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Determination of Basin Characteristics to Provide a Base for the Creation of Malatya Flood Risk Zones; The Example of Darende and Gürün

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Abstract

Floods are a natural disaster with great risks in that they occur suddenly and threaten large areas. In particular, the damages it causes can reach great material and moral aspects. Today, many studies are carried out to protect against the damages of flood disasters. Geographical Information Systems (GIS) are also used in the planning of these studies. The importance of Geographical Information Systems (GIS) software (ArcGIS, QGIS, Golabal Mapper etc.) is increasing day by day. As a tool, GIS is very powerful to address different water resources issues such as water quality, groundwater movement, groundwater pollution, river restoration, flood forecasting and management, etc. at local, regional, national and even global scale. GIS and GIS-based models can be useful for different hydrological modelling such as rainfall runoff. In this study, some basin parameters (precipitation, slope, aspect, soil, land use, distance to the stream and geology) of the region that forms a part of the Tohma basin and includes Darende and Gürün districts were determined using ArcGIS software.

Keywords: *Flood, GIS, ArcGIS*

Malatya Taşkın Risk Bölgelerinin Oluşturulmasına Altlık Sağlayacak Havza Özelliklerinin Belirlenmesi; Darende ve Gürün Örneği

Özet

Taşkınlar aniden ortaya çıkabilen ve geniş alanları tehdit eden büyük riskler taşıyan doğal felaketlerdir. Özellikle, bu felaketlerin neden olduğu zararlar büyük ölçüde maddi ve manevi boyutlara ulaşabilir. Günümüzde, sel felaketlerinin zararlarına karşı koruma amacıyla birçok çalışma yürütülmektedir. Coğrafi Bilgi Sistemleri (CBS) de bu çalışmaların planlanmasında kullanılmaktadır. Coğrafi Bilgi Sistemleri (CBS) yazılımlarının (ArcGIS, QGIS, Global Mapper vb.) önemi gün geçtikçe artmaktadır. CBS, bir araç olarak, su kalitesi, yeraltı suyu hareketi, yeraltı kirliliği, nehir restorasyonu, sel tahmini ve yönetimi vb. gibi farklı su kaynakları konularına yerel, bölgesel, ulusal ve hatta küresel ölçekte çeşitli sorunlara çözüm üretmede son derece güçlüdür. CBS ve CBS tabanlı modeller, yağış-akış gibi farklı hidrolojik modellere yönelik olarak kullanışlı olabilir. Bu çalışmada, Tohma havzasının bir parçasını oluşturan ve Darende ve Gürün ilçelerini içeren bölgenin bazı havza parametreleri (yağış, eğim, yön, toprak, arazi kullanımı, akarsuya uzaklık ve jeoloji) ArcGIS yazılımı kullanılarak belirlenmiştir.

Anahtar kelimeler: *Sel, GIS, ArcGIS*

1. Introduction

Given the central role of water in human life, any shifts in its condition undoubtedly bear implications for human existence. Throughout history, major river systems served as the cradle for the development of human civilizations. Countless societies have met their demise due to water scarcity (such as droughts) or devastating floods. The notion of mindful water consumption and effective flood and drought management has gradually waned. Present-day societal advancements and lifestyles have the potential to not only reshape water usage but also impact water quality. This transformation is often linked to demographic shifts, urbanization, industrialization, and the issue of water pollution.

The increasing frequency of natural calamities serves as a clear indicator for both the European Commission (EC) and the Member States of the European Union (EU) regarding the criticality of safeguarding the environment and the citizenry against these events. Robust scientific evidence substantiates a rise in average precipitation and extreme precipitation occurrences, suggesting a possible uptick in severe flood incidents [1]. Indeed, the risk of flooding and the vulnerability to such floods are on the ascent in Europe. The escalation of these factors can be attributed to population influx into flood-prone areas and the ongoing developmental activities in these regions.

A flood is an overflow of water that floods the soil and the tide flows into the land. Floods often cause large-scale loss of human life and extensive damage to property [2]. Flood risk analyses are often necessary to better understand flood events, especially for planning and prevention. Factors taken into account in the evaluation of flood risk analysis are rainfall, aspect, soil, slope, land use, land cover etc. Flood risk is basically determined as a result of probability and consequences. Accurate information on flood inundation and flood zonation is essential for sound planning and management of urban and rural areas. It also provides the basic data needed for a correct understanding of flood events.

