Research Article

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Modified Flash Flood Potential Index in order to estimate areas with predisposition to water accumulation

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Abstract: The purpose of this study is to bring a series of changes to the potential flashed-flood index proposed and used by Smith (2003), to estimate floodplains in the upper part of Trotus Basin. Trotuş Basin is located in the central-eastern part of the Eastern Carpathians (Romania) having an area of 4,456 km². The Trotus Basin is recognized as a basin where floods occur frequently due to climatic factors (precipitation, air temperature and winds) as well as due to the morphological characteristics (altitude, slope and versants orientation) that favour the formation of these phenomena. To develop a modified Flash Flood Potential Index was used six physical-geographical factors: land use, soil texture, rock's permeability, slope, profile curvature and flow accumulation. Each thematic layer has been classified in five classes, from 1 to 5, where 1 means a low contribution and 5 a strong contribution of factors in water accumulation and each factor was weighted according to its importance. The result was a grid layer representing the flood potential index. The maximum flood hazard was associated with an area of approximate 10% from the studied surface. To see the contribution of each factor in the achievement of this index a multiple linear regression was made. The result shows that three variables are statistically significant and explain 91.6% from the model. This means that MFFPI can be obtained only from these three significant factors (flow accumulation, profile curvature and land cover) in order to identify areas with flood predisposition, the non-significant variables being removed. In order to verify these results the obtained MFFPI was compared with the flood hazard map for this area and the procedure showed that this index can be used in the identification of the flood-predisposed areas.

Keywords: FFPI, flash flood, hazard, GIS, floodplain, physical-geographic

1 Introduction

Flooding is a global phenomenon causing widespread damage, economic damage and loss of human lives [1]. Floods occur when waters exceed the minor riverbed caused by flash floods with high amplitude. Flooding also includes sinking of land due to increasing groundwater or overloaded of drainage systems [2].

The flash flood "is a rapid flooding of water over land caused by heavy rain or a sudden release of impounded water (e.g., dam or levee break) in a short period of time, generally within minutes up to several hours, a timescale that distinguishes it from fluvial floods" [3]. The runoff effect is many times the result of interaction between the natural factors and anthropic specific to a certain area, for example, deforestation from recent years, allowing a fast concentration of leakage on the slopes entailing large amounts of alluvia into riverbeds [4].

Floods are one of the many natural hazards to which contemporary society is exposed, one of the main phenomena responsible for human, economic and environmental losses in a global context [5, 6]. They are responsible for a third of the economic losses as a result of natural disasters in Europe, being one of the most common types of disaster events [5].

Although the main factor that generates flooding is a climatic factor (rainfall) the hydrologic response is very different, depending on the physiographic characteristics (slope, soil texture, cover land, rocks permeability, and profile curvature) of the affected area.

Starting from this idea, Smith has developed a method for identifying areas with potential for transmission of flash floods, based on the calculation of a *Flash Flood Potential Index (FFPI)*. FFPI method was initiated by

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Smith [7] within the "Western Region Flash Flood Project", USA and applied for different case studies in the United States. Its purpose was to supplement conventional tools such as the Flash Flood Monitoring and Prediction System (FFMP) [8]. The method has been tested in several geographic landscapes such as Colorado [7], central New York and Northeast Pennsylvania [9] and central Iowa [8].

Flash Flood Potential Index proposed and used by Smith [7] aims to estimating an index to express synthetically the potential for floods at the level of a large river basin and small basin.

The goal of the FFPI is to quantitatively describe the risk of flash flooding for a given area based on its inherent, static characteristics such as slope, land cover, land use, and soil type/texture. By indexing the risk of flash flooding for a given area, the FFPI allows the user to see which sub-basins are more predisposed to flash flooding than others. Thus, the FFPI can be added to the situational awareness tools which can be used to assess the flash flood risk [8].

The datasets initially used to calculate the FFPI were the slope, land cover/use, soil texture and vegetation cover/forest density. According to Smith [7], these factors influence the occurrence of floods; soil texture and structure influence water infiltration and retention, slope and basin geometry determine the behaviour of water, such as speed and runoff concentration, forest and vegetation affect the rainfall interception, the land use, especially urbanization, play a significant role in water infiltration, concentration, and leaks behaviour.

