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Using analytical hierarchy process (AHP) for flood susceptibility mapping of Mersin, Turkey

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ABSTRACT

Overflowing and flood disasters caused by excess water in the river beds cause a major problem. Increasing precipitation, along with the growth of cities, destruction of river beds, inadequate infrastructure and climate change, triggers overflowing and flood disasters. Overflowing and flooding on settlements can cause great damage and destruction. Flood maps, which are necessary to prevent these material and moral damages, determine the regions to be affected by the flood in advance and play an auxiliary role in the measures that can be taken there. Remote sensing and geographic information systems play a major role in obtaining and processing this information. Due to size and complexity of data obtained from field, GIS makes it easier for us to process data. And allows us to observe results much clear. In this study, Analytical Hierarchy Process used for flood susceptibility mapping of Mersin. 10 factors affecting flood have been used to prepare susceptibility map. Results showed us that coastal zone and close locations to river beds are under risk of flood. Since most of the built-up area located on or around these risk zones, it is required to take measures immediately.

1. INTRODUCTION

Disaster is natural or human-induced phenomenon that interrupts normal life and social activities, causes physical, social, cultural and economic losses in society, (Gündoğdu and Özçep, 2003). Thus, disasters defined by their impact on communities. Disaster is the result rather than the event itself(Ergünay, 2002).

Disasters cause damage and death, which can be reduced by disaster management. According to UNDP %90 of natural disasters occur in developing countries(Witschi-Cestari, 2002), which makes them more vulnerable when their economic situations considered.

Flood events are related to the climatic and physiographic structure of the region. In addition, roads and sidewalks that control the flow of water on the surface, and natural drainage areas blocked by buildings covering a large part of the ground increase the effect of flood by restricting the flow of water(Konrad and Booth, 2005; Fernandez and Lutz, 2010). Especially in dense residential areas, the effect of flooding is felt much more severely because the affected areas often include non-drainable surfaces and insufficient underground drainage channels(Selçuk et al, 2016).

Disaster management is important in order to predict, prevent and protect against flood disasters. It is not possible to stop disasters (Onuşluel and Harmancıoğlu, 2002) yet it is possible to reduce its impacts to minimum. For this purpose, it is required to prepare a susceptibility map. When adequate measures are taken in flood sensitive areas it is possible to greatly reduce effects of floods. For this reason, potential flood and overflow areas should be obtained with reliable methods and these data should be taken into consideration in making planning decisions at all scales, directing investment projects, and establishing settlement and land use policies (UNECE, 2000).

There are many studies to predict possible flood locations. It can be separated to two categories; modelling and multi-criteria decision analysis. Hecras (Manandhar, 2010) and Floodsim (Hadimlioglu et al, 2020) are popular programs among flood modelling applications. Analytical Hierarchy Process (Das, 2019; Vojtek and Vojteková, 2019; Swain et al, 2020) and Fuzzy weight(Hong *et al.*, 2018; Wang *et al.*, 2019) are popular among Multi-criteria decision analysis. Yet

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there is no such thing as best in between all these methods. Because every study area has different (unique) character. Quantity and quality of data is another decision maker between these methods.

Purpose of this research is to prepare a susceptibility map for Mersin, Turkey by using AHP. This study will be the first susceptibility map for Mersin by using AHP. There are different types of studies for flood in Mersin. These studies are about flood risk which is not same thing as susceptibility mapping. Flood risk analysis is an analysis to determine the possible damage 'if' flood occurs in that area. In susceptibility mapping our purpose is to find out sensitive locations for flood which means possible flood locations if requirements are meet.

2. MATERIALS and METHOD

2.1. Study Area

Mersin (Figure 1) is a city located in southern part of Turkey. The surface area of Mersin province is 15,620 km^2. Except for 50% of the Tarsus district, all of it is within the Eastern Mediterranean Basin boundaries. Mersin province, which is surrounded by the Mediterranean in the south, is separated from the inner parts of Anatolia by the high plateaus and peaks of the West and Central Taurus Mountains from the north. Mersin, Antalya Karaman and Konya are located within boundaries of Eastern Mediterranean basin.

