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Investigation of flood risk areas in Ünye district with Best-Worst method using geographic information systems

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Abstract

One of the main issues of land management is identifying risky areas. Floods are natural events that develop depending on the climate and topographic characteristics of the regions. The effect of human activities is also seen in flood events. In this study, flood risk areas were determined in Ünye district using Geographical Information Systems (GIS). The Best-Worst Method (BWM), one of the Multi-Criteria Decision Making Methods (MCDM), was used in the study. First of all, the criteria affecting flood formation were determined as slope, aspect, height, and land use based on previous studies. Subclasses for each criterion were determined and weighted by the BWM method. The criteria were reclassified according to the weights given to the subclasses. The flood risk map was obtained by overlaying the criteria according to these weight values. It has been observed that the settlements with low slopes are the places that will suffer the most in case of possible flooding.

1. Introduction

Natural or artificial events that cause physical, economic and social losses for the whole or specific segments of the society, stop or interrupt everyday life and human activities, and in which the coping capacity of the affected community is not sufficient, are called disasters [1]. Natural events, described as natural disasters, are generally the natural results of the cycle of reorganizing the internal balances of nature. They are called natural disasters when human societies are damaged by this cycle [2]. Turkey is a country that is always faced with natural disasters due to its geological and meteorological characteristics [3]. In recent years, flood events have emerged as one of the natural disasters that have significantly affected human life and caused loss of life and property in Turkey and worldwide. Floods are natural formations that develop depending on the region's climatic conditions and geotechnical topographic features, but the effect of human activities on floods is undeniable [4]. The most important reason for the damages caused by floods in our country is the construction in the stream beds. This situation causes the residential areas to be flooded by the rising water level after heavy rain overflows from the narrowing stream bed [5].

Efforts to minimize the loss of life and property in a possible flood and to reduce the negative effects of the flood can be carried out with risk management in flood areas. In risk management studies; hazards and risks are determined, risk scenarios are prepared, protection and mitigation measures are selected, the results are presented with up-to-date maps and graphics, the usability of the resources and opportunities are determined, decisions about the most appropriate options and priorities for disaster protection and disaster response are eliminated and implemented. The knowledge gained is of great importance in determining the floods, performing risk analysis, and planning before and after the disaster. Generating and organizing knowledge requires time-consuming work. Therefore, Flood risk analysis is a complex issue that concerns many occupational groups [5].

With its query and analysis capabilities Geographical Information Systems (GIS) provides is an important decision support for the decision makers. GIS has been one of the leading sources used in the determination of possible risk areas in disaster and emergencies in recent years. There are many studies in our country in which flood risk analysis is made by using GIS [4-9].

In this study; Cevizdere stream, which has experienced flood events in the past and a major flood event in 2018, was investigated. The parameters affecting the flood were determined based on previous studies, and the weights of these parameters were calculated with the Best-Worst Method (BWM). By using the analysis capabilities of GIS, flood risk areas were tried to be determined. In this study, flood risk areas were tried to be determined by using fewer parameters than the parameters used in the studies conducted by Beden [4] and Ocak and Bahadır [7] in the same area, and the weights were determined by BWM, and the results were compared.

2. Material and Method

The analysis was carried out using the Multi-Criteria Decision Making Method (MCDM), and a flood risk map was created. MCDM Methods are the process of evaluating a finite number of options for selection, ranking, classification, prioritization or elimination by using a large number of criteria that are generally weighted, contradictory and do not use the same unit of measure, and some even take qualitative values [10]. The purpose of using MCDM methods is to keep the decision-making mechanism under control in cases where the number of alternatives and criteria is high and to obtain the decision result as easily and quickly as possible [11]. BWM, one of the MCDM methods, was used in this study. BWM is one of the multi-criteria decision-making methods based on pairwise comparisons. In the BWM method, not all criteria related to the decision problem are compared in pairs [12]. The decision maker determines the Best and Worst criteria, and pairwise comparisons are made between each of these two criteria and all other criteria. The most important feature of the method is that it requires fewer comparison data and obtains more consistent results than some MCDM methods.

