IDENTIFYING FLOOD-PRONE RISK AREAS, USING GIS. CASE STUDY: OZANA DRAINAGE BASIN, ROMANIA

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ABSTRACT

At a global level, the last 20 years have been characterized by the occurrence of extreme meteorological phenomena, which have directly determined extreme hydrological events. The appearance of these phenomena, along with the expansion of human settlements in the proximity of the river network, determines the growth of the risk, each year. In the hydrographic basin of the Ozana river, the settlements are located exclusively on the valley of the river and its' main tributaries, and their territorial extent frequently overlaps the floodplain. The current study emphasizes the identification of the land use categories, inside the built-up area of each village along the Ozana river valley, and their classification, according to economic losses that can be generated during a flash flood. Also, the 0.1% occurrence flood extent has been integrated into the analysis. The final results also reveal the regions inside the built-up areas, which have the largest probability of being exposed to flood risk.

Keywords: HEC-RAS, flood risk, flood hazard, GIS, probability

INTRODUCTION

The development of the global population is made in the vicinity of necessary resources to secure survival, but also near those who allow an easy access. From ancient times, the locations of the human settlements were in the proximity of drinkable water resources, rivers or coastal zones, which provided fast transportation. This location advantage was important from a social and economic perspective, but at the same time, it also represented a source of potential danger. The risk was represented by the possibility of occurrence of a high flow on the nearby rivers, which would have led to a raise in the water level and ultimately, to the manifestation of floods that would have had a catastrophic effect [1].
The rapid growth of the population during the last hundred years led to the development of villages and cities closer and closer to the river floodplains or towards the coastal areas, aspect which also determines the exponential raising of flood risk in those locations. According to UNISDR, during the period between 1995-2015, a number of 3062 floods have been recorded at global scale, which means 47% of all weather-related disasters and

43% of all natural disasters combined [2]. In Romania, of all natural disasters, floods have the highest probability of occurrence, with a frequency of 55.4% during the period of 1990-2014, also representing the natural disaster that produce the highest economical losses and highest mortality [3].

One of the greatest floods that took place in Romania during 2000-2010, when many of the rivers with high flow rates and discharge values have surpassed the recorded historical flows, affecting large areas for a long period of time. One of those scenarios happened on Siret river in 2015, when floods affected an area of 58323.9 hectares, the river recording a flow of 4650 m^3/s (the average flow is 210 m^3/s) [4, 5].

The aim of this paper is to determine the areas exposed to flood risk. The case study focuses on the hydrographic basin of Ozana river. The delineation of the exposed areas to flood risk was made possible through the generation of a flood extent layer, using HEC-RAS hydrological simulation software by including values of historical flood with the probability of occurrence of 0.1% (probable return period of 1000 years). The flood band that was obtained following the analysis, was superimposed over the built-up areas, situated on the river valley. The methodology that was used was made available by the European Parliament through the Directive 2007/60/CE for the identification of the degrees and categories of exposure to floods according to the land use.

STUDY AREA

The area which this study is focusing on, is given by the Ozana river basin, located in the Siret hydrographic basin, situated in the North-Western part of Romania. The watershed extends over 3 relief units, namely the Eastern Carpathians, the Moldavian Subcarpathian Hills and Moldavian Plateau, it is elongated on a West-East direction, for a distance of approximately 57 km, and it covers an area of 419 km^2 (Figure 1) [6]. From an administrative perspective, the basin is located in Neamt County, on the river valley, overlapping 15 localities, with a combined, total population of 35 270 residents (according to INSE).

