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DETERMINATION OF CATCHMENT CHARACTERISTICS OVER BALLIKAYA SUBBASIN IN CEYHAN WATERSHED VIA ARC-GIS ENVIRONMENT

CEYHAN'DAKI BALLIKAYA HAVZASININ KARAKTERISTIK ÖZELLIKLERININ ARC-CBS ORTAMINDA BELIRLENMESI

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ÖZET

Medeniyet göstergesi olan su canlıların yaşam faaliyetlerini sürdürebilmesindeki yegane kaynaklardandır. Mevcut su kaynaklarından faydalanabilme (su kaynaklarının kurumaya karşı kontrol edilmesi, kalitesinin korunumu gibi) veya oluşabilecek fazla suyun risklerini minimize etmek amacıyla (taşkın gibi) havza yönetimi günümüzde büyük rol oynamaktadır. Bu amaçla, doğru bir şekilde havza sınırlarının belirlenmesi ve buna bağlı olarak yağıştan akışa geçiş süreçlerinin simülasyonlarında kullanılmak üzere gelişen teknoloji ile birlikte sayısal yükseklik modelleri (SYM) kullanılmaktadır. Bu çalışmada, Ballıkaya mevkiindeki (Ceyhan Havzası) nehir ağının tanımlanması, akım güzergahının, kümülatif akım haritasının, havza sınırlarının saptanması bunlara ek olarak havza alanı ve eğimi gibi karakteristik özelliklerinin belirlenmesi amacıyla yüksek çözünürlükteki SYM haritalarından faydalanılmıştır. Bu çalışma, SYM verilerinin ve Arc-GIS programının havza analizlerinde ne kadar pratik ve önemli olduğunu ortaya koymaktadır. Elde edilen SYM haritaları Arc-GIS ortamında işlenmiş, bölgede oluşabilecek olası hidrolojik süreçlerin tahmini (yağış-akış hidrografının elde edilmesi, taşkın frekans tahmini gibi) için hazır hale getirilmiştir.

Anahtar Kelimeler: Arc-CBS, Ballıkaya Havzası, Havza Karakteristikleri, SYM

ABSTRACT

Water, an indicator of civilization, is one of the rare resources in which living organisms can continue their life activities. Watershed management plays a major role today in order to benefit from existing water resources (i.e. controlling water resources against drought, maintaining water quality) or to minimize the risks of excess water that may occur (i.e. flooding). For this purpose, Digital Elevation Model (DEM) is used in conjunction with developed technology to accurately determine catchment boundaries and accordingly to be applied in rainfall-runoff simulation process. In this study, high resolution DEM data was implemented to identify the river network in the Ballikaya region (Ceyhan Basin), establish the flow direction, flow accumulation, and basin boundaries in addition to these, to determine the characteristic features such as catchment area, and slope. This study indicates how convenient and important DEM data and Arc-GIS are in watershed implementations. Obtained DEM data was processed in the Arc-GIS environment, and it provides a capability for the prediction of possible hydrological planning over the region (such as obtaining the precipitation-flow hydrograph, flood frequency estimation etc.).

Keywords: Arc-GIS, Ballikaya Basin, DEM, Watershed Characteristics

INTRODUCTION

Due to the importance of water for the life of the various living organisms on the surface of the Earth, it is necessary to protect this natural resource and take all necessary measurements to maintain it. For this reason that human being tried to know the properties, structure, and movement of water in the atmosphere and to identify the dangers that threaten the existence of water resources in nature since ancient times. Watershed management plays an important role today because of increasing demand for water day by day and scarcity of water resources (Ercan and Yuce, 2016).