The BWM is a relatively new weighting method using pairwise comparisons to calculate criteria weights. Transportation, communication, energy, investment, manufacturing, supply chain management, aviation industry, education, performance evaluation, healthcare, finance, technology, and tourism are just a few examples of real-world challenges where the BWM has been used [12-19].

The steps of BWM can then be used to compute the weights of the criteria as follows [12].

Step 1. Identify a set of decision criteria. In this step, the decision-maker identifies n criteria that will be used to make a decision.
Step 2. Determine the most important “best” and the least important “worst” criteria.
Step 3. Assign a preference to the best criterion between 1 and 9, compared to the other criteria.
Step 4. Compared to the criteria, assign a preference to the least important criterion between 1 and 9.
Step 5. Find the optimal weights for the criteria.

This study investigated flood risk analysis based on four main criteria; elevation, slope, aspect, and land use. These criteria were determined based on previous studies in the literature as mentioned above. In the study, it was aimed to determine flood risk areas with a small number of parameters. To assess the risk areas in terms of flood, first of all, the necessary data were obtained from the relevant sources. Digital Elevation Model (DEM) with 25m resolution was used as altitude data obtained from USGS EarthExplorer. The slope and aspect characteristics of the study area were produced by performing slope and aspect analyzes with ArcGIS software using the Digital Elevation Model. Slope and aspect maps of the study area were produced. A relief map was obtained with the "Hillshade" analysis in the "3D Analyst" module to be used in the created maps. CORINE 2018 data was used as the land use data of the study area. Stream data of the study area were obtained from topographic Map. After producing all data, the land use data in vector structure was converted into the raster data structure. While transforming the land use data to a raster structure, the cell size was adjusted to be the same as the elevation data. The criteria and sub-criteria cultivated in flood risk were determined, and the weight values for these criteria were calculated using BWM. The criteria and weight values used in the study are given in Table 1.

Slope, aspect, elevation and land use in flood risk analysis were reclassified according to the weight values given to subclasses with the "reclassify" function of the "Spatial Analyst" tool group, a module of ArcGIS software, and made ready for analysis. A model was created with the "Model Builder" module to perform the analysis.

The weight values in the flood analysis for the reclassified slope, aspect, elevation and land use criteria were determined as percentages, and the "weighted overlay" function of the "Spatial Analyst" tool group was overlapped according to these values and the Flood Risk Map was created.

Table 1. Criteria, subclasses and weight values that are effective in determining flood risk areas

Criteria	**Weight**
Slope	
0-5	0.55
5-15	0.27
15-25	0.10
25+	0.08
Aspect	
Straight	0.28
North	0.17
Northeast	0.13
East	0.07
Southeast	0.06
South	0.04
South West	0.05
West	0.08
Northwest	0.12
Elevation	
0-20	0.59
20-100	0.20
100-200	0.13
200+	0.08
Land Use	
Farming areas	0.25
Industrial areas	0.15
Residential areas	0.18
Hazelnut gardens	0.06
Forests	0.03
Plant exchange areas	0.10
Roads	0.12
Open Spaces	0.11

Table 2. Weight percentages of analysis criteria

Criteria	**Weight values (%)**
Slope	0.30
Aspect	0.05
Land Use	0.25
Elevation	0.40

2.1. Location and features of the study area

The study area is Ünye district, which is located within the provincial borders of Ordu city. Ünye located in the Central Black Sea division of the Black Sea Region, in the west of Ordu Province. It borders with Fatsa in the east, Terme, İkizce and Çaybaşı in the west, Akkuş and Kumru in the south. The Black Sea coast is located on the northern side of the district. Its area is about 565 km^2 (Figure 1). There are 85 neighbourhoods within the boundaries of the district. According to the latest data, its population is 130,692 [20]. Ünye is under the influence of the Black Sea climate due to its location. Since it receives precipitation in all seasons, the number of cloudy days and annual precipitation are high. Humidity is high due to its low altitude compared to its surroundings and its close distance to the sea. The yearly average temperature is 14.4 °C and the average annual precipitation is 1183 mm [21].

2.2. Criteria Affecting Flood Risk

2.2.1. Slope

One of the most essential criteria effective in flood risk is the slope. Due to the low water holding capacity of the soil in areas with a high slope, the amount of water flowing into the flow is higher. For this reason, places with less slope are more risky areas in terms of flooding (Figure 2).

