

ASSESSMENT OF SOCIOECONOMIC VULNERABILITY TO FLOODS IN THE BÂSCA CHIOJDULUI CATCHMENT AREA

REMUS PRĂVĂLIE¹, ROMULUS COSTACHE²

ABSTRACT - Hydrological risk phenomena such as floods are among the most costly natural disasters worldwide, effects consisting of socioeconomic damages and deaths. The Bâsca Chiojdului catchment area, by its morphometric and hydrographic peculiarities, is prone to generate these hydrological risk phenomena, so there is a high vulnerability in the socioeconomic elements. This paper is focused on the identification of the main socioeconomic elements vulnerable to hydrological risk phenomena such as floods, based on the assessment of their manifestation potential. Thus, following the delimitation of areas with the highest flood occurrence potential (susceptibility to floods), major socioeconomic factors existing in the basin, considering human settlements (constructions), transport infrastructure, and agricultural areas (the most important category), were superimposed. Results showed a high vulnerability for all three exposed socioeconomic elements especially in valley sectors, of which household structures were the most vulnerable, given both their importance and the high number of areas highly exposed to floods (approximately 2,500 houses and outbuildings, out of a total of about 10,250, intersect the most susceptible area to floods in the study area).

Keywords: floods, vulnerability, socioeconomic risk elements, Bâsca Chiojdului catchment area

INTRODUCTION

Global economic losses, due to unexpected natural phenomena are estimated at approximately 40 billion euros per year (Munich, 2003). Hydrological risk phenomena such as floods, caused in most cases by flash-floods (which is why the floods are often treated in a causal relationship with flash-floods) fall into the category of natural hazards largely responsible for the damages that affect human society. In Romania, in 2005 alone, floods and flash-floods caused economic losses of about 1.6% of gross national product (Constantin-Horia et al., 2009).

In addition, it is considered that hydrological hazards, floods and flash-floods, are responsible for the loss of a large number of lives. Only in the period 1950-2006, flash-floods accounted for approximately 40% of the loss of lives out of all hydrological risk phenomena in Europe (Barredo, 2007). Meanwhile, the main indirect effects of flash-floods, floods are responsible in their turn for producing numerous casualties in the last five decades.

The most representative examples after the second half of the twentieth century are the cases of Great Britain in 1952 (34 deaths), Spain in 1962 (400 deaths), Italy in 1968 (72 deaths) and 1994 (69 deaths), France in 1999 (35 deaths) (Gaume et al., 2009). Romania is not excluded from the list of major disasters in Europe, where 76 deaths due to flash-floods and catastrophic floods were recorded in the summer of 2005 (Constantin-Horia et al., 2009).

Therefore, over the last decades, Europe has experienced an increase in the frequency of flooding events (Kundzewicz et al., 2013), closely related to global climate changes, which has caused considerable changes in rainfall regime (Trenberth, 1999; Groisman et al., 2005; IPCC, 2007). Climate scenario models estimate a future increase in rainfall intensity, which will aggravate hydrological hazards such as flooding in numerous European regions (Lehner et al., 2006; Dankers and Feyen, 2008).

¹ PhD Student, Faculty of Geography, University of Bucharest, Centre for Coastal Research and Environmental Protection, Meteorology and Hydrology, 1 Nicolae Bălcescu Avenue, Bucharest, Romania.
E-mail: pravalie_remus@yahoo.com

² PhD Student, Faculty of Geography, University of Bucharest, 1 Nicolae Bălcescu Avenue, Bucharest, Romania. E-mail: romuluscostache2000@yahoo.com

In this case, the analysis of socioeconomic vulnerability to potential hydrological risk phenomena is absolutely necessary. Although, in recent decades, specialized researches have led to the development of numerous methodologies and indicators of vulnerability (Balica et al., 2009), rigorous analysis of the vulnerability of socioeconomic elements to hydrological hazards remains rather difficult.

