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Delineation of the Watersheds Basin in the Konya City and Modelling by Geographical Information System

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Abstract: The purpose of this study is to delineation the watersheds basin in the Konya city from topographical map using Shuttle Radar Topography Mission digital elevation model (SRTM 1 Arc Second Digital Terrain Elevation Data - Global (approx. 30 m resolution)) in ArcGIS. Digital elevation model (DEM) was used as a main data source combination with the PC version of ArcGIS and Extract hydrologic information from a digital elevation model (DEM) in ArcGIS using Hydrology Tools. DEM's have been developed by the Earth Resources Observation Systems (EROS) Data Center of the United States Geological Survey (USGS), and downloaded from their internet site. A spatial hydrology model is one which simulates the water flow and transport on a specified region of the earth using GIS data structures, the boundary of the region is represented by a polygon, such as a river basin boundary or an aquifer boundary. The results showed that by using watershed function in ArcGIS for watershed delineation in the Konya city basin and sub basin can be determined. This work is mainly a case-study of simple applicability of GIS as a tool of watershed delineation and drainage extraction. Watershed boundary, flow direction ,flow accumulation, flow length, stream ordering have been prepared using Hydrology Tool; and contour has been prepared using Surface Tool in ArcGIS-10.3.1 software and DEM, and build model for these processes then show the DEM in three dimension in Arcsine. The total area of watershed calculated from watershed layer is about (40233.94 km^2) but according to Konya Wikipedia it is works out to be (38,873 km^2).
Keywords: *Digital elevation models, Watershed delineation, Flow direction, Model Building, Geographic information systems.*

Introduction

A key advantage of GIS is its ability to integrate, manage, and analyze large volumes of data, particularly over very large areas. GIS enables data to be integrated and viewed on the scale of an entire watershed, allowing a holistic approach to water resources management (Jordan 2004). ArcGIS Hydrology tools could be used to describe the physical components of a surface by identifying sinks, calculating flow direction and accumulation, stream order, delineating watershed and creating stream network (Pareta and Pareta 2012, FATTAH and YUCE 2015, Woodrow, Lindsay et al. 2016). Over the past 15 years, research has demonstrated the viability of techniques for automatically deriving a wide variety of topographic and topologic watershed information directly from Digital Elevation Models (DEM) (Charbeneau and Hodges 2005). Digital Elevation Model (DEM), is a grid of elevation values at constant horizontal grid spacing. Such a DEM can be used to determine topographic attributes such as slope (S) and aspect (ψ), and watershed attributes such as basin area and stream network topology (Goulden, Hopkinson et al. 2016). Delineating catchment areas by employing geographic information systems (GIS) and digital elevation model (DEM) is being preferred to manual techniques due to the improved accuracy, less duplication, easier map storage, flexibility, and simplicity in data sharing, timeliness, greater efficiency and higher product complexity. GIS tools can be automated in implementation of various practical applications of watershed delineation. DEM is a 3- D representation of a landscape, which is widely utilized in hydrological analyses including delineation of watersheds (FATTAH and YUCE 2015). The algorithms are essentially raster based, the products (watershed polygons, drainage line networks, and tabular attribute information defining watershed linkages) can readily be converted to vector form (Jenson and Domingue 1988). Flow routing algorithms use DEMs to estimate the direction of the downslope redistribution of topographically

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driven overland flow passing through each grid cell in the DEM (Tribe 1992, Woodrow, Lindsay et al. 2016). The large amount of spatially detailed information included in a raster and handled within a GIS offers opportunities for hydrologic modeling. Raster tools provide a convenient method for delineating watersheds from Digital Elevation Models (DEM), as well as calculating parameter values for watersheds based on raster datasets describing the spatial distribution of each parameter. Distributed parameters can be summarized and accumulated using a variety of raster tools available in GIS software. (Charbeneau and Hodges 2005). Watersheds can be delineated in Geographical Information Systems (GIS) by keeping track of flow direction and number of upstream points for each grid point in a DEM. Once the watershed is delineated it can then be used to crop out data from other layers (e.g. land cover, area, etc.), that are useful in hydrology (Isenstein, 2013, Mi-Hyun). The aim of this study is watershed delineation using digital elevation model (DEM) data and several tools from the Spatial Analyst toolbox in ArcGIS.

Materials and Method

Study Area

Konya, 261 km (162 miles) south of Ankara, Konya is a city in Central Anatolia in Turkey which has protected its name for centuries. By area it is the largest province of Turkey, Konya had three central district municipalities (Meram, Selcuklu, and Karatay) and a Metropolitan Municipality. The city lies at an elevation of about 3,370 feet (1,027 meters) on the southwest edge of the central Anatolian Plateau and is surrounded by a narrow fertile plain. Summers temperatures average 30 °C (86 °F). The highest temperature recorded in Konya was 40.6 °C (105 °F) on 30 July 2000. Winters average −4.2 °C (24 °F). The lowest temperature recorded was −26.5 °C (−16 °F) on 6 February 1972. Due to Konya's high altitude and its dry summers, nightly temperatures in the summer months are cool. Precipitation levels are low, but precipitation can be observed throughout the year (From Wikipedia, the free encyclopedia, Konya 2015, Meteoroloji 2016).

