PREDICTION OF HYDROLOGICAL MODEL OF YUVACIK CATCHMENT BY USING REMOTE SENSING AND GIS INTEGRATION

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Abstract – Application geographic information systems (GISs) and remote sensing integration to provide determination of runoff from watershed has performed increasingly attention in recent years. In this study, Natural Resources Conservation Service Curve Number (NRCS-CN) method was used to estimate Curve number according to the factors of hydrological soil group, land use, land treatment, drainage basin characteristics, meteorological and hydrological parameters. The study was performed on the Kirazdere sub-basin of the Yuvacık dam basin in north-west Turkey. Remotely sensed images from Landsat satellite was used to develop land use map of the study area. GIS analysis, based on land use and hydrological soil map data, was processed so as to determine spatially distributed runoff curve numbers on a 30-meter grid.

Keywords: Remote Sensing, GIS, Curve Number, DEM, Runoff.

1. INTRODUCTION

Land use characteristic is an inevitable parameter of hydrological model that affects infiltration, erosion, evapotranspiration. Accurate prediction runoff volume is need specifically distributed land use data within coordinated its location of basin. Quantification of the hydrological budget is extremely difficult over large spatial domains and over large time periods through direct observations, as in situ observations are labor intensive and expensive. Satellite remote sensing provides a methodology to overcome these issues with a broad spatial coverage and a repeat temporal coverage. (Lakshmi,2004).Remote sensing technology play an important role to determine measurements many hydrological parameters used in hydrological and environmental model applications. Due to pixel format of digital satellite image of remote sensing is suitable to integrate into geographic information system with spatial and non-spatial data. It is accepted that combining remote sensing data with vector data and statistical data has several advantages, and thus information is be only maximized, but land use planning is based on reliable decisions (Quarmby and Cushnie, 1989). To date, most of the work on adapting remote sensing to rainfall- runoff modeling has been performed with the Soil Conservation Service runoff curve number model. This approach's show that remote sensing data is an essential substitute for land use map so as to use to evaluate runoff coefficient parameter successfully. Several study represent that land use changes determined from Landsat images are useful in studying the runoff response of the basin. (Melesse et al. , 2002).

A GIS may be used to analyze and manage large quantities data that hydrological model demand and simples data input and model calculations, as well as providing an efficient way to display and manipulate results. It also makes the processes clear for the user to understand and modify for different conditions. (Frankenberger et al., 1999). It is used by hydrologist to estimate disturbed rainfall-runoff model parameters and capture, proceed and visualize hydrologic data. The high temporal and spatial variations of rainfall patterns and surface conditions exist in the basin, leading to complexities in the modeling efforts. Based on the GIS technique, the DEM of the study basin was successfully used to delineate the stream network and extract information of catchments characteristics. (Huang et al, 2003).

2. DATA

To apply the method to basin area, the model parameters are derived from remotely sensed and ground truth data. The ground truth data were collected by using Global Position system. The main satellite images used in this study are the Landsat TM. İt are taken from dry season to ensure comparable according to vegetation and soil moisture etc. Standard topographic map (scale 1:25000) is used to create Digital Elevation model. Hydrological soil group are classified by using soil maps

3. METHODOLOGY

3.1 Data Processing

Geographic Information Systems can be defined as computer based tools that display, store, analyze, retrieve, and generate spatial data. GISs include cell based analyses that are necessary for hydrologic modeling. Digital elevation models (DEM) are an array of elevation values that provide an estimate of terrain surface useful in computer-based hydrogeomorphological analysis, such as the automated extraction of topographic relief, elevation contours, basin stream networks and basin boundaries (O'Callaghan and Mark, 1984; Band, 1986; Moore et al., 1991).Digital elevation models (DEMs) are routinely used for hydrological applications because overland flow routing is controlled by topography (Moore et al., 1991).A 30 m Digital Elevation Model of the whole area was extracted from standard topographic map. Topographic information such as ground slope, flow direction, concentration time is derived from digital elevation model.

