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GIS TECHNOLOGY USED FOR FLOODS STUDY

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Abstract

The objective of the study is to develop a Geographic Information System (GIS) model which integrates a lot of information and various types of data required for hydrographic and geomorphologic analyses, applicable in the sphere of hydrology and geomorphology. The case study will show how to use a GIS tool, create a Digital Elevation Model (DEM), using terrain information, contours line with height information attached and rivers, and at the end to obtain watershed boundaries and determine which basins have higher possibility of flooding by analysis of its shape.
The raw data (primary database) will be obtained through vectorization from different maps used for analysing the geographic characteristics of the studied area. The paper focuses on prevention of potential disasters (floods), providing support in data collection and processing by transposing the real geographical problems in a computer-assisted modelling.

***Key words**: DEM, geomorphology, hydrology, GIS.*

INTRODUCTION

The aim of the study is to implement GIS technology in landscape modelling (studying the topographical surface) by numerical methods, having application in hydrology and geomorphology.
The fundamental objective of this study is to prevent any disasters and predict in a very clear manner which are the areas with the highest potential risk in the case of floods, focusing on achieving a geographic informational system which integrates all kind of information, all types of data that are needed for hydrological analyses from the automatic extraction of the river basins, watersheds, as well as finding those that have the highest risk of flooding, till study the gradients and orientations of the slopes.
Using GIS there is the possibility to conduct analyses and correlation of great complexity, which cannot be achieved with classical techniques (Balteanu et al., 2010), having in mind that the action of the natural factors is dependent on the local conditions (Lungu et al., 2015).
Basically floods have a strong impact on environment as well as on local economies (Stepanova and Rubel, 2015) and the reason which supports the use of GIS techniques in hydrology are that it's lead to achieve the goal in a definitely better manner, being no other practical methods of achieving those objectives.

MATERIALS AND METHODS

The softwares used for the study is the ArcGIS package, more accurate the *ArcMap 10.1* program with extensions and *ArcScene 10.1*.
To obtain the Digital Elevation Model (DEM), we vectorized a topographic map (which was spatially referenced, Stereographic 1970 projection) at scale 1: 25000 with the increments between contour lines of 10 meters and for the remainder graphic database (rivers, creeks, lake, countrysides), we used topographic maps at scale 1:5000 and orthophotomap up to date.
Primary database it was established by the followings layers (organized multilevel), which is presented in Table 1.
The first step in the implementation of the database it was represented by procuring cartographic materials, while the second step it was to convert the information from the analogic raster support to vector format through vectorial entities as points, lines and polygons.

Table 1. Primary graphical database structure

Layers	Entity	Contained spatial elements	Attributes	Layers	Entity	Contained spatial elements
Level curves	polyline	level curves	elevation	Level curves	polyline	level curves
Hydrography	polyline	hydrographic network from the surface	name and type	Hydrography	polyline	hydrographic network from the surface
Residential areas	polygon	limits of the residential areas	name	Residential areas	polygon	limits of the residential areas

For this study in order to obtain a better set of data in the shortest possible time we used the *ArcMap 10.1* program with *ArcScan extension*. To use this extension first the analog rasters maps must be converted into **.bmp* format.
The working mode it was an interactive digitizing, using the *Vectorization Trace* function within ArcScan extension, which requires the user intervention only in certain cases (e. g.: intersections or interruptions of the lines).
This process accomplishes the primary database and from now starts the creating of the derived database.
To understand the steps taken in this study we make a logical schema (Figure 1) which shows the chaining-mode of the steps that were made.

