MODERN METHODS OF IMPLEMENTATION AND INTERPRETATION OF DIGITAL TERRAIN MODEL

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Abstract

Modeling land surface is a particular case of modeling the areas which need special consideration for specific issues related to Earth representation or some parts of the terrestrial crust. This study had as main objective the achievement of a digital terrain model in a mountain area based on Triangulated Irregular Network (TIN). This studied area represents a part of the Retezat Mountains. The images obtained were analyzed with ArcGIS software. The database and algorithms used facilitated the creation of a 3D model for the studied area, with a spatial distribution similar to the real situation in the field. The obtained 3D model facilitated the graphical representation of different types of slopes, grouped into 6 classes at intervals of 10 units, according to slope values, covering 100% of the study area. The largest coverage consists of land with slopes between 10-40%. The 3D model also facilitated graphical and numerical representation of aspect and it allowed the Hillshade model to facilitate highlighting landforms directly from DEM model, emphasizing valleys, depressions, ridges, for an easier interpretation and use of the maps.

Key words: GIS, DEM, Slope, Aspect, 3D

Digital elevation model is an informatic "tool" consisting of field data and software which is a basic component of a GIS. A GIS is a technical and organizational complex - people, equipment (hardware), programs (software), algorithms and procedures which ensure the management, processing, manipulation, analysis, modeling and visualization of spatial data in order to solve complex problems of planning and management of the territory (Radulescu and Radulescu, 2013a,b).

Study of land cover, agricultural and non-agricultural land, watershed, the glosses and watercourses, human habitats under the aspect of geomorphology, spatial structure or some specific characteristics in relation to certain objectives (height, elevation, color, volume, temperature, crop water requirements etc.) have been approached in numerous studies, based on satellite images or by using drones (Jordan, 2003; Finkl et al., 2005; Maican et al., 2011; Hengl et al., 2012; Szymanowski and Kryza, 2012; Wang et al., 2013; Popielarczyk and Templin 2014).

The interest for representation of land cover and terrain in 3D informatics system is great for various practical applications in various fields. Terrain modeling based on satellite images or aerial (drone) was carried out under different research (Shi and Shaker 2003; Li and Batchvarova 2008; Gallay et al., 2013).

New models and methods for the construction of multi-resolution data structures have been promoted by some research in order to increase the accuracy in modeling land work (Sulebak and Hjelle, 2003; Maleika, 2015).

Some studies have evaluated the accuracy of calculation and possible errors in digital terrain modeling in LiDAR -derived digital elevation models, DEM interpolation or GRID structure (Bater and Coops, 2009; Rees, 2000; Aguilar et al., 2010; Maleika 2014; Gosciewski, 2014). Barazzetti et al. (2010) have communicated the results of research regarding digital LiDAR digital buildings models for true ortophoto generation. They estimated that, usually, the generation of orthophotos is carried out using digital terrain models (DTMs); meaning without taking into account vegetation, buildings, and other attached and detached structures.

In the context of general and specific interest for the analysis and modeling of land cover and terrain, this study had as main objective the achievement of a digital terrain model in a mountain area based on a Triangulated Irregular Network (TIN).

MATERIAL AND METHOD

The studied area includes Retezat Mountains, which are part of the Meridional Carpathians, mountain group – Retezat - Godeanu. The highest peak in Retezat Mountains is Peleaga with an altitude of 2509m. Retezat is

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the oldest national park in the country. Retezat has the largest number of glacial lakes in Romania (over 80).

Digital Elevation Models (DEMs) consists of a regular set of data regarding the planimetric position and the attitude of some points that describe the spatial configuration of landform structures and facilitates the reconstruction of their surface in new points. A DEM describes an area of land with a univocal function z = f (x, y), so for a position x, y from the field, there can be determined one value z. DEM is a matrix of levels, each cell array having the same size.

Cadell (2002) considers that the Digital Elevation Models (DEMs) are now commonly used in many geographically oriented applications. Their production is becoming quicker and easier due to better hardware and friendlier software environments.

Generating the digital terrain model refers to the data acquisition mode, the realization of the model by different interpolation methods and the choice of data representation structure (raster or TIN). TIN structures are "the soul" of 3D models because they are the base of terrain elevations in the 3rd dimension and without a well done TIN structure, the 3D model loses its accuracy.

The TIN is a special format, typically used in a 3D representation of topographic surface (digital terrain model) and it is generated by specific functions of GIS spatial data, stored in other formats (vector, GRID).