Method

Topographical map using Shuttle Radar Topography Mission digital elevation model (SRTM 1 Arc_Second Digital Terrain Elevation Data – Global) at 30 m horizontal resolution was used as main data source. Import several DEM files into ArcMap in order to cover the study area. DEM raster files were converted into a single DEM file using the Mosaic tool in the toolbox to combine all DEM files into one continuous raster layer and then clip raster within Konya Polygon Figure 1. The ArcGIS software (version 10.3.1) with the Hydrology tools extension used. The first step is projected DEM into a coordinate system in which the horizontal units of the x y coordinates are in meters, not degrees. It is important to use a DEM with no depressions or sinks, remove all sinks in the elevation grid from the DEM layer using the Fill function of the Hydrology toolbox, Sinks in elevation data are most commonly due to errors in the data. These errors are often caused by sampling effects and the rounding of elevations to integer numbers. As the cell size increases, the number of sinks in a dataset also often increases, the flow direction raster is generated from the DEM. The flow direction raster shows the actual direction of water flow. Each pixel in the flow direction raster is assigned a slope value, to create a stream network, use the Flow Accumulation tool to calculate the number of upslope cells flowing to a location. The output flow direction raster created in a previous step is used as input, where the cells taking place in the catchment area of each cell are calculated. Flow Accumulation defines a Stream Network, use the Stream to Feature tool in ArcGIS to convert the grid to a linear vector file (shapefile). Extract Stream orders, run Snap Pour Point to snap the pour points to the nearest point of highest flow accumulation. Delineate watersheds using the Watershed function of the Hydrology toolbox. Convert the Watershed layer from a raster to polygon (vector) format before assigning their attributes in the next section of the methodology; Basin is a watershed analysis system that can automatically calculate Depression less flow directions, delineate watersheds/sub watersheds, and extract realistic drainage networks from DEMs, Finally built Model for all these processes.

Eight-direction D8-Flow Direction grid

The flow direction is obtained by checking the elevation difference with the 8 neighbouring cells. The D8 flow direction grid defines the flow direction for each cell in a digital elevation model (DEM) as the direction towards one of its eight adjacent or diagonal neighbours with the steepest downward slope. Flow Direction Coding: 1 -East, 2 -Northeast, 3 -North, 4 -Northwest, 5 West, 6 -Southwest, 7 -South, 8 –Southeast (figure 2) (Garbrecht and Martz 1997). The ESRI Flow Direction Grid (D8) is an integer raster where values, indicated in Figure 3, represent flow direction from the Centre. The main applications of flow direction grids are automated delineations of streamlines and catchment boundaries. Flow direction grids are well suited to the calculation of convergent flow for various hydrological modelling applications associated with streamflow (Hutchinson, Stein et al. 2008).

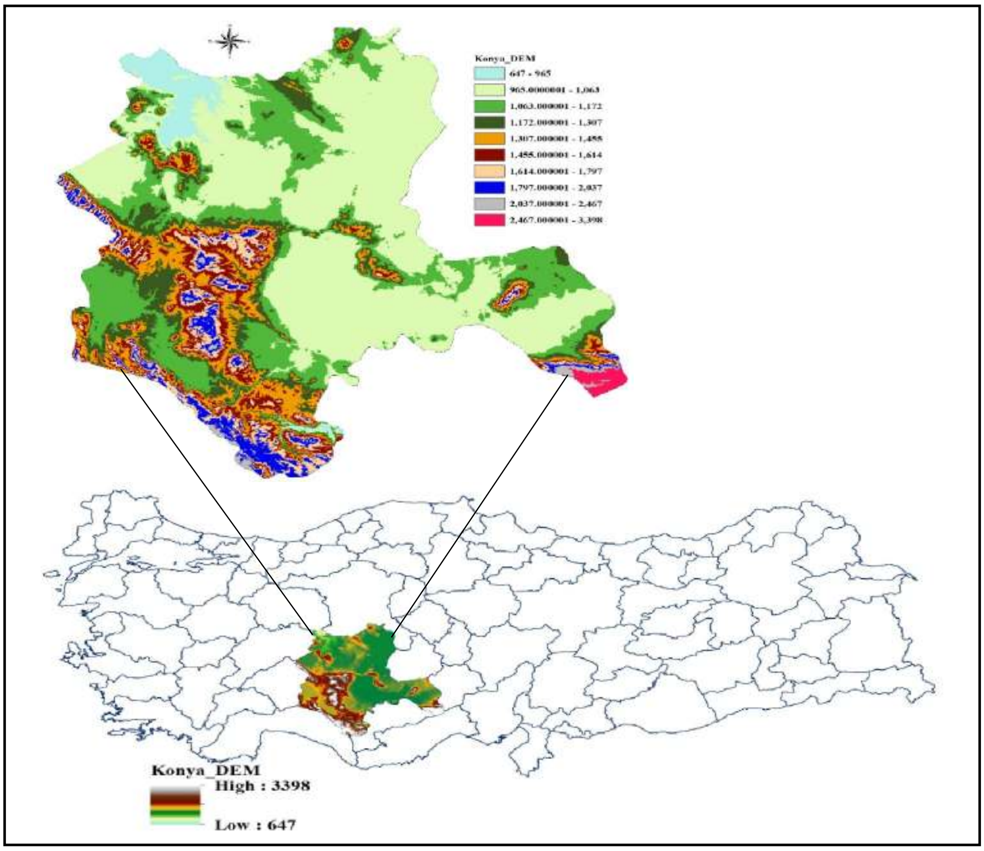
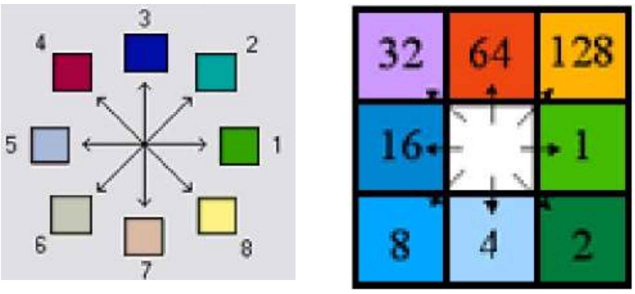