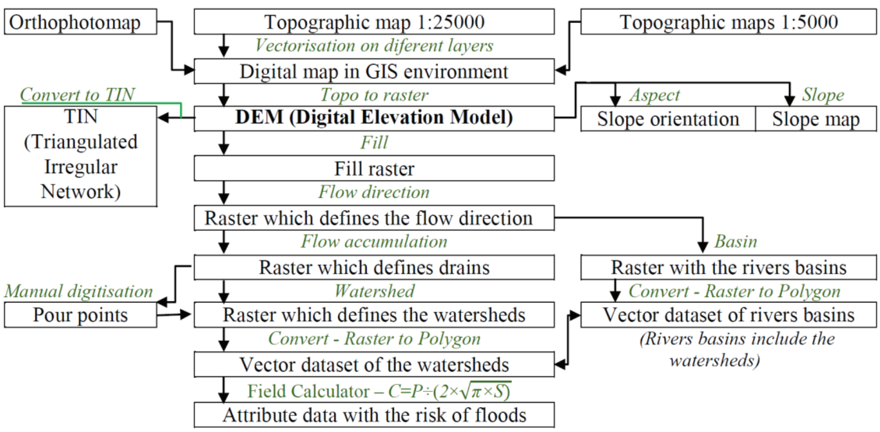

Figure 1. Schematic of workflow (Ferencz et al., 2016)

To view the terrain in 3D and performe the hydrological analyses, must be made the DEM. This was done using the *Topo to Raster* function from *3D Analyst* tools of *ArcMap 10.1* program, the result can be seen in (Figure 2).
If we have available the digital elevation model in raster format, we can choose to view it in 3D, but first is required to convert the DEM into a TIN structure using the *3D Analyst* tools. The 3D visualization of the TIN that was created in previous step it must be done in the *ArcScene* program.

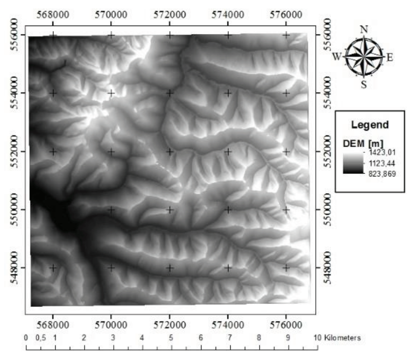

Figure 2. DEM in *Stereografic 1970* reference system (Ferencz et al., 2016)

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Derived database there was obtained after applying various analyses functions which lead to the exploitation of the DEM obtained in previous phases.
The first analysis was related to hydrography of the area, *ArcMap* offering for users a wide range of functions, shown in the (Figure 3) from below, that can be accessed from the main toolbar of the *Spatial Analyst*.

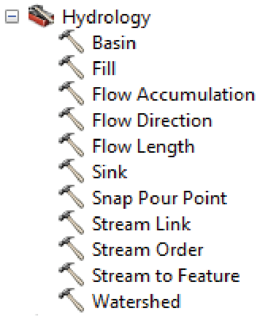
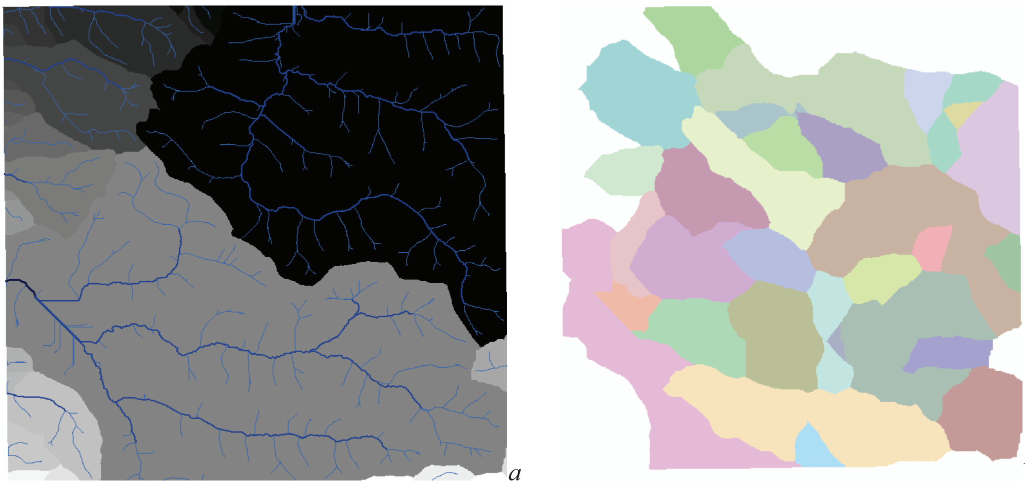