The process involved the development of raster datasets representing the type of physiographic characteristics that influence the hydrologic response and flash flood potential. Each layer is reclassified in 10 classes of values; for the initial analysis was used a simple equal interval classification scheme and the indexed values for each layers were averaged together to generate a composite index value grid of flash flood potential [8]. An index value of 1 indicates a minimum flash flood and an index of 10 indicates a maximum flash flood and each layer can be individually weighted according to the importance [10].

The indexed values for each of layers were averaged together to generate a composite index value grid of the flash flood potential, using the Equation (1) developed by Smith [7]:

$$FFPI = (n(M) + L + S + V)/N \quad (1)$$

Where,

n is the weight of slope layer;

M is Slope;

L is Land Cover/Use;

S is Soil Type/Texture;

V is Vegetation Cover/Forest Density;

N is Sum of weightings. (L , S and V are given weights of 1. N is slightly greater than 4 since M was given a weight of slightly more than 1) [8].

James Brewster implemented the FFPI for WFO Binghamton in 2009, he modified the FFPI from Smith's original version for use at WFO Binghamton. The changes made it consist in weighting factors, thus the final Equation (2) by Brewster [11] is:

$$FFPI = (1.5(M) + L + S + 0.5(V))/4 \quad (2)$$

Raymond Kruzdlo and Joseph Ceru brought another amendment at the original method, to implement the FFPI at WFO State College, Pennsylvania in 2010. The key modification was that all elements were given equal weighting, and the Equation (3) developed by Kruzdlo [12] is:

$$FFPI = (M + L + S + V)/4 \quad (3)$$

In 2012 Joseph Ceru [10] implemented the FFPI at WFO State College, Pennsylvania and make other change at FFPI original version, the modification was that extra weighting was given to Slope as well as Land Cover/Use.

The above conventional FFPI is to quantitatively describe the risk of flash flooding based on static characteristics of cell such as surface slope, land cover, land use and soil type/texture. By indexing a given cells risk of flash flooding, the FFPI allows the user to see which cells are more predisposed to flash flooding than others [13].

To complete the risk model, Lincoln, Zogg [14] proposed the addition of a vulnerability index to FFPI. A modified FFPI version has been obtained introducing the annual maximum daily rainfall statistics as a new factor measuring the potential influence of local climatology [15, 16].

In Romania, the method was applied and adapted by several authors for different regions of the country [17–22]. Tîrnovan [20] applied this method using four factors, respectively soil structure, the degree of afforestation, the rainfall and slope gradient, these thematic layers have been intersected and mediated to obtain an index of flood potential prevention. Another study conducted by [19] used four factors, soil texture land use, terrain slope and profile curvature to get an index meant to identify areas with a high potential for floods. This index was obtained starting from the methodology suggested by Smith [7] and modified by Mătreată and Mătreată [23] adapted by Minea [24] and assumed in Zaharia et al. [25]. In this case the author claims that the FFPI method has had satisfactory results herein, and reflects the reality of the field, specifying that following observations and personal investigations in the field, he found a strongly correlation between areas and classes of the index and flooded areas.

Until now, FFPI was used to estimate the production potential of floods. This study uses FFPI to identify floodplains in the study area, the Trotuș Source - Palanca. To achieve this objective, the following physiographic factors were used: land cover, soil texture, flow accumulation, rocks permeability, slope gradient, curvature profiles.

In this study, in addition to the basic aspects of the original method, the profile curvature and flow accumulation were added as evaluation parameters. The profile curvature highlights drainage sectors, thus in the convex areas (-) runoff is accelerated, and in concave areas (+) the accumulation is favoured and runoff is decelerated [26]. The flow accumulation is calculated as the accumulated weight of all cells flowing into each downslope cell in the output raster.

The proposed factors were selected taking into account the way in which they helps us to identify areas which are, or are not prone to the accumulation of water, aim that is successfully accomplish by the two new selected variables, profile curvature and flow accumulation.