Figure 1 Digital Elevation Map of Konya



Value	Direction of flow from centre
1	East
2	South East
4	South
8	South West
16	West
32	North West
64	North
128	North East
0	Indicates a sink

Figure 2 Raster values represent flow direction from the Centre.

2-4 Watershed Delineation

A watershed, catchment, or drainage basin is the natural hydrologic unit enclosed by a drainage divide lying upslope from a specified outlet, or "pour point." (Zhang, McBroom et al. 2011). The hydrologic modeling involves delineating streams network and watersheds, and getting some basic watershed properties such as area, flow length, stream network density, etc. (Karadağ 2013). Watershed delineation is one of the most commonly performed activities in hydrologic analyses (Abdullah 2011). The conventional watershed process includes sink filling, flow direction determination, flow accumulation and stream definition (Zhang and Huang 2009). Extracting characteristics of the watershed, such as stream network and catchment delineation is essential for hydrological analysis and water resource management in GIS (Li 2014). Watersheds can be delineated by several methods. One used extensively is hand delineation based on the contour information depicted on topographic maps. Even with the advent of GIS technology, this method is often still used prior to creating a digital watershed dataset (Bose, Sridhar et al.). Watersheds can be delineated from a DEM by computing the flow direction and using it in the Watershed function or basin function. The Watershed function uses a raster of flow direction to determine contributing area. We will use the pour points to delineate watersheds, the pour points for the watershed will be the junctions of a stream network derived from flow accumulation. Therefore, a flow accumulation raster must be specified as well as the minimum number of cells that constitute a stream, while the basin function creates a raster delineating all drainage basins in the study area also by depending on raster of flow direction.

Results and Discussions

As Shown in the (figure 1) in digital elevation model, it can be seen that the elevation of the north and east parts are low and start increasing towards the southwest part, where elevation ranges from 647 to 3398 m, it is mean that the slope increases towards south to south western part, and flow direction can be measured easily. The directions of the flow shown in the (figure 3A), some of the directions is towards the northeast and another directions toward northwest, and a flow direction grid with cells having one of the eight flow direction values (1,2,4,8,16,32,64,128) were added to the map document. The resulting flow accumulation raster allows to identify the contributing area at each grid cell in the domain, a very useful quantity fundamental to much hydrologic analysis, where the watershed in Konya is ground water therefore the flow accumulation sounds like an invisible, higher-flow cells will have a larger value, a display of cells with accumulated flow greater than 30,000,000 cells displayed in green as shown in the (Figure 3B).

