

INVESTIGATION OF RAINFALL- RUNOFF MODELLING OF THE VAN LAKE CATCHMENT BY USING REMOTE SENSING AND GIS INTEGRATION

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ABSTRACT:

The aim of this study is to determine runoff depth of the Van Lake basin by using remote sensing and geographic information system (GIS) integration. While determining the results we used various data sets such as Landsat satellite image, 1:25000 standard topographic map, and soil map data. Standard 1:25000 topographic maps were used to derive digital elevation model. Sub-basin area and physical characteristics of the study area such as slope and aspect maps were determined with the help of DEM into GIS as layers. Digital Elevation Model was used to determine basin model through Hec-GeoHMS . Landsat image was classified by using digital image techniques and integrated into GIS with hydrological soil map. Soil Conservation Curve Number method was used to determine curve numbers and runoff depth distribution of the basin area. We show that remote sensing and GIS technology are suitable for analysis of the runoff depth distribution of the basin area. The proposed method can be applied to predict for ungauged watersheds, flood, and other water resource applications.

1. INTRODUCTION

For the last years, engineers and planners have been working on the modeling of environmental system. An accurate modeling of basin will require determination of the spatial and temporal distribution of hydrological parameters. Remote Sensing and Geographic Information System with increasing the advancement of the computer technology have been applying to extract land surface properties at spatial and temporal scales which are very useful input data for hydrological model.

Land use and land cover have several impacts on the hydrological cycle such as floods, droughts, runoff, water- quality. Rainfall-Runoff model play an important role to understand hydrological condition of basin areas and predict their behavior over time. Accurate process for prediction runoff volumes is used to flood warning, navigation, water quality management and many water resource applications. Land surface characteristics are important to generate rainfall-runoff model, distributed model need remote sensing and GIS technologies to produce more accurate spatial data which play an important role to derive input data such as land use/cover, soil type.

Conventional hydrological model, to estimate runoff model input parameters have to be determined through ground truth measurement which still need huge economic and time-labor consuming. Therefore, remote sensing can also provide information about runoff input data most cost-effective and large-land coverage. Moreover, these data is suitable to enter into GIS. All kinds of data can be stored as different layer by using GIS techniques.

Remote sensing can be used to obtain extremely valuable input data for distributed hydrological model. Remote sensing can provide measurements of many of the hydrological variables

used in hydrologic and environmental model applications, either as direct measurements comparable to traditional forms, as surrogates of traditional forms, or as entirely new data set. A.M.Melesse, S.F. Shih ,2002).

GIS is a computer based system used capture, store, analyze, update and display data. GIS handle mainly two classes of data which are spatial data, identifying the location and topography of map and attribute data, identifying the characteristics of these feature. GIS technology provides a flexible environment for entering, analyzing, and displaying digital data from various sources necessary for urban feature identification, change detection, and database development. (Q.Weng,2001). With the aid of a GIS, distributed parameter of hydrological model, digital elevation model (DEM) processing have become popular analysis watersheds topographic.

In this study, Soil conservation curve number method was used to determine runoff depth with the aid of remote sensing and GIS technologies.

2. DESCRIPTION OF STUDY AREA

Van Lake locate in the eastern of Turkey at about 43°E and 38.5°N, and it is the largest lake in Turkey. Its average elevation is 1650 m above mean sea level. The average extent of the lake is 3600 km² . It is surrounded by relatively large drainage basin of 12 500 km² (M Kadioğlu et al, 1997). Only in the north-east, near Ercis and Muradiye, and in the north-west near Ahlat is a total of 19,000 ha of land irrigated with water from streams. The lake has no outlet and is fed by numerous streams including the Karasu, Hosap, Güzelsu, Bendimahı, Zilan and Yeniköprü Streams. Three of the rivers

only have hydraulic stations used to determine hydrological parameters Hosap river is one of them and the most longest river included four runoff gauge station to measure runoff value. In the last decade, the water level in Lake Van has risen about 2 m; and, consequently, the low-lying inundated along the shore are now concerning local administrators and government official, and affecting irrigation activities and people's properties. (Kaynak et al, 2002) The study region is then subdivided into different hydrologic sub-systems for analyze characterizing of hydrology. In this study, Hosap river sub-basin area is selected to determine runoff value with help of the remote sensing and GIS integration included Soil Conservation method. (Figure-1)