The watershed is a geographical area that contains common hydrological features and is shared in a single outlet and can contain several small basins called sub-basin and can be a part of large basin (Anonymous, 2019). The identification of basin boundaries is an important step for subsequent studies such as hydrological modeling, water resource management, and determining the nature of vegetation cover and soil type (Sufiyan and Zakariyab, 2018). Previously, the limits of the watershed were determined based on the paper topographic maps (Ercan and Yuce, 2016). Now, as a result of the great evolution of the information technology, man has created computer-based programs that enable us to identify and manage the catchment smoothly and effectively. One of the most important of these programs is Geographic Information Systems (GIS), which process and analyze aerial images taken by satellites and the extraction of the basin boundaries. The GIS is a decision support system by integrating spatial information to solve environmental issues. Data within geographic information systems are divided into two basic types: spatial data that determines the coordinates of the study site on the Earth's surface and non-spatial data describing the quality and characteristics of this data (Dawod, 2012).

Spatial data is represented in the GIS environment through two formats: vector and raster data. Vector data is represented as a point with coordinates (x,y), polyline, or a closed polygon to represent regions. Raster data, on the other hand, is a file format where geographically referenced data is stored in cells of a two dimensional grid; each cell is assigned an attribute value (Irwin et al., 2014).

Digital Elevation Model (DEM) is the basic data required when drawing the boundaries of a catchment using the GIS. The DEM data is a digital file that contains elevation information for the surface of the study area and can be in either a vector or raster format. The DEMs are obtained from the contour maps after being digitized by computer, aerial photos, satellite images or free global models available on the internet. The most common ways to get DEMs are global digital elevation models (i.e. GLOBE, ETOPO2, ASTER, and SRTM) because it's free and covers a wide area of the Earth's surface. The U.S. space agencies have developed SRTM model according to three levels of spatial resolution capacity. The SRTM-30 has low spatial resolution capability, up to 30 seconds (900 m) of latitude and longitude. SRTM-3 and SRTM-1, on the other hand, have finer spatial resolution ability up to 3 seconds (90 m) and 1 second (30 m) for each pixel length, respectively (Dawod, 2012).

The main objective of this study is to derive the boundaries of the basin based on DEM via Arc-GIS environment for the study area located in Gaziantep, Turkey. The obtained high resolution DEM data (30m x 30m) is applied in order to accurately visualize the basin. Additionally, some watershed characteristics (basin area, slope, geomorphology and etc.) are calculated with Arc-GIS based hydrological analysis tool. This can provide an opportunity for the estimation of future hydrological planning over the region.

STUDY AREA AND DATA

Arc-GIS program produced by the American ESRI company, in 1969. The DEM data for the study area was obtained from the U.S. Geological Survey (USGS) with 30 m×30 m horizontal resolution as shown in the following Figure 1. Discharge point coordinates of the watershed obtained from the General Directorate of State Hydraulic Works, in Turkey.

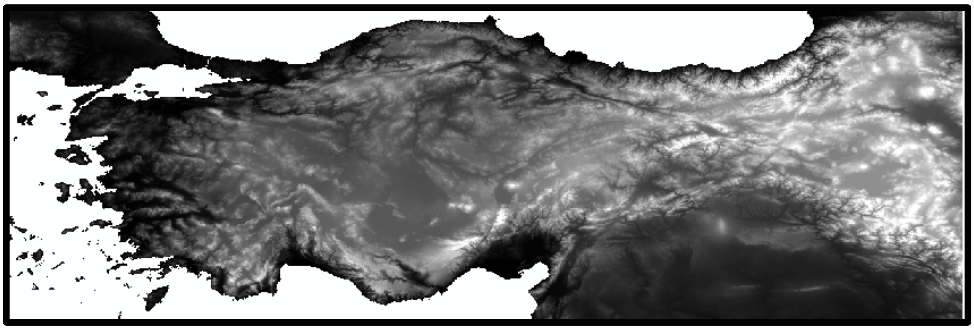


Figure 1. Digital Elevations Model For Turkey (Source: Anonymous, 2018)

In this study, Ballikaya region is selected to acquire basin characteristics such as area, stream, and drainage line. The watershed is located in Gaziantep province, in Turkey (Figure 2). The basin boundary extends between latitudes 37º04'30" N and 37º12'00" N, and longitudes 36º50'00" E and 37º02'30" E with outlet point 37°08'04"N and 36°52'40"E coordinates. The catchment area is approximately 78 square kilometers. In addition, the vegetation cover of the study area is mainly composed of agricultural lands, and forests. Soil type consisting of red Mediterranean, and lime brown forest soil.

