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DETERMINATION OF BASIN CHARACTERISTICS BY USING GEOGRAPHICAL INFORMATION SYSTEMS (GIS)

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Abstract. Climate change, population growth, and economic development will significantly affect the availability of water resources for agriculture in different regions. It is estimated that this effect will occur as a decrease in rainfall and an increase in drought in the Thrace region. To produce the sufficient amount of food which will be demanded by the increasing population, inadequate water resources must be used more efficiently. In this study, the Watershed Modelling System (WMS) version 7.1 was used for the delineation of boundaries of Topcu sub-basin of the Ergene river basin located in the Thrace region of Turkey. Digital elevation model (DEM) which has been obtained from Aster satellite for the year 2007 was used for extracting drainage networks and watershed delineation. Typical properties like drainage areas, characteristic length and slope of sub-drainage areas have also been determined. The largest sub-basin area is 121.8 km^2 while the smallest sub-basin area is 4.7 km^2. These parameters have been stored to use for later hydrological analyses.

Keywords: basin, WMS, hydrology, GIS.

AIMS AND BACKGROUND

Watersheds play an important role in hydrological modelling and many hydrogeological processes, such as soil erosion, mass movements, sediment transport and land cover changes, which are strongly linked to this spatial reference unit[1]. GIS is well suited for efficiently deriving watershed and drainage network characteristics[2].

Digital elevation models (DEMs) are useful and popular tools from which topographic parameters can be quickly and efficiently extracted for various hydrologic applications[3]. Generation and application of DEMs for hydrological modelling[4,5] and grid size[6,7] on the derived parameters (slope, aspect and drainage network) have been widely published.

Most modelling users of elevation data order the data directly in raster format which can easily obtained from remotely-sensed images[8]. There has been a huge amount of research and development in using the raster data for different hydrologic studies[9,10].

There has been a great amount of studies carried out on the usage of DEM data which belong to the Aster satellite image. In accordance with the process of

DEM data, it is stated that Aster Dem can be used in analyses in scaled 1:25 000 to up[11,12].

In this study, with the usage of the DEM, which has been obtained from the Aster satellite images, the determination of basin characteristics has been aimed at. The study was carried out in Topcu sub-basin of the Pinarbasi basin in Tekirdag in the Thrace region. WMS was used in the determination of basin characteristics.

EXPERIMENTAL

This research project was conducted in Topcu sub-basin of the Ergene river basin. It is located in the Thrace region of Turkey, Topcu sub-basin is located between 41°23′-41°35′ north latitudes and 27°36′-27°46′ east longitudes.

A Topographic parameterisation program (TOPAZ) developed by the USDA-ARS, National Agricultural Water Quality Laboratory was used. A modified version of the program is distributed with Watershed Modelling System (WMS) for the purpose of computing flow directions and flow accumulations for use in basin delineation with DEMs**.** Topaz is based on digital elevation drainage network model (DEDNM) analytical software[13]. DEDNM module is based on the D-8 method for flow routing[14,15]. D8 method is the simplest and most widely used method. It consist of 5 stages for determination of drainage networks and basins. The first procedure is the removal of 'pits' or artificial errors in the DEM, the second is computing depressionless flow direction, third is computing flow accumulation, fourth is assigning a constant threshold and the last procedure is extracting the drainage network and determination of watershed[16,17].

During the study, DEM has been used which is obtained from the ASTER satellite image. ASTER is a high-spatial-resolution multispectral imager currently scheduled for launch into Earth orbit in mid-1999, on the first platform of NASAs Earth Observing System (EOS AM1) (Ref. 18).

Filling depressions in a DEM. A common problem with drainage network delineation using DEM is the presence of depressions. A DEM depression occurs when all neighbouring cells are higher than the processing cell, which has no downslope flow path to a neighbour cell. Depressions could be real components of the terrain, but are also the results of input errors or interpolation artifacts produced in DEM generation or resampling process[19]. If these problems are correct, it will cause to inaccurate representation of flow accumulation, and thus drainage networks. Therefore, the depressions are commonly removed prior to DEM processing for drainage identification[20].