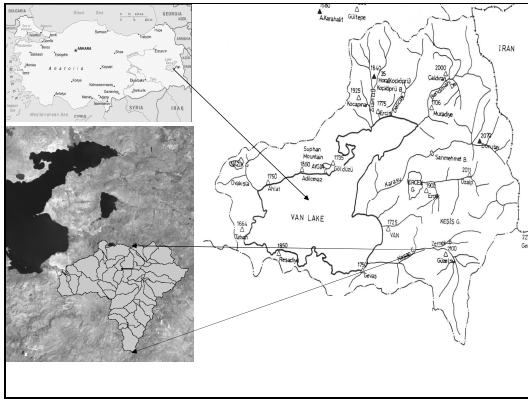


Figure1. Study area

3. DATA AND METHODOLOGY

Data Sources

In the study, a variety of data including satellite images, digital elevation model, soil map, standard 1:25000 scale topographic maps and various thematic maps obtained from various sources have been used as data sources together with ground truth studies that have also been carried out. Landsat TM image from May 1987 was acquired and used in the analysis. The Landsat TM data have spatial resolutions of 30 m. The thermal band (6) was not used in the study because it represents emitted energy or radiant temperature and has large spatial resolution (120 m). TM bands 1-3 represent visible electromagnetic radiation with wavelengths 0.45-0.52, 0.52 and 0.60 and 0.63-0.69 μm , respectively. Band 4 represents near infrared with wavelengths of 0.76-0.90 μm , and bands 5 and 7 represents mid-infrared with frequencies of 1.55-1.75 μm , and 2.08-2.35 μm , respectively. The radiometric resolution of all the data was 8 bit with 256 levels of brightness. Digital elevation model derived from 1: 25000 scale topographic maps to analyze basin area. Digital soil maps of basin areas are prepared by KHGM (General Directorate of Rural Services) in relation with 1:25000-scale topographic maps. Digital soil maps prepared by KHGM include several parameters for each polygon existing in the map.

Geometric correction

Remote sensing data are distorted by the earth curvature, relief displacement and the acquisition geometry of the satellites (i.e. variations in altitude, aspect, velocity, panoramic distortion). The intent of geometric correction is to compensate for the

distortions introduced by these factors so that the corrected image will have the geometric integrity of a map (Lillesand and Kiefer 2000). Rectification is the process of projecting the data onto a plane, and making it conform to a map projection system. Satellite images are rectified using 1:25000 standard topographic map and are geometrically corrected to the coordinate system using the Universal Transversal Mercator (UTM) projection system with 0.5 pixel RMS accuracy.

Classification

Image classification is the process of establishing a link between a category of interest and a related spectral class. Unsupervised classification is based on the fact that most remotely sensed image composed of spectral classes that are reasonably uniform with respect to reflectance across one or more spectral channels, and can therefore be defined and mapped. In this study, the Iterative Self Organizing Data Analysis Technique (ISODATA) unsupervised classification algorithm was used (Tou et al, 1974). The purpose of classification is to link the spectral characteristics of the image to a meaningful information class value, which can be displayed as a map so that resource managers or scientist can evaluate the landscape in an accurate and cost effective manner (Weber et al, 2001) Firstly, Landsat data acquired on May 1987 applied pre-processing techniques such as image enhancement to increase visual distinctions. Landsat image classified by using ISODATA unsupervised algorithm techniques.

SCS Curve Number Method

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

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

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,

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

The SCS method defined the value of the initial abstraction I to be approximately equal to 20% of the watershed storage S,

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

Solving equation 1 and 2 simultaneously,

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

The watershed storage, S , and the curve number CN are related by,

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

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).

In this study, we focused to improve characterization of hydrologic condition of basin by using data acquired from Landsat satellites. Spatial data obtained from remote sensing was processed using digital image processing techniques in order to identify model inputs as land cover/use, drainages,

Digital Elevation model integrated into GIS, processed with the aid of Hydrological HMS program into Arcview derived physical characteristics of drainage basin area such slope, aspect, sub-divided basins areas. (Figure-2)