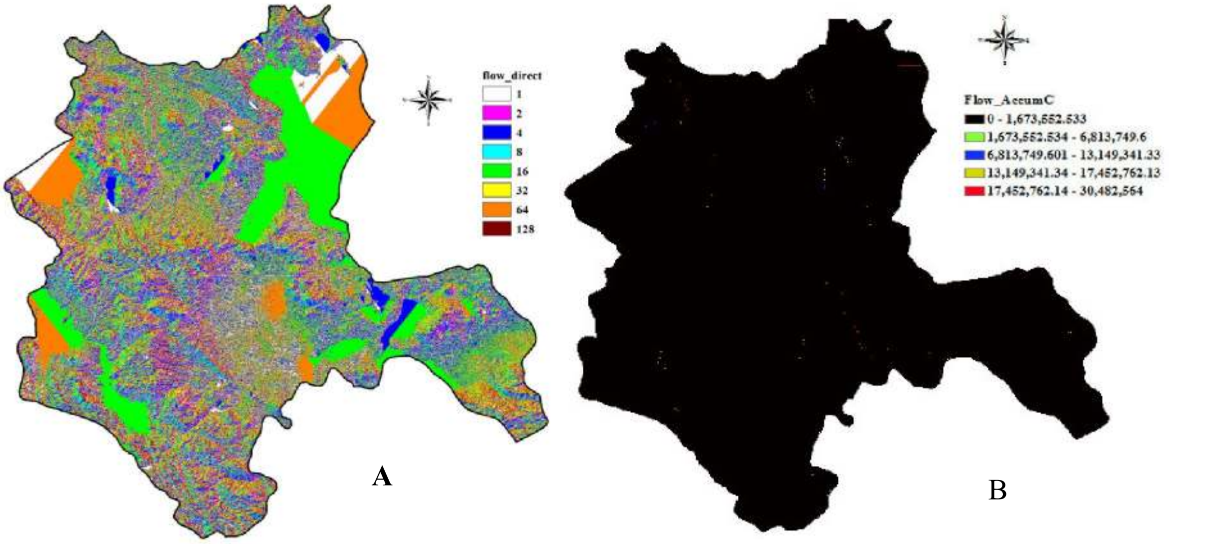


Figure 3 A-Flow Direction **B**-Flow Accumulations

The stream ordering was done with a stream network the largest streams in our study area were assigned the order five shown in the (figure 4). Watersheds can be automatically delineated using the Basin command. Pour points are automatically selected from where the grid drains at its edges, and watersheds are delineated (School of Forest Resources), in this study 3768 catchment watersheds delineated automatically by using basin function of the Hydrology toolbox (figure 5A) with the area of each watershed where the total area of the watersheds is about (40233.94 km^2) shown in (Figure 5B), the Watershed function also provides the capability to delineate catchments upstream of discrete links in the stream network (Figure 6). Figure 7 shows the flow length to the ultimate pour point for each cell. Flow length is the distance travelled from any cell along the surface flow network to an outlet. This can be used to find areas that are closer to headwater locations or closer to stream outlet and calculates the upstream or downstream distance, or weighted distance, along the flow path for each cells, also is often used to calculate the time of concentration of a basin. This would be done using the UPSTREAM option (ArcGIS Desktop Help). In the figure, the cells that are blue are farthest from the stream outlet, and those cells that are red are closest to the outlet. Figure 8 shows the three dimension analysis of Konya DEM and the Stream Network of water resources.

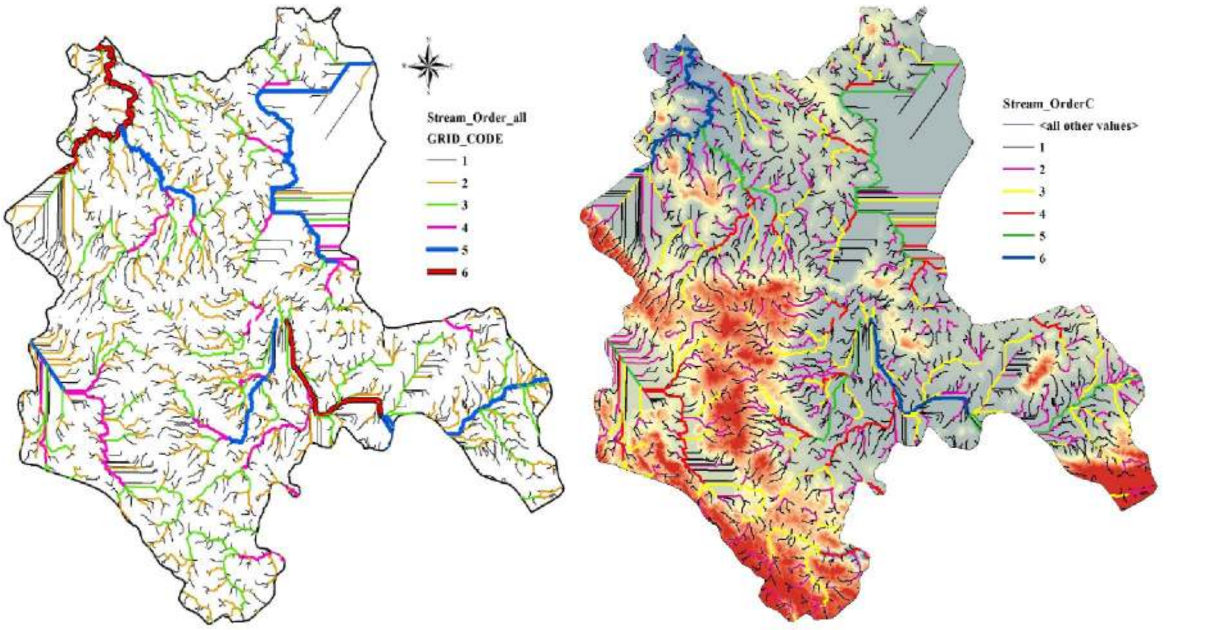


Figure 4 Stream Order Polygon and Raster.

