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A WAY OF DETERMINING HOW SMALL RIVER BASINS OF SOMES RIVER ARE SUSCEPTIBLE TO FLASH-FLOODS

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Abstract: The increase in intensity of torrential rains of Romania over the last decades, as a consequence of the general tendency of global warming, has triggered many flash-floods especially in small and very small river basins which in turn have generated a lot of damages, from loss of human lives to important material prejudices. The paper focuses on determining the vulnerability degree of small river basins from Someş river basin regarding flash-floods in general and is composed primarily of two parts: in the first part we have presented one of the most destructive flash floods that took place in Someş river basin, on the 20-21 June 2006, in the second part we have calculated an index that estimates the vulnerability degree that small river basins from Someş river basin have when discussing the matter of flash floods.

Keywords: small river basins, flash floods, vulnerability.

1. INTRODUCTION

Flash floods have gathered the concern of the international scientific community since they have started to develop more and more often and produce more and more losses, both in terms of human lives and material destruction. There have been elaborated many scientific works regarding flash floods and many research projects have been put into action, mainly being part of FP4 – FP 6 frameworks:

- „Torrent hazard control in the European Alps. Practical tools and methodologies for hazard assessment and risk mitigation” – THARMIT (http://www.geol.unipd.it/03_ricerca/progetti/tharmit/tharmit.htm);
- „An European flood forecasting system” – EFFS (http://efas.jrc.ec.europa.eu/)
- „Observations, Analysis and Modelling of Lightning Activity in Thunderstorms, for use in Short Term Forecasting of Flash Floods” – FLASH (http://flash-eu.tau.ac.il);
- „Integrated flood risk analysis and management methodologies” – FLOODsite (http://www.floodsite.net/default.htm).

These projects have focused on the following items:

- observing by radar, satellite and field recorded data the triggering rain for the flash flood;
- identifying the main type of drainage (liquid, hyperconcentrated, solid);
- analysis of the hydrological regime of the flash flood;
- assembling meteorological and hydrological models;
- regionalizing the phenomenon;
- integrated measures for mitigating the development risk.

Since flash floods characterize small river basins which are hydrometrically unmonitorized, the data acquired in order to provide accurate analysis of the phenomenon depend very much on the after-event recordings and observations. There is a project which focuses primarily on gathering data after the proper event took place and this is called „Documentation of Mountain Disasters” – DOMODIS (1998-2002). This project took into consideration disasters that happened in a mountainous area (flash floods, land slides, avalanches produced in the Alps).

Since our country has also recently been affected, especially over the last two decades, by such phenomena, local scientists produced many works dealing with them (Ceobanu & Grozavu, 2009; Drobot, 2008; Mătreață et al., 2009; Napradean & Chira, 2006; Teodor, 2008).

There is also the HYDRATE project (2006-2010) to which our Institute of Hydrology has its share among other 18 institutions from 11 countries. This projects aims at: analyzing flash floods all over Europe; developing common basis for observing such phenomena over Europe, creating a set of methods and technologies that would provide better forecasts and deliver immediate warnings against these events.

Flash floods usually develop over short periods of time and affect small areas, thus not permitting the conventional monitoring systems to provide accurate data regarding them (the amount of rainfall that has triggered the event and the water discharges carried during the event). As a consequence, the weather and hydrological mechanisms that are responsible for the generation of such flash floods are little understood and this leads to inaccurate forecasts of these phenomena.

The main cause for these flash floods is represented by heavy torrential downpours, which have great intensities. In Romania such flash floods may take place all over the country and particularly during the warm period of the year, often having catastrophic traits (Mătreață & Barbuc, 2008). Most of them take place in the Carpathian and sub-Carpathian areas, where moisture laden masses of air hit the long, steep and usually fragmented slopes of the mountains. Because of this, the moisture contained in the clouds is released to the ground under the form of heavy torrential downpours. It is generally acknowledged that if these downpours exceed 25 mm of rain they can easily produce such flash floods.

Flash floods are also encountered in low terrain areas, such as the flash floods that have affected some parts of southern Dobrogea, generated on small river like Topolog, Casimcea, Cartal, Sacele, Iris. In this part of Romania heavy rains are brought by the atmospheric low pressure centers that come inland from over the Black Sea (Stănescu & Drobot, 2002).

Another cause for such phenomena is the urban ground, which has a high degree of impermeability, because of the construction materials of which it is made of.

