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LAND USE AND SUPERFICIAL RUNOFF IN THE LOWER CATCHMENT BASIN OF THE UZ RIVER (PERIOD 1990-2012)

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Abstract. – Land use and superficial runoff in the lower catchment basin of the Uz river (period 1990-2012). The Uz River catchment is situated in the east of Romania; it is a component of the catchment basin of Trotus. In the lower sector of the Uz catchment basin, the risk of flash floods is accentuated by the physical and geographical conditions favouring the occurrence of extreme phenomena. The present research was conducted using specific indices, GIS techniques, etc, which enabled the delimitation of areas prone to floods. Land use, the physical-geographical and socioeconomic factors (lithology, slope, soil texture, profile curve, and land use) were integrated and processed in GIS. Land use was extracted from Corine Land Cover for the years 1990 and 2012. The changes in land use were highlighted through the application and spatial modelling of binary change index and of the Markov model. Each factor was ascribed bonitation grades by their degree of contribution to the rapid runoff from the slope. The values obtained for the flash flood potential index ranged between 1.56 and 4.71 during the period 1990-2012. The most important changes of the flash flood potential index value were found for the left slope of the Uz River valley, in the area of the localities of Salatruc and Darmanesti. Land use change, even at small scale, has increased hydrological risk phenomena because the minor riverbed was modified and a part of the floodplain forest was eliminated.

Key words: physical-geographical factors, GIS, FFPI (Flash Flood Potential Index), floods, hydrological risk

1. INTRODUCTION

Global hydroclimatic changes imposed a new approach in the analysis of change in land use because of their consequences. The history of floods produced in the lower sector of the Uz catchment and the danger of a possible disaster motivate the present research. The causes of the emergence and the manifestation manner of flash floods constituted the main argument of research for the catchment basins of the Carpathian Mountains (Cojoc et al., 2015; Corduneanu et al., 2016;

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Mihu-Pintilie & Romanescu, 2011; Romanescu & Nistor, 2011). Because the frequency of flood risk phenomena has increased, specialists from all States of the world are interested in researching them (Adjim et al., 2017; Brinke et al., 2017; Kominkova et al., 2016; Radevski & Gorin, 2017; Raška, 2015). Floods represent the most important risk phenomenon, with the most serious economic and social consequences, especially for the rivers in the east of Romania situated in a temperate continental climate with excessive influences (the rivers of Siret and Prut) (Corduneanu et al., 2016; Romanescu et al., 2011a,b).

The study was conducted in order to highlight the areas prone to floods in the lower catchment basin of the Uz River, as a consequence of land use changes. The change in land use in the period 1990-2006 manifested itself in the increase in superficial runoff potential (Andronache et al., 2017; Cojoc et al., 2015; Mierla et al., 2014, 2015; Petrisor, 2015; Romanescu et al., 2017). This fact is proven by the historic floods recorded in the year 2005, which caused major damage in the localities of Salatruc and Darmanesti (Romanescu & Nistor, 2011; Romanescu & Stoleriu, 2013a).

2. STUDY AREA

The catchment basin of Uz is situated in the east of Romania; it is a component of the catchment basin of Trotus. The Uz catchment basin is localized between the meridians of 26°00’16” and 26°30’56” Long E and the parallels of 46°08’44” and 46°23’27” Lat N (Fig. 1). It covers a surface of 475 km^2. The area studied here covers 76 km^2 and it is located downstream from the Poiana Uzului reservoir, situated on the Uz River.