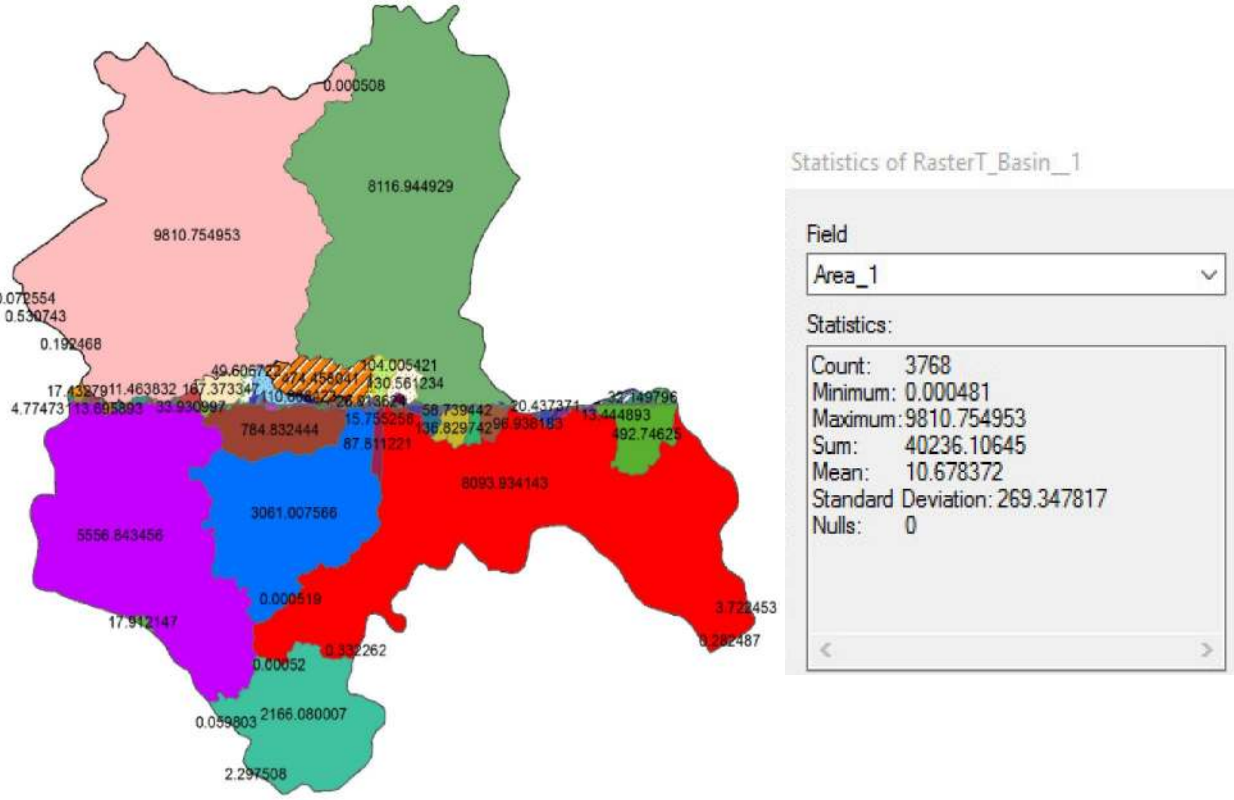


Figure 5 A- Automatically delineating watersheds, area of each Watershed in km^2, **B**- Statistics for Watershed Area of Konya Basin.