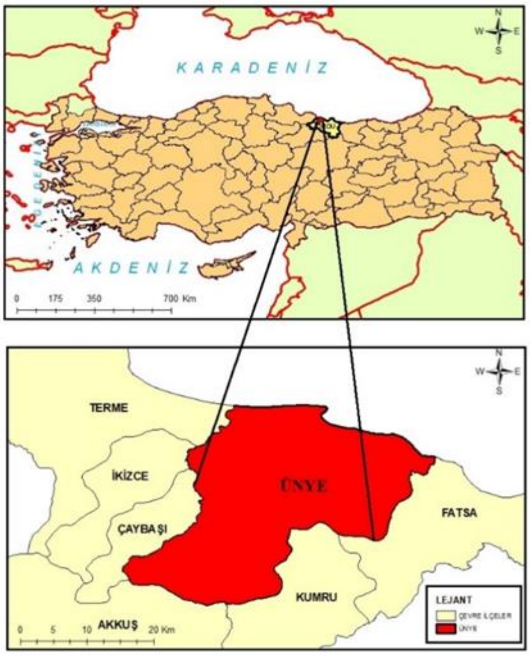

Figure 1. Study area

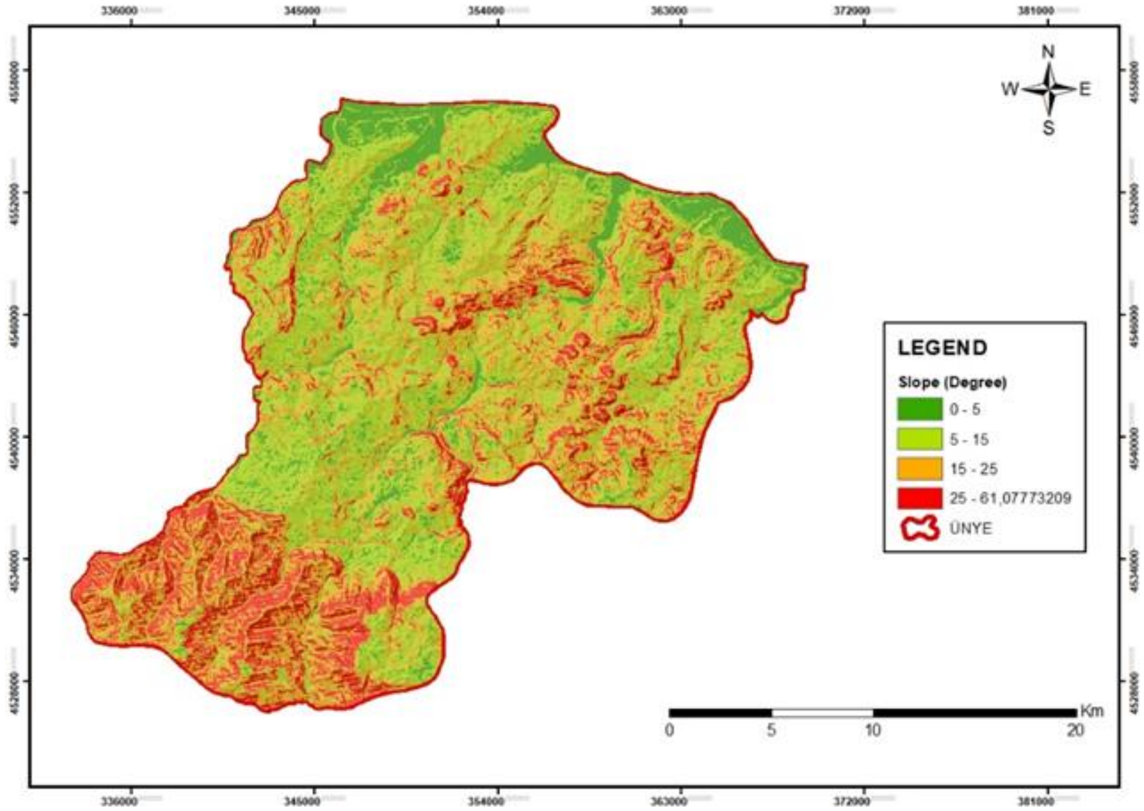

Figure 2. Slope map

While creating the slope classes of the study area, the classifications in the study by Özcan [5] were taken into account. Four slope classes were designed for the study area. Areas with a slope of 0°-5° were determined as the areas with the highest risk in terms of flood risk and the highest weight value was assigned to these areas.