The Uz River springs from the Ciucului Mountains, from the altitude of 1,175.33 m and it is a right tributary of the Trotus River. Its length is 46 km and it confluences with the Trotus River in the locality of Darmanesti, at an altitude of 320.43 m (Miftode & Romanescu, 2016; Miftode et al., 2016). From a lithological perspective, the substrate of the studied area is comprised mainly of tough rocks with low permeability (flysch). The minor and major riverbeds of the Uz River include gravels, sands, and loess deposits. The slope has an important contribution to superficial runoff. In the lower catchment basin, which represents a depression area, the slopes with values lower than 20° are predominant. The biggest slopes are found in the area of the springs of the main Uz tributaries. The areas with values of slopes exceeding 15° have high runoff potential (Miftode et al., 2016). As for the soil cover, loams and clay loams are dominant. Along the main river, soils have a varied texture. Soil texture is very important because it influences water infiltration. The lower catchment basin is covered by forests, except for the valley of the Uz River and for the component hilltops, where the anthropogenic factor has intervened. The lower catchment basin of the Uz River comprises two types of climate. In the western sector, the specific climate is the one of average-height mountains of the Eastern Carpathians. In the eastern part, (the depression of Darmanesti) there is a climate of depression (of shelter). The mean annual amount of precipitations ranges between 630 and 1,000 mm.

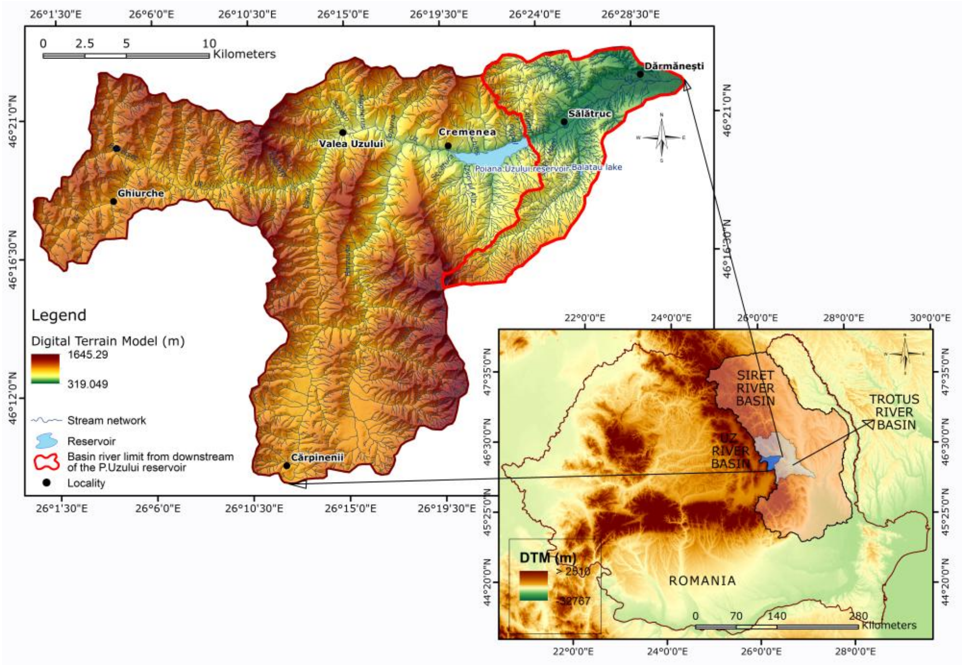

Figure 1. The geographical location and mathematic coordinates of the Uz river basin

3. MATERIAL AND METHODS

The study was conducted by covering a two phases: the analysis of land use (1990-2012) using the binary change index and the Markov model, as well as the spatial modelling, using the ArcGIS v.10.2.2 software; the calculation and spatial modelling of the flash flood potential index (FFPI), also by using the ArcGIS v.10.2.2 software (Castillo & Gomez, 2016; Conrad et al., 2015; Hapciuc et al., 2016; Li et al., 2015; Romanescu et al., 2012; Romanescu & Stoleriu, 2013a,b; Satdarov, 2016; Yang et al., 2014). The purpose of spatial modelling of the binary change index was to highlight the areas where changes of land use occurred.

The application of the Markov model details the information about changes produced in land use. It shows the direction of these changes and the surface of each conversion emerged in land use. The first step in the spatial modelling of detailed changes was to group the types of land use into six categories and to ascribe alphanumeric codes to each category (codes between 10 and 60 for the year 1990 and codes between 1 and 6 for the year 2012) (Table 1). Subsequently, a conversion was made from the vector format into a raster format, taking into account these codes. The spatial modelling of the binary change index was conducted by subtracting the two rasters of land use, corresponding to the years 1990 and 2012.