The humidity of the soil as well as the state of compaction that characterize it may be another cause that amplifies the effects of flash floods.

An important aspect is that the severity of the phenomenon is increased when dealing with deforested slopes or agricultural fields that are ploughed along the slope.

We will now present one of the most destructive flash floods that took place in Romania over the last few years: Ilişua River (Someş river basin), 20-21 June 2006.

2. ILISUA RIVER FLASH FLOOD, 20-21 JUNE 2006

Ilişua is a right side tributary of Someşul Mare, the confluence being situated next to the village of Cristestii Ciceului, where there is also a hydrometrical station, with the same name.

Its river basin is located in the central-northern part of the country, in Bistrița Năsăud county. It springs from the southern slopes of Tibles Mountains at 1020 m high, it has a length of 52 km, a general vertical gradient of 1.5% and with its middle and lower reaches it marks the border between Năsăud Hills to the east and Ciceu Hills to the west, both sub-units of the Someş Plateau. It meets Someşul Mare River at an altitude of 242 m. The area of the basin is 353 sq km, its mean altitude is 493 m and the general vertical gradient 163‰. (Fig. 1).

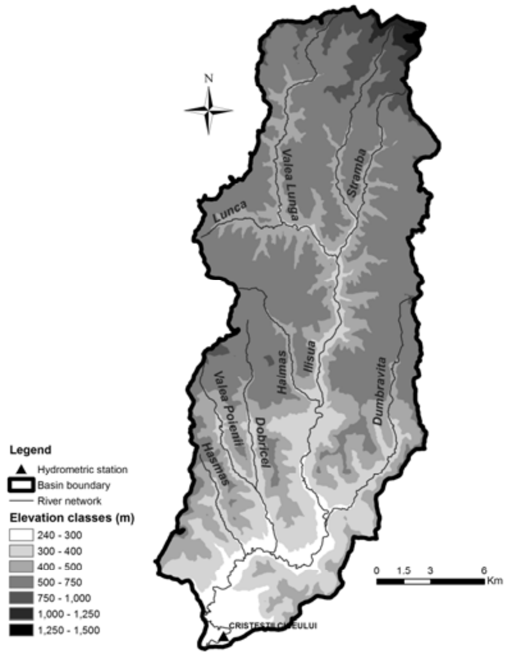

Figure 1. The elevation, river network and hydrometric stations of Ilişua river basin

Cristeştii Ciceului hydrometric station has been established in 1948. The hydrological characteristics of the river in the section of this station are:

- the mean annual discharge (1950-2007): 3.34 m^3/s;
- the specific discharge: 9.46 l/s/sq km;
- the minimum discharge: 0.023 m^3/s (30.08-02.09.2003);
-the maximum recorded discharge 294 m^3/s

(13.05.1970);

-maximum discharges with different probabilities : 0.1% - 560 m^3/s, 0.5% - 400 m^3/s, 1% - 330 m^3/s, 5% - 185 m^3/s, 10% - 125 m^3/s.

- the number of floods which have overcome the flood water level: 4, but only the one in 2006 had the characteristics of a flash flood.

2.1 The meteorological and hydrological characteristics of the flash flood

The 20-21 June 2006 flash flood had the character of an exceptionally quick flood, characterized by a rapid grow of the liquid discharges throughout the entire river basin, thus producing important loses.

Between June 1 and June 19 the soil covering Ilişua river basin had been humidified by a series of rainfall that amounted 65.9 mm at Cristeştii Ciceului hydrometric station (250 m alt.) and 84 mm at Agrieş hydrometric station (350 m alt.). This somehow prepared the frame for the catastrophic flood that followed.

On June 20 the entire area of Ilişua river basin has been confronted with severe weather patterns (Fig. 2). This weather was produced at the contact between two very different masses of air, one was hot and the other one much colder, which triggered the formation of heavy downpours that felt over a short period of time. The amount of rainfall was unequal over the river basin, thus at Cristeştii Ciceului hydrometric station 61 l/sq m were recorded, but locally 125 l/sq m were recorded. The heavy downpours first covered the upper part of the river basin, around 12.30 pm local time and were generated by very strong super cells (over 25 l/sq m).

