Determination of flood risks in the yeniçiftlik stream basin by using remote sensing and GIS techniques

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ABSTRACT: Floods are among the most devastating natural hazards in Turkey and worldwide, causing the largest amount of casualties and property damage. GIS and remote sensing methods are very attractive, fast, and reliable tools for various flood applications and management. In this study, we investigated floods which occurred and are likely to occur in a study area in Istanbul, Turkey, to determine the potential use of these tools with respect to these floods. Floods which caused loss of life and property in the Yeniçiftlik stream basin located within the boundaries of Beykoz, a suburb of Istanbul, attracted our attention due to their negative impact on human life and activities, and this was selected as the study area. Many geographical parameters such as vegetation, topographic and geologic features, precipitation, and land use features play a significant role in the occurrence of flood related disasters. Data used were topographic, soil, vegetation, and geological maps at scale 1:25000, IKONOS pan-sharpened imaging (02.03.2008), as well as aerial photographs taken in 2006. Using the Arcinfo 9.2 Spatial Analyst module, flood risk maps were created, assigning different weights to vegetation, geologic and land use features, and other morphometric features such as slope, aspect, and so on. Land use and vegetation features were determined by applying a supervised classification technique to IKONOS data. All data were processed using HEC-GeoRAS (in ArcGIS) and HEC-RAS software. The results indicate that the precision and diversity of the data used greatly affects the precision of these risk maps.

1 INTRODUCTION

Floods are one of the significant natural disasters that substantially impact the economic and social lives of people in many regions and countries (CEOS, 2003). Various computer models have been developed in order to understand floods that occur and demonstrate their impacts. It is possible to classify the basic components of these models into four parts: hydrological models, hydraulic models, flood mapping, and generation of spatial data for use in the model (Snead, 2000). Together with developments in GIS technologies and the increase in resolution of Digital Terrain Models (DTM), applications for research related to hydrology, water resources, and the environment have increased. Integration of GIS with hydrologic and hydraulic modeling software has been realized for various purposes. Among these, HEC-GeoRAS is an ArcGIS extension program that has been produced for generating spatial data. With this extension it is possible to extract and process geometric data pertinent to river basins over the existing DTM, read the database pertinent to HEC-RAS hydraulic software, and map water levels and floods (Özdemir, 2007). HEC-RAS is a one-dimensional hydraulic program in which water surfaces related to continuous flows can be calculated and discontinuous streams can be modeled (USACE, 2002). It has data storage and management capacity and is widely used throughout the world . With the utilization of GIS and development of this technology, hydraulic models of river systems can be generated more easily (Maidment, 2000 and 2002). Thus by using flood modelings performed with GIS and hydraulic software, it is possible to calculate the distribution area of water surfaces of potential floods and to make relevant volume and depth calculations. The study field was located within the borders of the Beykoz district of the Istanbul province between UTM/ED_1950/Zone35N, Max. West: 681127-436675, Max. East: 686377-436675, Max. North: 4561198-271090, and Max. South: 4549558-271090 coordinates. Yeniçiftlik stream basin has a perimeter of 33 km and a surface area of 31.1751 km^2; the north–south length of the basin is 12.555 km, and the east–west length is 3.75 km. The research field comprised a 3.66 km^2 area of this basin (Figure 1).