2.2.2. Aspect

Another criterion that is effective in flood risk is aspect. Flat and near-flat areas are areas where precipitation and water can accumulate. These areas are the most risky areas in terms of flood risk. The saturation of soils on north-facing slopes causes surface waters to flow rapidly and increases the risk of flooding [7].

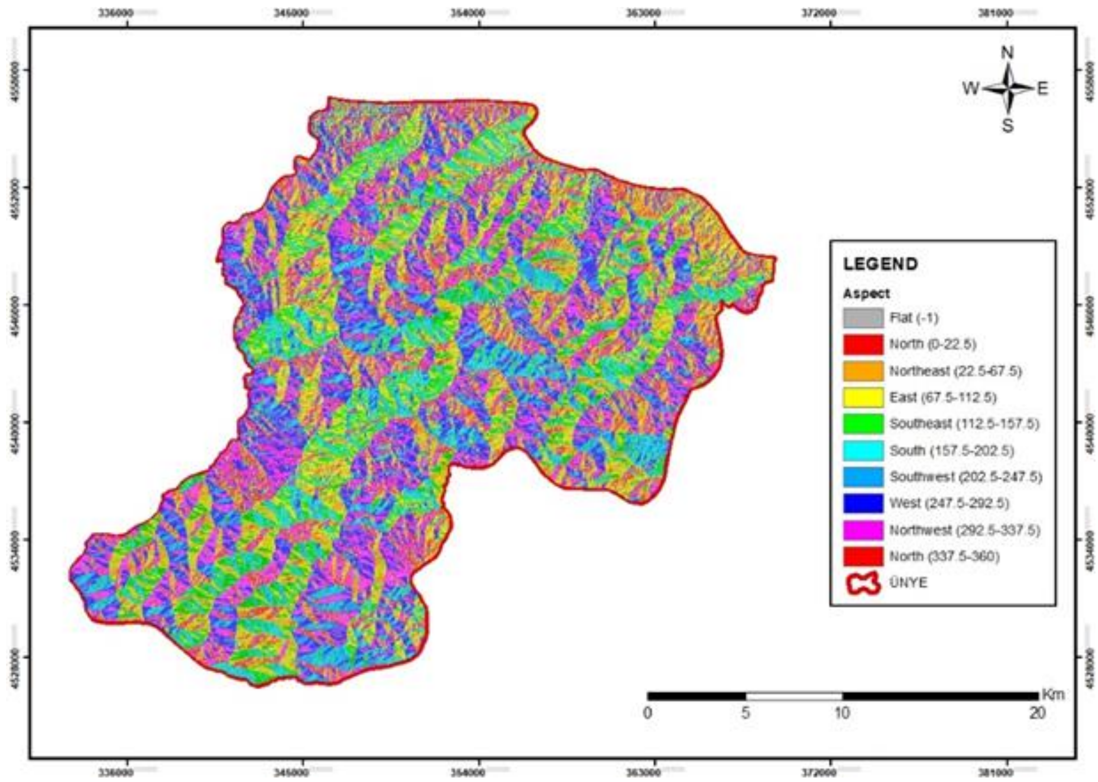

Figure 3. Aspect map

In the study area, 4 classes were created for aspect and flat areas were determined as the areas with the highest risk. Areas facing north have also been identified as high-risk areas (Figure 3).

2.2.3. Elevation

Another important criterion in the formation of a flood is the altitude. As the altitude increases, the precipitation falling on the basin also increases. In areas with high elevation, water passes to the surface flow faster and increases the risk of flooding in lower elevations (Figure 4).