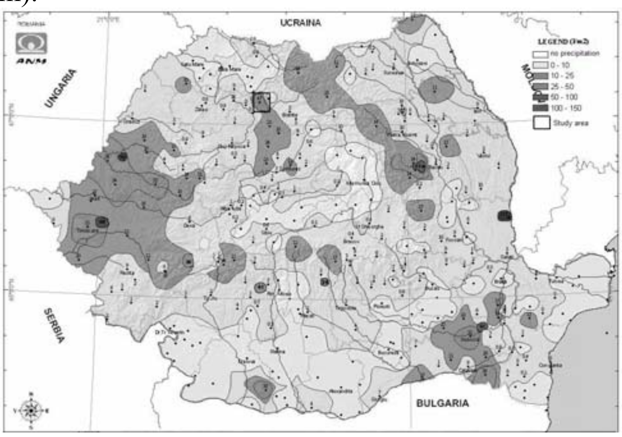

Figure 2. The 24 hours recorded precipitations (20-21 June 2006) at the monitoring stations (Source: Romanian Meteorological Administration)

These super cells began to slowly migrate southward, but in the same time in the upper part of the river basin other powerful super cells started to emerge, which amplified the effects of the first ones. Thus the flood wave has been continuously fed for more than 8-9 consecutive hours with heavy, extended downpours, the entire river basin being affected in this period of time by strong air uprisings, that formed huge thunder clouds.

The phenomena described above generated on Ilişua river at Cristeştii Ciceului hydrometric station an increase of the liquid discharge from about 5.6 m^3/s (90 cm water depth) at 8.00 pm on June 20 to 103 m^3/s (290 cm water depth) at 1.00 am June 21. The flood level, which was considered to be at 270 cm water depth, was thus overwhelmed. The liquid discharge continues to grow, reaching 212m^3/s (410 cm water depth) at 2.30 am. This maximum discharge of 212m^3/s corresponds to an exceeding probability of 3% (Fig. 3.).

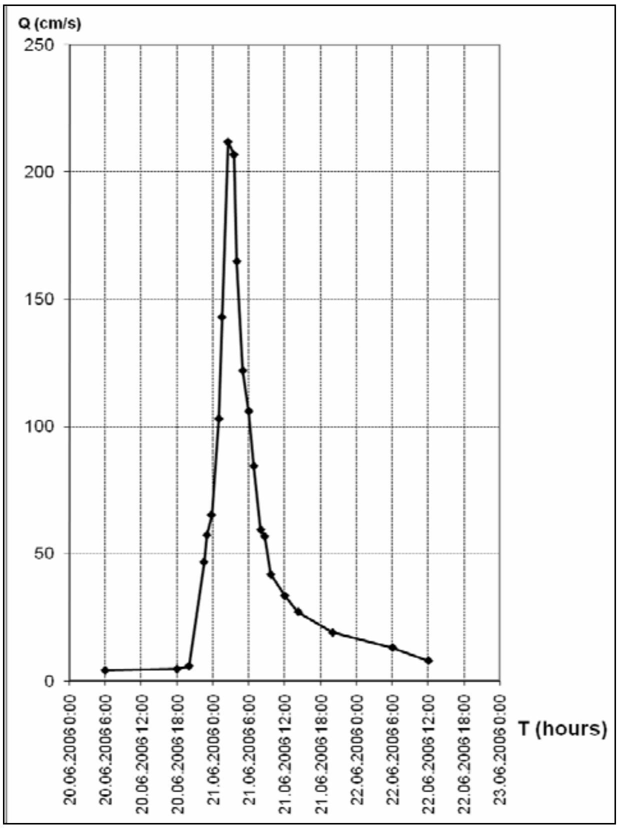

Figure 3. The 20-22 June 2006 flood wave hydrograph for Ilişua river – Cristeştii Ciceului hydrometric station

At Cristeştii Ciceului hydrometric station (353 sq km area), the 20-22 June 2006 flood had the following traits: the maximum water discharge was 212 m^3/s, the total length in time was 34 hours, the drained water layer was 22.8 mm thick and the drainage index was 0.36.

In Tarlişua village there have been recorded most human life loses and the most important material loses too. According to the local authorities the phenomena started to develop at 4.15 pm. At the beginning the rain was steady, but after 4.45 pm to 5.15 pm the rain started to increase in intensity, taking the form of a heavy torrential downpour. From 5.00 pm local authorities started to observe an increase of the water discharges on Ilişua river. The flood wave hit Tarlişua village at 5.15 pm, only 15 minutes after it was formed, thus having a catastrophic impact against the community. The inhabitants of this small village had literally no time to save their lives or their possessions.