This paper is based on a spatial analysis of the vulnerability of the most important socioeconomic components (built-up and agricultural areas) at hydrological risk hazards (floods) in the Bâsca Chiojdului catchment area, hazards specific to the curvature of the Carpathians, where the analysed basin is mostly located.

POTENTIAL FLOODING IN THE STUDY AREA

Located in the curvature of the Carpathians (Figure 1), in Romania, in the space of interference between the Carpathians and the Sub-Carpathians, Bâsca Chiojdului catchment is prone to the genesis of floods due to associated causes: geographic and anthropogenic.

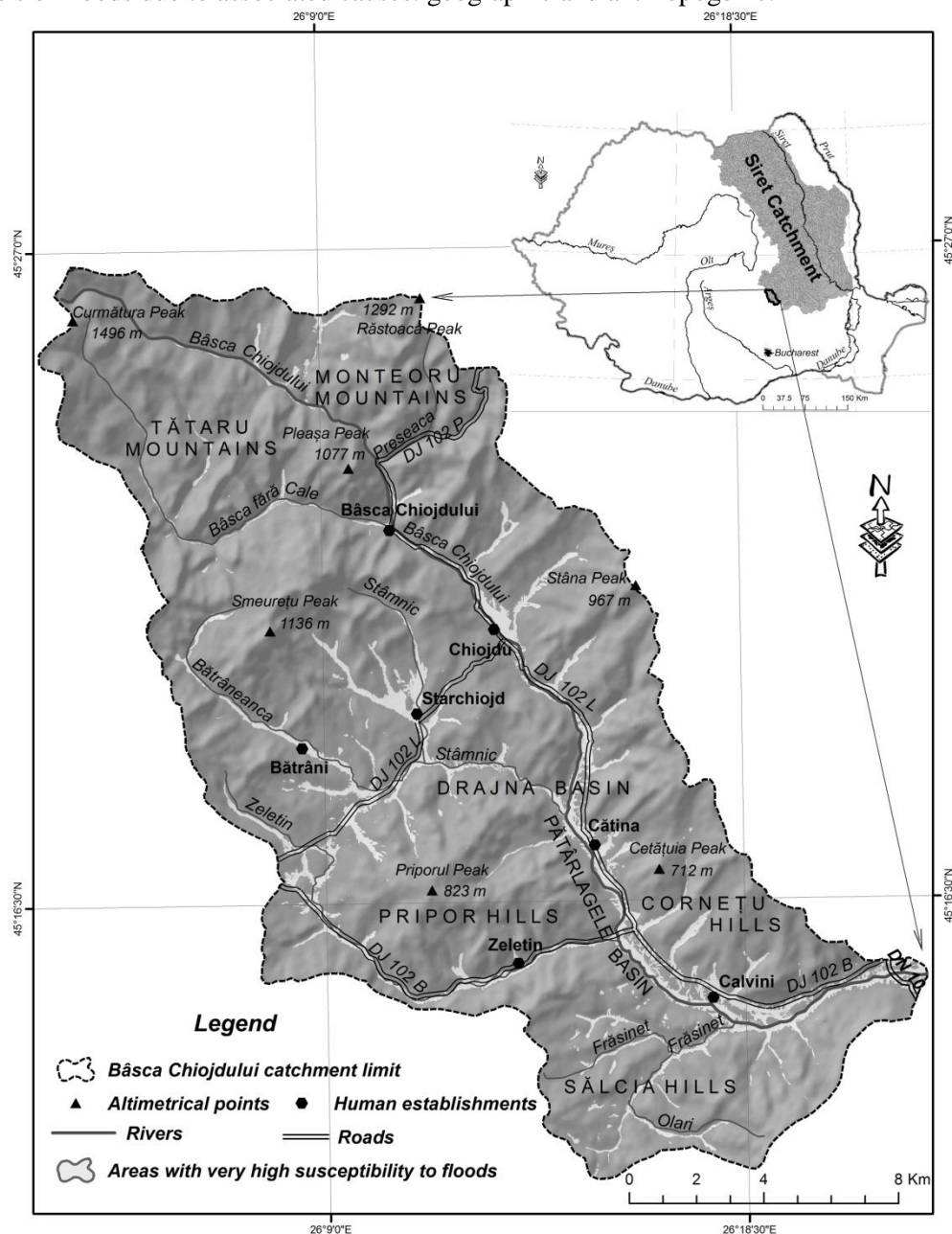


Figure 1. Location of the Bâsca Chiojdului catchment area

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The synergetic context of lithologic (clays and marls present over large areas), morphometric (low slope in the river valley sectors, prone to flooding), hydrographic (convergence and high density of the river network), and anthropogenic factors (intense deforestation in the last century specific to the curvature area) favoured and increased the frequency and the intensity of hydrological risk phenomena such as floods (Zarea, 2011; Costache & Prăvălie, 2012; Prăvălie & Costache, 2014).

Therefore, there is a high flood occurrence potential, especially in the river valley sectors, areas which concentrate most of the human settlements and agricultural areas. Expert analysis on the flood occurrence potential (Costache & Prăvălie, 2012) concluded that flooding is most likely to occur in the valley areas of the Bâsca Chiojdului, Stâmnice, Bătrâncea, and Zeletin rivers (Figure 1).

One of the major causes of flood formation is flash-floods. It was found that, at the river basin level, there is a high favourability for flash-floods especially on high slopes, deforested and generally characterized by increased convergence of torrential and fluvial organisms (Prăvălie & Costache, 2014). These slopes are generally located in the northern basin of Drajna, in areas with a low degree of afforestation, neighbouring mountain units. Therefore, extensive surfaces with high flood occurrence potential in the area of the villages of Bătrâni, Starchiojd and Chiojdu are in a strong causal relationship to surfaces with increased flood occurrence potential located north of the above-mentioned localities. In other words, in the central area of the analyzed river basin, the main flood-triggering factors are the upstream flash-floods with major potential of propagation in the river sectors located immediately downstream (Figure 2).