Corroborating these somewhat static physiographic characteristics information about the hydrologic response and the potential for flooding in a particular area is obtained. However, like other characteristics, potential flooding may take more dynamic [7].

Starting from this concept, the present study modified the initial index, FFPI, in order to achieve an index allowing the estimation of areas which favour the water accumulation respectively the production of flooding. The novelty consists in the fact that each class of the five factors was weighted according to the contribution to water accumulation, adding two new factors (profile curvature and flow accumulation) and introducing the multiple linear regression to identify the influence of each factor in the achievement of this index. This new index and implicitly the two input variables can be applied in any area to estimate the areas prone to water accumulation, more exactly the areas with low drainage. However, depending on the area and availability of the data you can make improvements and adjustments, taking them by the ability of the author to adapt the methodology to a new area.

2 The study area

Trotuș Basin is located in the central - eastern part of the Eastern Carpathians (Romania) (Figure 1) having an area of 4.456 km² (Figure 2). Trotuș River is the right tributary of the Siret River (with a basin of 44.871 km²) occupying a central - southern position.

Trotuș River flows from the Ciuc Mountains and after a route of 140 km, oriented NW - SE, by crossing the mountain ridges of Ciuc, Tarcăului and Goșmașului, the eastern part of Nemira, Oituz and Casin mountains, Mountains Berzunți, sub-Carpathian depression Tazlău - Casin, its eastern part (Petricica Bacaului Ridge) and the sub-Carpathian massive of Ousorul, spilling into Siret River near Adjud.

Although quite high and massive, mountains on the right part of Trotuș present some passers-by that allow better linkages with Transylvania: Ghimeș Pass (1006 m) - railway and DN 11 A, Uz Pass (1085 m) and Oituz Pass (866 m) - crossed by roads.

Trotuș Valley consists of a series of micro-depressions at the main confluences (Palanca, Brusturoasa, Agăș, Comănești, Dofteana, Targu Ocna, Onesti) separated by narrow sectors (up to defiles), crossing the mountain peaks.

Regarding climate elements, rainfall and air temperature are the parameters with the greatest importance in the formation of floods. Rainfall is the most important element for the formation of floods and for the side effects that are induced. The multiannual average rainfall amounts are between 528.8 l/m² Adjud, 583.5 l/m² in Târgu Ocna, 571.6 l/m² in Brusturoasa and grow to 800-1000 l/m² on the highest peaks of the mountains.

The type of vegetation and especially its absence are very important in the formation and evolution of floods. In the high mountain area, the conifer and mixed forests are predominant, occupying area in different proportions, up to 80%. In the high areas, alpine grasslands are dominant.

The hydrological importance of this arrangement of vegetation types in the mountain between morphological (relief high, steep slopes, and hard rocks) and morphometric characteristics (generally flat sub-basins with a rapid concentration of the runoff) is that large floods occur on the deforested upper courses, fading slightly when crossing surfaces with massive coagulated forests.

Soils show their importance to the formation of floods by type, thickness, texture, and state of development. In the highlands, covered by alpine pastures, on hard rocks spodosols and skeletal soils were formed with a thin profile, less permeable due to the proximity of surface bedrock; the runoff is quickly concentrated and floods are large enough. In the area of forest, soils are deeper, looser and have at its surface a litter of certain thickness. All these, coupled with the forest action (tree and canopy density and height) help to reduce runoff and reach a tendency to spill mitigation.

Figure 1: Position of Trotuș Basin within the country.

3 Data and methods

Trotuș River Basin is quite frequently affected by floods and this study aims to estimate floodplains in the upper part of the basin, specifically Trotuș Source - Palanca. To this aim, we combined a modified Flash Flood Potential Index method [7] and multiple linear regression to identify the contribution of each factor used in obtaining the potential flooding index. Analysis and process of these factors were done using the ArcMap 10.2 software and multiple linear regression was performed in IBM SPSS 20 software.

The main stages of this method are represented in diagram from Figure 3.