2.2. The loses produced by the flash flood

- human lives: 10 deaths and 3 missing persons;
- important material loses, 16 villages were affected in which many houses, households and gardens were flooded and destroyed, agricultural fields were flooded and crops destroyed, bridges, roads, hydrotechnic alleviations were partially or completely affected;
- an increase in turbidity of the water courses in the basin, due to soil erosion and damaged areas of land, that reached at Cristeştii Ciceului hydrometric station very high levels of solid suspended sediment discharge: 17 000 kgs/s;
- the local vegetation and plant cover were seriously affected by the flood wave;
- the general landscape was re-shaped;
- the quality of ground waters was affected (ground waters are used as source of drinking water for the inhabitants) since many wells were covered with mud and thus became unusable;
- important flows of water and mud affected the slopes of the hills and mountains creating new gaps and torrents;
- the soil cover was seriously eroded.

3. DETERMINING THE VULNERABILITY DEGREE TO FLASH FLOODS IN SOMES RIVER BASIN

The Someş river basin is situated in the north-western part of the country, with an area of 15740 sq km (representing 6.6% of the total area of Romania). The length of the river on the Romanian territory is 376 km. The Someş system is formed of two main tributaries, Someşul Mare (130 km/5033 sq km) and Someşul Mic (178 km/3773 sq km), the springs of the first one being considered the starting point of the whole system. The river basin has 403 codified rivers, the total length of the hydrographic network being 5528 km.

The actual level of the monitoring and modeling weather and hydrological systems doesn't allow us to have a clear understanding upon the formation of flash floods phenomena, especially because of the spatial-temporal scale on which these events occur (convective cells that last 20-30 minutes, small river basins that have merely a few square kilometers, increasing duration that is no more than half an hour up to a few hours) and the characteristics of high variability including an unpredictable behavior of these events.

Taking into consideration these limits and the necessity of providing a good sustainable management for these severe phenomena, we therefore propose a methodology for estimating the probability for the emerging of such flash floods in small river basins. The method we have proposed is an adaptation of the procedures used in the project "Western Region Flash Flood Project".

Such kind of robust risk index methods for estimating the flash flood potential in small basins, have already proved to be useful in providing supplemental information for the real-time operational flash flood warnings decision process.

In order to determine the vulnerability degree to flash floods of the rivers in Someş river basin, we have used a methodology that aims at establishing an index which would characterize in a synthetic manner the vulnerability to flash floods of the rivers in small hydrographic basins, based on the influence of the most important geographic factors on the basin response (Flash flood early warning system reference guide, 2010).

The main generating factor for flash floods events (heavy torrential rain) was not included in the analyses, taking into account that such torrential rain events could occurred in any place, especially under the potential impact of the climate change.

The main geographic factors were chosen according to the research results that were achieved after the small river basins rainfall-runoff data were intensively studied and analyzed. These research indicate the following factors as having the most important influence upon the maximum water discharge in small basins: the hydro physical characteristics of the soil cover (highly correlated with the type of texture that a particular type of soil has), the degree of vegetation cover in a particular area (Cp) (mainly the areas covered by forests), and the general basin slope (Ib) (Miţă & Mătreaţă, 2004; 2005, Szendrei & Nemeskeri, 2007).

For each of these main factors we have created a raster layer at 1 km resolution, using specific GIS processing techniques, with 5 categorical values corresponding to a relative risk induced index from 1 (minimum risk) to 5 (maximum risk).

For this data processing we have used the GIS data available within the GIS Department from the National Institute of Hydrology and Water Management.

In order to classify the soil types in 5 categories and assign each category with a risk index, we have adjusted the synthesis table regarding “The adaptation of the hydrological risk groups of soils to the Romanian classification of texture” (Drobot & Chendeş, 2008) which have only 4 classes, considering for the last 5 class a group which contain soils that have a high percentage of clay and are generally impermeable to infiltrations of water.

For the slopes and vegetation cover index, we have used the 5 classes that are generally used in synthesizing the values of the maximum runoff coefficient corresponding to the 1% rain in small river basins. These classes have emerged from deep analysis that were carried out regarding the variability of the maximum runoff coefficient in small river basins depending on these physical geographical factors, based on the data from the representative river basins, (Table 1), (Miță & Muscanu 1986; Miță et. al., 1988; Diaconu & Şerban, 1994).

