APPLICATION OF GIS AND REMOTE SENSING IN 3D MODELLING AND DETERMINATION OF MORPHOMETRIC FEATURES OF THE "AGRI VOLCANO", AGRI, TURKEY

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ABSTRACT

Improving research methods and techniques present researchers with many advantages. Geographical information systems (GIS) and Remote Sensing (RS) are methods that researchers apply to reach the end-users. GIS and RS have developed in parallel and have uses in many scientıfic disciplines including in geomorphological and 3D imaging studies. To illustrate the potential of GIS and RS to determine 3D images, geomorphological features and the way they are examined, the Ağrı Volcano (Mount Ararat) within Ağrı city was selected as the study area. Data sources included 1/25000 scaled topographical maps, The Shuttle Radar Topography Mission (SRTM) data and Landsat 1987 TM, 2000 ETM satellite images. Geometric corrections of satellite and topgraphical maps were applied using ERDAS 9.1 software. Contour lines and vectoral data from 1/25000 scaled topographical maps were digitised using slope, aspect and other morphometrical features from Digital Elevation Model (DEM). Drainage network features derived from DEM and topographical maps were also evaluated. In order to create a 3D model of the Ağrı Volcano, Landsat satellite images, SRTM and DEM data were used. With the aid of the ArcGlobe and ArcScene modules of the ArcGIS software, various point of view were achieved.

Keywords: *GIS, Remote Sensing, Ağrı Volcano, 3D image, Morphometry.*

1. INTRODUCTION

Recent developments in RS and GIS have significantly facilitated the identification of spatial characteristics and creation of 3D images thereon. In particular, developments in image processing software have allowed more comprehensive use of the generated data. Researchers can now benefit from the fact that high resolution satellite images and digital geographical data contain more information. One of the most important advantages that GIS offers is the ability to comprehensively analyses data in correlation under GIS environment. Today, GIS and RS are used in many studies and disciplines. These include natural disasters, hydrology, geomorphology, flora, map generation and different modeling studies.

There are a lot of software programs for generating 3D models. These software programs require certain data, which include DEM, Satellite Images, etc. The ability to see nature from a 3D point of view provides significant contributions to many disciplines. In this context, RS and GIS offer important advantages, providing fast, reliable and accurate data. GIS technology offers the potential to generate data sources that may contain many geomorphological elements such as the DEM, slope map, aspect map, various profiles (longitudinal and transverse sections of valleys, etc.) and block diagrams. Furthermore, GIS offers important functions with regards to updating and monitoring the spatial analyses of morphometric parameters related to river basins (drainage density, river frequency, array branching rates, etc.), and other associated databases (Goodchild and Parks et al., 1993). In the light of the abovementioned applications, Ağrı Volcano was selected as the study area and 3D models were created using different software. These models were based on various data. Furthermore, certain morphometric characteristics of Ağrı Volcano were identified.

2. STUDY AREA

The study area was Ağrı volcano, the highest volcanic mountain of Turkey, located within the borders of the Ağrı and Iğdır provinces. The study area is located approximately between 4419743-4374047 Y coordinates and 414510-457127 X coordinates (UTM, WGS 84, Z38N) (Figure 1). The study area covers 1334 Km^2. Altitude varies between 900 m and 5165 m (16,940 feet). Classified as a stratovolcano, Ağrı volcano consists

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of lava, volcanic breccia and trass. Slopes feature early basalt streams. Located to the southeast of Ağrı volcano is little Mount Ağrı. little Mount Ağrı is 3896 m high.