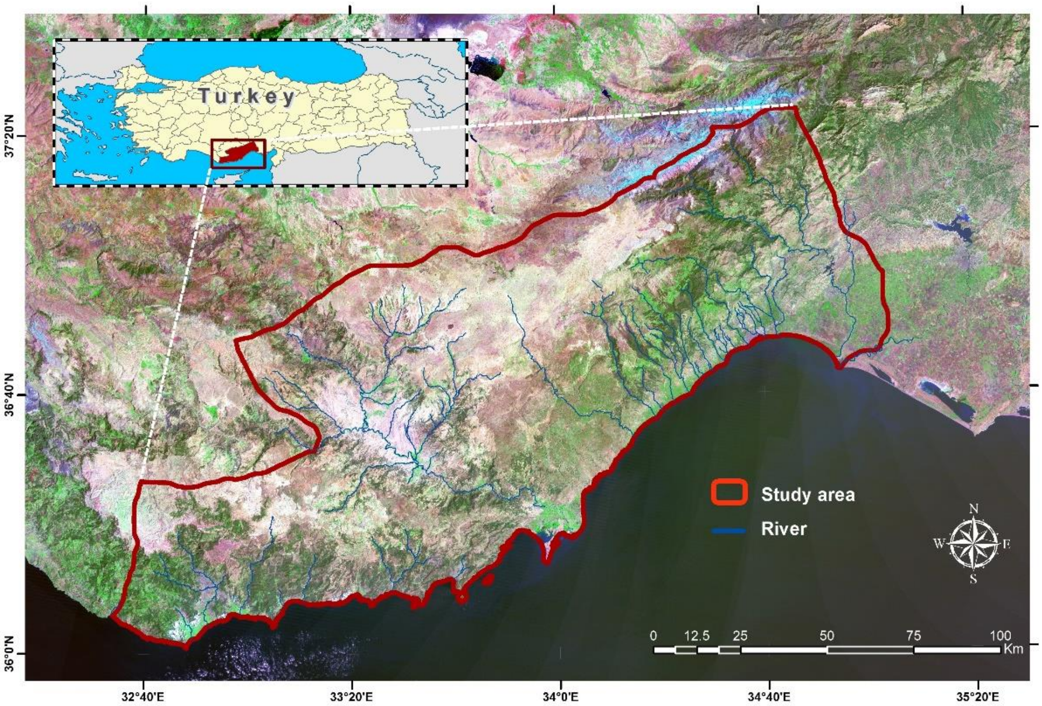

Figure 1. Study Area; Mersin, Turkey

According to 'Eastern Mediterranean Basin Flood Management Plan'; approximately 2.12% of Turkey's population is located within the basin, covering the provinces of Mersin has the largest population among the provinces. More than %90 of population of Mersin is located within the basin. The Eastern Mediterranean Basin generally has a Mediterranean climate with dry and hot summers and mild and rainy winters. It transitions to Central Anatolia Terrestrial Climate in the northern and upper parts. In these regions, summers are dry and hot, winters are cold and usually snowy. (DAHTYP, 2019).

2.2. Material

Elevation, slope, distance to river, distance to drainage, drainage density, landcover, TWI, SPI, aspect and curvature data have been used in this project to create a susceptibility map for Mersin. Elevation, slope, aspect and curvature produced from DEM (Yılmaz and Erdoğan, 2018) of Mersin. While landcover is a separate data, others produced with combination of DEM and river and/or stream lines.