Flow direction. DEM-based flow direction methods can be widely distinguished in 2 categories. One of them is 8-direction (D8) method[21,22], and the other one is multiple flow direction method[23,24]. The D8 method[15,25] defines landscape properties for each individual raster cell by the evaluation of itself and its 8 immediately adjacent cells. The downslope flow routing concept defines the drainage and flow direction on the landscape surface as the steepest downslope path from the cell of interest to one of its 8 adjacent cells[26,27].

Each grid cell owned a height value on DEM. There are 8 possible directions for each cell. Flow direction in each cell can be only to one cell which has the lowest elevation values. Depending on flow direction process cell (x) is encoded to correspond to the orientation of one of the 8 cells[14].

Flow accumulation model. Flow accumulation is a measure of drainage area in units of grid cells. The flow accumulation value of a cell is the sum of the flow accumulation values of the neighbouring cells and the number of neighbouring cell which flow into it. Accumulation should start from the upstream end of all flow paths and work downstream. If one of the cells assign zero it means that it does not receive the flow from any neighbour cell and if it assigns 1 it means it receives the flow from 1 cell[14].

Drainage network. TOPAZ is based on tree concept and one of this is critical source area (CSA) concept. This concept defines the channels drainage the landscape as those raster cells that an upstream drainage area greater than a threshold drainage area which is called critical source area (CSA). The CSA concept controls the watershed segmentation and all resulting spatial and topologic drainage network and sub-catchment[28].

Determination of basin. With the aid of the flow accumulations, the location of the watershed outlet was determined and outlet feature point was created. All cells which have flow direction towards the outlet are accepted in this basin[14].

Determination of sub-basin. Several automated tools can delineate reasonable sub-watershed maps on the basis of a DEM (Ref. 29). Flow direction and drainage network are used for determination of sub-basins. Within the drainage network, each flow parts set apart from the intersection point. Flow areas which belong to each branch were determined automatically. Sub-basin can be created by selecting an outlet or changing a node to an outlet. According to this selection, WMS creates one or more sub-basin.

RESULTS AND DISCUSSION

The results of Pinarbasi and Topcu sub-basin, which were investigated using the Topaz model on WMS are given below. Natural depressions were identified with WMS and by the help of a Topaz file, filling has been prevented. With the help of the Topaz model, before getting into flow direction calculations, the depression cells which have developed for any reason have been fixed. By comparing the elevation values of each 3×3 matrix cells with the aid of D8 method in the Topaz model, flow direction model in which the flow will be towards the lowest elevation value has been created.

Flow direction derived a grid of flow accumulation, counting the number of cells upstream of a given cell (Fig. 1). As the flow accumulation model has been created streams in the area has been viewed in different thicknesses according to the value they have. Through the model, when a stream gets flow from many cells then the thickness of it will be accordingly more. Thus, the cell at the outlet point of basin is composing the thickest line since the outlet point is received the most flow in the basin. Moreover, to reinforce the visual analysis, streams can be shown thinner or thicker with the selection of flow accumulation threshold.

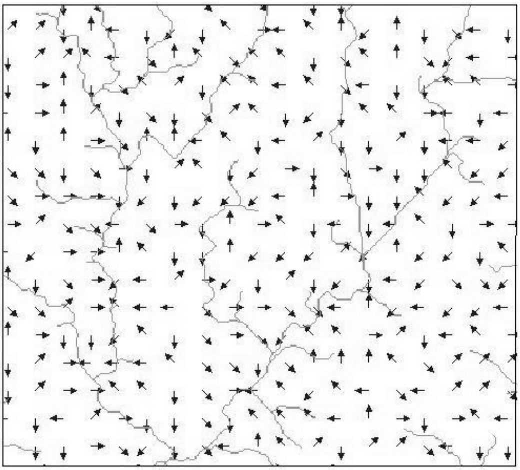

Fig. 1. Flow direction and flow accumulation model

The outlet point on the stream which gets the biggest flow has been identified, thus the biggest drainage network in that region has been created. By covering the drainage network with a polygon, the boundaries of the basin have been determined. Consequently, the sub-basin has been constituted in the way as the main basin constituted. With this method many sub-basin can assign (Fig. 2).