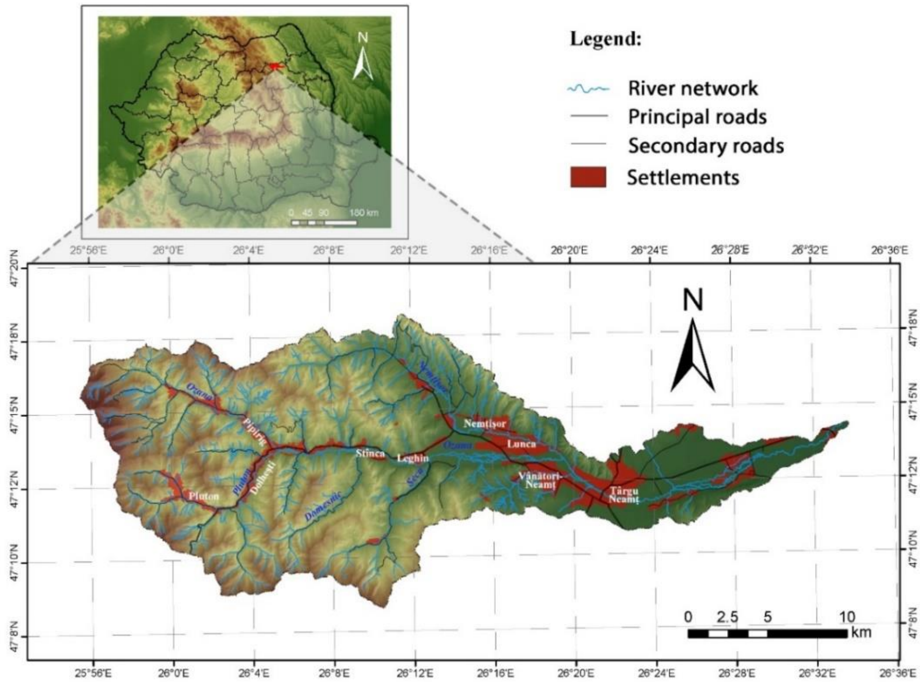

Figure 1. Geographical location of Ozana river catchment

According to the data from Siret Basinal Water Administration, for the period between 1961-2013, the average multiannual quantity of precipitations was calculated to be 857 mm in the mountain area, 789 mm in the transition area of Eastern Carpathians and 658 mm in the plateau area. The average flow rate of Ozana River is 3.42 m^3/s at discharge point in Moldova river. The input of the river is from rainfall and of snow origin, with important flow fluctuations during all seasons, due to the difference in precipitation fall (because of the irregular character of the temperate continental climate) [6]. Transition seasons can imply great amplitudes concerning maximum flows, during the autumn, the flows varying from 0 m^3/s to 328 m^3/s (at Dumbrava gauging station).

Over time, in the area of Ozana watershed, numerous floods have occurred, that have generated material damages and loss of numerous human lives. The most powerful flood that took place in Ozana river basin happened between the 16th and 28th of August 2005 [7]. The recorded quantity of precipitations registered a deviation from the multiannual average, with values between 150 mm and 250 mm of rainfall at the monitoring stations from inside the basin. The total rainfall quantity that fell over the entire area of Ozana river basin in August 2005 was 288.3 mm at Pluton station, 301.6 mm at Leghin station, 266 mm at Dumbrava station, these values representing the maximum rainfall recorded for the year 2005.

MATERIALS AND METHODS

The methodology workflow is formed of two main parts:

1. The first part consists of obtaining the flood extents for Ozana River valley.

During this stage, the used data was in the form of flow values, river water levels from control sections and the size characteristics of the hydrotechnical constructions taken from Siret Water Basin Administration. To be able to determine the hazard at different probabilities of flow rate passing, the flow values were calculated for three specific sections, being determined by the location of the gauging stations, one of them located on Pluton River in Pluton Village and the other one in Leghin Village, at the exit of the river from the mountainous region (Table 1). The data concerning the frequency of flood occurrence were calculated through the use of empirical Weibull Curve and Pearson III theoretical curve. Based on the hydrological recordings, the data involving the relief configuration and the land use data, the flood simulation on Ozana River valley was made using HEC-RAS software [8, 9]. After the simulation was finished, the flood extent for a flow probability overcoming 0.1 %, was obtained.

The choice of simulating a flood with a probability of overcoming higher than 1% was considered due to the fact that the area extent of this scenario is unknown and, at the same time, only empirical, approximated values regarding the flow and water level that the river can reach were available. This being the case, the creation of probability occurrence values and estimation of water levels the river can reach was necessary. On Ozana River valley, 14 out of 15 settlements undergo the possibility to be affected by a flood or flash flood, with a probability of occurrence of 0.1%. In this case, the villages could be flooded over surfaces varying between 0,5 hectares and 50 hectares.

2. The second part consists in the extraction of land use from the inside of villages and the classification using 4 categories, according to the anthropogenic elements that were flooded and also the economic impact which the aforementioned subjects have on local communities. In this situation, the severity of the risk to which the villages are exposed

can be evaluated accordingly. The database used was Corine Land Cover 2012 vector layer, downloaded from land.copernicus.eu.
For classifying the risk categories where the flooded land lots from inside of localities fit, according to the category of usage, the methodology provided by the European Parliament through the Directive 2007/60/CE was used [10]. The utilized layers were the land use layer of Ozana River valley and the flood extent for the probability of occurrence of 0.1 % (returning period of 1000 years).