- i **Collection** of required data and their georeferencing in the same coordinate system. Flow accumulation, slope gradient, profiles curvature were extracted from Digital Elevation Model (DEM), using tools from Spatial Analyst Tools. The DEM was developed with a grid cell of 10 m ($10 \times 10 = 100 \text{ m}^2$) obtained through the manual vectorisation of contour

lines from topographical maps of Romania, at scale 1:25.000. Land cover was extracted from the Corine Land Cover dataset [27], soil texture was extracted from the Romanian soil maps in digital format, at 1:200000 scale and type of rock was extracted from a geological map of Romania in digital format, at 1:200000 scale.

- ii **Conversion** from vector layers (polygon topology) into raster. Land cover, soil texture, and permeability rocks were extracted in vector format, the reason why layers were converted to raster format using Conversion Tools, with a resolution of 10 meters.
- iii **Reclassification** of raster layers. Each of the six physiographic factors obtained in the form of thematic raster layer was reclassified into 5 classes, corresponding to their hydrological response and adapted to the local features, using the Reclassify function from Spatial Analyst Tools. Class 1 signifies a low contribution in the water accumulation, while class 5 corresponds to a high contribution in the water accumulation.

Table 1: The final score of each class used to calculate the MFFPI.

No	Factors	Weight for factor	Classes	Weight for class	Final score
1.	Slope (°)	3.0	60° – 10°	1	3
			10° – 8°	2	6
			8° – 6°	3	9
			6° – 3°	4	12
			3° – 0°	5	15
2.	Flow accumulation	2.5	0 – 1	1	2.5
			1 – 2	2	5
			2 – 3	3	7.5
			3 – 4	4	10
			4 – 5.6	5	12.5
3.	Profile curvature (radiani/m)	2.0	–18 – –49	1	2
			–9 – –0.5	2	4
			–0.5 – 0.5	3	6
			0.5 – 1.5	4	8
			1.5 – 23	5	10
4.	Soil texture	1.0	Sand-Clayey	1	1
			Sandy loam - Clayey	2	2
			Various texture	3	3
			Clayey – Clayey-Argillaceous	4	4
			Clayey-Argillaceous -Argillaceous	5	5
5.	Rocks Permeability	1.0	Gravel, sands and loess deposits	1	1
			Sandstones and marls, clays with blocks, sandstones, conglomerates n/Sandy flysch	2	2
			Beds of Krosno-Pucioasa type; clays, gray marls with insertions of sandstones/Shaly flysch with black insertions	3	3
			Red and white massive limestones/ Calcarenites, spatic limestones, red flints/ Dolomites and limestones with Diplopore annulata	4	4
			Micashists, tuffites metamorphic rocks, red and green clay, Phyllites, sericitous-chloritous schists	5	5
6.	Land cover	0.5	Forest	1	0.5
			Shrubs and herbaceous vegetation	2	1
			Crops	3	1.5
			Pastures	4	2
			Water	5	2.5

Figure 2: Trotuș Basin and the study area

These thematic layers representing physiographic factors were weighted and then summed in Map Algebra from Raster Calculator tool and the result is an index that estimates the floodplain in the study area. This index is reclassified in 5 classes where 1 means the minimal probability of floods (hazard) and 5 maximum probabilities of floods (hazard).

Reclassification of factors was made according to the description below and data presented in Table 1. The slope with a value between 10° and 60° has a minimal influence on water accumulation and production of floods, so that was indexed by 1, while a slope with values between 10° and 0° has significant influence in the accumulation of water, such as the slope decreases with the more favouring accumulation, so was indexed upward. The curvature profile is parallel with the direction of maximum slope and a negative value indicates that the surface is convex up in that cell, a positive value indicates that the surface is concave up on that cell, while a zero value indicates that the surface is linear. A convex profile curvature accelerates the flow and a concave profile curvature decelerates flow.

Also, a concave profile curvature (+) favour the storage of water, while the convex profile (-) prevents the accumulation of water. Likewise, the forests have deemed to retain part of the water, thus hindering the flow, while urban areas, with an impervious ground, have the opposite effect.

Rocks were classified according to permeability, so was assumed that gravel, sand, and deposits of loess are permeable, thus preventing the accumulation, respectively flow of water, while micashists, tuffites, metamorphic rocks, red and green clay are less permeable, which has an important role in the formation and accumulation of water flow in the river bed. This classification has been adapted according to Smida, Maiza [28].