The correspondence between these five classes of values used for slopes and the forest coefficient and the potential index associated is shown in table 2. The final grids obtained at 1 km resolution, after the GIS processing, are presented in figure 5 – 7.

Figure 4. Someş river basin (elevation, river network and main cities)

Table 1. The values of the runoff coefficient established after the forest index, the basin slope and the texture of the soil (for a 125 mm rain and a previous 5 days rain of 40 mm)

Cp(%)/ I_b(%)	0-20	20-40	40-60	60-80	80-100
Low Texture					
5-10	0.44	0.42	0.40	0.38	0.36
10-20	0.46	0.44	0.42	0.40	0.38
20-30	0.48	0.46	0.44	0.42	0.40
30-40	0.50	0.48	0.46	0.44	0.42
40-50	0.52	0.50	0.48	0.46	0.44
Mean Texture					
5-10	0.55	0.53	0.51	0.49	0.47
10-20	0.57	0.55	0.53	0.51	0.49
20-30	0.59	0.57	0.55	0.53	0.51
30-40	0.62	0.60	0.58	0.55	0.53
40-50	0.64	0.62	0.60	0.57	0.55
Heavy Texture					
5-10	0.66	0.63	0.61	0.58	0.56
10-20	0.69	0.66	0.63	0.60	0.57
20-30	0.73	0.69	0.66	0.63	0.60
30-40	0.75	0.72	0.69	0.65	0.63
40-50	0.78	0.75	0.72	0.68	0.65

Table 2. The value classes for slopes, forest coefficient and the index for the potential of flash flood emerging.

Classes for slopes (%)	Classes for forest coefficient (%)	Index for the potential of flash flood emerging
5-10	80-100	1
10-20	60-80	2
20-30	40-60	3
30-40	20-40	4
40-50	5-20	5