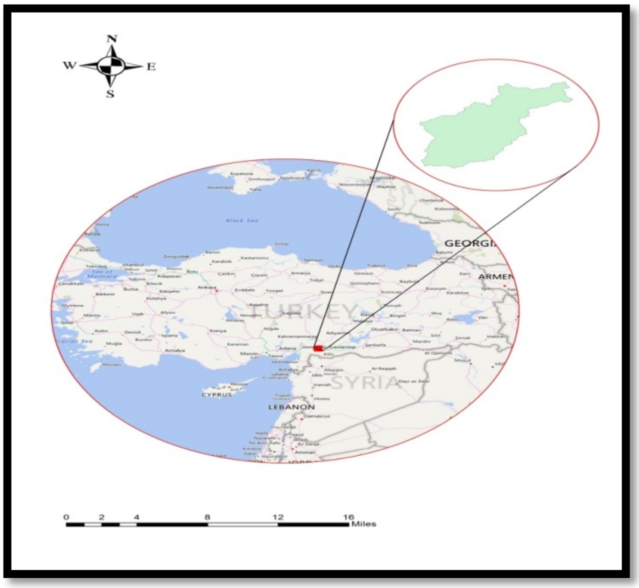


Figure 2. Location of Study Area

METHODOLOGY

Before starting the hydrological analysis process, the Geographic Coordinate System (WGS1984) of the study layer must be converted to the Projected Coordinate Systems (UTM) to avoid errors during measurements. Drawing the boundaries of the watershed using a DEM data is a sequence of steps where the output of each process is used as input for the next process (Ercan and Yuce, 2016).

Terrain Preprocessing

The DEM cells have some errors and abnormal values due to a defect in the model (SRTM) where some cells have high or small elevation values unexpectedly compared to its neighboring cells attribute. Therefore, these must be eliminated by the fill sink tool as shown in Figure 3. The abnormal values in digital elevations can hamper water flow between cells; thus, they have to be removed (Dawod, 2012).

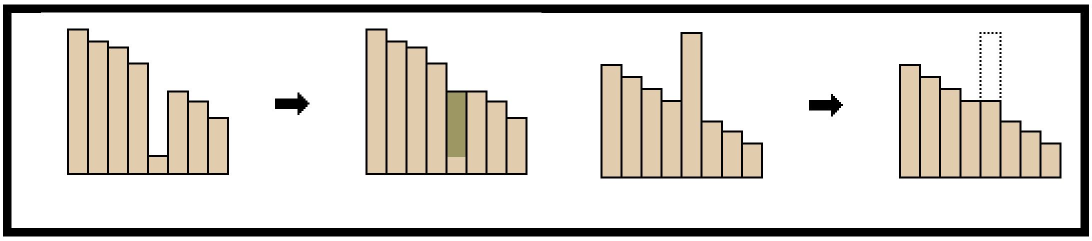
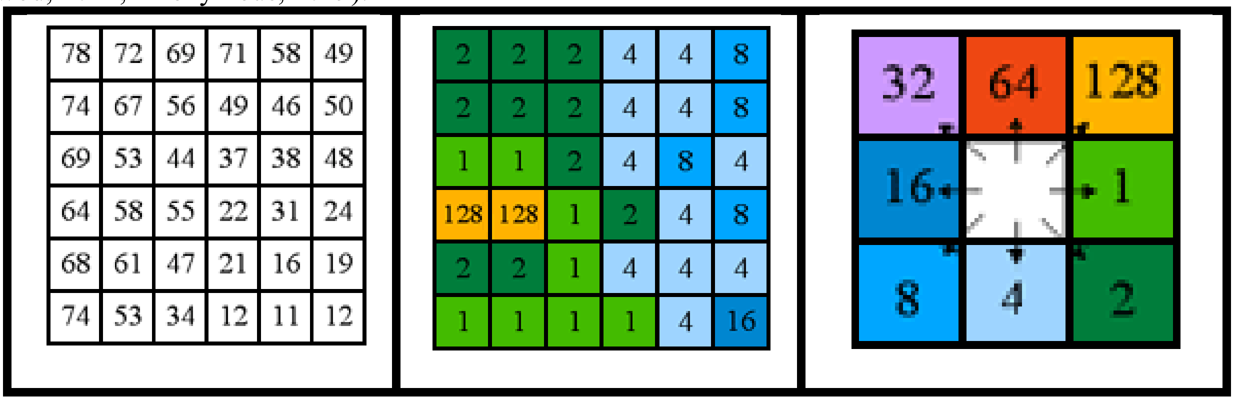