Table 1. Codes for land use in 1990 and 2012

1990		**2012**	
code	**Land use**	**code**	**Land use**
10	Urban surface	1	Urban surface
20	Surface with agricultural cultures	2	Surface with agricultural cultures
30	Surface with pastures	3	Surface with pastures
40	Surface with forests	4	Surface with forests
50	Surface with deforested shrubs	5	Surface with deforested shrubs
60	Aquatic surface	6	Aquatic surface

The FFPI index was proposed by Smith in 2003 and calculated for the Colorado Basin River. Subsequently, the index has been adapted, utilized, and improved. For the lower catchment basin of the Uz River, the spatial modelling of the flash flood potential index was conducted for the years 1990 and 2012. Hence, five physical-geographical and economic-geographical factors influencing superficial runoff (lithology, slope, soil texture, profile curve, and land use) were analyzed and integrated into the GIS setting.

Slope rasters and profile curves were obtained by processing the digital elevation model, using the *Slope* and *Curvature* functions of the ArcGIS v.10.2.2 software. The lithology factor was obtained by vectoring the Geological Map of Romania, at a scale of 1:200000. Soil texture was obtained by vectoring the Map of Soils of Romania, at a scale of 1:200000. Land use was extracted in a vector format from Corine Land Cover, for the years 1990 and 2012 (Siret Water Basin Administration, 2016) (Fig. 2).

The three other factors (lithology, soil texture, and land use) were converted from the vector format into raster format and processed in ArcGIS v.10.2.2. For obtaining the flash flood potential index, the five factors were recategorized; they received bonitation scores depending on their contribution upon superficial runoff (Table 2).

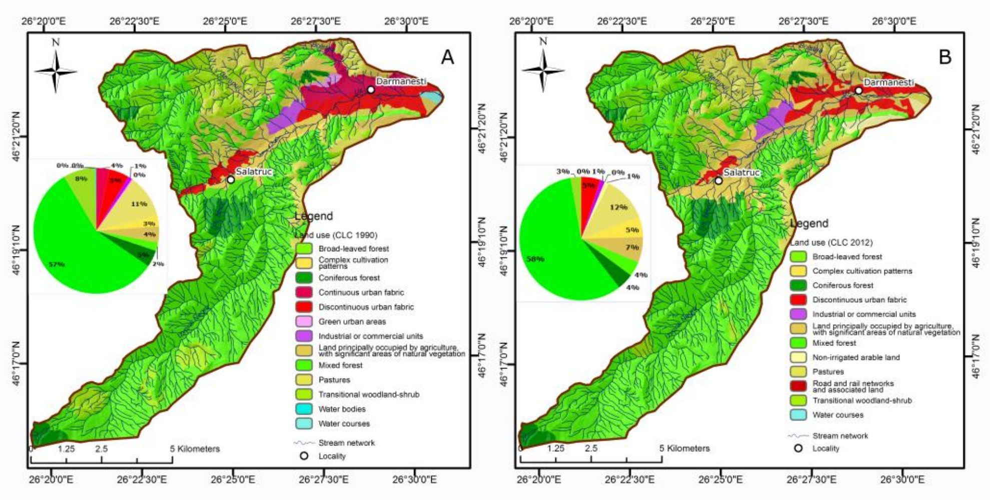

Figure 2. Land use in the lower basin of the Uz River.

Afterwards, the AHP (Analytic Hierarchy Process) extension of the software was used. The AHP method was designed in 1980 by Saaty and it is a multi-criteria method of analysis based on comparisons between pairs of factors that – in the present research – influence superficial runoff.

In order to highlight the most exposed surfaces to superficial runoff, for the period 1990-2012, the classes of the FFPI index (obtained for each of the aforementioned years) were regrouped and added up, and they were ascribed alphanumeric codes: the classes 1, 2, and 3 received the value 0; the classes 4 and 5 received the value 1. The raster obtained for the year 1990 was subtracted from the raster corresponding to the year 2012.