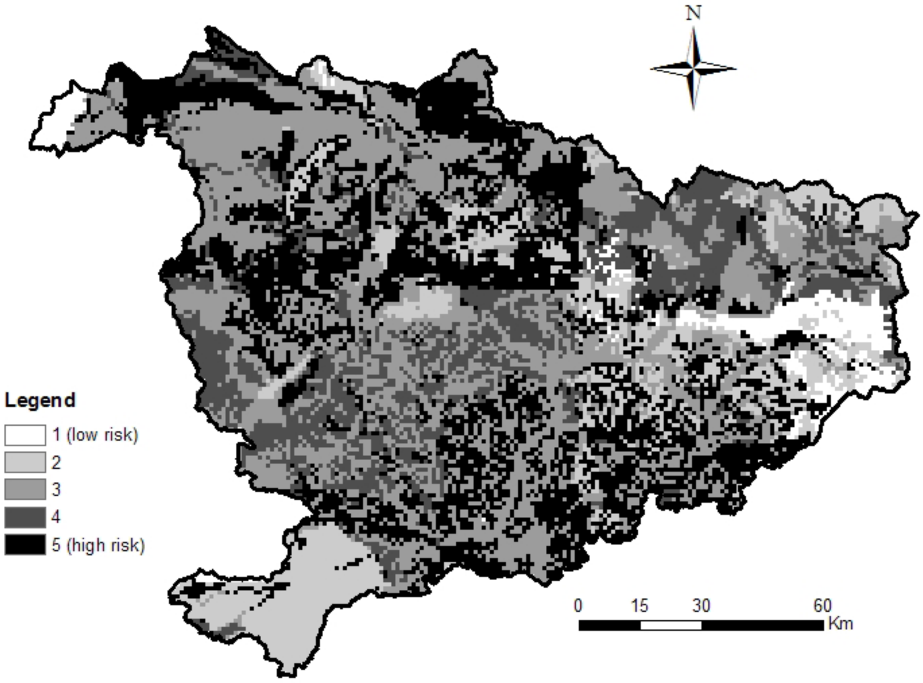

Figure 5. The soil classification at a resolution of 1 km

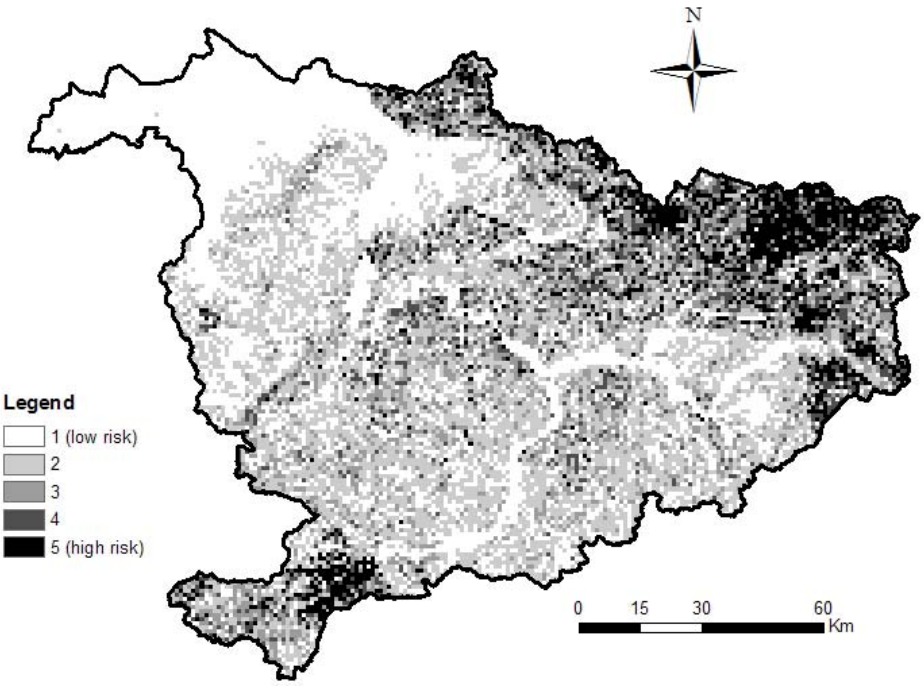

Figure 6. The slopes classification at a resolution of 1 km

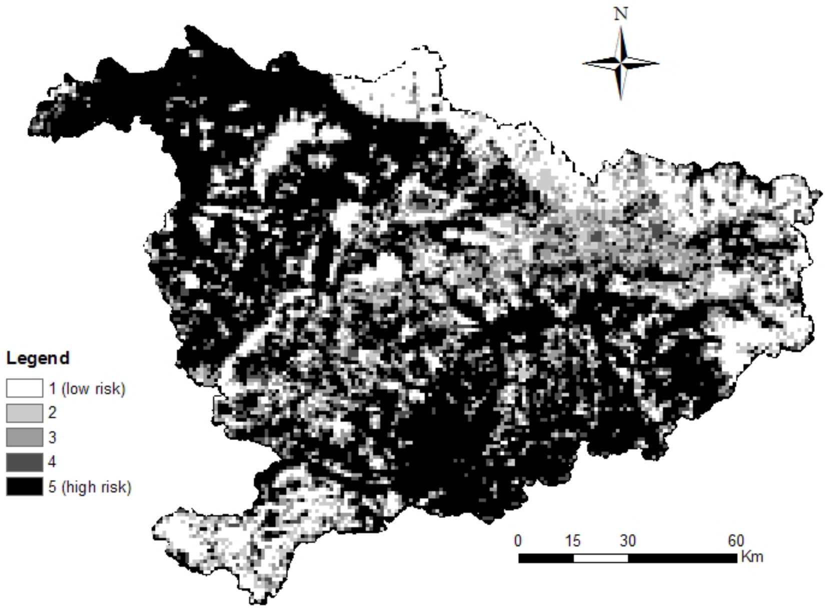

Figure 7. The classification of the vegetation cover index at a resolution of 1 km

By calculating the weighted mean value of the three grids we have obtained the final grid with the values of the synthetic index at a resolution of 1 km that estimates, based on the influence of various physical geographic factors, the degree of vulnerability to flash floods. These values have been determined taking into account indexes of 0.25 for slopes and vegetation cover and 0.5 for soil (Fig. 8).

The values of these weighted averages have emerged as a direct result of the analysis that was carried out on the influence that each physical geographic factor has upon the maximum runoff coefficient corresponding to the rain with an exceeding probability of 1%, respectively from the variation interval of the runoff coefficient in the whole range of values of the analyzed factor taking into account a constant level of the other two factors (Miță & Muscanu 1986; Miță et. al., 1988).