3.2 Image analyses

Preprocessing is important step to improve the quality of the data with appropriate enhancements filter techniques. Raw digital images are a representation of the irregular surface of the earth and contain geometric distortions are so significant that they can not used as maps. (Lillesand and Kiefer, 1999). A first order polynomial equation is used to convert source file coordinates to

rectified map coordinates, which resulted in an improvement quality of satellite image data sets.
Landsat image and was registered to UTM zone 35N, ED50 datum International 1909 geoid were carried out by GPS-measured control points using the nearest neighbor-resampling algorithm. Landsat image was classified using unsupervised classification method to analyze land use/cover. Individual land use/land cover types captured in remotely sensed synoptic imagery exhibit a range of reflectance values throughout the spatial extent of the data product.(South et al,2004).In this study the Iterative Self Organizing Data Analysis Technique(ISODATA) which may serve as the benchmark for all unsupervised classification algorithm was used. It is an iterative method that uses the Euclidean distance as the similarity measure to cluster the data elements into different classes. (Dhodhi et al.,1999). This method is used to derive land cover characteristics of basin with the advantages of the manipulation of classes in signature files as in controlled classification.

3.3 SCS Curve Number Method

Soil Conservation Model is distributed watershed modeling the most widely used in hydrological model. Estimating direct runoff from storm rainfall is based on methods the Soil Conservation Service model developed by United States Department of Agriculture (USDA, 1972). The SCS method computes direct runoff through an empirical equation that requires the rainfall and a watershed coefficient as inputs. (Nayak et.al, 2003). The general equation for the SCS curve number method is as follows;

$$\frac{F}{S} = \frac{Q}{P - I} \qquad (1)$$

Where F, actual retention (mm); S, watershed storage (mm); Q, actual direct runoff (mm); P total rainfall (mm); I, initial abstraction (mm).

From the continuity principle,

$$F = (P - I) - Q \qquad (2)$$

The SCS method defined the value of the initial abstraction I to be approximately equal to 20% of the watershed storage S by means of rainfall and runoff data from experimental small watersheds.

$$I = 0.2S \qquad (3)$$

Solving equation 1 and 2 simultaneously,

$$Q = \frac{(P - 0.2S)^2}{P + 0.8S} \qquad (P \geq 0.2S) \qquad (4)$$

Which is the rainfall-runoff relation used to compute direct runoff from storm rainfall in the SCS method. The watershed storage, *S, and* the curve number CN are related by,

$$S = \frac{25400}{CN} - 254 \qquad (5)$$

The parameter CN, having a range of values between 0 and 100, called the curve number. In this method, a curve number (CN) is assigned to each watershed or portion of watershed based on soil type, land use and treatment, and antecedent moisture condition. (Hydrology Handbook, 1996).

4. DESCRIPTION of STUDY AREA

In this study Kirazdere is one the most large sub-basin of Yuvacık dam basin is selected. (Figure 1) Yuvacık dam watershed is located in the eastern part of Marmara Region of Turkey at about 40°32´-40º41´North and 29º29´-30º08´East.The watershed has an area of 25759 hectares. Yuvacık dam was built in 1999.It is play an important role to supply water of the city of Izmit in Turkey. Yuvacık dam basin encompasses mainly three important sub-basins. One of them, Kirazdere sub- basin includes one rainfall and runoff gauge station. Mean annual precipitation is approximately 771.7 mm, and the average annual temperature is 14.8°C.

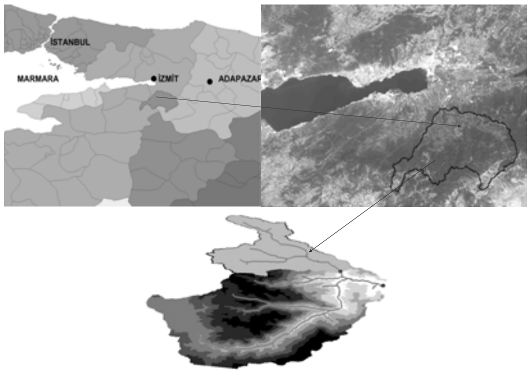


Figure 1. Study area

5. RESULT

Standard topographic maps (scale 1:25000) were used in our study to create digital elevation model with 30 m grid size. Basin basin physical characteristics were determined by using digital elevation model for input data to hydrological model application (Figure 2). Longest flow path and centroid length characteristics were calculated by means of GIS: the longest flow path, upstream elevation, downstream elevation, slope between the endpoints, and slope between 10% and 85% of the length. (Table1)