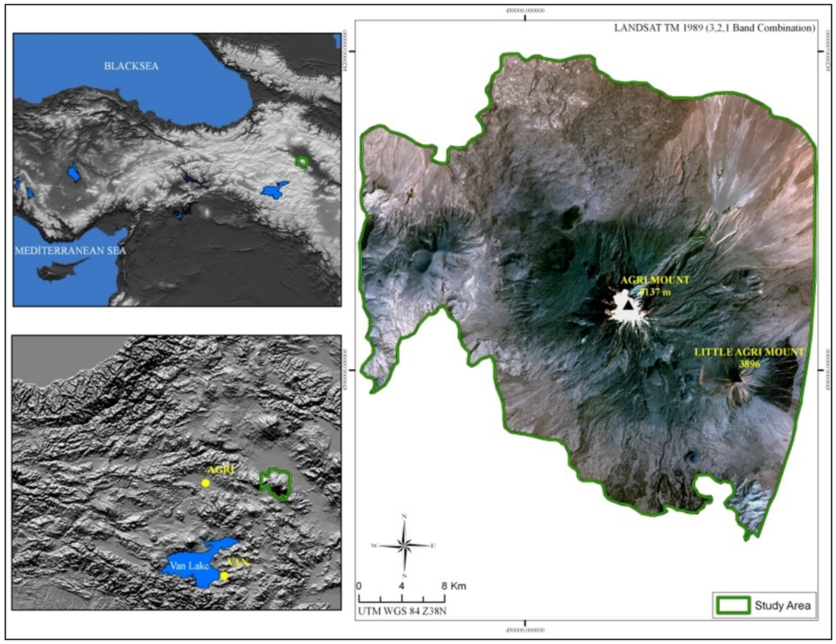

Figure 1: The Study Area.

3. DATA AND METHOD

Data resources for this study consisted of 1/25000 scaled topographic maps, LANDSAT 2000 ETM and 1989 TM satellite images and SRTM data. In order to perform 3D modeling and to identify certain morphometric characteristics of the study area, geometric corrections on 1/25000 scaled topography maps were performed using ERDAS imagine 9.1 and ArcGIS 9.2 software. Vectoral data on topography maps (contour lines, hills, rivers) were digitised using ArcGIS 9.2 software. The Archydro tool of ArcGIS 9.2 software was used to generate flow accumulation and natural flow models of rivers. DEM, 3 arcsecond (90 m) SRTM data and LANDSAT satellite images were used to create 3D models of the study area. ArcGlobe and Global Mapper 7.0 software were used for 3D applications. Slope and aspect maps were generated and their areal distribution identified graphically. Global Mapper 7.0 software was used to create 3D models generated from SRTM data in Hgt format, which is gathered at 3 arcsecond (90 m) intervals.

4. 3D MODELS

4.1. 3D Modeling from SRTM Data

The Shuttle Radar Topography Mission (SRTM) satellite went into orbit in 2000 in order to obtain 3D topographic data from Earth by means of radar interferometry, and successfully completed its mission within 11 days. SRTM is one of the most important single pass spacecrafts. The SRTM instrument was made up of three sections, the main radar antenna, the mast, and the outboard radar antenna (Figure 3). SRTM data consists of two bands, namely C-band and X-band. The SRTM C-band operated with the ScanSAR mode and collected data on almost the entire Earth. The X-band did not have the ScanSAR mode and therefore contains square-shaped data gaps (Jacobsen, 2004). The C-band collected data at 3 arcsecond (90m) intervals with a scan width of 225 km and the X-band collected data at 1 arcsecond (30m) intervals with a scan width of 45 km (Sefercik, 2007). Please refer to figure 2 for the data collection method of the SRTM satellite. Topographic data from the C-band were used in this study to create the C-Band Altitude Model of Ağrı volcano Global Mapper 7.0 software was used to create the 3D model (Figure 4).

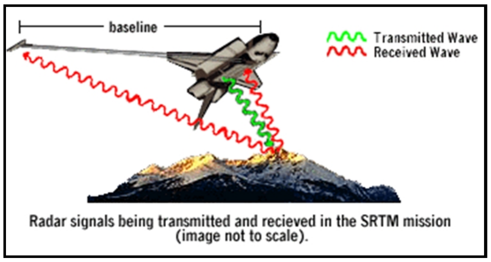

Figure 2 : SRTM Data Collection Geometry.

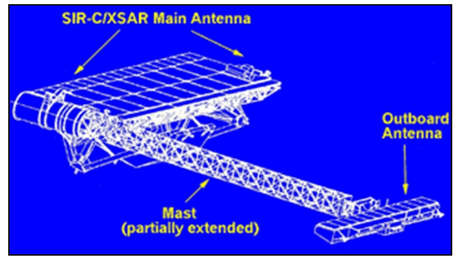

Figure 3: Instrument of SRTM.