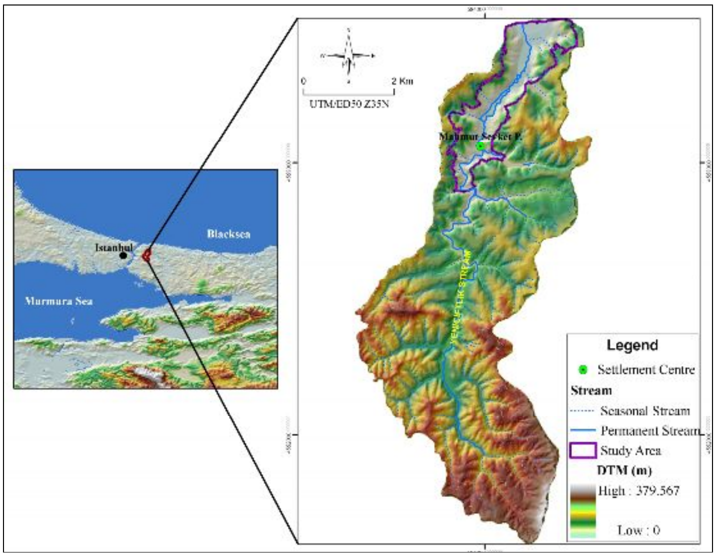

Figure 1. Study Area.

2 DATA AND METHOD

Data resources used in the study were topographical data at scale 1:25000, IKONOS pan-sharpened (02.03.2008) satellite imaging, aerial photographs (2006), and digital soil, geological, and vegetation data at scale 1:25000. Two different methods were applied to determine the flood areas. The first of these methods was assessed using HEC-GeoRAS and HECRAS, using the data generated. Applications related to this method are shown in Figure 2. Since there was no high resolution DTM for the study field, stages of the study were compiled under four main headings: Triangular Irregular Network (TIN) generation, processes performed using HEC-GeoRAS, processes performed using HEC-RAS, and generation of flood maps. One of the most significant stages in flood mapping is the generation of high resolution DTMs (Sugumaran and Davis et. al., 2000). For this the TIN model, which best reflects the linear layers from geometric data, was used (USACE, 2005). TIN were generated using data generated by 5–10 m contours on topographic maps at scale 1:25000. The geometric data to be used in flood mapping were generated using HEC-GeoRAS. IKONOS pan-sharpened satellite imaging and aerial photographs were used for generating these. Data completion for geometric data was performed using HEC-RAS.

The second method used was Multi-Criteria Decision Analysis (MCDA). In this method the parameters are taken into consideration one by one in order to determine the areas of risk. Basic elements of the basin's flood risk comprised the geographical properties of the basin and its flood characteristics. A flow chart detailing the method is shown in Figure 3. Applying this method, the parameters pertinent to flood risk in the study field were assessed and weight values were assigned to each.

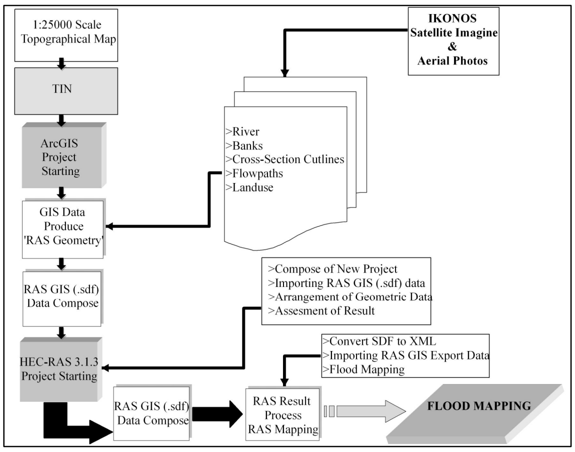

Figure 2. Flow chart of Hec-GEORAS and Hec-RAS Applications.

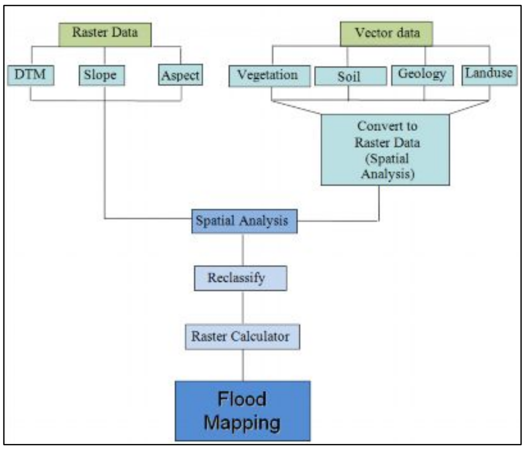

Figure 3. Flow chart of MCDA method.