Flow accumulation identifies how water accumulates in each cell from the adjacent surfaces, the cells with high storage being usually river channels and network. Since the range of values for flow accumulation was very large, raster flow accumulation was scaled applying a logarithmic function.

In order to obtain a result that reflects match better the reality, this method was extended introducing weights for

Figure 3: The conceptual framework of this methodology

each factor and respectively for each class according to importance. This method of weighting was adapted for the study area for each of the six factors taken into account. Thus, the sum of the weights of the 6 physiographic factors was 10 points, as shown in Table 1.

The final score of each class was determined by the product of the weight of class and weight of each factor taken into account, the final results being presented in Table 1.

Classification and weighting of factors were made in order of importance (contribution) in terms of regarding flood production. This was done taking into account the experience gained in previous applications of this type of methodology, described in the scientific literature and adapted to the reality of our study area.

iv Multiple linear regression. To identify the influence of each factor in the achievement of this index was made multiple linear regression. In this analysis, the MFFPI was the dependent variable, while used factors were independent variables.

To extract the necessary data for processing, altimetry quotas were used as points and using the Extract Multi Values to Points tool corresponding values were extracted

from the final index and from all 6 thematic layers representing the factors taken into account in this study.

The extracted values were exported and introduced in the analysis software, where they were then standardized to the Z scores, each having the mean 0 and the standard deviation 1; this stage makes possible the limitation of range of variation of variables. Standardized variables were subjected to multiple linear regression using “Stepwise” method.

4 Results

Applying the methodology described above the spatial representation of the values of each physiographic factor, spatial representation of potential flooding index and the significance of each factor in obtaining potential flooding index were obtained.

Using the weight for each class, specific maps for all the six physiographic factors were obtained, namely: flow accumulation (Figure 4a), rocks permeability (Figure 4b), soil texture (Figure 4c), profiles curvature (Figure 4d), land cover (Figure 4e), and slope gradient (Figure 4f).

Figure 4a: The spatial representation of the values of flow accumulation.

Figure 4c: Soil classification according to texture.

Figure 4b: Rock's permeability according to type of rocks.

Figure 4d: Spatial representation of profile curvature.

Figure 4e: Spatial representation of the land cover.

Figure 5: The spatial representation of the potential flooding index.

In the next step, each factor was weighted using the values from Table 1 all being cumulated in a single layer. The result is the MFFPI, a layer that estimates the potential of floods, in other words, identify the area where water accumulates based on physical-geographical factors.

The obtained values of MFFPI ranges from 1 to 4.65 and the map was reclassified using five probable hazard classes, as follows: 1 – 1.50 – very low probability of hazard; 1.50 – 2 - low probability of hazard; 2 – 2.50 - medium probability of hazard; 2.50 – 3.50 - high probability of hazard; 3.50 – 4.65 – very high probability of hazard. The obtained potential flooding index is shown in Figure 5.

Looking at the potential flooding index map can be noticed that a percentage of 10% from the total area has the greater possibility to be affected by a high-intensity flood (high and very high hazard), while in 16% of the surface the hazard is at a medium value. The map shows large areas without rivers but with a medium potential of flash floods; this means that the occurrence of the floods, can be the result of a combination of geographic factors even in the absence of a river.

Analysing this index, we can see that the areas with high flood predisposition are those near the rivers respectively river beads.

Figure 4f: Spatial representation of slope gradient.

Figure 6: Comparison between MFFPI and flood hazard map.

In order to verify if the results indicated by this index are in line with the reality, a comparison on a section of the study area was made, between the proposed MFFPI and the flood hazard map obtained in another study [29]. Full hazard map was obtained using the Swiss method of hazard assessment, combining three flood scenarios (0.1, 0.01 and 0.001 probability) and the water depth, and has three classes low hazard, medium hazard and high hazard.

Making this comparison (Figure 6), we notice that the flood hazard map corresponds to areas of MFFPI with a very high and high predisposition to floods according. This means that the factors used to obtain the index are corrects, and the index can be used to estimate areas with flood potential.