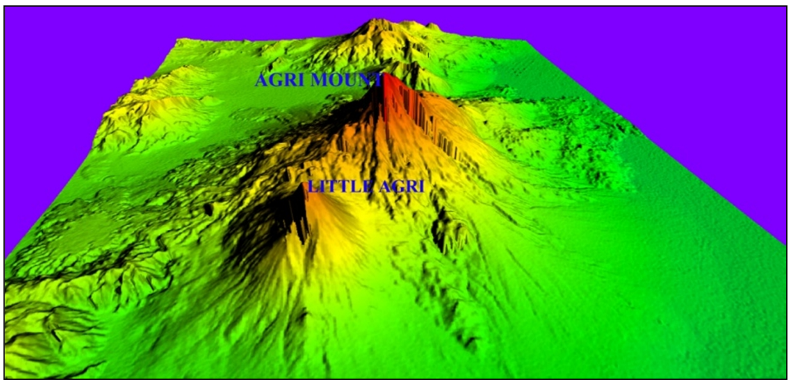

Figure 4 : 3D Model of Ağrı Volcano Generated from SRTM Data.

4.2. 3D Generation from Satellite Images

Today, satellite images taken at different times with different spatial resolutions are used to create 3D models. Landsat satellite images are among the data used for this purpose. LANDSAT TM (08.31.1989) and ETM (08.13.2000) satellite images were used for this study (Figure 5 and 6). LANDSAT satellite images have different features (Table 1). The 3, 2, 1 band (0.45-0.69 µm) combination of ETM and TM satellite images were used to create 3D models. DEM generated from 1/25000 scaled topographic maps was used for 3D models created from satellite images.

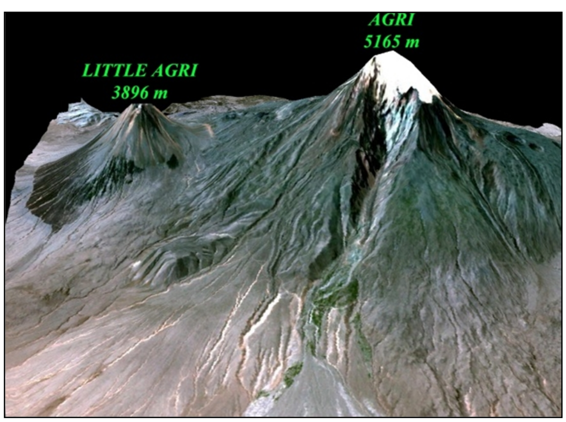

Figure 5 : Landsat TM image overlaid on DEM study area.

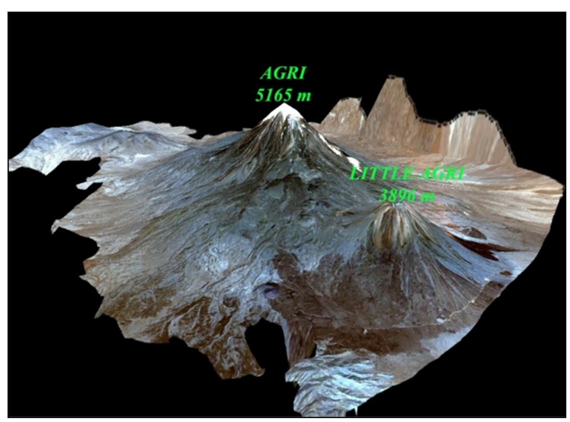

Figure 6 : Landsat ETM image overlaid on DEM study area.

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Table 1: LANDSAT Satellite Images and Their Features.

Satellite	Sensor	Spectral Range	Band #s	Scene Size	Pixel Res
L 1-4	MSS multi-spectral	0.5 - 1.1 µm	1, 2, 3, 4		60 meter
L 4-5	TM multi-spectral	0.45 - 2.35 µm	1, 2, 3, 4, 5, 7		30 meter
L 4-5	TM thermal	10.40 - 12.50 µm	6	185 X 185 km	120 meter
L 7	ETM+ multi-spectral	0.450 - 2.35 µm	1, 2, 3, 4, 5, 7		30 meter
L 7	ETM+ thermal	10.40 – 12.50 µm	6.1, 6.2		60 meter
L 7	Panchromatic	0.52-0.90 µm	8		15 meter

4.3. 3D Modeling from DEM

DEMs can be obtained by using different methods such as stereoscope satellite images and land readings. Having been used as the basis of this study, the 1/25000 scaled topographic maps were digitised by using 10 m contour line intervals. First the irregular Triangle Network (TIN) was generated from the contour line curves and altitude points using the 3D Analyst module. All points in this data structure are generally interconnected via Delaunal triangulation, which combines the centres of adjacent thiessen polygons (Kumler, 1994). The TIN model is then converted into Raster format and DEM is generated accordingly. The grid size of this conversion was 10 m. Selection of this value was affected by the use of contour lines at either 10 m or 5 m intervals. Having been created from contour lines, the DEMs with small intervals feature higher altimetry accuracy and constitute useful data resources (Wilson and Gallant, 2000). The 3D model was created by using the generated DEM (Figure 8). The DEM was also used to create the Hillshade 3D model (Figure 7).