There are a number of methods for obtaining 3D models, including the study of terrain or land cover. The most commonly used are those based on regular surface scale (GRID) and Triangulated Irregular Network (TIN), both methods are commonly used to create and represent areas in a GIS ((El-Sheimy et al., 2005).

Triangulated Irregular Network (TIN) allows viewing highly suggestive of topographical surface features (approximated by a triangular irregular network). Based on this model it was possible to perform complex analyzes on the morphology of the land, such as: slope, aspect, line and area of visibility etc. for the studied.

In this study, to create a TIN structure were necessary contours of the area of interest. For this purpose was used a topographic map that included the study area which was scanned and georeferenced, (*figure 1.*).

The georeferencing facilitated to transform the map from analogical format to digital format in coordinates, through ArcGIS software, assuming that the projection system was known and the points on that map were known as the coordinates x and y. Based on the data obtained it was possible to build 3D models of the study area.

Figure 1 **The Map of Retezat Mountains**

RESULTS AND DISCUSSION

Using ArcGIS software, based on digitizing the contours was created the digital elevation model, Figure 2, facilitating the creation of TIN structure of the study area.

Based on the DEM the TIN model was created, that represents a special format typically used in a 3D representation of topographic surface and is generated by specific functions of a GIS from spatial data stored in other formats (vector, GRID).

Figure 3 shows the TIN structure of the studied area, viewing with graphical tools, the ranges of the elevation in this area, respectively 700-2400 m.

Based on this model, complex analysis can be perform, visual or quantitative, on the morphology of the land, such as: slope, aspect, line and area of visibility etc.

Surface slope represents it's inclination to the horizontal plane and was calculated with the tangent function. Basically, it was given by the angle between the plane of the earth's surface and the horizontal plane. The calculation was done in the right triangle slope determined by the earth's surface plane, vertical plane and horizontal plane using the tangent function.

The slope is one of the most geomorphologic parameters used being linked to the intensity of geomorphologic processes, and it can be calculated according to the relation (1).