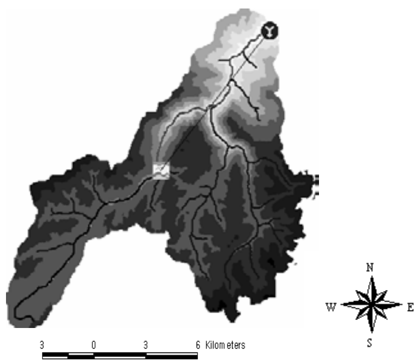


Figure 2. Physical characteristics of basin area

Table1.The stream physical characteristics

Wshid	DSElv	Slp_Endpt	Slp_1085	LongestFL	CentroidalFL
67	0.0017	0.011	0.010	20583.658	9736.0220

Soils are classified into four hydrologic soil groups, which are A, B, C, D; each group was used to determine curve number. Soils in group A have well drained, in group B moderately-drained, in group C poorly drained, in group D very poorly drained. (Figure 3).

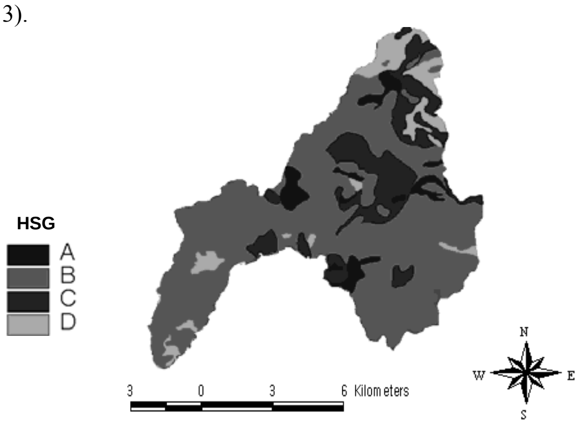


Figure 3. Hydrological soil map

Classified Landsat images integrated Geographic Information System with Hydrological soil map applied Soil Conservation Soil Curve Number Method to calculated curve numbers distribution of sub-basin area.(Figure 4) To calculate curve numbers and runoff depth for the entire sub-basin, vector coverage of soil showing the HSG, and land cover and land use classification (Anderson et al., 1976) were overlain each other.

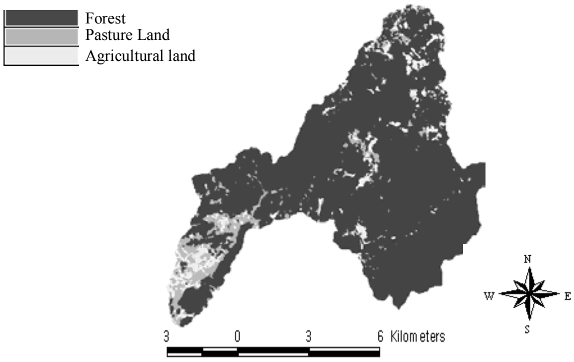
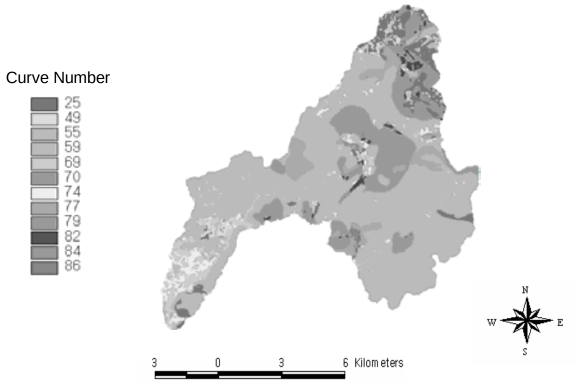


Figure 4.Classified image

The soil layer and classified image were both converted a 30 meters grid cell size in order to calculate curve number value. Curve numbers were calculated by means of National Engineering Handbook (NEH 4) chapter 4 guidelines. (Figure 5).



6. CONCLUSION

In this work, we showed that remote sensing satellite images are used determine curve number distribution of the basin area with 30 m spatial resolution. It would be used to calculated runoff depth for a 100-yr maximum design rainfall event for the Yuvacık basin area. The steps and methods used in this study can be further developed and applied to a watershed. The results of that study would be very useful for flood forecasts and the development of hydraulic structure. These parameters are useful to understand hydrological characteristics of basin area. Thus, it has become inevitable to determine rainfall/runoff model by using remote sensing and GIS technologies. So, to achieve the obtaining runoff depth of the basin area, Soil Conservation Model was used. Curve number is a model coefficient, which was determined based on the factors based on land use/cover from classified Landsat images and hydrological soil groups.

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