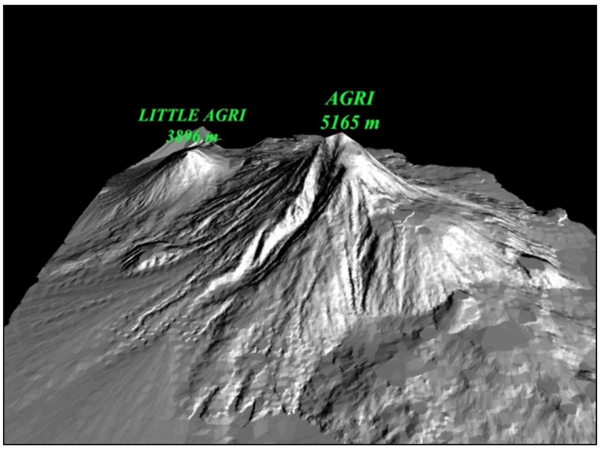


Figure 7 : Hillshade Model of the Study Area.

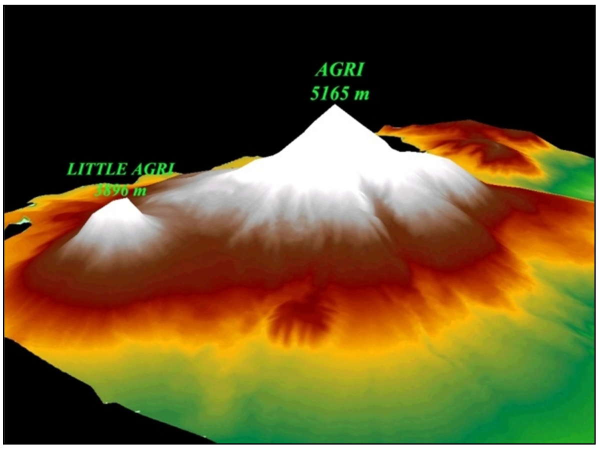


Figure 8 : DEM of the Study Area.

5. MORPHOMETRIC CHARACTERISTICS

Ağrı volcano is classified as a stratovolcano, having a cone shape with a sharp summit. he most important evidence of this is the severe landslide that occurred on the northeast slope on 20 June 1980. Traces of glacial topography are found on the summit of Mount Ağrı. This study will explain only the slope, aspect and drainage characteristics. Relief analyses of the study area were evaluated together with results from previous studies in order to identify morphometric characteristics. Slope and aspect characteristics were identified, areal distributions calculated and various profiles generated. In addition, the Archydro tool of ArcGIS 9.2 software was used to identify drainage characteristics.

5.1. Slope Characteristics

Slope is the difference in altitude between two points located at a certain horizontal distance (Bilgin, 2001**)**. Water and other materials start flowing in parallel with the slope direction due to gravity. Therefore, slope is very important with regards to hydrological and geomorphological studies. GIS defines slope as the maximum rate of change from each cell on the raster base to other surrounding cells (Burrough and Mcdonell, 1998). The desired definition can be selected and the slope map generated according to the study. The Surface Analysis module of 3D Analyst was used to generate the percentage slope map (10x10) of the area from the DEM at 10 m intervals. The Spatial Analyst module was also used to do areal calculations of slope values and their digital equivalents (Figure 9). These values and characteristics provide quantitative and reliable information on the study area. Slope values tended to increase on the NE slope of the mountain and sections where glacial valleys are located. This will be seen clearly when the 3D slope model is examined (Figure 10). The red zones correspond to sections with higher slope values and green zones and shades of green correspond to sections with lower slope values. Slope values are divided into 6 groups. These groups are shown in the table below.