Importance of each data can be explained as; Water accumulates in lowest elevation point of basin. Thus, as the elevation decreases chance of flood increases. Slope is effective on movement of water. Areas with lower slope accumulates water therefore it has higher risk for flood. River locations are natural path for water. Closest locations to river have higher risk of flood. Distance to drainage is similar with river. River is something that occurs on the ground level and drainage is a system operates underground. If water can access to underground level it will accumulate within drainage system. Drainage density defined as the total stream length per unit area. Higher density will increase the risk of flood. Land cover data has 5 groups. These groups were separated by their runoff, infiltration, evaporation and evapotranspiration. Highest risk groups were artificial surfaces and water bodies. TWI represents the ratio of slope and specific basin area that describes the effect of topography on the distribution of soil moisture in an area. SPI is power of water flow. Regions with lower power will accumulate water so low SPI has higher chance of flood. Aspect is effective on soil moisture and hydrological conditions. Flat surfaces have highest risk, north, northeast and northwest 2nd in rank east and west are 3rd and south, southeast and southwest are the least flood risk areas. Curvature is our last data that has impact on flood. Curvature is shape of surface which can be convex or concave. For the values it has been separated in to 3 categories. Areas of between (-1)-1 values are highest risk areas, values below -1 comes 2nd and values above 1 comes in 3rd place in ranking of curvature.

2.3. Method

In this study Analytical Hierarchy Process has been used for flood susceptibility mapping. AHP is used in a multi-purpose decision-making situation with multiple criteria, in which a large number of decision makers are present, when choosing among many alternatives under certainty or uncertainty. Using a hierarchical model consisting of objectives, criteria, possible sub-criteria levels and options for each problem, AHP can be explained as a decision making and estimation method that is used if the decision hierarchy can be defined, and gives the percentage distributions of decision points in terms of factors affecting the decision.

Ranking of dataset for AHP is elevation(meter), slope(°), distance to river(meter), distance to drainage(meter), drainage density (km/km^2), land cover (level), TWI (level), SPI (level), aspect and (plan)curvature. Rank of dataset depends on expert opinion. While elevation has the highest rank, highest impact, and curvature is the lowest one. There are 2 weight calculation processes in AHP. One of them is between these 10 factors and other one is within every single factor. Also, every single factor has been grouped in to 5-10 classes depending on type of data. Range of classes determined based on expert opinions. In this step, every single group weighted according to their impact on flood. Weight of every single factor; Elevation (0,26), Slope (0,22), Distance to river (0,15), Distance to drainage (0,11), Drainage density (0,07), Landcover (0,06), TWI (0,03), SPI (0,02), Aspect (0,019), Curvature (0,014). For the last step in Arcgis program weight of factor and class have been multiplied to calculate the weight of every single pixel. Pixel size of every single parameter is 30x30 meters. Final calculation gave us the susceptibility map of Mersin.

3. RESULTS

Figure 3 shows the susceptibility map of Mersin. It has been produced by multiplying parameter's weight and group's weight. Coastal locations and surroundings of rivers are most sensitive areas according to this research. Figure 2 shows us conditioning factors of this research. It can be clearly observed even through those maps because highest risk groups in every single conditioning factor were located within those areas.