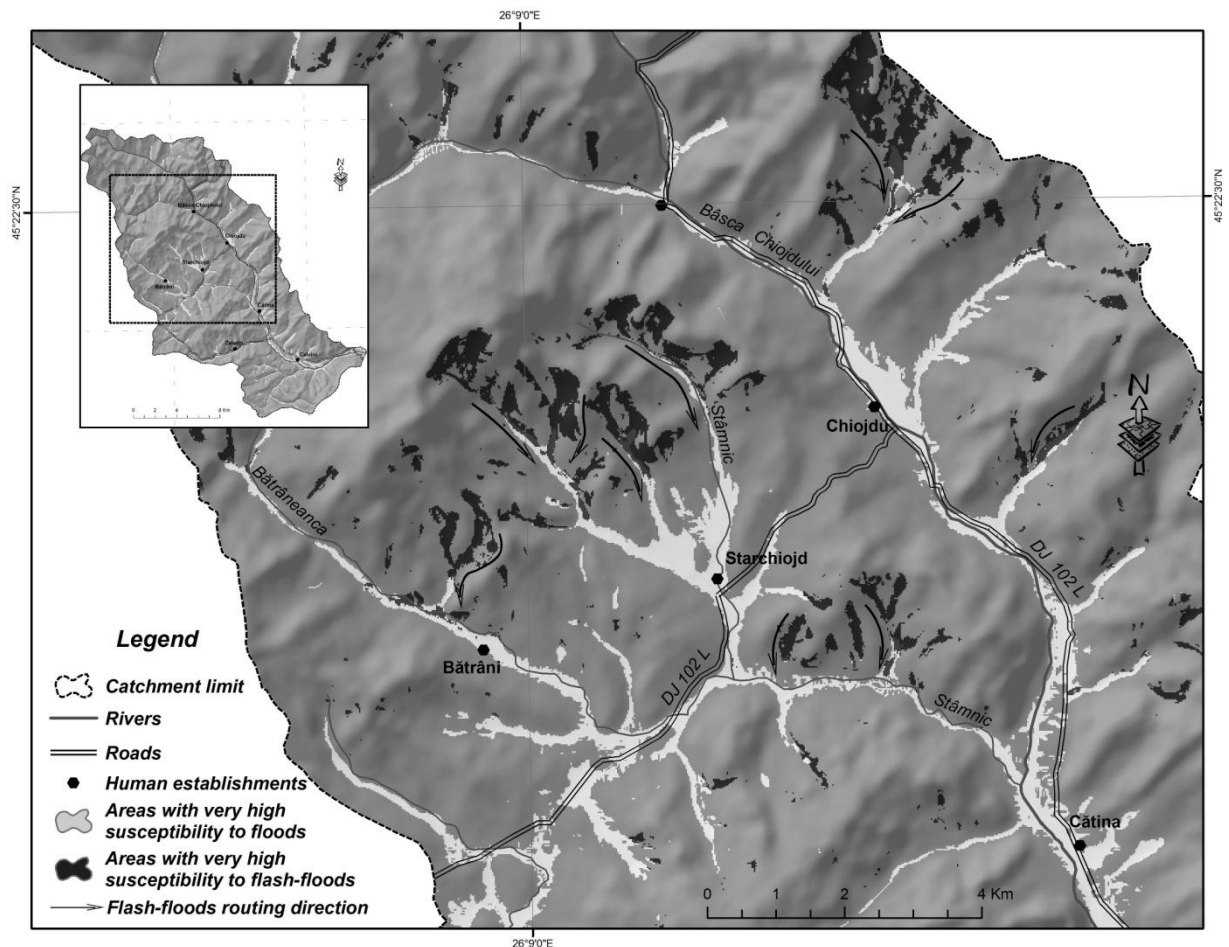


Figure 2. Direction of propagation of the flash-floods with high occurrence potential from upstream to downstream of the highly flood-prone areas

DATA AND METHODS

To highlight the exposure of socioeconomic elements to potential floods in the Bâsca Chiojdului catchment area, the flood occurrence susceptibility index called the *Floods Susceptibility Index* (Costache & Prăvălie, 2012) was first calculated and spatialized in the analyzed basin, in GIS environment. Another useful indicator was *Flash-Floods Susceptibility Index*, referring to the flash-floods occurrence susceptibility (Prăvălie & Costache, 2014), the hydrological risk phenomena with major role in emerging floods (Figure 2).

Floods Susceptibility Index, the main support in the assessment of vulnerability of socioeconomic elements in the current study, was calculated and spatialized by summing a large number of environmental variables in GIS environment that play a major role in the emergence of floods: lithology, elevation, altitude above the channel network, slope, the annual average precipitations, the convergence index, texture of soils, and land cover in the basin area. Finally, the area with the highest flood occurrence susceptibility was delimited (Figure 1), which corresponds to the fifth class of the *Floods Susceptibility Index* - the class with the highest flood occurrence potential (Costache & Prăvălie, 2012).

The second stage consisted in the extraction and the spatialization, from the maps and digital materials available (orthophotomaps 1:5000, the 2005 edition and the European database CORINE Land Cover, 2006), of the most important socioeconomic risk elements such as built-up areas, agricultural lands and transport infrastructure. To highlight built-up and agricultural areas (two categories of agricultural areas existing in the perimeter of the analysed basin were defined, namely the arable land and the predominantly agricultural with natural vegetation), the European database CORINE Land Cover 2006 was used (Figure 3), while, in order to extract the detailed street network, the 2005 edition of the 1:5000 scale orthophotomaps were used as a cartographic support for line vectorization. For a more detailed vulnerability assessment of built-up areas, the most expensive socioeconomic component, a quantification of the number of houses and outbuildings was performed. The 1:5000 scale orthophotomaps were used as a base support also for point vectorization.

The last stage consisted in the intersection of socioeconomic risk elements extracted from the above-mentioned sources with areas characterized by a very high susceptibility to flood occurrence, areas corresponding to the fifth class of *Floods Susceptibility Index* (class with the highest potential of flood occurrence).