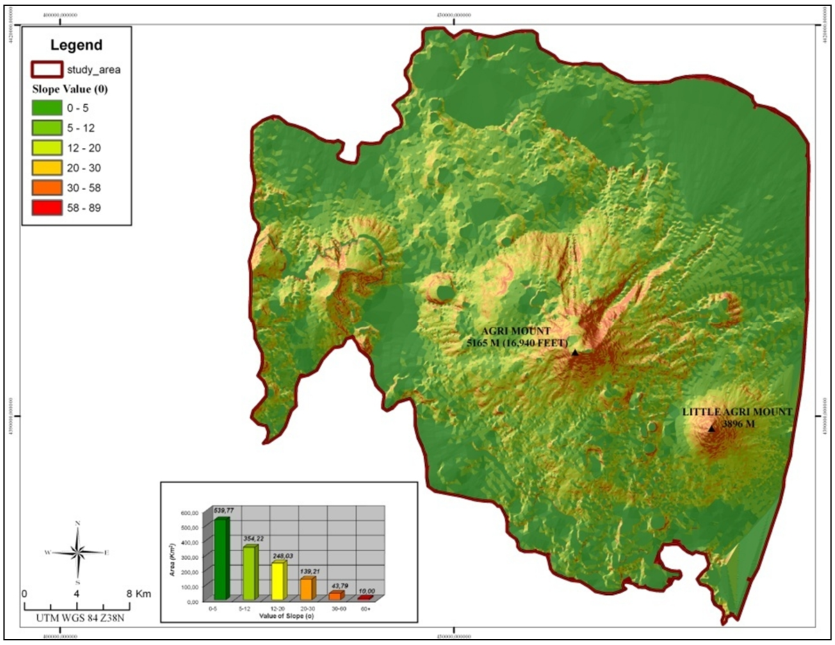


Figure 9 : Slope map of study area.

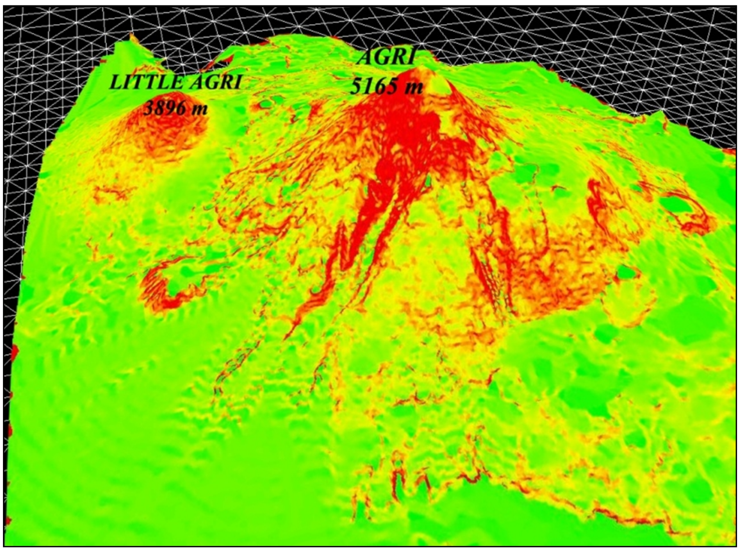


Figure 10 : 3D Slope Model of Ağrı Volcano.

5.2. Aspect Characteristics

Having been defined as the direction of the slope surface, aspect is measured at ($0\text{-}360^{\circ}$) degrees clockwise. Flat areas are assigned a -1 value because they do not face any direction. Aspect factor plays an important role in the duration and severity of humidity, precipitation, wind and sun on the land. Measured in degrees, aspect is calculated by using definite differences (Wilson and Gallant, 2000). As in the identification of slope characteristics, the Surface Analysis module of 3D Analyst was used to identify aspect characteristics of the study area. Aspect was divided into 9 groups including four cardinal directions, four intercardinal directions and flat areas areas (Figure 11). Areal calculations of aspect values were made and maps generated accordingly. ArcGlobe was used to generate the 3D aspect model (Figure 12).