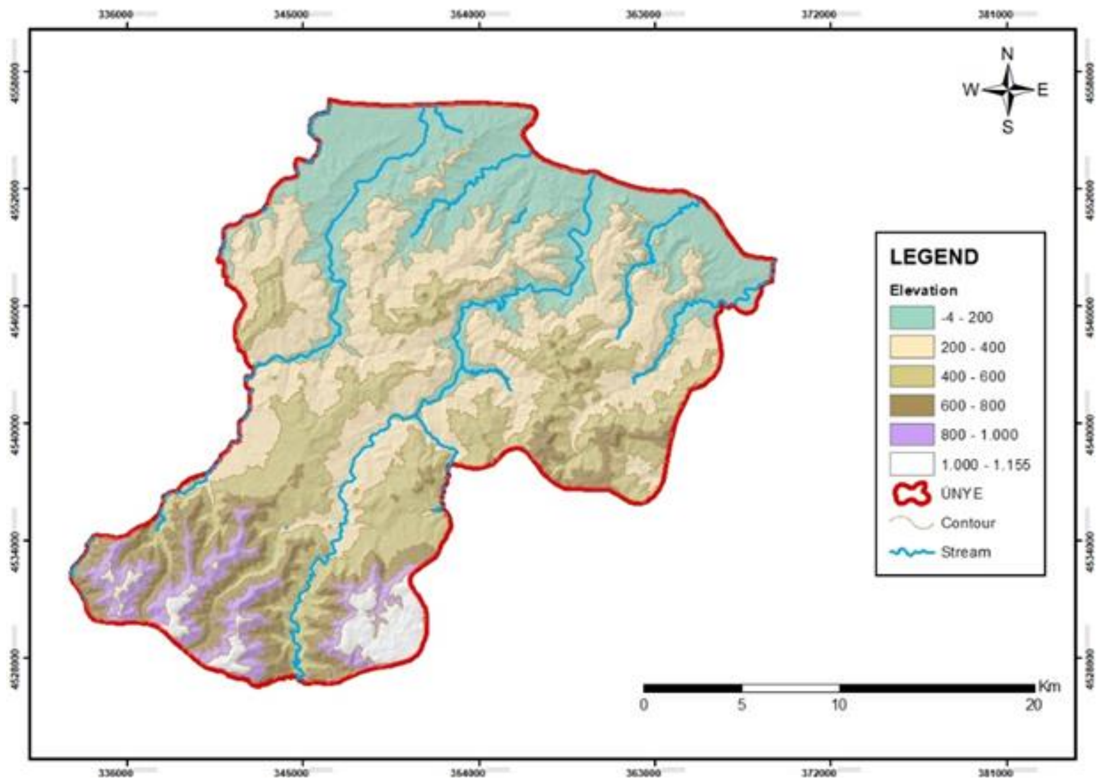

Figure 4. Elevation map

While creating the altitude classes in the study area, the classes used by Ocak and Bahadır [7] were considered. The altitude between 0 and 20 m has been determined as the most risky area in terms of flooding and the highest weight value has been assigned to these areas.

2.2.4. Land Use

In this study, land use was chosen as the fourth criterion effective in flood formation. Due to the moist soils in agricultural areas, residential areas and industrial areas, rain water quickly passes to the surface flow. Therefore, these areas increase the risk of flooding. Since hazelnut orchards are areas that require plenty of precipitation, they absorb water easily, reduce the flow of surface waters, and reduce the risk of flooding. Forest areas also reduce the risk of flooding.