Figure 3. Hydrology toolbar

The functions that were used for creating the derived raster database structures, as well as their application order it was: *fill* – filling depressions; *flow direction* – determining the direction of drainage water on the slope; *flow accumulation* – leak accumulation; *basin* – determining boundary of the rivers basins (hydrographic basins that were obtained can be visualized in Figure 4.a.); *watershed* – determining the watersheds (Figure 4.b.), using the raster obtained after perform the *flow accumulation* function and from the digitized points where was recorded the highest accumulations of water, those points are located in the nodes of the hydrographic network and they are named "*pour points*" – each digitized point will be the lowest pixel of his watershed.



a b

Figure 4. Hydrographic basins (a); Watersheds (b) (Ferencz et al., 2016)

Having the watersheds in raster format, all that remains is to convert them into polygons entities and to calculate their surfaces.

To be differentiated between them, the watersheds are labeled with their unique ID, as shown in the Figure 5.

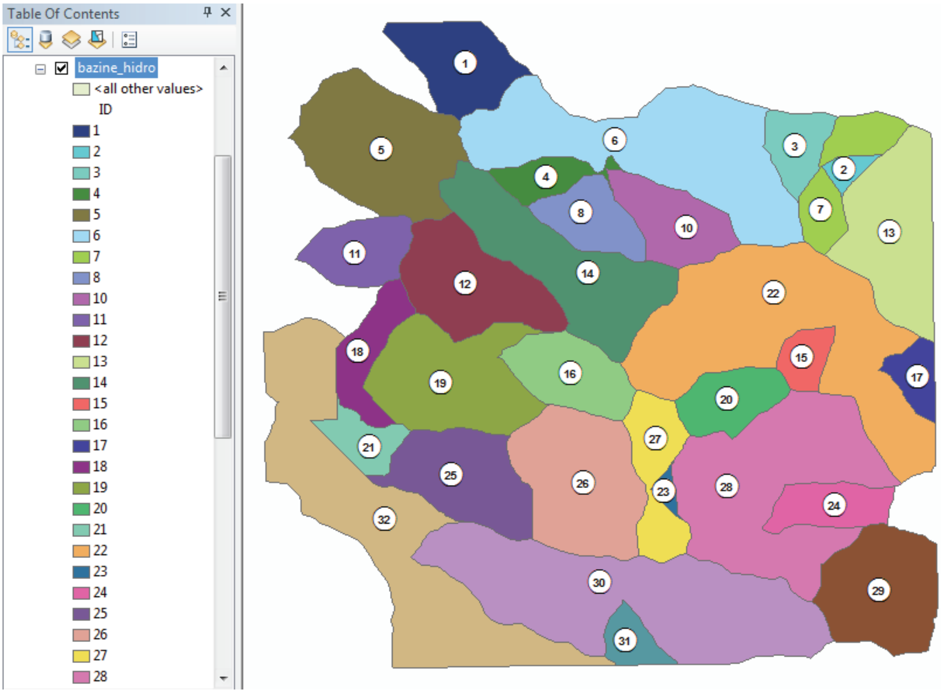


Figure 5. Identifiers of watersheds (Ferencz et al., 2016)

As describes Bilasco S. in his PhD thesis entitled "Implementation of GIS in Flood Modeling on Slopes," (2008, Cluj Napoca, Romania) the form of watersheds influences the regime of floods, by the way how are located the tributaries rivers and creeks in plan. If the watershed shape is closer to a circular one then the flood will be more concentrated. The coefficient of circularity characterized the watersheds circular shape, taking into account the area of the surface and its perimeter (Bilasco, 2008).

$$C = \frac{P}{2\sqrt{\pi S}}$$

where:
C – coefficient of circularity ($C \geq 1$);
P – watershed perimeter (km);
S – watershed area (km^2).
As the coefficient of circularity is closer to one, the risk of possible floods is in increase.
Using the *Field Calculator* function from the attributes table of the layer that contains the watersheds, we determined the circularity coefficients of the watersheds by introducing the calculation formula submitted in the relationship one.
Having the values calculated for perimeter (km) and area (km^2) we determined the circularity coefficients for all watersheds, as shown in the Figure 6 from below.