The main causes of changes in flood risk are climate change and land use. The most common impacts are: urban growth, improperly sized bridges, deforestation and consequent erosion, construction of roads or other structures, subsidence in flat areas, alteration or diversion of the water source [3]. Usually, flood assessment starts with an assessment of the potential hazard of physical flooding or flood hazard. In terms of flood hazard, there are many dimensions (duration, velocity, debris, water depth, etc.) that preclude doing this directly. Furthermore, the methodology of such an assessment is highly dependent on the scale and specific characteristics such as the geographical setting and the presence of defence structures, the purpose of the assessment and the available data [4].

Geographic Information Systems (GIS) serve as digital representations of geographical attributes and features, connecting spatial elements with corresponding data in tabular form. In the realm of water resources, these features encapsulate various elements like stations, drainage bars, currents, and surface elevations. They compel researchers and software developers to devise intricate tools accessible through both commercial and open-source implementations. The application of GIS has notably mitigated the limitations in mapping and computational tasks, consequently amplifying their utilization in practical engineering [5].

As a formidable tool, GIS proficiently tackles a spectrum of water resource challenges, encompassing issues such as water quality assessment, groundwater dynamics, groundwater contamination, river rehabilitation, flood prediction, and management, among others, spanning local, regional, national, and even global contexts [6]. GIS, in conjunction with GIS-based models, proves invaluable in various hydrological simulations, such as rainfall runoff analysis. For instance, a GIS-based model can be constructed to compute water runoff or inundation in a specified area. This model considers parameters like soil composition, topography, vegetation cover, slope, aspect, and more, which are then assessed against historical data. The calibrated model can subsequently forecast new data, such as the movement of floods, for different potential climate scenarios and climate change impacts. Implementing such models within a GIS environment alleviates the need for numerous equations and calculations associated with diverse parameters [7].

This study will provide valuable information for flood hazard analysis in the analysed region. It is considered to be of great benefit for planners and managers to solve the conflict between human and river system functioning. The maps obtained in the study will constitute important bases for determining flood zones that may occur in the region and creating flood susceptibility maps. Flood susceptibility mapping is essential for characterizing flood risk areas and planning mitigation approaches..

2. Materials and Methods

2.1. Geographical information systems

Understanding what a Geographic Information System represents can be helped by considering the components of the term individually. Geographic: The totality of graphic and non-graphic information about objects (geographic entities) that have a specific location and form. This term is used because GIS is concerned with the "geographic", implying that information about location is known or can be calculated in terms of geographical coordinates (latitude, longitude) [8].

Information: This is derived from the interpretation of data. This is usually in the form of colour maps and images, but also tables and statistical graphs and various on-screen responses to interactive queries. Computer technology has enabled information to be processed and managed much more efficiently. System: This means that a GIS consists of several interrelated components with many different functions. Therefore, a GIS has functional features for data collection, input, transformation, manipulation, combination, visualisation, analysis, querying, modelling and output [8]. A convenient way to define a geographic information system that gives more insight into what GIS can do is to say that it is a set of computer tools capable of capturing, storing, using, analysing and displaying geographic information for a specific purpose [9].

Geographical Information System (GIS) supports the strategic planning process at every stage by providing information patterns that are flexible and well suited to the questions asked. On the other hand, GIS cannot be supportive if the problem definition is not valid. GIS enables permanent, efficient and valuable environmental data collection, which is one of the basic conditions for a successful strategic planning model implementation. The widespread network of data collection units saves considerable time and allows for much more data input, even faster data overlap capability. GIS is an important tool in providing the information basis for all necessary analyses that need to be carried out in the strategic planning process [8].

2.2. ArcGIS software

ArcGIS is a system developed by Environmental Systems Research Institute, Inc. (ESRI) for processing geographic information. ArcGIS is used for various services such as creating and using maps, compiling geographic data, analysing maps, and sharing geographic information. Maps developed using ArcGIS provide a deeper level of analysis than traditional paper maps because of the types of data that can be entered and the tools available for processing the data. [10].