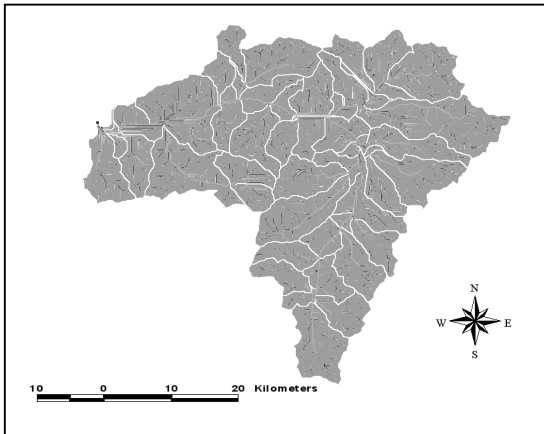


Figure 2 Sub-basin area

Soil maps of rural areas are supplied by KHGM (General Directorate of Rural Services) in relation with 1:25000-scale topographic maps. 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)

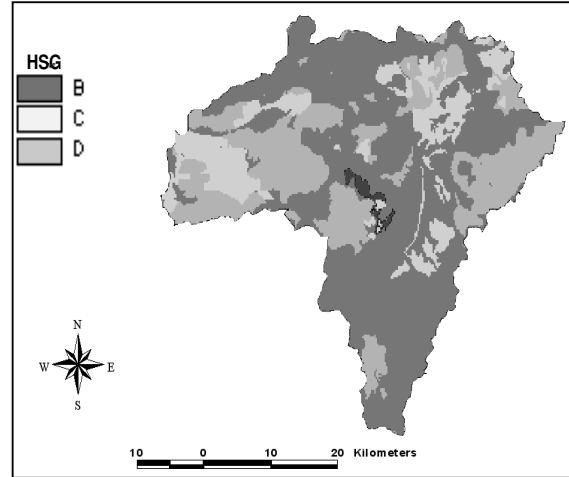


Figure 3 Hydrological soil map

4. DISCUSSION AND RESULTS

Classified Landsat images integrated Geographic Information System with Hydrological soil map applied Soil Conservation Soil Curve Number Method to calculate curve numbers distribution of sub-basin area. To estimate 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. The soil layer and classified image were both converted a 30 meters grid cell size in order to calculate curve number and runoff depth value. Curve numbers were calculated by means of National Engineering Handbook (NEH 4) chapter 4 guidelines.

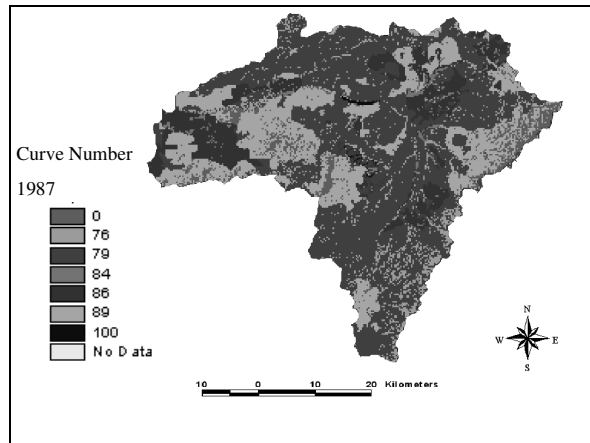


Figure 4 Curve Numbers 1987

Runoff depth distribution of the basin was calculated by using curve number distribution values with in case of total daily 85 mm rain fall in the GIS as layer.

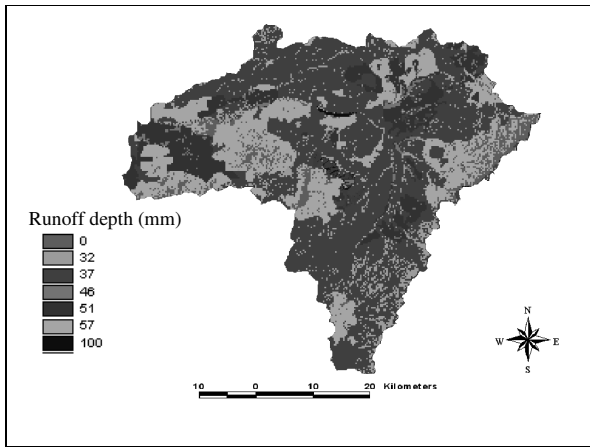


Figure 4 Runoff depth distribution 1987 (mm)

5. CONCLUSION

In this work, we showed that remote sensing satellite images are very useful to determine runoff distribution of the basin area with 30 m spatial resolution. There are several parameters effecting water level fluctuations such as climatic condition like rainfall and runoff. Water level of the Van Lake has been changed abruptly in recent years because of these parameters. Due to lack of the rainfall and runoff gauge station, it has not been able to understand hydrologic condition of Lake Van catchments. 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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