Table

bazine_hidro

FID	Shape *	ID	GRIDC	Sup_km	Perim_km	Coef_circ
0	Polygon	1	29	1,75	5,77	1,23
1	Polygon	2	26	0,23	2,42	1,42
2	Polygon	3	24	0,85	4,01	1,23
3	Polygon	4	22	0,67	5,2	1,79
4	Polygon	5	30	3,59	8,15	1,21
5	Polygon	6	23	5,53	13,86	1,66
6	Polygon	7	25	1,19	6,49	1,68
7	Polygon	8	20	1,17	4,76	1,24
8	Polygon	10	21	1,5	5,46	1,26
9	Polygon	11	31	1,23	4,5	1,15
10	Polygon	12	15	2,54	7,04	1,25
11	Polygon	13	28	2,96	7,9	1,29
12	Polygon	14	19	3,42	9,89	1,51
13	Polygon	15	18	0,55	2,95	1,13
14	Polygon	16	14	1,58	5,14	1,15
15	Polygon	17	17	0,56	3,4	1,28
16	Polygon	18	11	1,06	5,87	1,61
17	Polygon	19	12	3,1	8,82	1,41
18	Polygon	20	9	1,15	4,36	1,15
19	Polygon	21	13	0,7	4,24	1,43
20	Polygon	22	16	6,76	15,99	1,74
21	Polygon	23	7	0,14	2,12	1,62
22	Polygon	24	5	1,02	4,82	1,35
23	Polygon	25	1	2,28	6,87	1,28
24	Polygon	26	10	3,26	7,13	1,11
25	Polygon	27	8	1,36	6,65	1,61
26	Polygon	28	6	5,32	13,49	1,65
27	Polygon	29	4	2,57	6,22	1,1
28	Polygon	30	2	6,58	14,89	1,64
29	Polygon	31	3	0,53	3,23	1,25
30	Polygon	32	0	6,48	19,38	2,15

31 (0 out of 31 Selected)

bazine_hidro

Figure 6. Attributes table for the *bazine_hidro* layer

The gradients of slopes were determined using the *Slope* function, available for users under the *Spatial Analyst Tools* extension, *Surface* tools. The tilt of the slopes was expressed in sexagesimal degrees, using the DEM obtained from the level curves level curves, the result is shown in Figure 7.

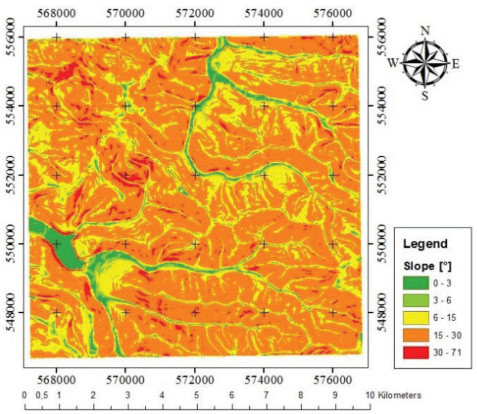


Figure 7. The averages tilt of the slopes in Stereografic 1970 reference system, Ferencz et al., 2016

Slopes orientation is shown in Figure 8 and it was obtained in a similar way, by applying the *Aspect* function from the *Surface* tools on the DEM (Digital Elevation Model) obtained through vectorization.

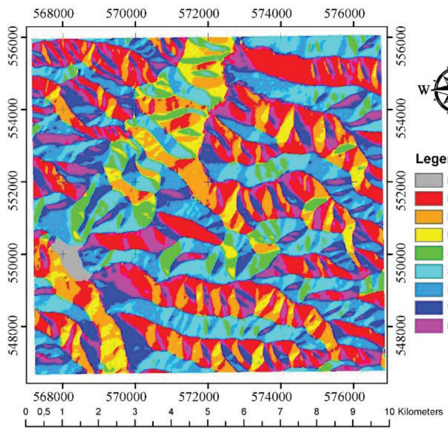


Figure 8. Slopes orientation in *Stereografic 1970* reference system, Ferencz et al., 2016

RESULTS AND DISCUSSIONS

Analyzing the coefficient of circularity we could conclude that the watersheds with the highest risk of floods are with the small values of circularity coefficient (close to the value one and which have a circular shape as shown in Figure 9.a.), namely 11, 15, 16, 20, 26, 29 while those watersheds whose value of circularity coefficient was bigger (which doesn't have the geometrical shape close to a circle – see watershed geometry identified with ID 32 from Figure 9.b.), the possibility of occurrence floods is less and those watersheds are: 4, 6, 7, 22, 28, 32.