3 HYDRAULIC MODELING AND FLOOD MAPPING

3.1. *Creation of geometric data*

In order to conduct hydraulic modeling of rivers, geometric data for river basins are required (Özdemir, 2007). These data generally comprise establishing the connection of river systems, bed cross-sections, defining connection points, data pertinent to hydraulic structures, and cross-section interpolations. Geometrical data used in the study included rivers, riversides, flow paths, cross-sections and land use. Only data from the 3.66 km^2 study area of the Yeniçiftlik stream basin were used. In generating geometric data, the generation of TIN models as base data was performed as a priority. Digitalization of geometric data in the area to be modeled after TIN generation and data entry processes were performed (Figure 4).

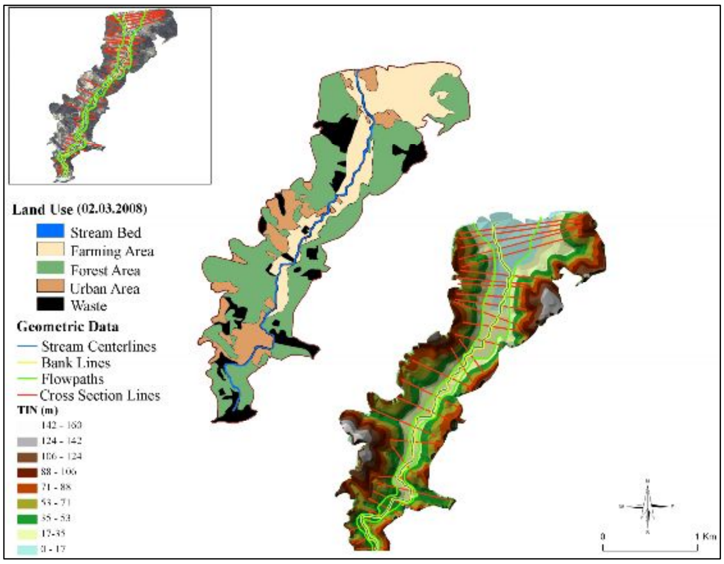

Figure 4. Using geometric data in flood mapping.

Land Use Type	Manning's N
Stream Bed	0.050
Farming Area	0.060
Urban Area	0.055
Forest Area	0.150
Waste	0.070

Figure 5. Manning's value.

In digitalizing these data, the TIN model, IKONOS pan-sharpened satellite imaging, and aerial photographs were used. Some characteristics emphasized in the digitalization of the geometric data and data entry were as follows:

- Rivers, river coasts, and stream paths were digitalized towards the flow direction.
- Definitions of river paths were conducted (such as right, left and center).
- Bed cross-section lines were digitalized towards river stream direction, from left coast to right coast.
- Cross-section lines intersected the river and stream paths once and both lines intersected with each other.

A land use layer was generated using IKONOS pan-sharpened satellite imaging. For types included in this layer Manning's N value, which is accepted as an indicator of the action demonstrated against the stream hydraulically, was assigned (Figure 5; Fleckkenstein, 1998; Özdemir, 2007).

3.2 *Generation of the flood model*

HEC-RAS is one-dimensional software in which the steady and unsteady streams are modeled (Merwade, 2006). Geometric data for the river basin and data for the stream have to be entered in order to conduct the modeling (Özdemir, 2007). Geometric data pertinent to the study field were generated using HEC-GeoRAS and other data were completed in this section (Figure 7). Subsequently the data was transferred to HEC-RAS software. After completing the entry of geometric data, stream data for the river in the area in which modeling was to be conducted were entered. Stream data for the repetition frequencies of floods were accepted as Steady Flow data. Since the gradient value of the study field was not very high, subcritic was selected for stream calculation. Subsequently, models for 10, 50, and 100 years were generated (Figure 6).