Table 2. Classification natural and anthropogenic physical-geographical factors in the lower catchment of the Uz River

Factor\ Bonitation score	**1**	**2**	**3**	**4**	**5**
Lithology	Gravels, sands; Sands, gravels, loess deposits	Diluvium-proluvium deposits	Sand stones, tuffaceous sandstones, andesites, cinerite; Conglomerates, sandstones, marls and charcoal	Shale limestone flysch (Horgazu); Sandstone flysch (Tarcau), sandstone flysch with shale interleaves, shale flysch with stripes; Shale flysch with shale interleaves, conglomerates with green shales elements; Sandstone shale flysch, shale flysch; Black shale flysch (Audia)	-

The slope (°)	0-3	3-7	7-15	15-25	>25
Profile curve	-	-	-25.9 – 0	0 – 0.09	0.9 – 15.4
Soil texture	Clay-sandy; Water	Clay; Varying texture	Clay…clay-loamy	-	-
Land use	Broad-leaved forest; Coniferous forest; Mixed forest; Water bodies and courses	Transitional woodland-shrub	Complex cultivation patterns; Land principally occupied by agriculture with significant areas of natural vegetation	Pastures	Continuous/Discontinuous urban fabric; Green urban areas; Industrial or commercial units; Road and rail networks and associated land

4. RESULTS AND DISCUSSIONS

The methodology of study applied for this research involved the main components of the natural environment that have an influence on superficial runoff. Upon applying the aforementioned methodology, it has been found that in the period 1990-2012, change in land use accounts for 9% of the total surface of the studied area, especially in the basins of the main tributaries of the Uz river: Camp, and Izvorul Negru (Fig. 3A). This aspect is suggested by the binary change index (Table 3).

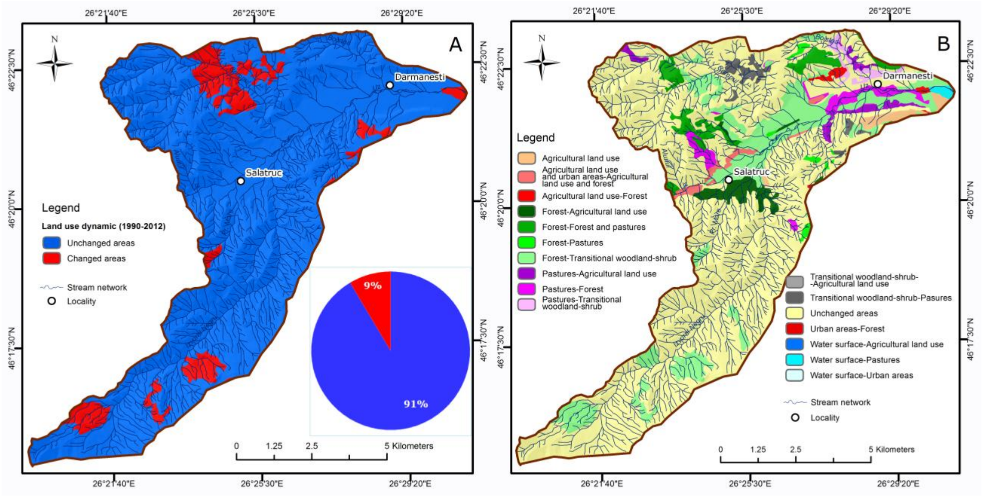

Figure 3. The binary change index of land use during 1990-2012 (A) and the Markov model for detailed changes in land use during 1990-2012 (B)

It has been concluded that the deforested areas cover a surface of 4,877.2 ha; the forested areas cover 5,073 ha, along a period of 22 years. It can be stated that not all conditions of sustainable development have been met. Based on the Markov model, the map of detailed changes in land use was obtained. This stands to highlight a great number of major changes in land use (Fig. 3B). The Markov matrix indicates the conversion of lands with various uses in areas prone to superficial runoff: pastures, agricultural fields, and fields with deforested shrubs. These areas account for 27.7% of the surface of the studied area. The conversion to agricultural fields cover a larger surface (999.1 ha), while the conversion to fields with deforested shrubs accounts for the smallest surface (211.8 ha).