Figure 3. Illustration of Fill Sink (Source: Anonymous, 2019)

Flow Direction And Accumulation

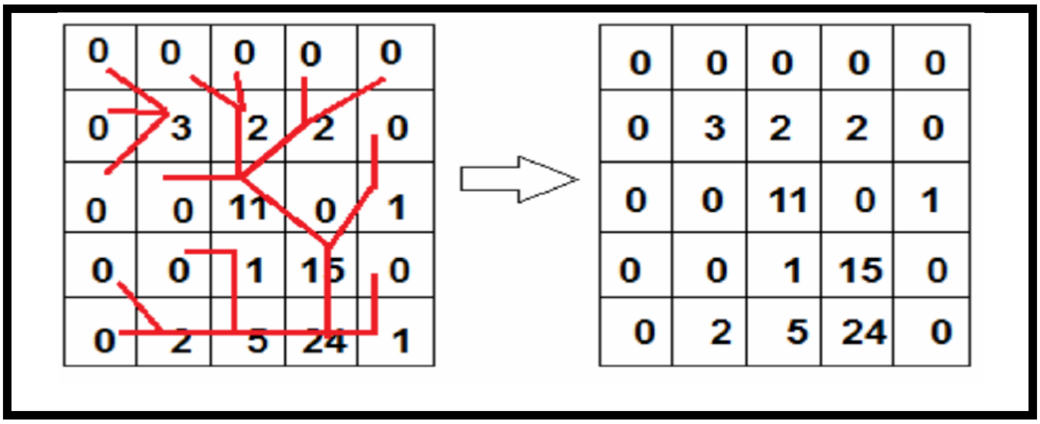
Determination of flow direction is the most crucial step when conducting any hydrological modeling and is considered as input parameter when drawing basins and watershed boundaries (Ercan and Yuce, 2016). The flow direction of each cell is calculated using the corrected DEM produced by fill sink tool. The principle of this tool is to give a number ranging from 1 to 128 for each cell of the DEM data according to the elevation of the cell and adjacent cells (Figure 4a). As it can be seen from the Figure 4a, the number 78 (northwest corner) is accompanied by cells 67, 72, and 74, the lowest adjacent cell (67), because the water always moves in the direction of the steepest slope. From the Figure 4b, the same thing indicated with number 2 (northwest corner) in the way of flow direction instead of elevation. Then, these numbers represent the directions of a river (1-East, 2-South East, 4-south, 8-Southwest, 16-West, 32-northwest, 64-north ,and 128 -northeast) out of each cell of the DEM (Figure 4c). (Dawod, 2012; Anonymous, 2019).



a) Elevation Surface **b)** Flow Direction **c)** Direction Coding

Figure 4. (Source: Anonymous, 2019)

After calculating the flow direction, the cumulative flow is accounted. This tool figures the cumulative water value in each raster cell and the cumulative values are represented by a number indicating the number of cells that are poured into this cell (Anonymous, 2019). For instance, from the following Figure 5, the cell with the number 11 means that the water flows to it from 11 adjacent cells. Thus, the main stream inside the basin is the cells where the flow values are high and the sub-streams are the cells with relatively lower flow values (Ercan and Yuce, 2016).



a) Flow Direction For Each Cell **b)** Flow Accumulation Values In Each Cell

Figure 5. (Source: Dawod, G.M., 2012)

Pour Point And Watershed

Later, the main stream is determined within the basin through the flow accumulation tool, the drainage point of the basin is defined by which the rain water is discharged out of the basin boundary. The pour point of watershed is mostly located on the main stream and then the catchment boundary can be efficiently determined using the watershed tool. If the pour point is adjacent to the main stream then we use the snap pour point tool to match the outlet of watershed on the main stream (Irwin et al., 2014).