$$\text{Slope } (\%) = \frac{\text{Heigh}}{\text{Base}} \cdot 100 \qquad (1)$$

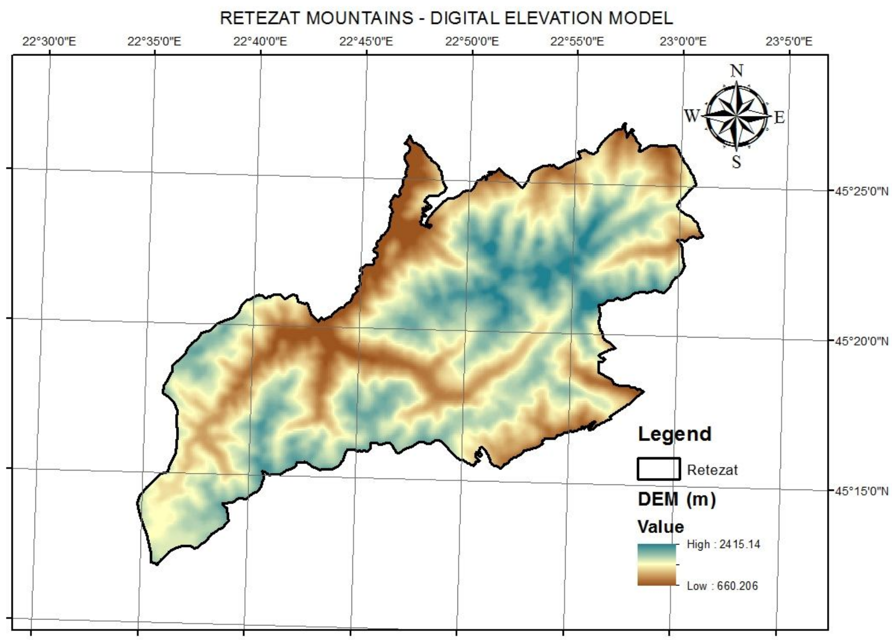

Figure 2 **Digital Elevation Model of Retezat Mountains**

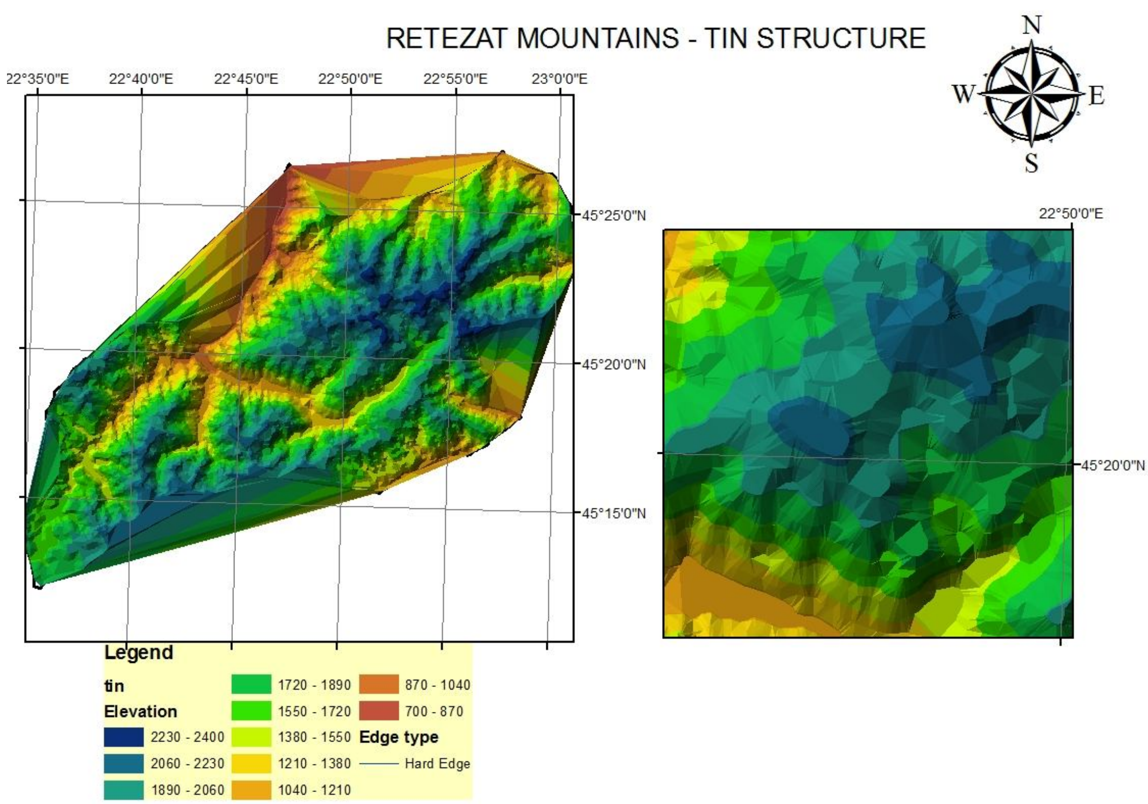

Figure 3 **TIN structures of Retezat Mountains**

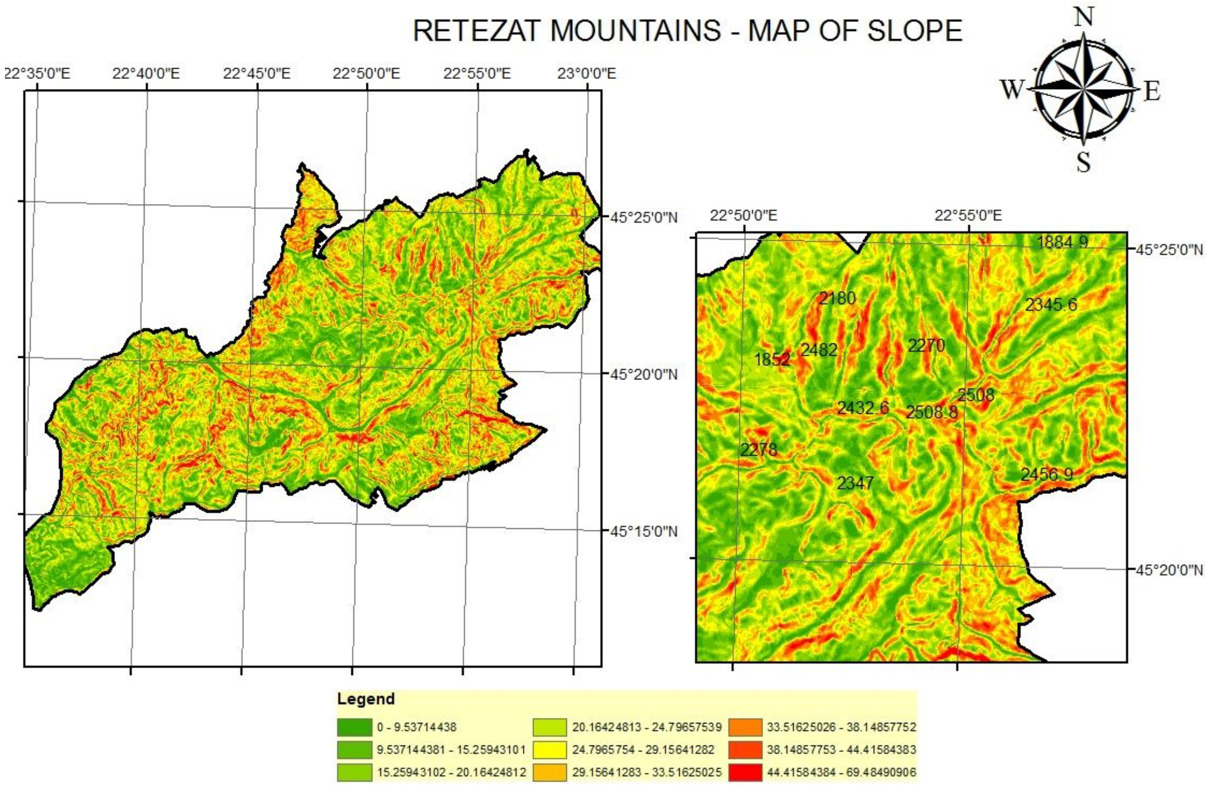

Figure 4 **Retezat Mountains - Map of Slope**

In this study, 3D model facilitated the graphical representation of different types of slopes, Figure 4 and extracting information on percentage distribution of land slope, the data are presented in *Table 1*.

Table 1

Percentage distribution of the slope in Retezat Mountains

Class	Slope (degree)	Percent (%)
1	0-10	9.45
2	10-20	33.62
3	20-30	40.07
4	30-40	15.50
5	40-50	1.33
6	50-60	0.02

The **Aspect** represents the earth's surface orientation towards cardinal directions and it can be determined simply by reference to the north, but mathematically and geometrically it depends on the earth's surface declivity.

From digital model of the studied area, with ArcGIS software, it was possible to represent the aspect of the study area based on a color palette as well as numerical data. The aspect is used in various fields such as: monitoring area, construction of new objectives, appropriate land use, etc.

In this study, the 3D model facilitated the graphical representation of the aspect, Figure 5, and extracting the percentage information regarding their distribution, data are presented in Table 2.

Table 2

Percentage distribution of the Aspect in Retezat Mountains

Aspect	Percent (%)
NORTH	13.73
NORTHEAST	11.52
EAST	11.91
SOUTHEAST	11.86
SOUTH	10.44
SOUTHWEST	10.26
WEST	13.09
NORTHWEST	17.14

Also, from 3D model of the studied area was obtained the **Hillshade** model, which facilitated the highlighting of landforms directly from DEM model, emphasizing valleys, depressions, ridges, for a better and easier visualization, interpretation and use of the map.

A Hillshade is a 3D model in shades of grey, with the relative position of the sun for shading the image, *Figure 6*. This function uses the latitude and azimuth properties to specify the position of the sun.
Also, based on the models previously created was done an interactive 3D map of the study area, map that can be populated in a GIS environment with information from various fields: agriculture, forestry, tourism, geography, etc. to improve the decision process, *Figure 7*.