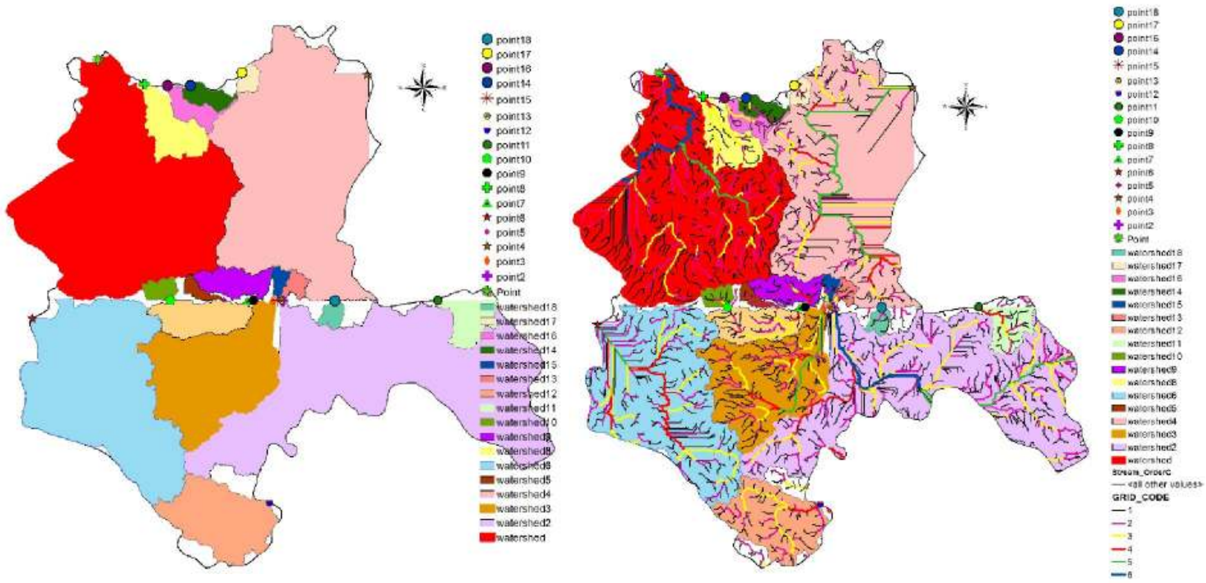


Figure 6 Watersheds Basin, Stream Order with Pour Point for each Watershed.

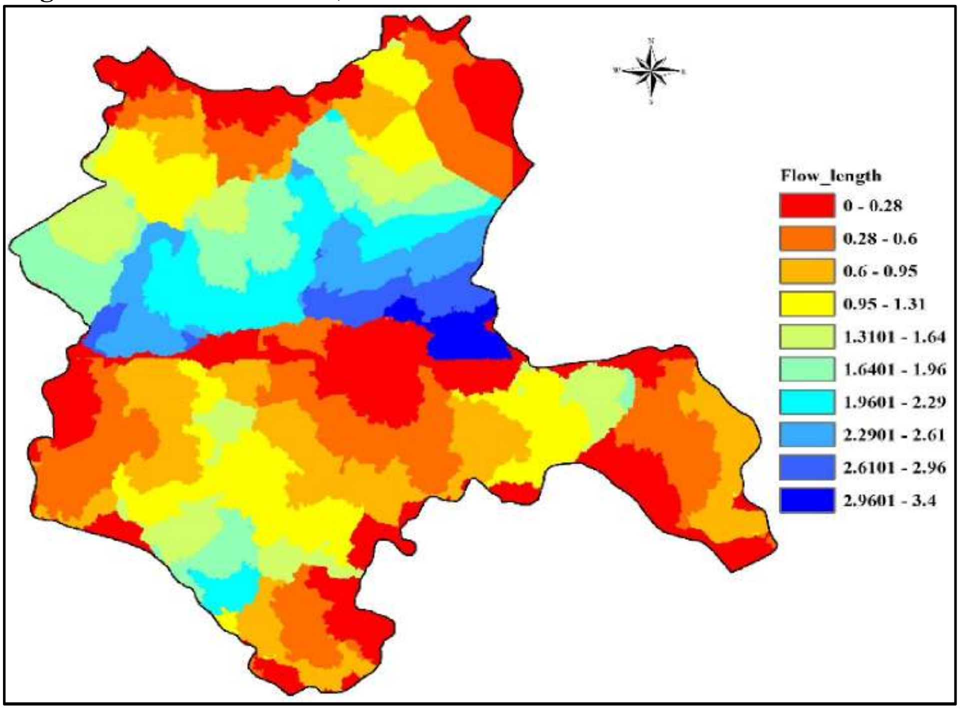


Figure 7 Flow Length

Conclusion

The rapid growth in information technologies, causes GIS has become an important Interface/tool to access geographic information for spatial analysis and applications. Additionally, the system also provides useful functions, such as extract contour, flow direction, flow accumulation, stream network and watershed delineation etc. and exporting them to vector format for further analysis. The described watershed delineation methodology is used to identify the area of interest for which the hydrologic modelling will be performed. The methodology used in this paper allows efficient and consistent watershed delineation on DEMs of any size, where can be used into water resources management.