RESULTS AND DISCUSSIONS

After transferring the digital elevation model into the Arc-GIS environment, the model is converted from the global geographic projection (WGS1984) to the local metric projection (ED1950). The model is, then, corrected and the errors removed by the fill sink tool in such a way as to ensure the flow of water without any obstacles. From Figure 6, it appears that the white areas represent the high points of the study area and the areas in black are the valleys and the water collection areas.

Figure 6. DEM For Ballikaya Watershed

As a next step, blanks are filled in the DEM data; then, the flow directions are determined in the Ballikaya region. As it can be seen from Figure 7, digital model cells are digitized with numbers varies between 1 to 128.

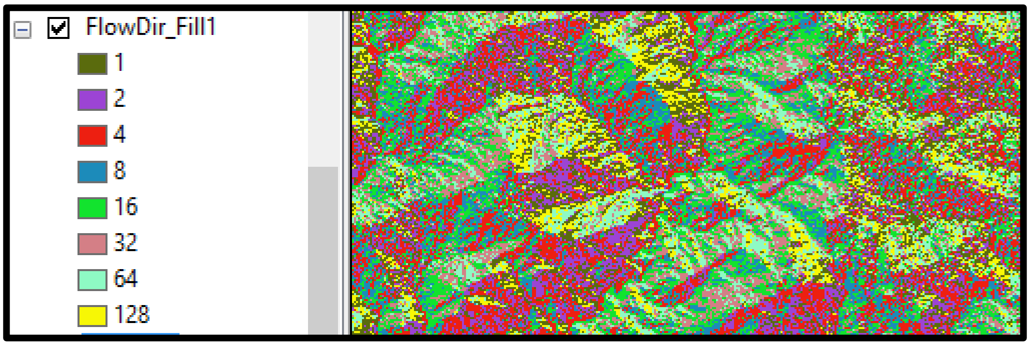


Figure 7. Flow Direction In Ballikaya Watershed

Cumulative flow is calculated based on flow directions and each cell carries a digit indicating the number of cells that flow into it. Cells with the number 0 mean that they are poured into another lower cell. The main stream within the basin consists of cells with high flow values (Figure 8). The discharge point of the basin with the coordinates (37°08'04"N - 36°52'40"E) is designated as a shape file of the type of points with the same type of metric projection (ED1950) to be used as an input to draw the basin boundary. Generally, at the point of drainage of the basin is a station to measure the flow of rain to draw the hydrograph between the flow and time.