RESULTS AND DISCUSSION

Areas with the highest values of susceptibility index for floods formation in the Bâsca Chiojdului catchment area totalize approximately 2,438 hectares, this area representing 7.17% of the entire basin. They occur mainly along the main collector river valley and along major tributaries such as Bătrânceanca, Stâmnic, and Zeletin. The vulnerability of areas to floods is given mainly by land use, built-up areas being most exposed, followed by arable lands and predominantly agricultural lands with natural vegetation. The latter usually contain, for the most part, arable lands near residential areas, which is why this category was considered as very important and bounded in the CORINE Land Cover database. This vulnerability is primarily related to the potential of floods to generate damages and losses of human lives, a potential that exists in any extreme natural phenomena (Grecu, 2009).

Thus, in the case of the Bâsca Chiojdului catchment area, built-up areas falling within the critical class of flood occurrence potential spread over an area of 893 ha. This value is approximately 40% of the built-up areas (2,230 ha) in the study area (Figure 3).

Besides built-up areas, agricultural land is another component of human society vulnerable to potential floods. To highlight the vulnerability from this point of view, the major categories of land use within the CORINE Land Cover database were delineated (arable lands and predominantly agricultural lands with natural vegetation), categories which can bear major damages in case of flooding. Thus, arable lands overlapping flood-prone areas reach approximately 11 hectares, this amount representing 23% of all arable lands (48 ha) in the study area. Such areas are located in the village of Chiojdu (Figure 3), where the major riverbed width of the main river allows the placement of arable lands.

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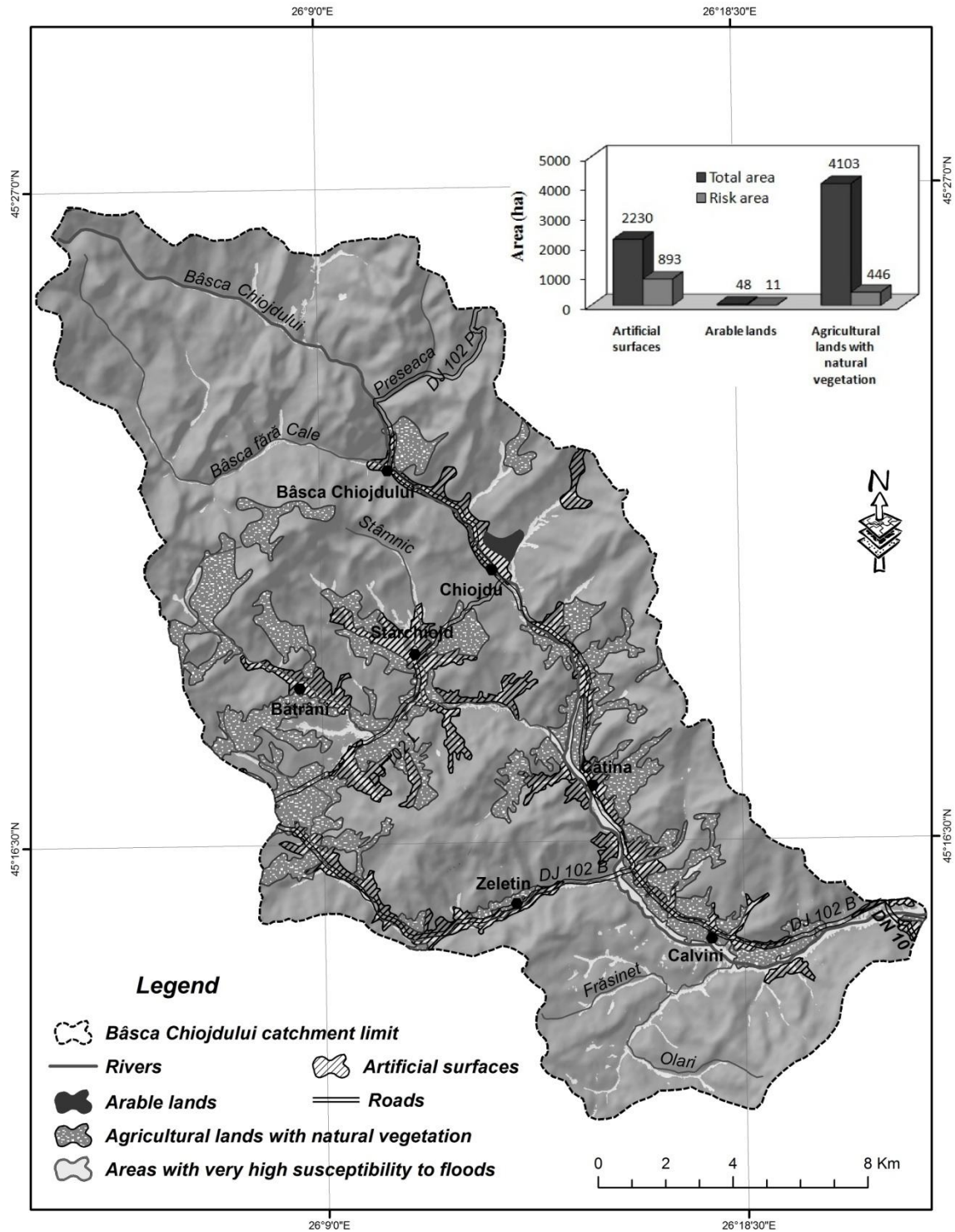