3. Study Area and Data

In the first study, flood risk maps were prepared for the Darende district of Malatya province and Gürün district of Sivas province in the Tohma basin. The elevation map of the study area was created by using 30 metre resolution Digital Elevation Model (DEM) data downloaded from "viewfinderpanoramas.org". Slope and aspect maps were produced from DEM data with a resolution of 30 metres. With the downloaded DEM data, hydrology analysis was performed in ArcGIS environment and the drainage network of the study area was extracted and the rivers were mapped. The precipitation map of the study area was created from the data obtained from the General Directorate of Meteorology (MGM). Soil and land use maps were created with the data obtained from the Ministry of Food, Agriculture and Livestock. For the geological map, a geological map was prepared from the data obtained from the General Directorate of Mineral Research and Exploration (MTA). Figure 1 provides a map of the study area.

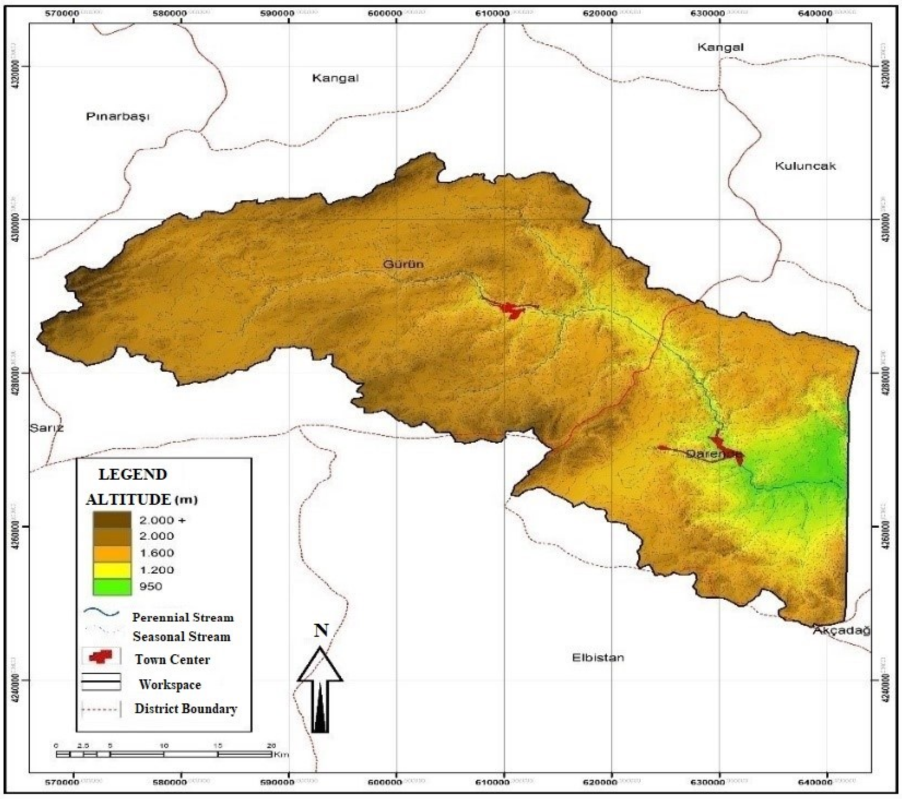

Figure 1. Working Area [20]

The study area covers the Tohma stream basin located within the borders of Gürün district of Sivas province and Darende district of Malatya province. The area originates in Gürün district of Sivas province and continues in Darende district borders of Malatya province by being fed by its tributaries. The Tohma Stream takes its source from the high hills of Gürün and passes through Darende with the tributaries that feed it.

The basic morphometric and hydrographic characteristics of the basins were calculated using Geographic Information Systems (GIS) techniques. After digitising the appropriate layers, land use and geological maps were made. Based on these maps, rainfall, aspect, slope, soil, land use, distance to the river and geological parameters were extracted to assess the flood hazard.

In the study, seven different basin characteristics (precipitation, slope, aspect, soil, geology, land use, and distance to the river) were created using meteorological data related to the basin and 1/25000 scale topographic maps within the ArcGIS software environment.

