z. 2009. Taşkın afet ve modern hesaplama yöntemleri. Su Vakfı, Ankara, Türkiye, pp: 1-20.
- Tanriverdi M. 2019. Determination of flood areas of Şanlıurfa provincial center by multi-criteria decision analysis based on geographic information systems (GIS). PhD Thesis, Harran University, Institute of Science, Şanlıurfa, Türkiye, pp: 74.
- Turkish Statistical Institute. 2023. *Agricultural statistics of Türkiye*, 2023. Turkish Statistical Institute.
- Turoğlu H, Özdemir H. 2005. Bartın'da Sel ve Taşkınlar: Sebepler, Etkiler, Önleme ve Zarar Azaltma Önerileri. Çantay Kitabevi, İstanbul, Türkiye, pp:45-59.
- Yomralıoğlu T. 2003. Coğrafi Bilgi Sistemi Politikası. TUJK 2003 Yılı Bilimsel Toplantısı, Coğrafi Bilgi Sistemleri ve Jeodezik Ağlar Çalıştayı, 24-26 Eylül 2003, Konya, Türkiye, pp:15-19.
- Zhou Q, Su J, Arnbjerg-Nielsen K, Ren Y, Luo J, Ye Z, Feng J. 2021. A GIS-based hydrological modeling approach for rapid urban flood hazard assessment. *Water*, 13(11): 1483.