The map of the FFPI index value distribution was elaborated for the years 1990 and 2012 and it underlines the changes produced in land use influencing superficial runoff within the lower catchment of the Uz River. The values of the FFPI index for a period of 22 years range between 1.56 and 4.71.

Table 3. Markov matrix for land use changes during 1990-2006

1990\2012	**1**	**2**	**3**	**4**	**5**	**6**	**Total 2012**
10	11	12	13	14	15	16	**765**
	471.8	**284**	**9.2**	**0.003**			
20	21	22	23	24	25	26	**539.3**
	10.6	**422.9**	**96.2**	**9.6**			
30	31	32	33	34	35	36	**851.1**
	0.0033	**138.8**	**654.8**	**57.6**	**0.04**		
40	41	42	43	44	45	46	**4877.2**
	0.0007	**150.3**	**41.9**	**4,603.6**	**81.4**		
50	51	52	53	54	55	56	**630.8**
		3.1	**95.4**	**402**	**130.3**		
60	61	62	63	64	65	66	**24.9**
	0.0008	**0.001**	**23.6**	**0.3**		**1.1**	
Total 1990	**482.4**	**999.1**	**920.9**	**5073**	**211.8**	**1.1**	**7688.3**

The classes that underline the areas with high and very high superficial runoff potential are extremely significant. They are generally found in the W-NW of the basin studied, especially in the origin area of the main tributaries of the Uz River. The most affected sub-basins belong to the creeks of Campul and Paraul Mare.

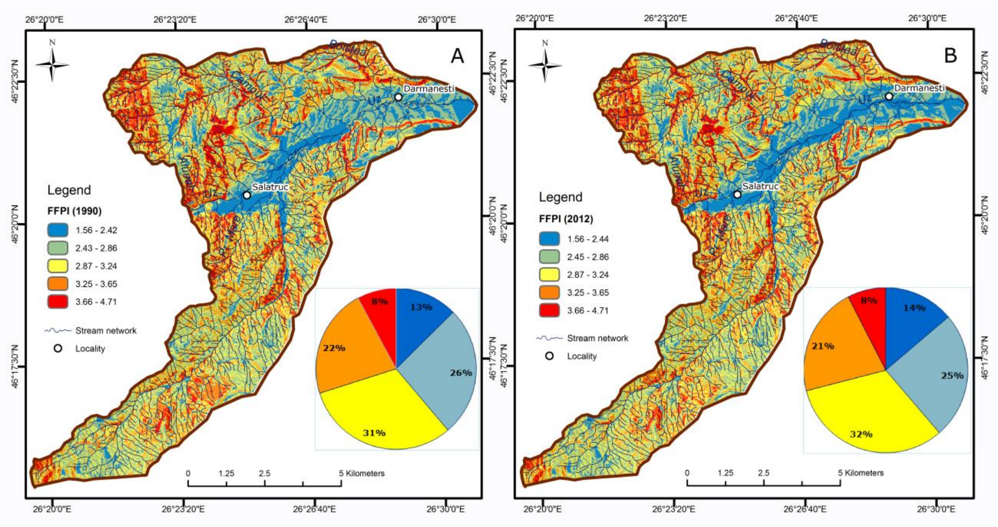

Figure 4. FFPI values for the lower catchment basin of the Uz River – 1990 (A); 2012 (B)

The two classes account for around a third of the surface studied (in the year 1990, a percent of 30%; in the year 2012, a percent of 29%). The weighting has decreased by 1% in a period of 22 years (Fig. 4).