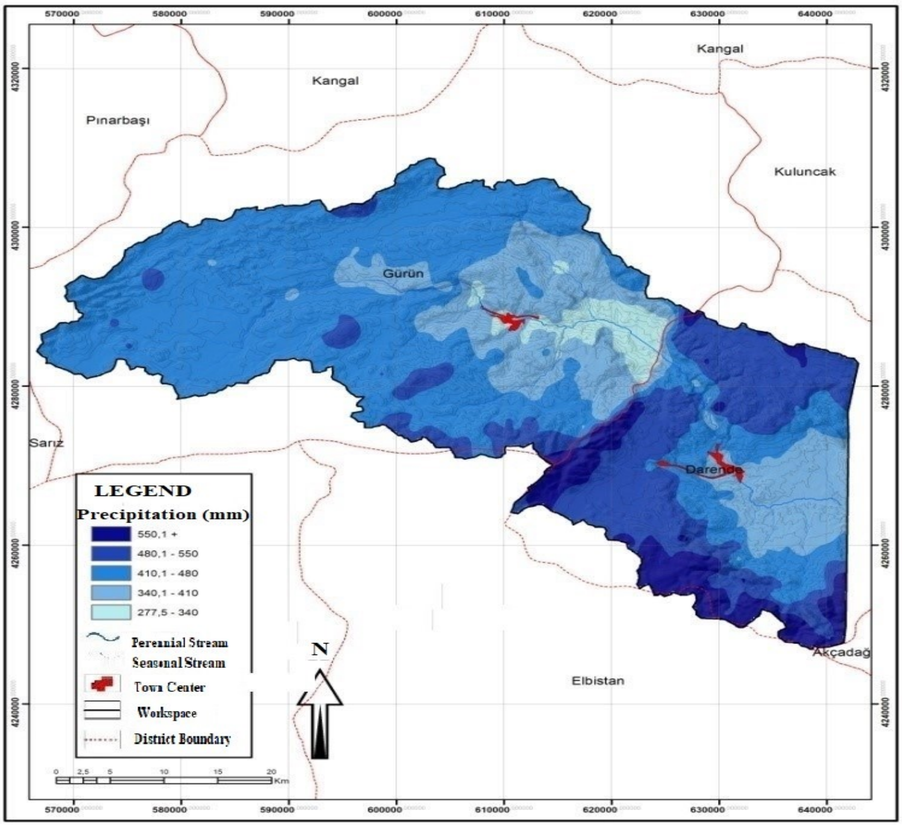

Figure 2. Rainfall Map [14]

One of the most important factors in flood formation can be considered as precipitation. Precipitation, which is one of the most important factors that will flow on the surface in case of exceeding the water retention capacity of the soil, creates the risk of flooding. Precipitation map was created with a method developed by Schreiber. This method developed by Schreiber is recommended by physical geography and bioclimate workers [11,12]. In Schreiber's formula, an increase of 54 mm in precipitation every 100 m (subtraction occurs if the nearby station is below) and this method was first applied to the conditions in Turkey by Erinç [13]. When examining the precipitation map in Figure 2, it is evident that the areas with the highest precipitation are located in the highlands north of the Darende plain, whereas the areas with the least precipitation are in and around Gürün [14].

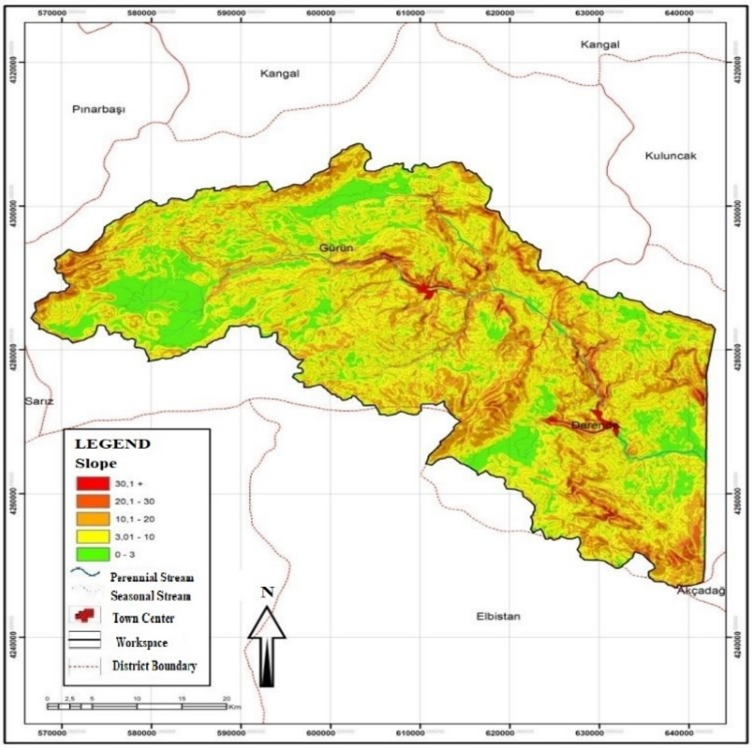

Figure 3. Slope Map [14]