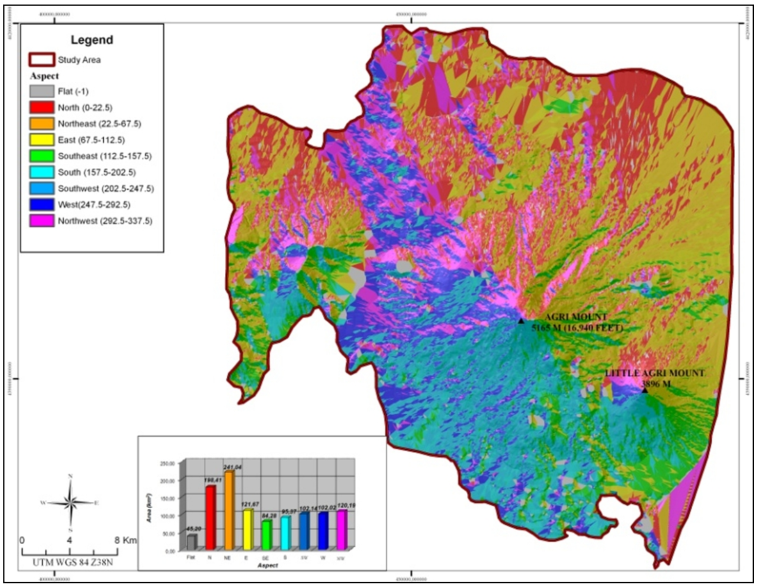


Figure 11 : Aspect of Study Area.

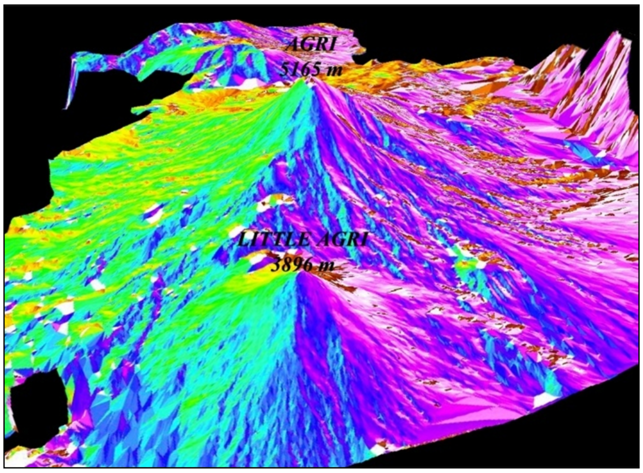
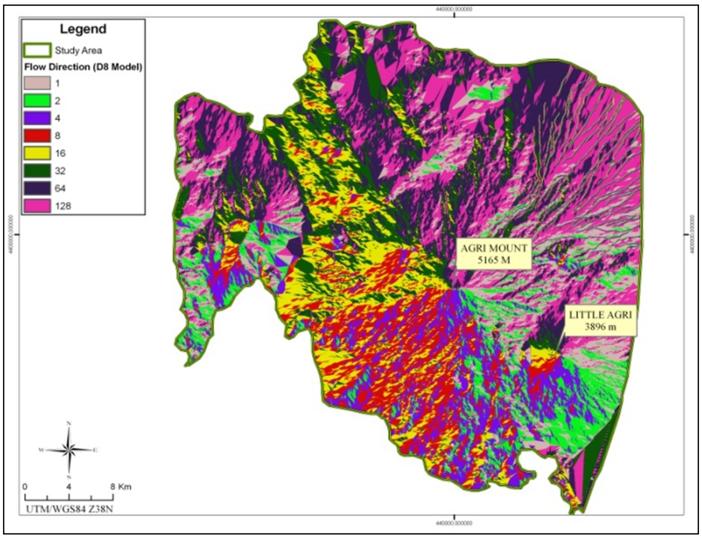


Figure 12 : 3D Aspect Model of Ağrı Volcano.

5.2. Drainage Properties Generated from DEM

For DEM generation, contour line curves on the 1/25000 scaled topographic maps were manually digitised and DEM of the study area was obtained with a grid interval of 10 m. The Hydrology Tools module of ArcGIS 9.2 software was used to generate rivers from DEM. The higher the DEM resolution, the more realistic the rivers are ; otherwise, large flat areas will produce an unnatural drainage network (Maidment, 2002; Özdemir, 2006). After DEM was selected, the noise and abnormal heights on the DEM were corrected in order to eliminate interruption of the river network (Tarboton and Bras et. al., 1991; Özdemir, 2006). The Filled DEM data was used to generate Flow Directions (Figure 13). The D8 method was used to determine natural flow directions. There are eight valid output directions relating to the eight adjacent cells into which flow could travel. This approach is commonly referred to as an eight direction (D8) flow model and follows an approach presented in (Jensen and Domingue 1988). The direction of flow is determined by finding the direction of steepest descent, or maximum drop, from each cell. The distance is determined between cell centers. Another model generated by using DEM in hydrology studies is the Flow Accumulation model obtained from the Flow Direction model (Figure 15). Water flow directions are identified from DEM and a water flow directions model is created accordingly. Starting from the top right corner on the water flow directions model, the flow accumulation values are calculated cell by cell. If a cell does not receive a flow from another cell, its value will be zero (Figure 16). Each grid (pixel) cell on the DEM has a numeric value. The flow from the cell can only be to one neighbouring cell with a lower altitude value. There are 8 possible directions for each cell. Figure 14 shows the possible flow directions from cell 50 and the values to be assigned to cell 50 in the new water flow direction model. These values define the flow directions in software operating under GIS. Accordingly, if flow is to the right of cell 50, the flow direction value of cell 50 will be 8; and if flow is to the left of cell 50, the flow direction value will be 4; and if flow is to the bottom of cell 50, the flow direction will be 2 (Jenson and Domingue 1988; ESRI 1992a, 1992b).