Table 1. Flood overcoming probabilities at gauging stations from Pluton, Leghin and Dumbrava

Overcoming probability/Station	Pluton	Leghin	Dumbrava
	Discharge estimation (m^3/s)		
0,01%	150	639,65	893,11
0,1%	113	480,34	676,29
1%	75	320,35	458,51
5%	49	209,53	307,68
10%	38	161,04	241,69
20%	27	113,25	176,64
50%	12	49,53	89,91
80%	5	16,97	45,60
95%	2	5,20	29,57
99%	1,2	2,43	25,80
99,9%	1,1	1,74	24,86

The first step in this case is to identify and classify the elements that are exposed to hydrological risk, represented by the human factor through settlements, objectives of community interest, economical activities, transportation routes, elements which belong to the cultural and community area (Table 2) [11].

Table 2. Flood risk exposure and the matrix for the probability of occurence of 0.1% [11]

Degree of exposure	Elements exposed to risk	Hazard level		
		P1	**P2**	**P3**
E0	Pastures, meadows, forests, transition areas with shrubs (generally cleared)	R0	R1	R1
E1	Irigated/non-irigated/with complex crops/mixed with natural vegetation/orchards/vines agricultural lands	R1	R2	R3
E2	discontinuous urban area and rural area	R2	R3	R4
E3	roads, airports, continuous urban area, industrial and commercial units	R2	R4	R4

According to the probability of occurence of a flood, but also to the degree of exposure of the studied objectives, a matrix for assigning hydrologic risk classes can be created [12-27]. For Ozana River valley, the inundability extent corresponds to P3 probability, thus, the flooded terrains were classificated accordingly.

RESULT AND DISCUSSION

The surface flooded by Ozana River in the inside of villages situated in the river valley were classified using 3 categories: low risk, high risk and very high risk. Villages from the mountainous area are affected by a greater proportion in the inhabited and transport sectors than areas from the subcarpathian and plateau zones (Figures 2, 3, 4, 5). The reason for this fact is given by the low inhabited area, which in turn makes the territorial extent of the villages to occurre in areas with risk to floods, whereas in the subcarpathian and plateau areas, the widening of the river channel, the terraces and the low values of slopes have determined the villages to be built on areas with higher elevation.

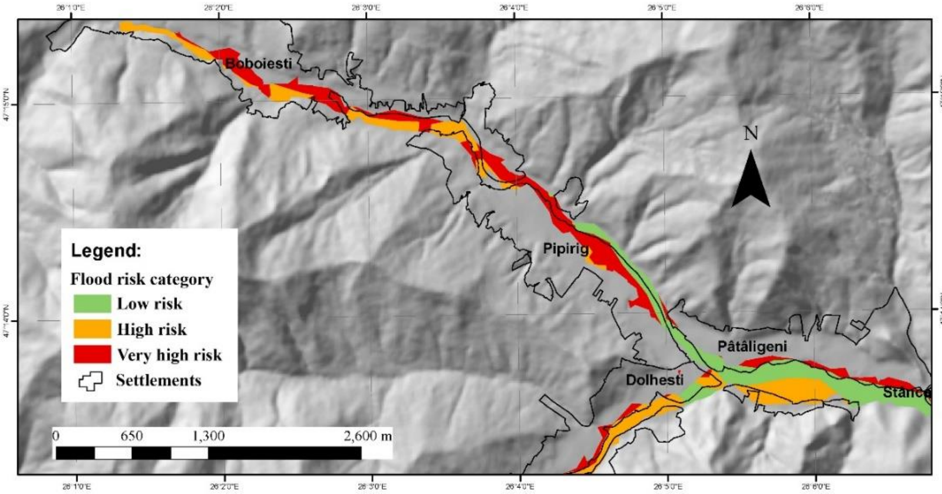

Figure 2. Risk categories associated to the 0,1% flood band (mountain area)