In order to highlight the spatial dynamic of land use in these areas, the values of the classes of the FFPI index (for each year) were regrouped and added up and they were ascribed alphanumeric codes, as follows: the classes 1, 2 and, 3 received the value 0; the classes 4 and 5 received the value 1. After recategorizing and using the ArcGIS v.10.2.2 software, we subtracted the raster obtained for the year 1990 from the raster obtained for the year 2012. Hence, a new raster was obtained that underlines the areas where significant changes have occurred concerning superficial runoff (Fig. 5). The changes produced in the period studied represent a percent of approximately 10% of the total surface. These areas are encountered mainly in the localities of Salatruc and Darmanesti.

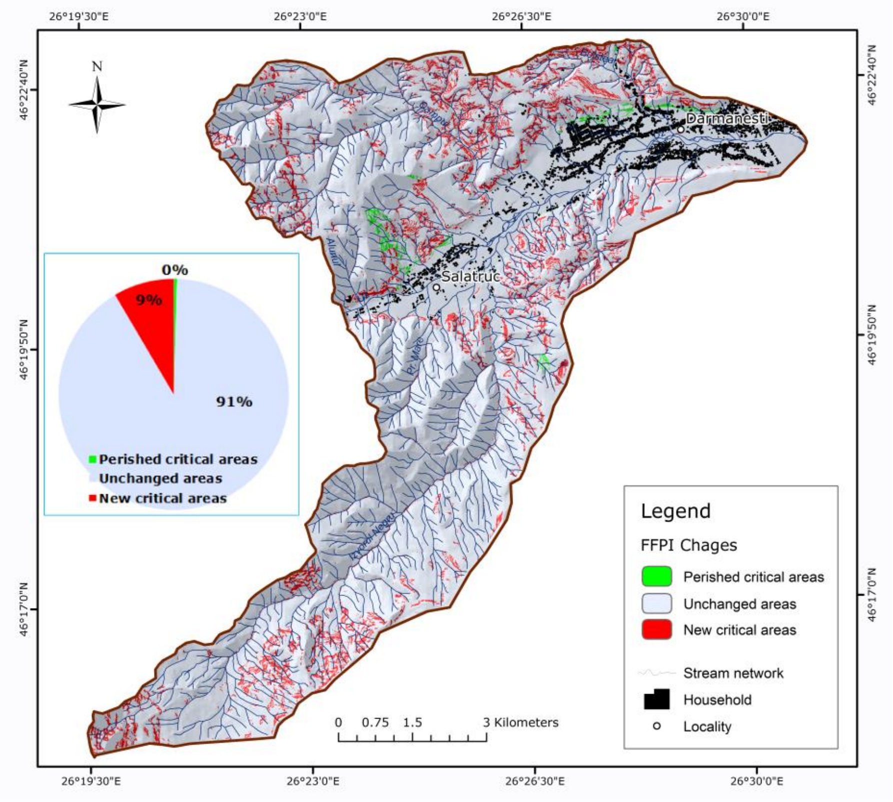

Figure 5. Changes in high and very high FFPI values, during 1990-2012

In the summer of 2005, a historic flash flood occurred on the Uz River, at the Darmanesti hydrometric station, (registering a historic flow of 132 m^3/s). The flash flood managed to flood the locality and it produced significant material damage (Miftode & Romanescu, 2016). For the areas where the values of the FFPI index show great changed in the period 1990-2012, it has been concluded that the weighting of the surfaces featuring high values (9%) is much higher than the one of surfaces where they disappear (0.2%). The change in land use greatly influenced the increase in superficial runoff potential within the period 1990-2012.

5. CONCLUSIONS

The map of distribution index values underlines the major changes in land use as a consequence of anthropogenic intervention upon the natural environment. The greatest conversion occurred for agricultural fields (999.1 ha). The highest value obtained for the FFPI index (4.71) confirms the existence of areas highly prone to superficial runoffs, (areas resulted after land conversion). The degree of vulnerability to floods of human settlements (the localities of Salatruc and Darmanesti) and of other surfaces situated at the foot of slopes and along the rivers is increasingly higher during heavy rainfall. It is very important to know the consequences of changes in land use in order to establish measures for preventing and mitigating the disasters produced by floods. The most important measure would be to stop deforestations as soon as possible and to reforest the slopes.

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