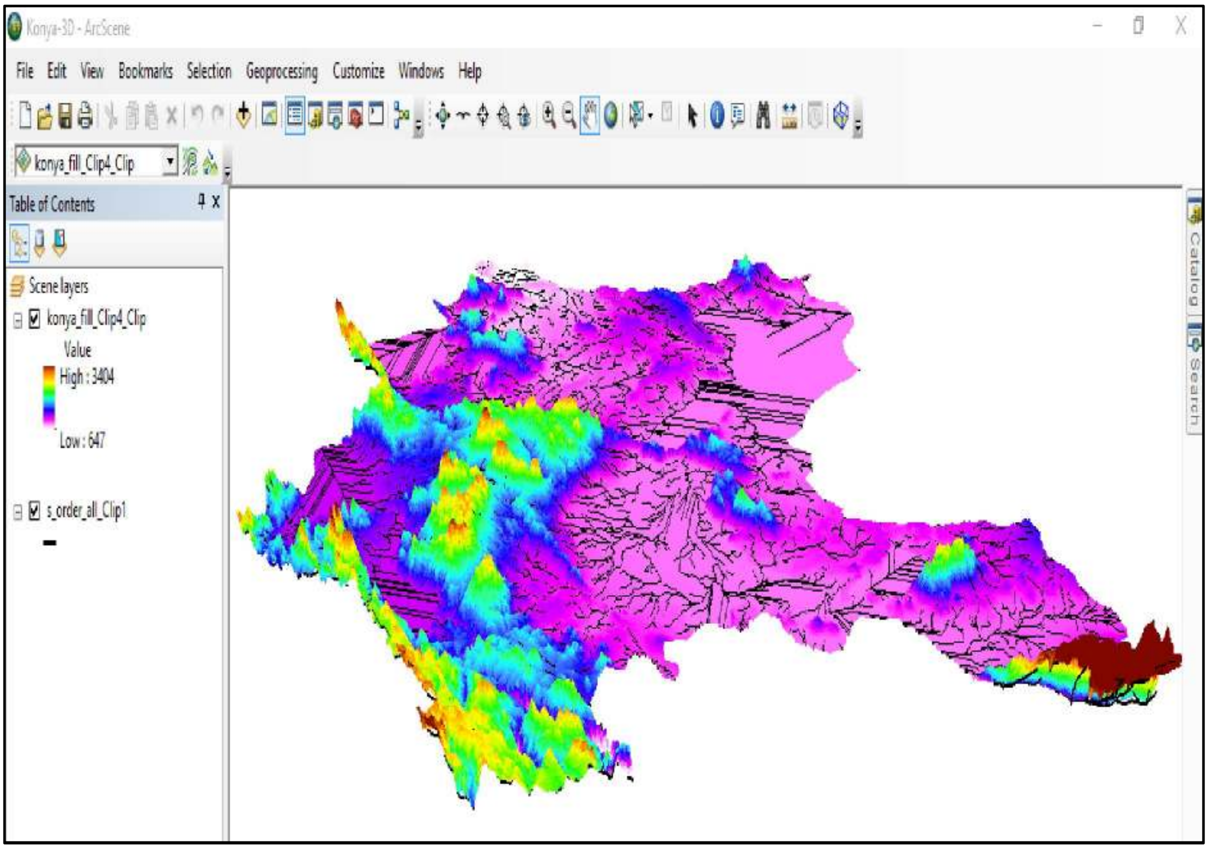


Figure 8 3D Analysis for Digital Elevation Model of Konya with the Stream Network.