Slope plays a crucial role in controlling the flow of surface water to a specific location. Steep slopes generate more velocity than gentle slopes and can, therefore, discharge runoff more rapidly. On flat or gently sloping areas, runoff is stored over an area and is released gradually over time [4]. When examining the slope map in Figure 3, it can be concluded that the flat areas in the study area are high-risk flood areas, while areas with high slopes indicate lower flood risk [20].

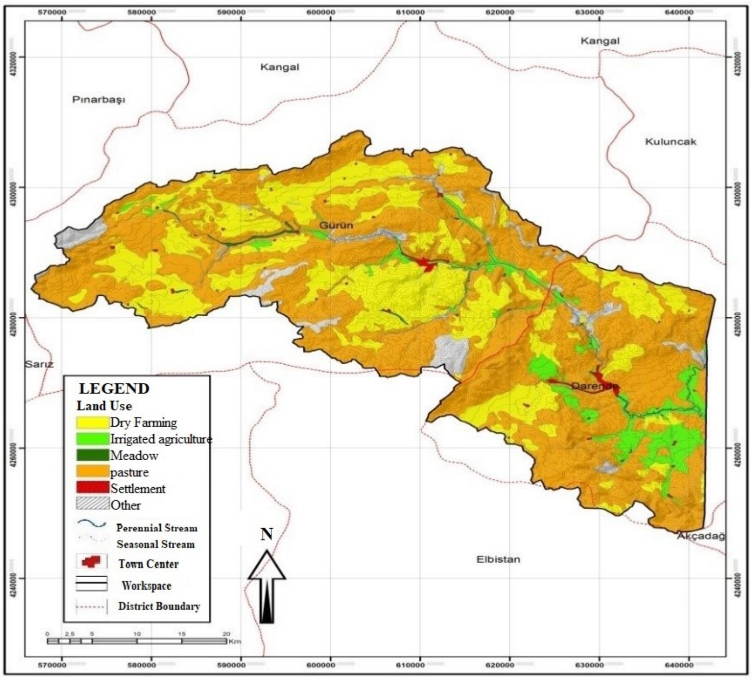

Figure 4. Land Use Map [14]

Land use refers to the long-standing process of altering the natural environment to meet human needs. The destruction of forests for agricultural purposes and the conversion of agricultural lands into settlements increase flood impact factors. According to the land use map in Figure 4, the study area is predominantly composed of pasture and dry farming lands [14].