For a better representation and in order to have the obtained results validated in a comprehensive analysis, we have calculated, using GIS methods, the mean values of the general index of vulnerability in various sub basins of the Someş river basin. In this stage of work we have also performed an adjustment of the global index of vulnerability, adjustment that was carried out on cadastre sub basins and that attributed to each sub basin that has a general slope lower than 5% the minimum value of the index calculated before (1.58), (Fig. 9).

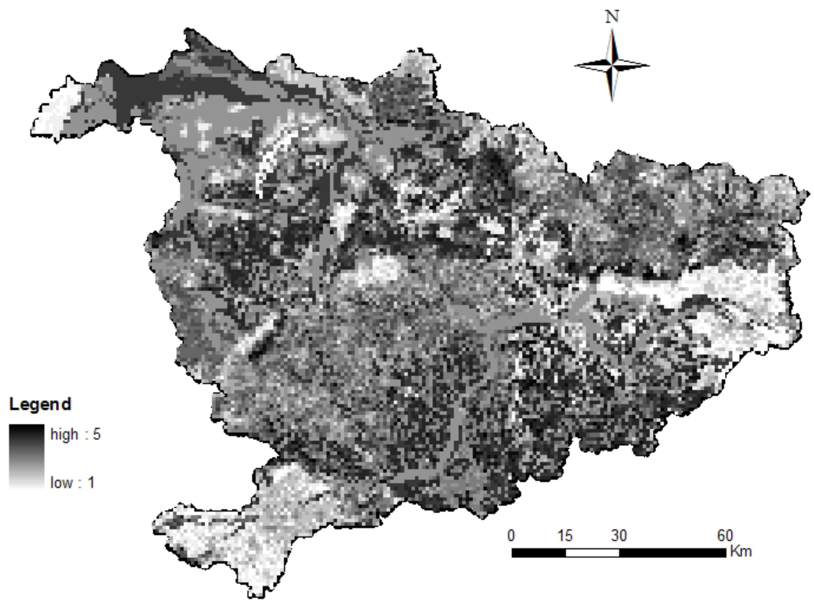

Figure 8. The values of the global index of vulnerability to flash floods at a resolution of 1 km

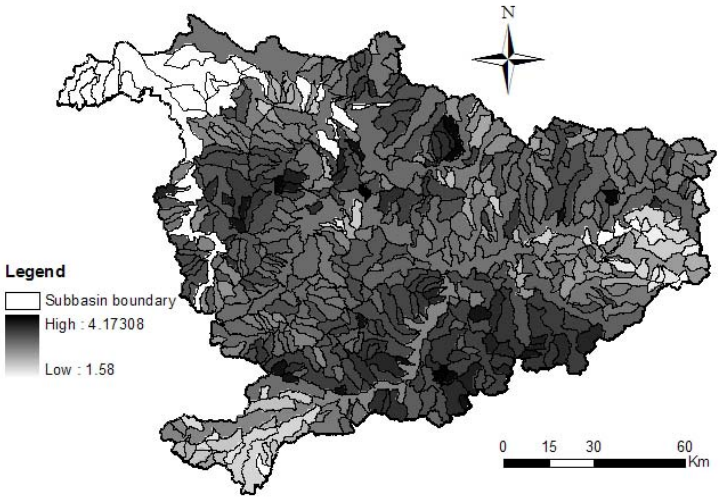

Figure 9. The values of the global index of vulnerability to flash floods in small basins, within the Someş river basin

As a first step in the validation process and further adjustment of these global vulnerability index estimates we have analyzed in details the index values obtained for the Ilişua basin.

Figure 10 exhibits the map with the distribution of the mean values of the global vulnerability index in the cadastre sub basins of the Ilişua river basin, while table 3 displays the same values of this index.

We can observe that the values of the vulnerability index are relatively high compared to the values of the same index established for the entire Someş basin. By means of a weighted averaging with the basin area we have obtained for Ilişua basin a global value of the vulnerability index of 3.22, which confirms the possibility for this river basin to be confronted with severe flash floods.

In future we have to apply this methodology to other hydrographic basins as well and to analyze the obtained results according to the data provided by monitoring posts located in various small river basins from all over the country during such flash floods.

The verification will allow us to perform a better adjustment of the classes and intervals regarding the physical geographic factors influence on flash flood formation processes, in order to obtain a better representation of the values of the global vulnerability index.