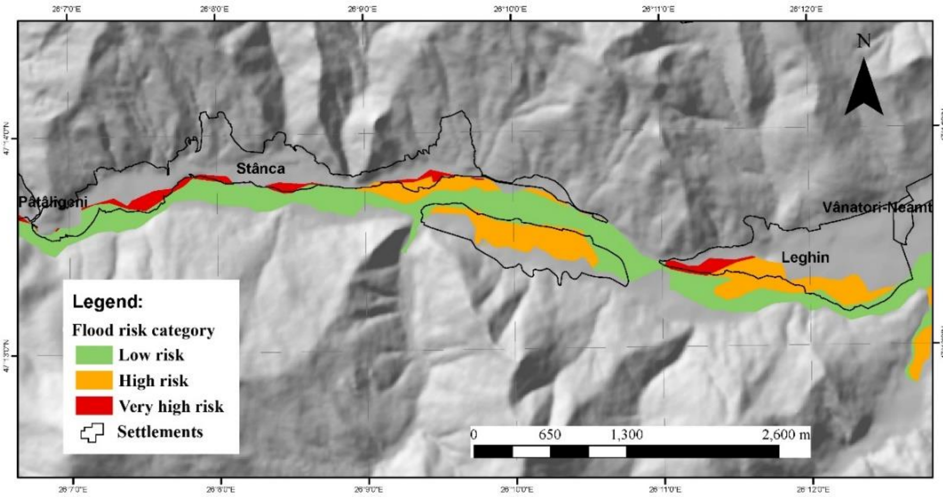

Figure 3. Risk categories associated to the 0,1% flood band (mountain area, transition area towards the Subcarpathian area)

The villages located on Ozana River valley, conditioned by the terrain – mountain area – have extended more towards the lower terraces and even towards the floodplain of Ozana river. For this reason, these villages are highly exposed to risk of flooding. Approximately 40% of the land occupied by the settlements could be affected in the future, by a flood of 0,1%.

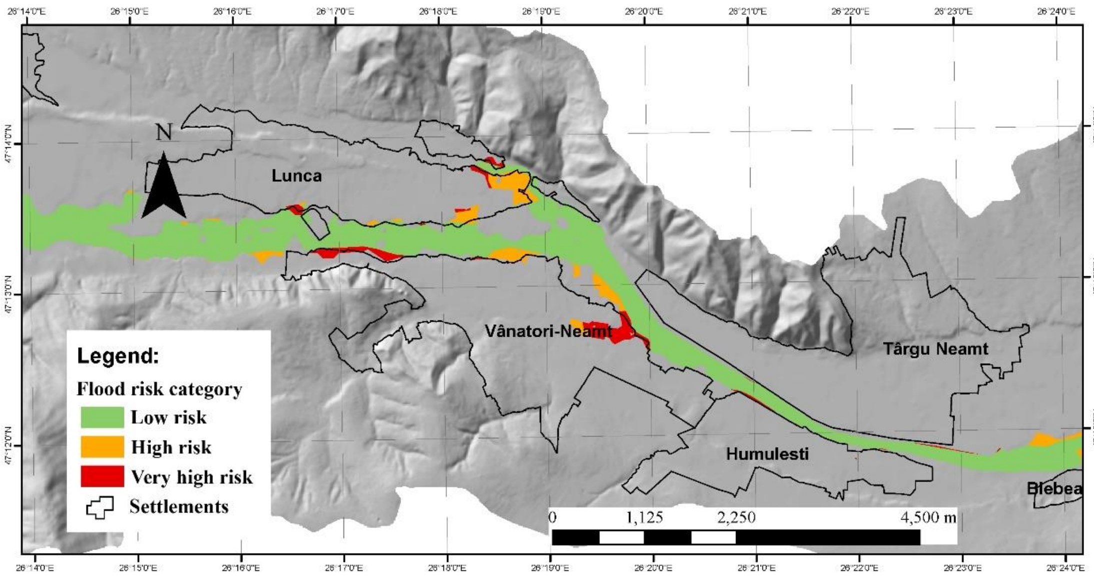

Figure 4. Risk categories associated to the 0,1% flood band (Subcarpathian area, Ozana-Topolita Depression)