Many raster GIS programs have similar capabilities, but WMS has been designed specifically with the purpose of hydrologic and hydraulic modelling in mind. The drainage module in WMS allows you to automatically delineate streams and watershed/sub-basin boundaries on the land surface represented by the DEM. A lot of factors related to geometry and topography are calculated by WMS such as area, average basin slope, basin length, etc. (Mann and Parsons, 2004). Parameters belonging to the Pinarbasi basin and Topcu sub-basin are given in Table 1.

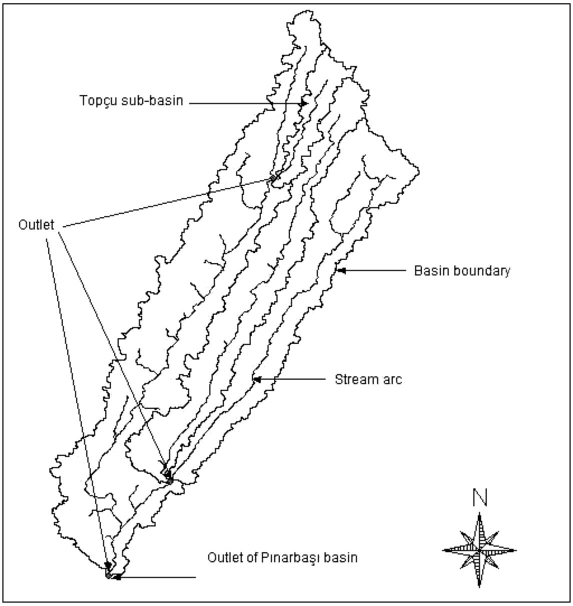

Fig. 2. The Pinarbasi basin

Table 1. Some of topographic parameters of the Pinarbasi and Topcu basins

Variable	Parameter	
	Topcu	Pinarbasi
A (basin area)	5.79 km^2	119.63 km^2
BS (basin slope)	0.0626 m/m	0.0699 m/m
AOFD (average overland flow) (distance within the basin)	0.51 km	0.65 km
%NF (north aspect)	0.45	0.45
%SF (south aspect)	0.55	0.55
L (basin length)	5.76 km	24.28 km
SHAPE (shape factor)	5.72 km^2/km^2	4.93 km^2/km^2
Sin (sinuosity factor)	0.98 (MSL/L)	1.23 (MSL/L)
AVEL (mean basin elevation)	239.41 m	183.50 m
MFD (maximum flow distance)	7.40 km	32.14 km
MFS (maximum flow slope)	0.0113 m/m	0.0061 m/m
MSL (maximum stream length)	5.63 km	29.90 km
MSS(maximum stream slope)	0.0098 m/m	0.0050 m/m
CSD (centroid stream distance)	0.17 km	15.06 km
CSS(centroid stream slope)	0.0080 m/m	0.0033 m/m

CONCLUSIONS

With the help of DEM data which acquired from the Aster satellite images, basin characteristics have been tried to be identified. DEM data are commonly used in hydrologic models. Raster type DEM data are preferred since it is easy to store, update and use. According to the developments in computer and GIS technologies, not only the accuracy of the DEM data increase but also instruments aiming to process the data differently are being developed. This has let us reach the accurate data easily.

In this study, with the help of WMS which can process direct raster data and can make automatic hydrologic analysis, drainage networks and basin area which belongs to research area have been identified. During the calculation, basic characteristics of the basins on which the research is conducted have been calculated as well. The data of drainage network and basins have been transformed into different formats to be used in latter studies.

Geographical information systems (GIS) are special systems since geographical information can be stored safely in the creation of digital databases and can be quickly reviewed and commented by users. Therefore, GIS is considered as an useful tool for integrated water management.

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