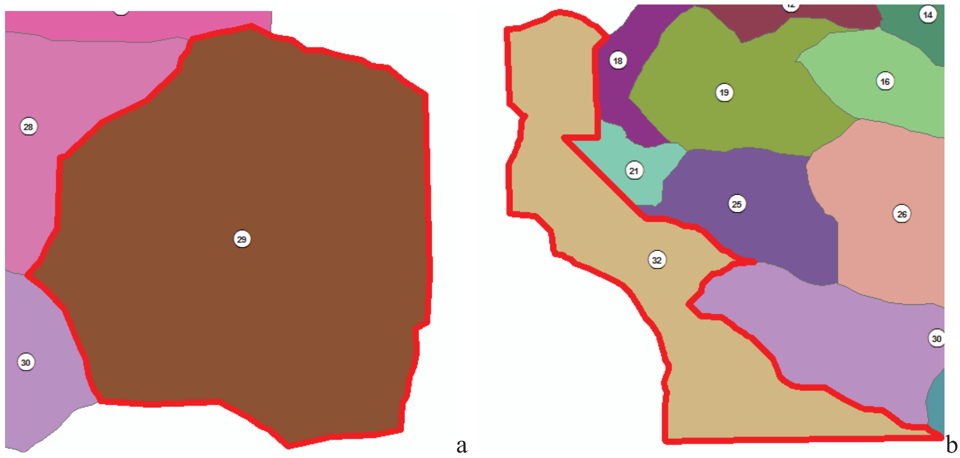


Figure 9. Circularity coefficient (a. minimum, b. maximum), Ferencz et al., 2016

The coefficient of circularity is the radius of the circle in which the watershed is inscribed. Radius is measured from the gravity center of the watershed.

The map of slopes and the map of slopes orientations are part of the elevation data, which can be used to perform a variety of cartographic analyses (ESRI, 2012).

Looking at the map of the slopes it can be observed that it is a predominantly mountainous area with an average inclination of slopes situated between the range of (15^0, 30^0), which was obvious on the topographic map also, given the short planimetric distance between the level curves lines.

CONCLUSIONS

This study presents theoretical and experimental information for the implementation of a geographic information system in order to provide standard products as maps and statistical tables used for risk calculation of the areas.

After storing information inside of a GIS and applying on them several sets of analyses, is ensuring achieve of the objectives in a categorically superior manner than traditional techniques.

If obtaining methods of the initial data were reasonable then surely the spatial data derived that result after applying the analyses will be also accurate.

Above all was prepared the primary database by vectorization, and then for the second step we generated the DEM, using elevation data which was attached to the graphic entities. The vectorization was made using automatic and manual digitization. We need to make manual vectorization to avoid the error created by the automatic vectorization, on the bottom of the slope, on the river valley. If we have a very large slope, during the automatic vectorization, when the tool use a specific algorithm, it’s very important to have a good density of terrain data information, otherwise there will be holes on the bottom of the slope, near to the revers, which will consist in a inaccurate result. The creation of the DEM it was the most important step of the work, because it will serve as input for all future analyses. After applying all the necessary functions that are required for hydrological analyses we obtained the watersheds, followed by calculation of the geometric features thereof (perimeter and area), afterwards we applied the relationship one to find the circularity coefficient of all watersheds, coefficient that is an indicator of the possibility risk of floods.

Given the previously announced things, we consider that the work brings many contributions in terms of how to pick up, process, analyze the information with the purpose of investigating and inventorying the current situation and we consider that the application can be used in further developments.

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