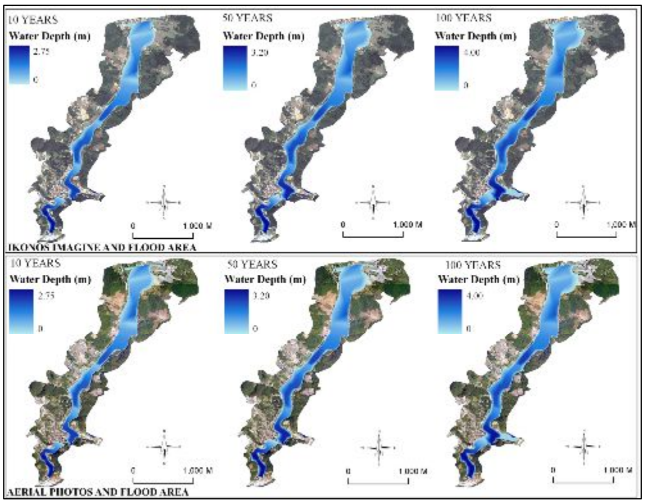

Figure 6. Models pertinent to different flood repetition frequencies.

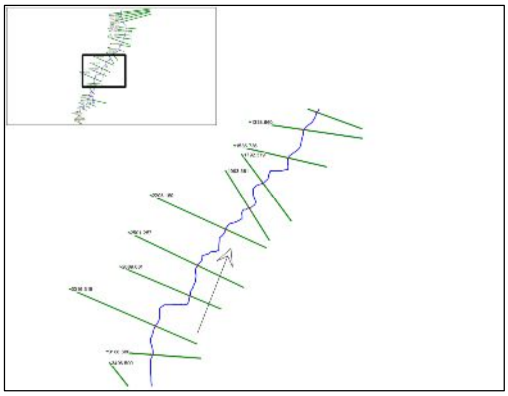

Figure 7. Geometric data generating from Hec-RAS.

3.3. *Multi-criteria decision analysis (MCDA)*

This is the process of assessing options of a definite number using numerous criteria which are generally weighed, contradict one another, do not use the same unit of measurement unit, and may even take qualitative values for the purposes of selection, sorting, classification, prioritization, or screening (Yoon ve Hwang, 1995). In the method applied, parameters were taken into consideration one by one while areas of risk were determined. Basic elements relevant to the flood risk conducted for the study field comprised the geographical properties of the basin and its flood characteristics. The flow chart of the method is detailed in Figure 2. Since a critical stage is the generation of basic base maps whilst carrying out the risk analysis of the study field, base data for topographic, vegetative, soil, and geographical characteristics were generated from data for the basin digitalized in the digital media. Land use characteristics and geological and soil data were converted into raster data structure for analytical purposes. In the method applied, the parameters for flood risk in the study field were assessed and weight values were assigned to each (Figure 8). Weight values ranged between one and 10. Those closer to one have the least risk and those closer to 10 have the highest risk. The reclassify module of the Spatial Analyst module is used for applications at this stage. Due to the fact that the impacts of parameters on relevant disasters show varying rates, different values are assigned to each by means of this module. The overlay process is realized following this value assignment. This process was performed using the Raster Calculator module of the Spatial Analyst module. As the method was applied, the flood risk map of the study field was determined (Figure 9). Five different degrees were selected for flood risk. Examination of the flood risk map shows in particular that the risk is quite high in parts where the gradient values are low and the settlement and agricultural areas are intense (Figure 9 and 10).

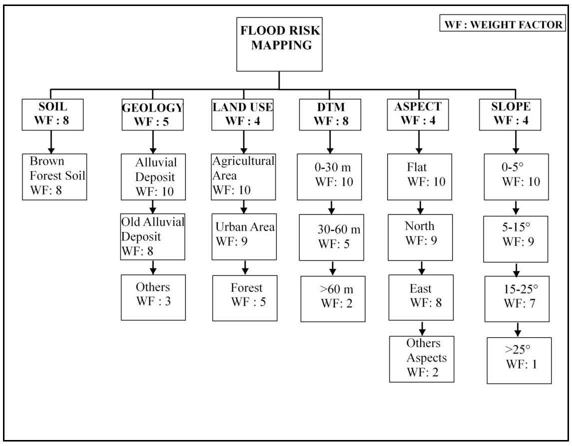

Figure 8. Decision hierarchies for flood hazard index ranking.