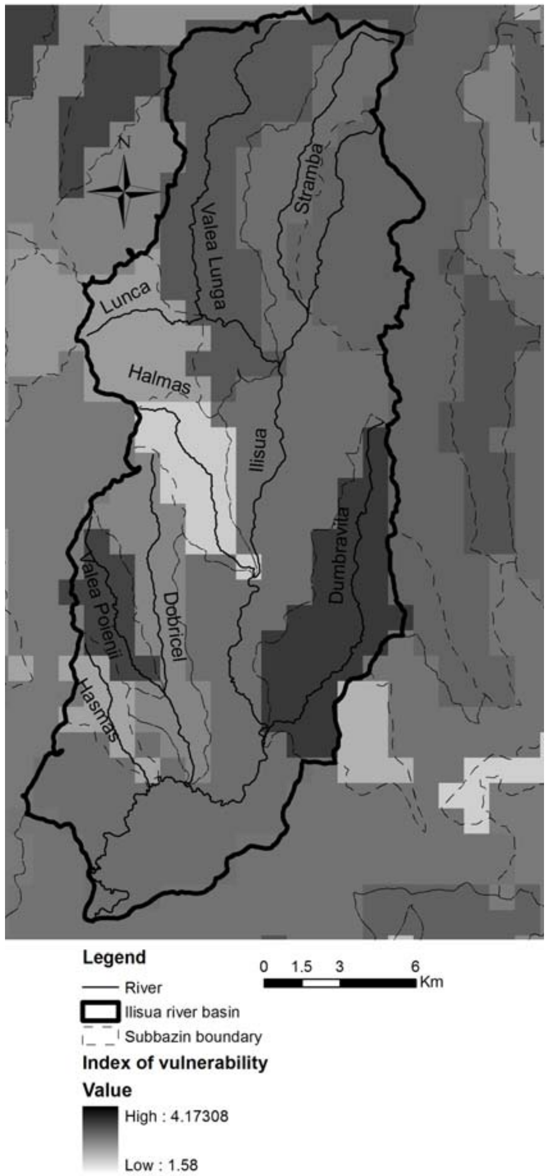

Figure 10. Global index of vulnerability to flash floods in the cadastre sub basins of Ilişua river basin

4. CONCLUSIONS

Flash floods are floods that occur over a short period of time which is why it is very difficult to provide an accurate forecast of these phenomena.

Table 3. The cadastre code, the area and the values of the global index of vulnerability to flash floods in the cadastre subbasins of Ilişua river basin.

Crt. no.	Cadastre code	River	Area (km^2)	Global index of vulnerability
1	II 1.27	Ilişua	146	3.21
2	II 1.27.1	Strâmba	30.0	3.30
3	II 1.27.2	Valea Lungă	57.9	3.40
4	II 1.27.2.1	Lunca	19.8	2.80
5	II 1.27.3	Hălmaş	9.23	2.75
6	II 1.27.4	Dumbrăvița	37.9	3.67
7	II 1.27.5	Dobricel	25.2	3.02
8	II 1.27.5.1	Valea Poienii	13.2	3.58
9	II 1.27.6	Hăşmaş	16.5	2.40

The main characteristic of these flash floods is that they have a very short increase period, usually 4-6 hours, and occur only in small river basins, that have an area from a few sq km to a few hundred sq km.

In order to better understand the mechanisms that trigger the formation of these flash floods, both meteorological and hydrological, we need to observe the past flash floods and to develop better technologies and instruments that could help us giving more accurate forecasts.

Thus, in the first part of the paper we have presented the general picture of the 20-21 June 2006 Ilişua river flash flood, that was the effect of heavy torrential rains that felt over an almost saturated soil cover while in the second part of the presentation we focused on the methodology used for determining the vulnerability to such flash floods of small rivers in Someş river basin, which could helps us further in achieving good reliable forecasts.

Such kind of robust risk index methods for estimating the flash flood potential in small basins, have already proved to be useful in providing supplemental information for the real-time operational flash flood warnings decision process.

The presented risk index method is adapted to the Romanian small river basin rainfall-runoff response, as the classification process is based on the results obtained from the Romanian representatives river basins data.

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GIS data sources

*** Corine Land Cover 2000, INCDDD Tulcea, EEA, MMGA.

*** The soils map in electronic format, 1:200000, ICPA București. (in romanian)

*** The digital land mark SRTM, corrected and reinterpolated, INHGA.

*** GIS Data Sources, INCDDD Tulcea, MMGA.

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