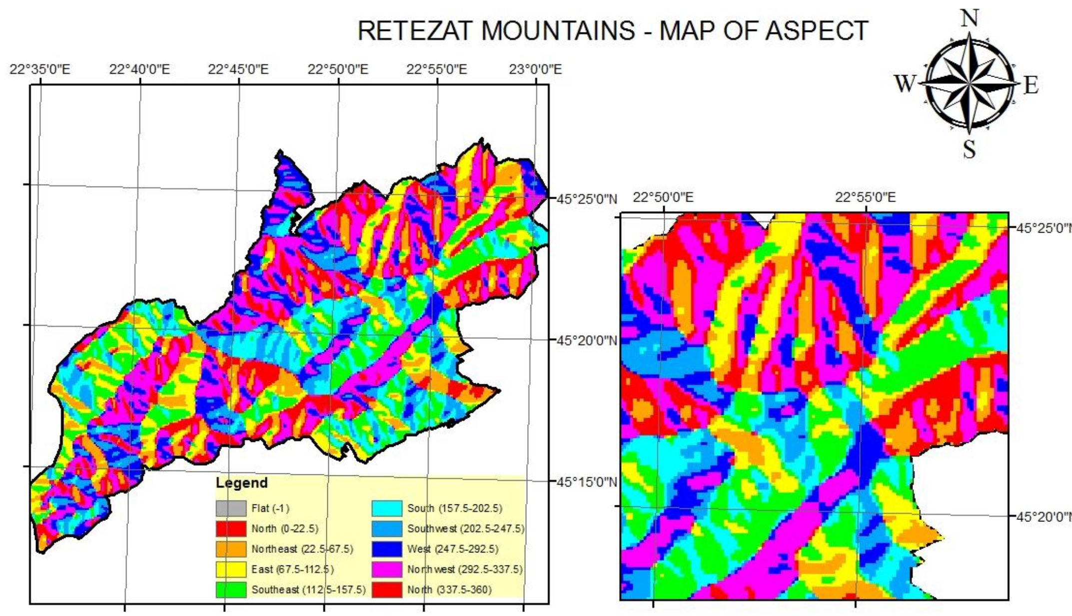

Figure 5 **Retezat Mountains - Map of Aspect**

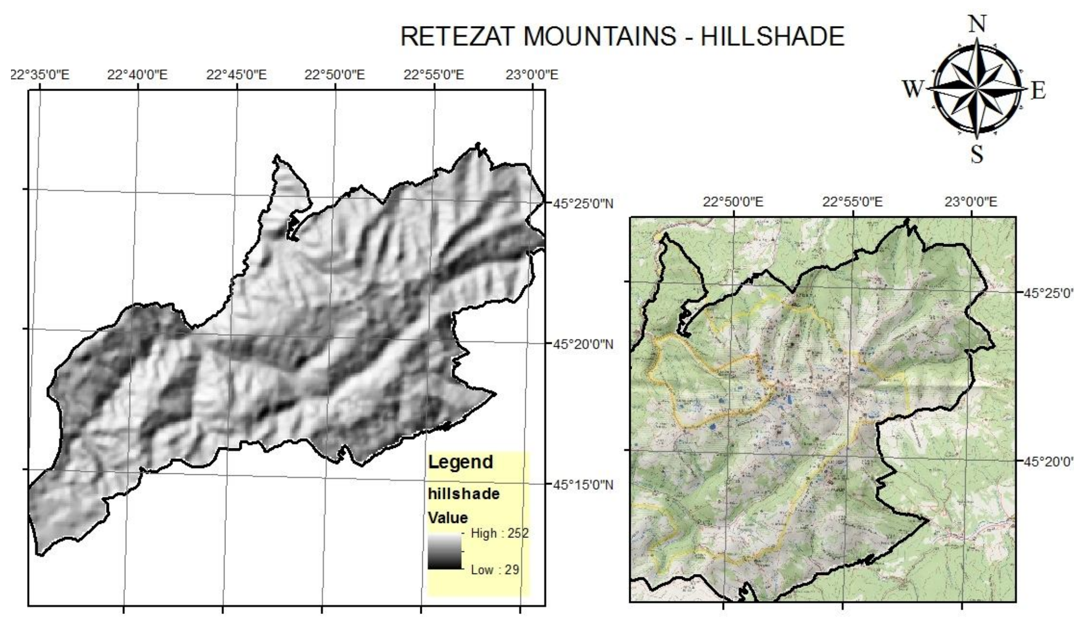

Figure 6 **Retezat Mountains - Hillshade model**

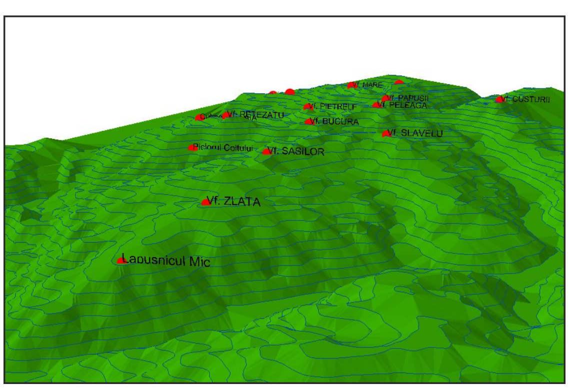

Figure 7 **The 3D Map of Retezat Mountains**

CONCLUSIONS

Georeferencing facilitated making the map with the studied area in coordinates using ArcGIS software, based on obtained data system it was possible to create 3D models of Retezat Mountain area.

Based on the 3D model, the Triangulated Irregular Network (TIN) was created which facilitated the complex analysis on the morphology of the land, slope, aspect, line and area of visibility for the studied area.

According to the TIN structure achieved, the ranges of elevation of the studied area were between 700 - 2400 m. Also, 6 classes were identified on the slope of the terrain and the percentage distribution of land was obtained in relation with the aspect, the parameters analyzed covering the entire study area, indicating the high accuracy of the model and this approach method.

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