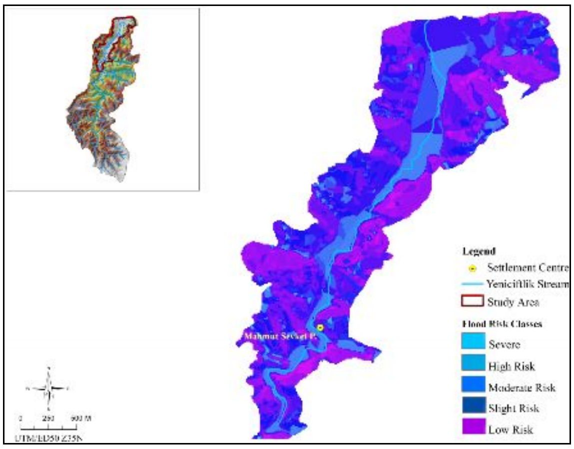

Figure 9. Flood risk mapping generating from MCDA method.

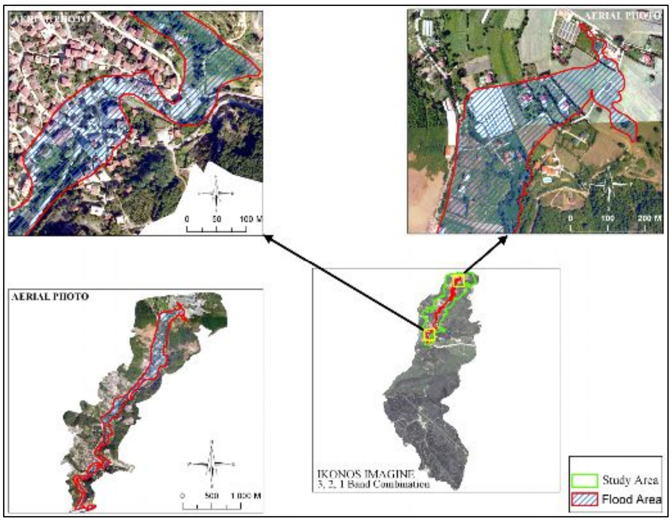

Figure 10. Displaying aerial photos of flood area determined by MCDA method.

4 CONCLUSION

In this study an area of 3.66 km^2 in the Yeniçiftlik stream basin was examined. Flood risk analysis was performed using Remote Sensing and GIS. Remote Sensing data were used in determining land use, demonstrating changes in land use, determining the river basin characteristics of the study field, and creating geometrical data for the floods. As the study field is a basin with flood risk potential any flood taking place may significantly impact the settlement areas, industrial zones, and productive agricultural fields. In the hydrologic and hydraulic modeling conducted for flood risk studies, flood rates for 10, 50, and 100 years were calculated using maximum flood rates for 33 years, and flood risk maps were generated through hydraulic modeling using the values obtained. A TIN model was used for the geometric data generated in the hydraulic model application, and the river's central line was digitalized over stream paths and cross-sections, satellite imaging, aerial photographs, and the TIN model. Land use factors between the cross-sections were determined, flood models were created according to different repetition frequencies, and a 100 yearly potential flood model was utilized for determining the flood areas. In MCDA, another method used, criteria for risk analysis were determined using the Analytic Hierarchical Method. In the study, the flood risk was considered according to five parameters: the DTM of the basin, gradient, aspect, geological characteristics, and land use. As a result of the model generated it was determined that the flood potential of the study field is high. Due to the risk of flooding in the coming years it will be necessary to take relevant precautions in this area and implement them rapidly. It has also been determined that in order to conduct a more realistic modeling using HEC-GeoRAS and HEC-RAS hydraulic software, further data would be required.

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