To identify the influence of each factor in the achievement of the Modified Flash Flood Potential Index, a multiple linear regression was made.

First, the standardization of data was made, followed by nonparametric tests to verify data distribution; the results showed that the data have not a normal distribution, the value of Sig.(2) being less than 0.5. After these tests, the correlation between variables was checked using Person Correlation. The result showed that it is a correlation between 4 variables, flow accumulation, profile curvature,

rocks permeability and land cover; the other 2 variables, soil texture and slope gradient, were excluded. The obtained values for the correlation test are presented in Table 2.

The selected four variables, flow accumulation, profile curvature, rocks permeability and land cover, were subjected to multiple linear regression using “Stepwise” method.

Analysing the result obtained by multiple linear regression can be concluded that there is a very small autocorrelation of error because the amount of test Durbin-Watson is 1.960 (about 2). The R Square value is 0.916 indicates that the model explains the variability of data, as can be observed from Table 3.

The result of the multiple linear regression shows that three of the four correlated variables are significant in statistical terms and explains 91.6% from the potential flooding index, the fourth variable, rocks permeability being excluded. These variables are represented by flow accumulation explaining 89.5%, profile curvature 2%, and land cover explaining 0.1% of the model. The rock permeability, soil texture, and slope gradient do not statistically influence the index.

Following the linear regression, three significant variables were used, flow accumulation, profile curvature and land cover, in order to compute a new MFFPI, presented in Figure 7. For this, the factors were cumulated using the initial weights from Table 1.

As the initial index (Figure 5), this index composed only by three significant factors (Figure 7) indicates the riverbed as having a very high and high flood predisposition, which means that, in this case, the other three variables (slope gradient, soil texture and rocks permeability) are redundant as the linear regression indicated and can be eliminated. MFFPI can be obtained only from these three significant factors (flow accumulation, profile curvature and land cover) in order to identify areas with flood predisposition.

5 Discussions

The purpose of this study was to estimate areas with high potential for water accumulation and potentially producing floods in the study area. For this, a modified version of the Flash Flood Potential Index method proposed by Smith (2003) was used. The initial index FFPI developed by Smith it is composed of 4 variables, respectively: slope; land cover/use, soil type/texture and vegetation cover/forest density. This variable was averaged together

Table 2: The correlations between variables.

	Potential flooding index	Potential flooding index	Flow accumulation	Profile curvature	Slope gradient	Land cover	Rocks permeability	Soil texture
Potential flooding index		1						
	Pearson Correlation		.946**	.725**	-.090	.205**	-.199**	.094*
	Sig. (1-tailed)		.000	.000	.056	.000	.000	.047
Sum of Squares and Cross-products		316.000	298.967	229.155	-28.283	64.722	-62.800	29.744
Covariance		1.000	.946	.725	-.090	.205	-.199	.094
N		317	317	317	317	317	317	317

Table 3: The result of multiple linear regression.

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				Durbin- Watson
					R Square Change	F Change	df1	df2	
1	.946 ^a	.895	.895	.594	.895	2687.864	1	315	1.953
2	.956 ^b	.915	.914	.536	.020	72.888	1	314	
3	.957 ^c	.916	.916	.532	.001	5.560	1	313	
4	.957 ^d	.917	.915	.533	.000	.619	1	312	
5	.957 ^e	.917	.915	.533	.000	.113	1	311	
6	.957 ^f	.917	.915	.534	.000	.068	1	310	

a. Predictors: (Constant), Flow_accumulation

b. Predictors: (Constant), Flow_accumulation, Profile_curvature

c. Predictors: (Constant), Flow_accumulation, Profile_curvature, Land_cover

d. Predictors: (Constant), Flow_accumulation, Profile_curvature, Land_cover, Rocks_pereability

e. Predictors: (Constant), Flow_accumulation, Profile_curvature, Land_cover, Rocks_pereability, Soil_texture

f. Predictors: (Constant), Flow_accumulation, Profile_curvature, Land_cover, Rocks_pereability, Soil_texture, Slope_gradient

g. Dependent Variable: Potential_flooding_index

Figure 7: Potential flooding index (MFFPI) using flow accumulation, profile curvature and land cover.

and divided by the sum of the weights, while the MFFPI was composed of 6 variables with potential in estimating floodplains (slope, soil texture, land cover, rocks permeability, plan curvature and flow accumulation), each variable was weighted according to importance, as shown in Table 1 and was cumulated in a single layer. Both methods provide a synthetic index, FFPI an index that identifies areas with potential of flash floods producing, while MFFPI identify areas that are prone to water accumulation and implicitly to the formation of floods.