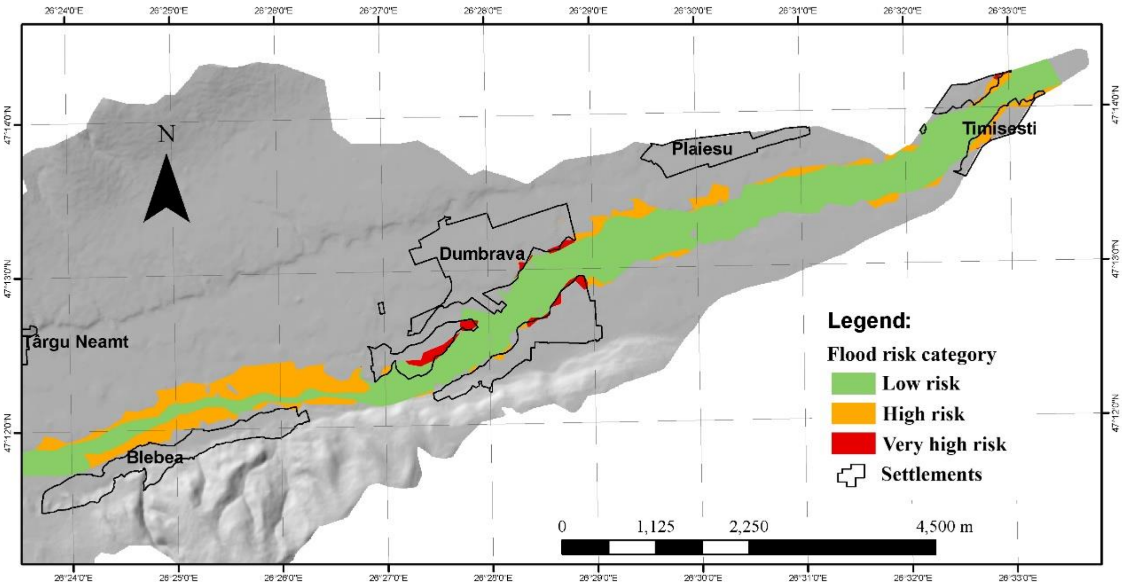

Figure 5. Risk categories associated to the 0,1% flood band (plateau area)

The floodable area from inside of the villages counts a total of 222 hectares, out of which the low risk category cumulates 20%, 43% is represented by a high risk and the rest of 37% of land is incorporated in the very high risk category. Therefore, after a flood with a probability of returning every 1000 years, approximately 80% from the territory inside of the localities situated in Ozana River Valley have high and very high degrees of flood risk. These high values indicate the possibility for the aforementioned areas to be associated with large-scale human and economic losses, which could be substantial. The villages which have the largest surfaces included in the very high-risk category are: Pipirig, Vanatori, Boboiesti, Dumbrava and Stinca (Table 3). In this particular situation, the local authorities need to take the necessary measures to avoid a hydrological event to become a disaster scenario for Ozana valley. One of the measures that can be taken could

be banning the construction of households in the floodplain area and supporting the construction of a hydrotechnical defense system for the vulnerable areas in the villages.
Unfortunately, the territorial expansion is associated with stopping the rain water to reaching the soil, which is blocked by construction of transportation ways and urban cemented sites. An important difference between the villages from Pipirig Commune and other localities situated on Ozana valley is given by the average degree of hydrotechnical constructions on Ozana River, torrents and small streams, which can make this commune to be more exposed to flood risks.

Table 3. Risk categories from the inside of localities situated on Ozana River valley (ha)

Settlements	R1	R3	R4
Vanatori	0.38	3.37	15.17
Dumbrava	6.94	2.28	11.61
Dolhesti	2	5.29	0.22
Stinca	14.88	27.4	9.78
Tgargu Neamt	0	0.42	0.12
Lunca	6.21	16.97	4.14
Pipirig	3.44	3.5	17.72
Timisesti	1.3	10.37	0.51
Boboiesti	0.05	8.45	12.61
Leghin	3.77	17.55	4.4
Pitiligeni	4.88	0	6.44

CONCLUSIONS

Covering a small area from the surface of the country of just 419 km^2, the hydrographic basin of Ozana River sits in the category of small rivers from Romania. Because of the variable physical-geographical conditions, areas with different ways of manifestation for different types of flood risk could be identified. By applying a 1D flood simulation method using HEC-RAS modelling software, the areas situated in different risk categories from the interior of settlements located on Ozana valley were identified. The results obtained following these methods can be used in the development of protection plans against floods, but also for more efficient political programs of water management.
The risk analysis for a flow rate with a probability of occurrence of 0.1% for the villages located on Ozana River valley between Boboiesti and Timisesti has identified 222 hectares of possible flood-prone terrain in the builtup areas of the villages. Among the total area of flooded terrain, 40% poses a very high risk because of the placement of the buildings in the immediate vicinity of the river. The most exposed villages from this perspective are: Pipirig, Vanatori, Boboiesti, Dumbrava, with over 10 hectares of land included in the very high risk category.
Based on the results generated by the simulation, the population can be acknowledged following a series of campaigns for informing the local residents about the selective risk that each locality or even household is exposed to. This way, the people can actively contribute to the measures needed to be taken or even to take some measures by themselves towards diminishing of the potential damages that can be produced by future floods on Ozana River valley.

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