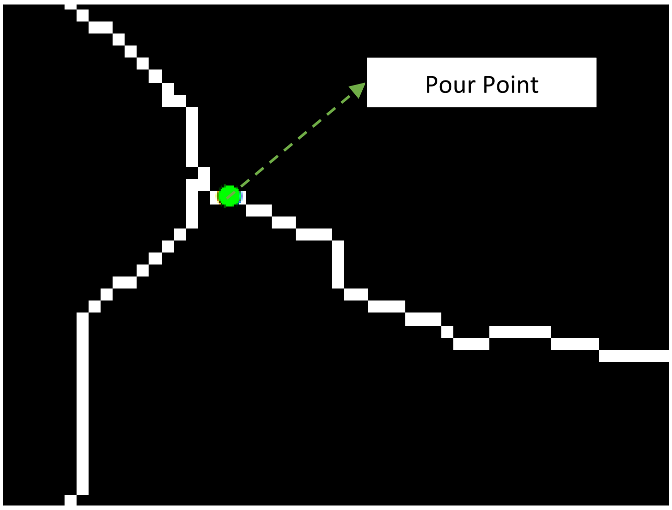
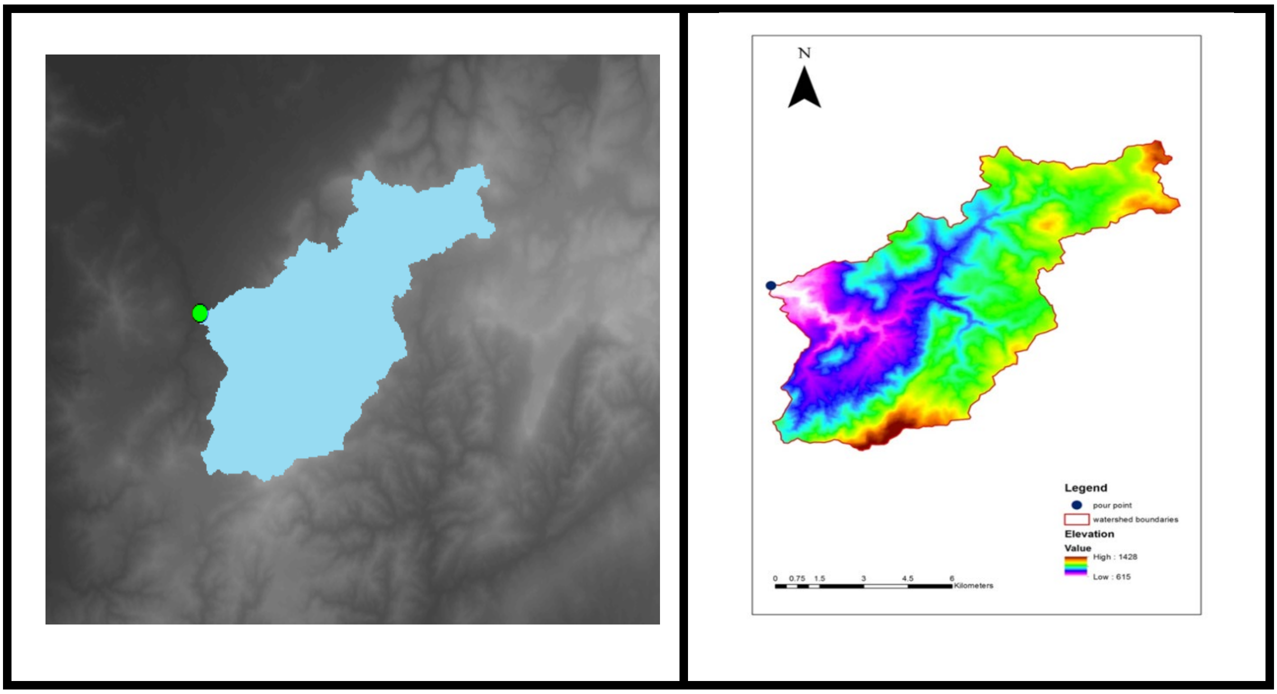


Figure 8. Flow Accumulation And Pour Point In Ballikaya Watershed

Finally, the watershed boundaries is set through the watershed tool based on the discharge point and flow direction. The below drawing of the basin (Figure 9a) is in raster format; however, this figure should be converted from the raster to vector (polygon) format in order to determine the basin area and water stream length (Figure 9b).



a) Ballikaya Watershed (Raster) **b)** Ballikaya Watershed (Polygon)

Figure 9. Ballikaya Watershed

CONCLUSIONS

Watershed analysis refers to the process of using topographic maps and following water flows to delineate stream networks and watersheds. The development of today's computer and photogrammetry has made it easier and faster to delineate a catchment. Using freely available digital elevation models on the internet and the Arc-GIS program, the boundaries of the watershed can be accurately defined without relying on paper topographic maps. The use of satellite data for processing digital image such as the Digital Elevation Models (DEM) provide visual and high graphics data for topographical analysis (Sanders, 2007 and Srivastava et al., 2011). This study demonstrates how practical and important the DEM data and the Arc-GIS program are in the watershed studies and provides the opportunity for future hydrometeorological studies over the Ballikaya region. This study is the starting point for future studies such as soil type identification, vegetation cover, flood analysis and other hydrological studies of this basin.

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