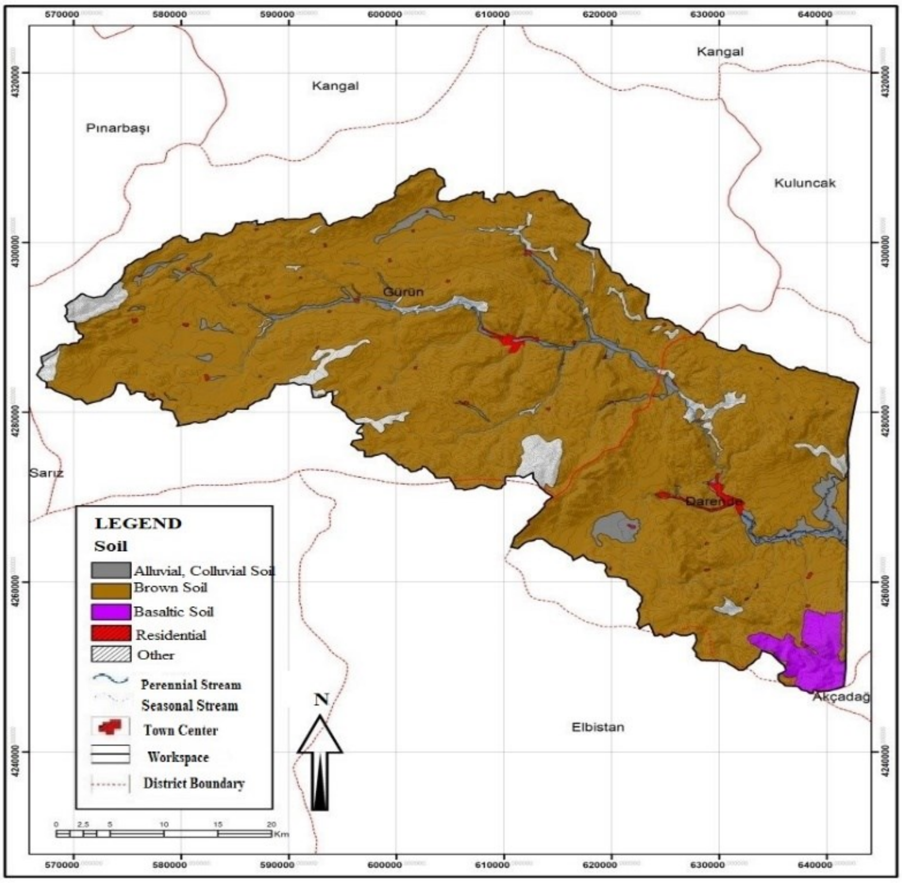

Figure 5. Soil Map [14]

The development of settlements in river basins narrows soil regions and renders the soil less suitable for use. Particularly in today's context, the increase in the construction sector has led to the occupation of areas where water could be retained, reducing the soil's capacity to absorb water. These factors increase the likelihood of water flow and contribute to flood risk. Furthermore, the moisture content of the soil, whether it is dry or wet, affects the intensity of flooding [15]. According to the soil map created in Figure 5, brown soils are predominant throughout the area. Moreover, areas with alluvial soils on this map are the riskiest for flooding [14]. This is because the high groundwater level in alluvial soils reduces their permeability characteristics [12].

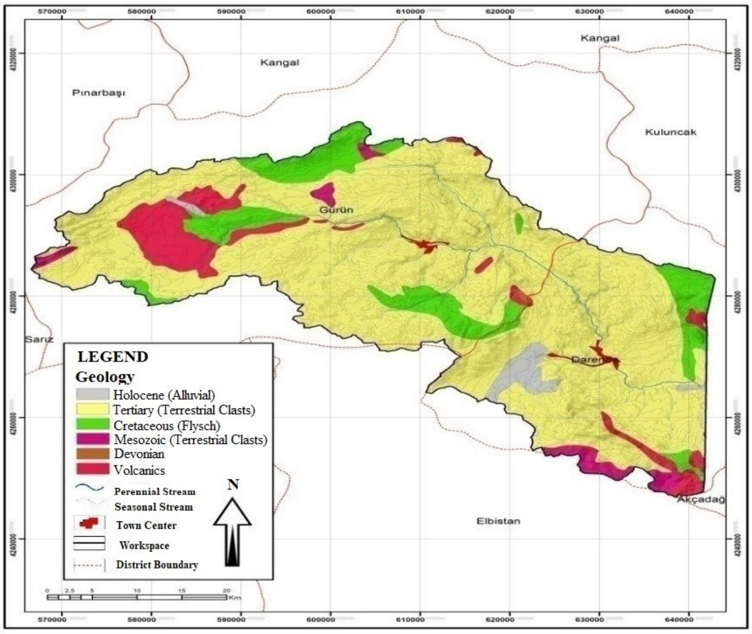

Figure 6. Geology Map [14]

Geology is an indirect factor that affects flood risk. The geological structure of the basin influences the degree to which rainfall infiltrates underground. When examining the geological map of the study area created in Figure 6, it is evident that tertiary formations are more prevalent in the area [14].