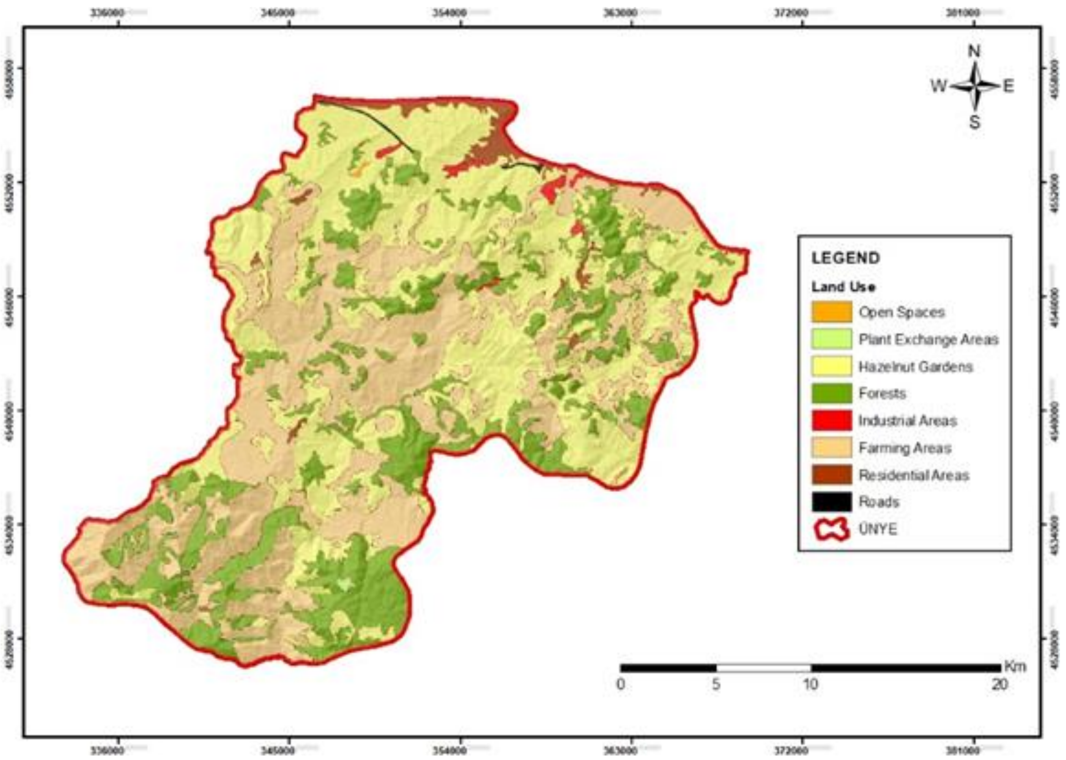

Figure 5. Land use map

The land use status of the study area is divided into 9 classes. Agricultural areas were determined as the areas with the highest risk, and these areas were given the highest value (Figure 5).

3. Results

In this study, the areas that will be affected in the event of a possible flood in Ünye district have been tried to be determined using few criteria. For this purpose, slope, aspect, elevation and land use criteria in terms of flood risk are discussed. Maps belonging to these criteria were produced. Each criterion was divided into subclasses and weighted using BWM and reclassified according to these values and a flood risk map was produced (Figure 6). In the flood risk map, the flood risk is classified in five groups as “Very High”, “High”, “Medium”, “Low” and “No Risk”.

4. Discussion

According to the flood risk map created, it is seen that the 55.7 km^2 area in Ünye district is a very high-risk area in terms of flood risk. These areas correspond to a small part of the entire study area. However, since they are the areas above the residential areas, it is seen that they are the p1laces that are most likely to be damaged in the event of a flood. A total of 90.8 km^2 of the study area poses a high risk of flooding. It is understood that these two areas are the areas remaining in the coastal areas. 293.3 km^2 of the study area is medium risk, 108 km^2 is low risk and 16.1 km^2 is risk-free (Table 3). It is seen that the risk of flooding decreases as you go to higher elevations in the study area. The fact that the areas where Tabakhane Stream, Cevizdere and Curi Stream are located in the district are densely populated also poses a risk in terms of flooding. The presence of agricultural lands and hazelnut orchards in the area where Cevizdere is located causes severe property losses in case of a possible flood.