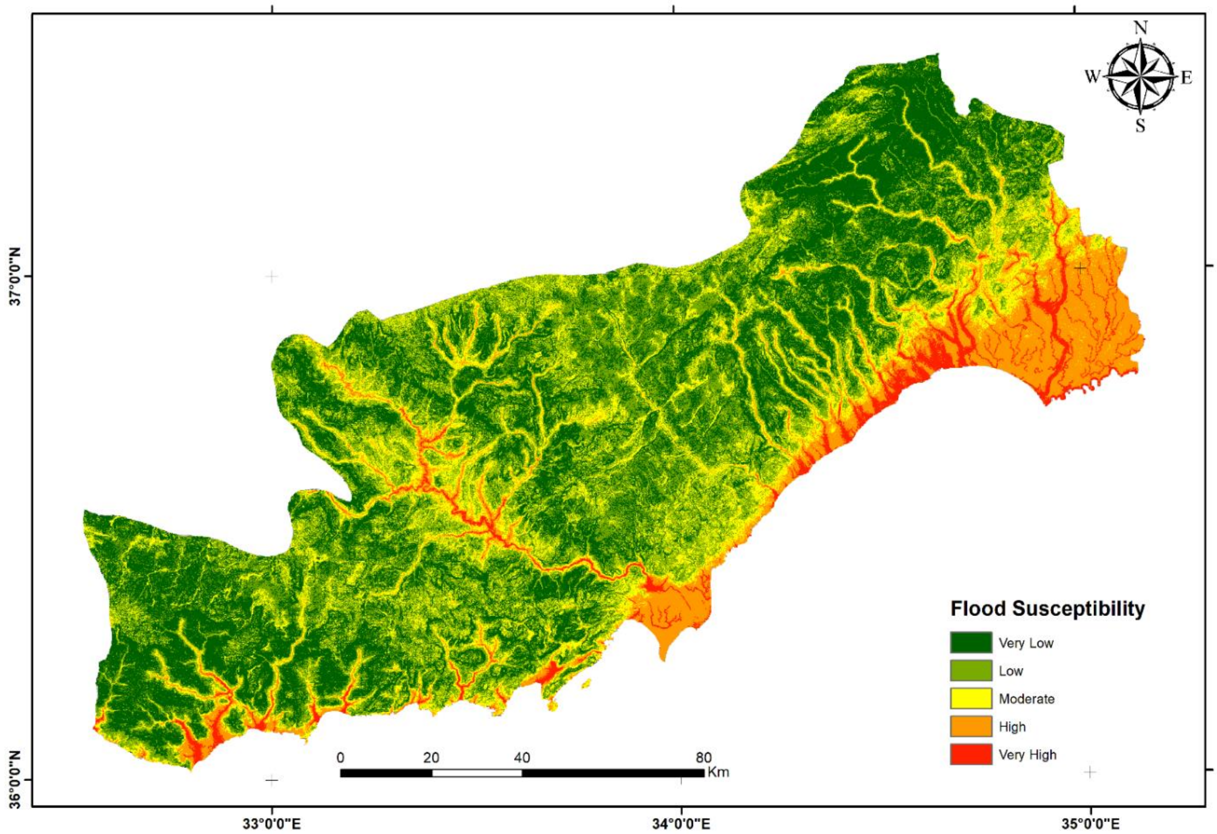

Figure 3. Flood susceptibility map of Mersin

Susceptibility map shows that Mersin is under risk by % 3,07 Very high, %11,42 High, %18,67 Moderate, %31,48 Low and %35,34 Very low. These percentages were calculated by pixel ratios.

But more than %50 population of Mersin and especially high populated districts are under risk of flood.

4. DISCUSSION

AHP is a simple and executable weighting technique that depends on expert's opinion. Assigning weights for parameters may introduce some uncertainty. Analytical Hierarchy Process can be used for regional and local susceptibility analysis(Liu *et al.*, 2018).

Study area (Mersin) is a coastal zone with low elevation. Most of the built-up areas of districts were constructed over river zones by drying them. Especially high populated districts such as akdeniz, mezitli, toroslar, yenişehir. Elevation, distance to river and drainage density are important factors for flood susceptibility mapping. Thus, high risk within these parameters creates greater risk for flood.

High and very high risk zones validated by checking flood events of Mersin. Validation showed us that floods occur on sensitive (high and very high) areas of susceptibility map.

5. CONCLUSION

Flood is one of the most destructive natural disasters worldwide. Thus, prediction of flood areas is important to foreseen future risks. Method and materials can be different while preparing a susceptibility map. There is no such thing as best in method. Every study area requires a pre research to find out which method is better for that zone. Another factor for choosing method is materials that will be used. Finding all datasets is not possible for every study area. Quantity and quality of datasets a big factor while choosing suitable method.

Flood susceptibility map can be used for land selection of investments, agricultural activities, industrial zones, residential zones. Being able to see sensitive locations will allow us to prepare for risks in existing developed areas.

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