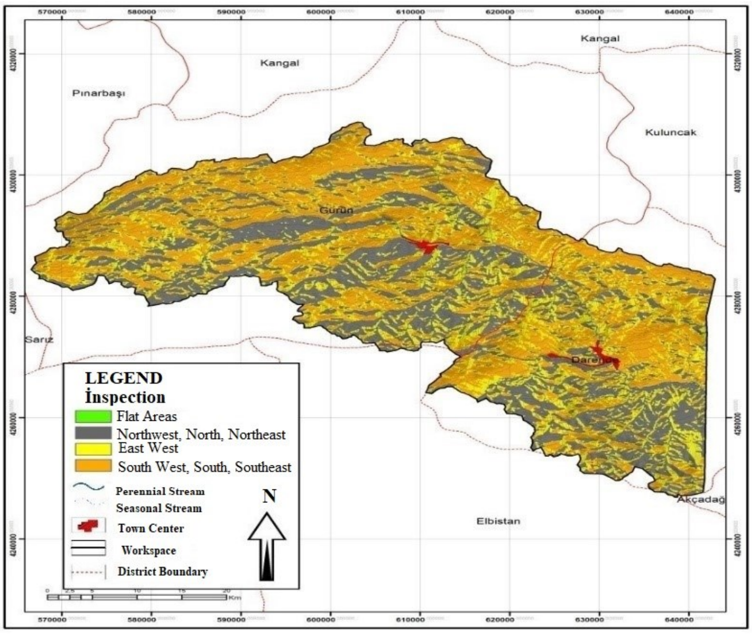

Figure 7. Aspect Map [14]

Aspect defines the steepest descent direction on a surface, which can also be considered as the slope direction or compass direction [16]. In Figure 7, it can be observed that the aspects in the study area are in the southwest, south, southeast, northwest, north, and northeast directions.

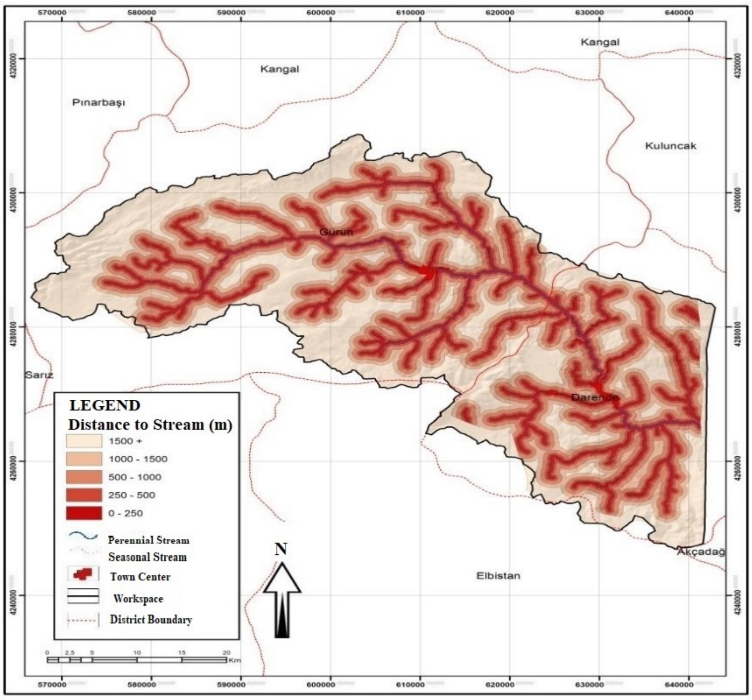

Figure 8. River Distance Map [14]

Distance to the river is a factor to be considered in flood analyses since areas close to the river are more likely to be at higher risk of flooding. By calculating the distance to the rivers and their tributaries in the study area, a river proximity map was created as shown in Figure 8 [14].

4. Conclusion

Nowadays, the use of Geographic Information Systems (GIS) is emerging as a powerful tool for the assessment of different types of natural hazards. Floods are among the most serious natural hazards and have disastrous socio-economic impacts. It is therefore urgent to develop flood susceptibility maps to identify flood-prone areas. These maps will assist authorities, planners and decision-makers in making rapid assessments and taking appropriate measures to reduce and minimise the consequences of potential impacts from flooding.

Flood risk is mainly determined as a function of probability and consequence. Accurate information on flood inundation and flood zonation is essential for sound planning and management of urban and rural areas. It also provides the basic data needed for a correct understanding of flood events.

In this study, ArcGIS, a Geographic Information System (GIS) software, was used to create some basin characteristics (precipitation, slope, aspect, soil, geology, land use, and distance to the river) for the study area. It is believed that determining these characteristics will serve as a foundation for identifying potential flood-prone areas in this region. The creation of flood maps of this nature will provide valuable insights for the local population to take preventive measures and mitigate potential risks to life and property.

Declarations and Ethical Standards

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article. The author(s) of this article declare that the materials and methods used in this study do not require ethical committee permission and/or legal-special permission.

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