Fifgure 13 : Flow Direction of Ağrı volcano.

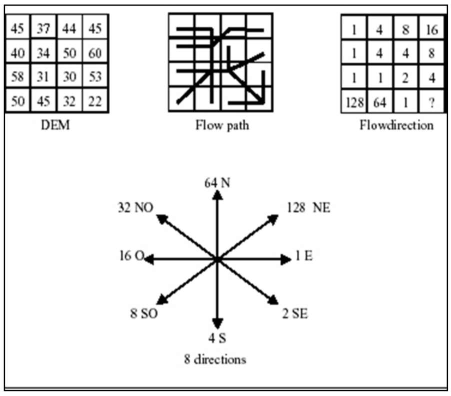


Figure 14 : Calculation method of Flow Direction.

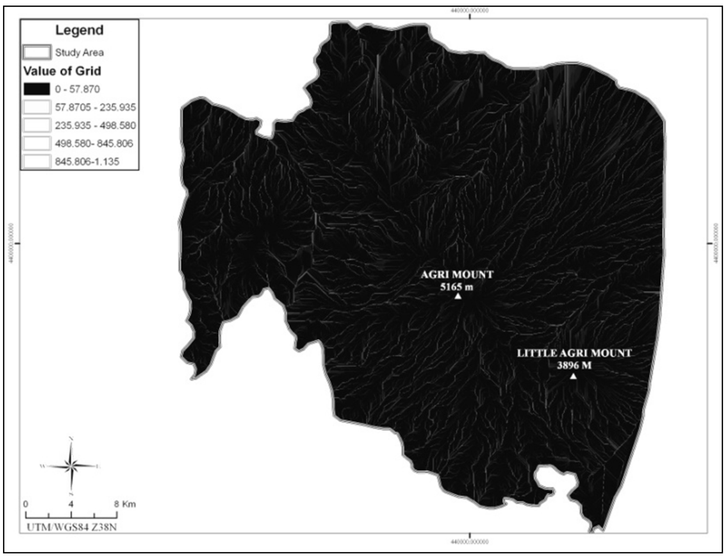


Figure 15 : Flow Accumulation of Ağrı volcano.

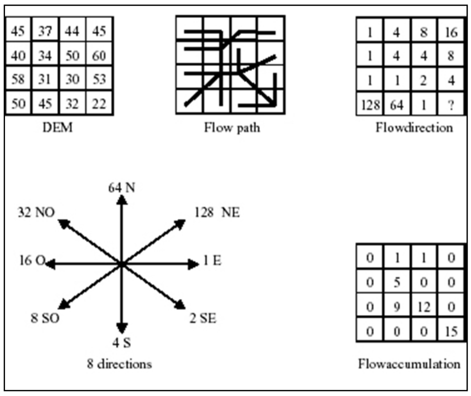


Figure 16 : Calculation method of Flow Accumulation.

CONCLUSİON

It is not possible to show all applications of GIS and RS in this study. Therefore, only some of the topics have been reviewed. 3D models of Mount Ağrı were created and some of its morphometric characteristics were specified. In the 3D models, it is clearly seen that Mount Ağrı is a strato volcanic type mountain. Also, when we look at the morphometric characteristics, it is observed that slope values range from 0 to 60 degrees. The dominant direction is the Northeast in the aspect values. It is observed that surface waters have a significant impact on formation of the Mount Ağrı. The flow collection and natural flow models produced using DEM of the Mount Ağrı prove this point clearly. GIS and RS, which both have significant resources for utilization and analysis of spatial characteristics, have been used in multi-directional manner in this study also. GIS and RS have important potential in assessment and interpretation of the data produced within the same geometric features.

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