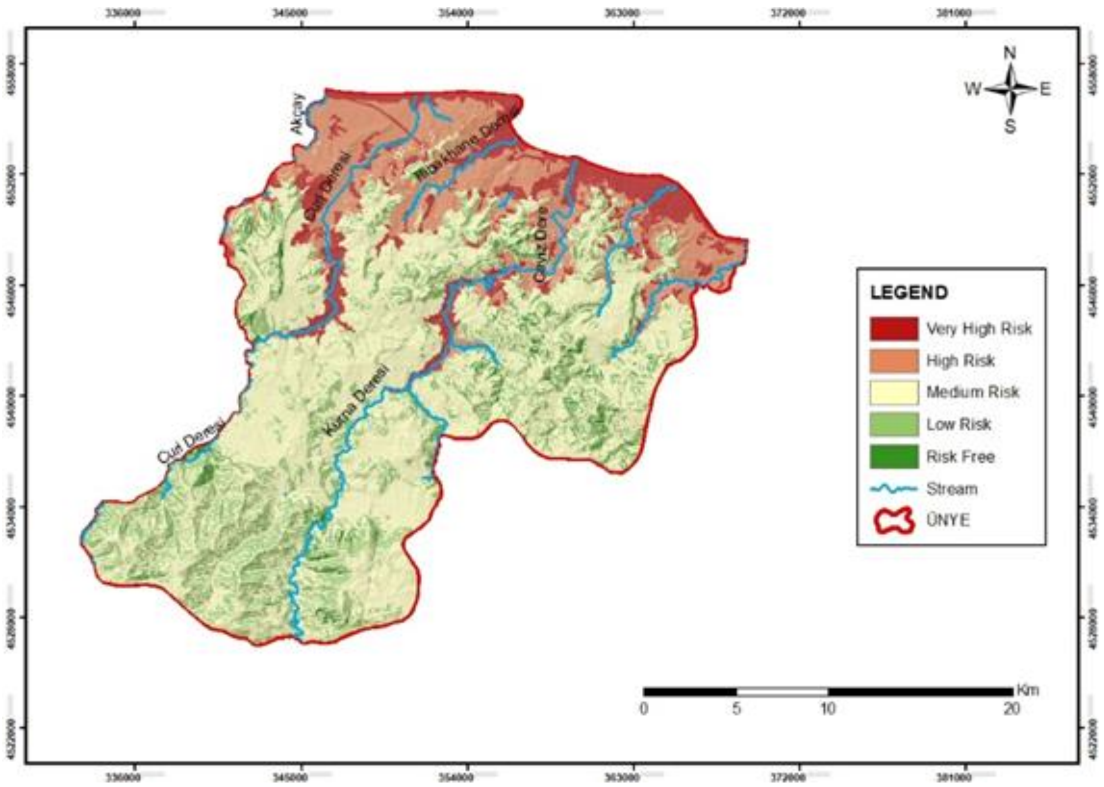

Figure 6. Flood risk map

Table 3. Created flood map risk classes, areas and rates

Risk Groups	Area (km^2)	Ratio
Very High	55.7	9.9
High	90.8	16.1
Middle	293.3	52.0
Little	108.0	19.1
Risk free	16.1	2.9

The risk classes presented in (Table 3) are compared with the Ocak and Bahadır [7] study, while the Very High and High risk groups constitute 26% of the total area in the current study, this ratio remains at 8.5 % in the other study. Areas in the medium risk group accounted for 52% of the total area in the current study, while this rate was 29.5% in the other study. It is thought that this situation is due to the reflection of the number of criteria in the current study on the result obtained, and that few criteria show more areas as risky.

5. Conclusion

In recent years, GIS has been an effective tool in studies on flood risk, as in many other fields. In this study, the flood risk in Ünye district was analyzed using GIS.

Elevation, slope, aspect and land use were used as the risk factors in the current study. Compared with the previous studies that used more criteria in the same region, it was observed that, the results are not close to each other in very high and high risk areas, but the results are close to each other in total medium and low risk areas. In addition to increasing the number of effective criteria in the analysis, it is predicted that using data with higher resolution will provide more precise results. It is anticipated that conducting more detailed and comparative studies in the region, which is at risk in terms of flooding due to the streams and topographic structure it contains, will be beneficial in terms of reducing the risk. According to the results, measures should be taken to minimize the risk, and early warning systems should be developed. Since the damages caused by the flood may be more, especially in the residential areas where the population is dense, necessary planning should be made in terms of risk in these areas. The results of this and similar studies should also be considered when planning for construction in places where the risk is high. The people living in the region should be informed about the possible floods and the social and economic damages they will cause.

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Author contributions

Nilay Yıldız*:* Conceptualization, Methodology, Data curation, Software, Writing-Original draft preparation. **Aziz Şişman**: Visualization Reviewing and Editing.

Conflicts of interest

The authors declare no conflicts of interest.

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