Figure 3. Spatial delimitation of the main socioeconomic risk elements from the CORINE Land Cover database, 2006

Predominantly agricultural lands with natural vegetation (generally arable lands situated in the inhabited area of river valleys) stretch over approximately 4,100 ha, of which 11% (446 ha) intersect surfaces with a high risk of flood occurrence. This type of land use is located primarily in the major riverbed of the Bâsca Chiojdului river, downstream the village of Chiojdu. In addition, predominantly

agricultural lands exposed to flooding occur in the upper and middle sectors of the following rivers: Bătrânceanca, Stâmnice, and Zeletin.

Based on the 2005 orthophotomaps, for a more detailed analysis of built-up surfaces, the number of houses and outbuildings located in areas with very high susceptibility to flood occurrence was defined (Figure 4). All houses and outbuildings in the analyzed river basin reach to approximately 10,246 of which 2,483 (24%) are in flood-prone areas (Figure 5).

The highest density of buildings located in areas with high susceptibility index is recorded in the village of Starchiojd, where up to 29 buildings (houses and outbuildings) are located in an area of one hectare (Figure 5). High values of building density in highly flood-prone areas also occur in the following localities: Bătrâni, Bâsca Chiojdului, Chiojdu, and Calvini. In this area, construction density reaches 17 buildings / ha (Figure 5).