Compared to the original method, the introduction of linear regression is a very important point because it helped us to identify the physical-geographical factors with a bigger influence on characterization of water accumulation and implicitly, on floods occurrence. According to the linear regression, only three of the six physical-geographical factors used to get the index are significant in statistical terms for the potential flooding index. These variables explain 91,6% from the index and are represented by flow accumulation, profile curvature, and land cover.

According to the result of linear regression, MFFPI can be obtained only from these three significant factors (flow

accumulation, profile curvature and land cover) as we can see in Figure 7.

In contrast to original method proposed by Smith [7] or proposed by Tîrnovan [20] which only shows the results, or Minea [19], and even with the study conducted by Rete-gan and Borcan [30], that try to validate the method comparing the obtained result with the real situation on the field, this study brings as a novelty a validation method that confirms the areas with flood potential indicated by the index. The MFFPI obtained was compared with flood hazard map corresponding to a section of the study area to verify if the results provided by this index are realistic, (Figure 6). Corroborating also this information with field analyses, we consider that this index provides clear results regarding to the predisposition of an area to the occurrence of floods.

Considering that the results of this method were confirmed in the present study, we consider that this method can be successfully used in the development of territorial planning, for prevention and monitoring, because it indicates the sensitive areas in the case of floods from a structural point of view, this being one of the great advantages of this method. Another advantage would be that data are easy to process, making it more practical than other methods.

In our opinion, at this moment to obtain the MFFPI we can use only the spatial data and also can be used the numerical data, for example values of maximum daily rainfall basis on a multiannual period over 20 years, but it will also be represented spatial after performing interpolation. Also, like any method and MFFPI has a certain degree of uncertainty, this varying according to the accuracy of the data, therefore, as the accuracy of the data is better, the uncertainty of the result will be smaller. Other limits are represented by the fact that is a synthetic index and the users must to find a validation method in order to confirm the result and also some errors may appear from exploited DEM data (slope, flow accumulation and profile curvature), because the DEM was generated from a topographic map, with a scale of 1:25.000, which means that accuracy is not excellent. Achieving of DEM from other sources with better accuracy eliminate these errors.

6 Conclusion

The morphometric characteristics of Trotus River basin, but also the anthropic activity, such as deforestation, favour the formation of floods in the study area.

MFFPI was calculated initially from six physical-geographical factors, like slope, soil texture, land cover, rocks permeability, plan curvature and flow accumulation, but linear regression has shown that the factors contributing the most to the achievement of the index were flow accumulation, plan curvature and land cover.

The results show that the index (Figure 5) has values between 1 and 4.65, of which 12.53% for Class 1 – very low probability of hazard, 62.19% for Class 2 – low probability of hazard, 15.78% corresponding to class 3 – medium probability of hazard, 8.80% for Class 4 – high probability of hazard and 0.71% for Class 5 – very high probability of hazard.

The areas indicated by MFFPI as being prone to flooding were confirmed by the flood hazard map (Figure 6), which makes this method applicable to different watershed, in order to estimate areas with potential for flooding and the results to be used in territorial planning and in the development of flood management plans.

A new MFFPI was calculate after linear regression, as initial index (Figure 5), this index composed only of the three significant factors (Figure 7) indicate the same area with flood predisposition, which means that MFFPI can be obtained only from significant factors (flow accumulation, profile curvature and land cover) in order to identify areas with flood predisposition, the other three variables (slope gradient, soil texture and rocks permeability) are redundant.

Also the method used in this study highlights the importance of physical-geographical factors in the formation, occurrence and the expression of flooding.

Conflict of Interests: The authors declare no conflict of interest.

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