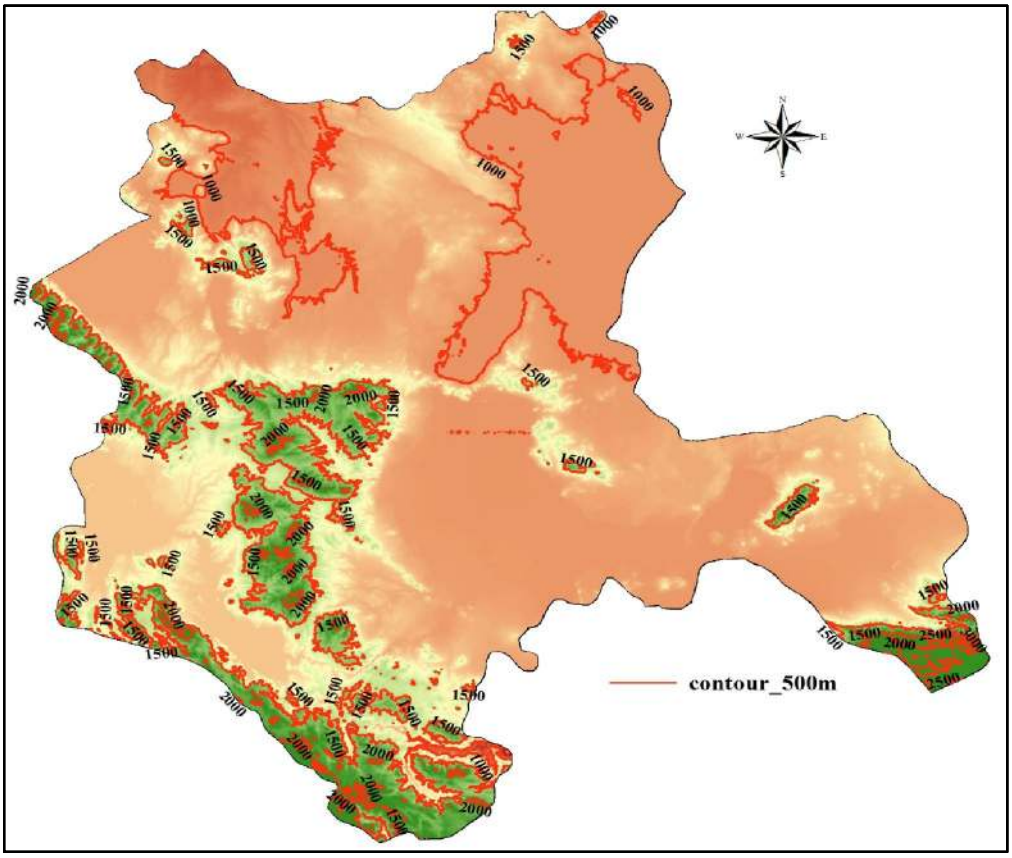


Figure 9. Contours Creates from a Raster Surface.

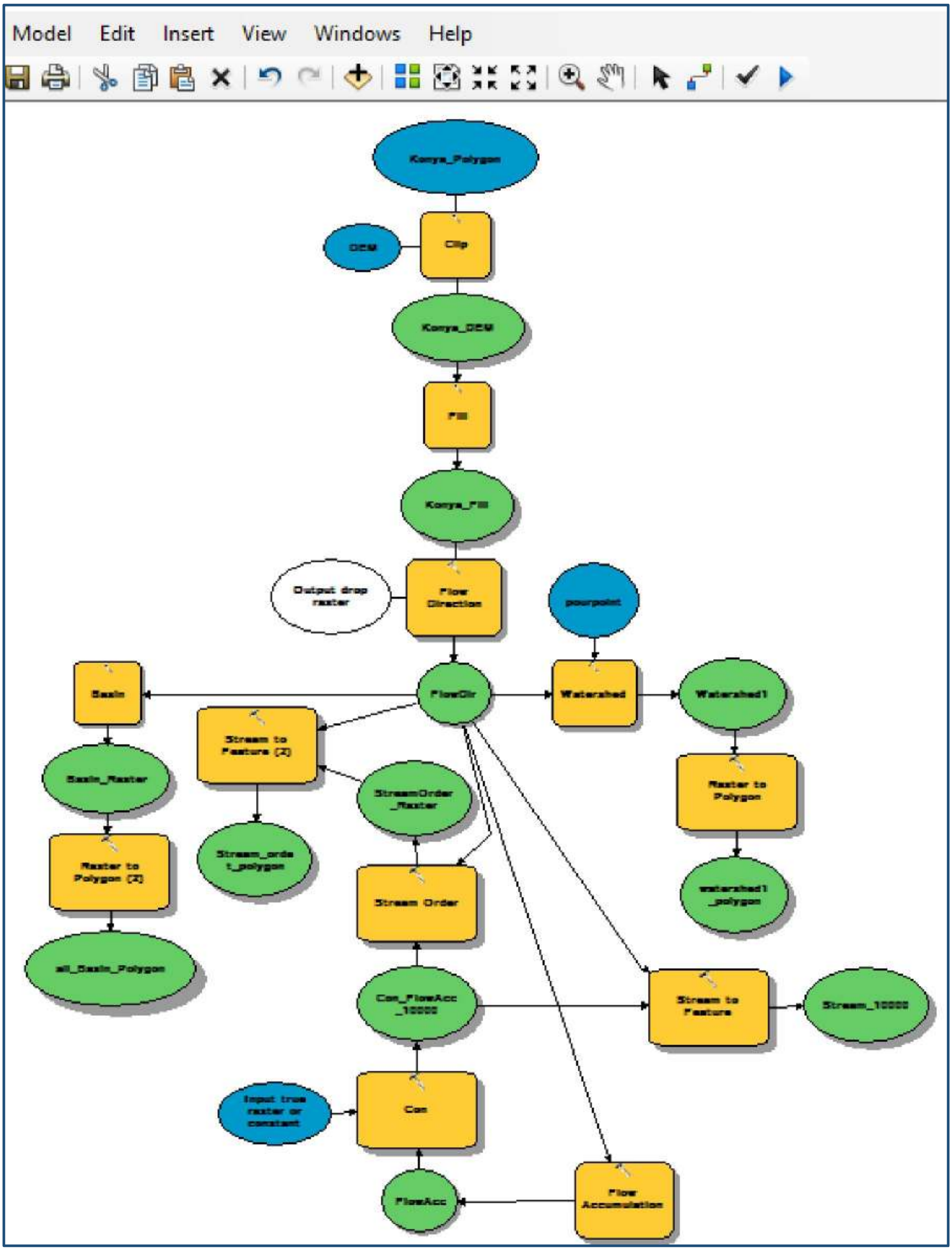


Figure 10 The Tools Using in Model Building with Processing to Watersheds Delineation

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