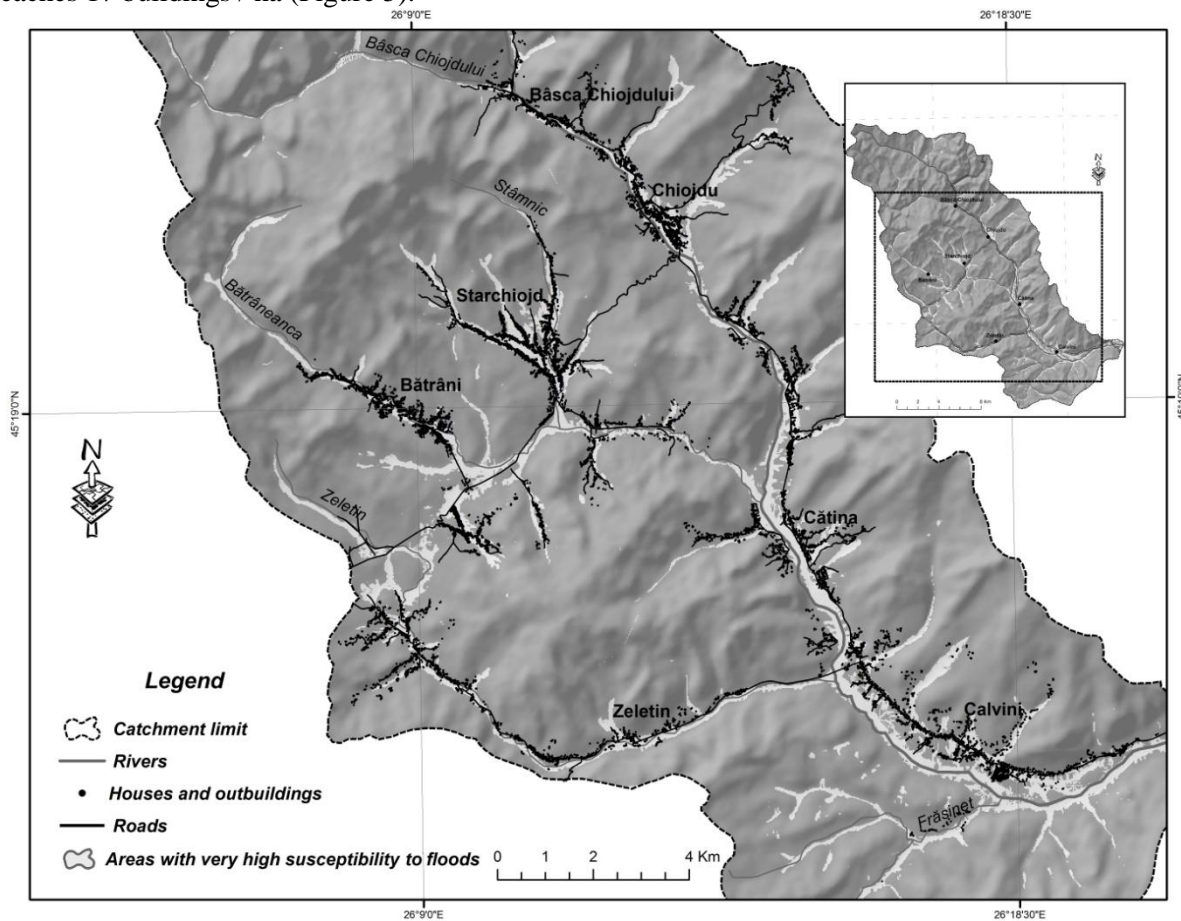


Figure 4. *Spatial distribution of houses, outbuildings and roads (national, county, and village) in the Bâsca Chiojdului catchment area*

Road infrastructure is another component vulnerable in case of flooding (Figure 4). It totals over 156.3 km of national roads, county, and village roads. Over 30% of total road infrastructure is represented by county roads (DJ 100M, DJ 102B, DJ 102L) (Figure 1). The most important road which crosses the Bâsca Chiojdului catchment area is national road DN 10. A 2.3 km-long road segment lies in the southeastern part of the basin, near the confluence of the rivers Bâsca Chiojdului and Buzău.

Nearly 50% of all roads in the area are located on the surfaces characterized by a very high flood occurrence potential. Their length is 71.3 km, out of which county roads represent 30%. The main county road with increased vulnerability to flood risk is DJ 102L, which follows the watercourse of the Bâsca Chiojdului river, from the upper basin, intersecting DN 10 at the confluence of the collector river and Buzău river. For approximately 15.5 km, DJ 102L crosses zones with very high

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susceptibility to flood occurrence. The importance of this road is given by the fact that it makes the connection between the main localities located on the Bâsca Chiojdului river, namely Chiojdu, Cătina, Calvini, and Cislău. Another county road with a high vulnerability to flooding is DJ 102B, approximately 5 km in length, which follows the Zeletin Valley. Its importance lies in the fact that it links the area with the town of Vălenii de Munte and further with the city of Ploiești via DN 1A. The most important road in the Bâsca Chiojdului catchment area, DN 10, crosses over a length of 1.23 km an area with a very high potential for flooding (53% of the total length of 2.3 km), situated at the confluence of rivers Buzău and Bâsca Chiojdului.

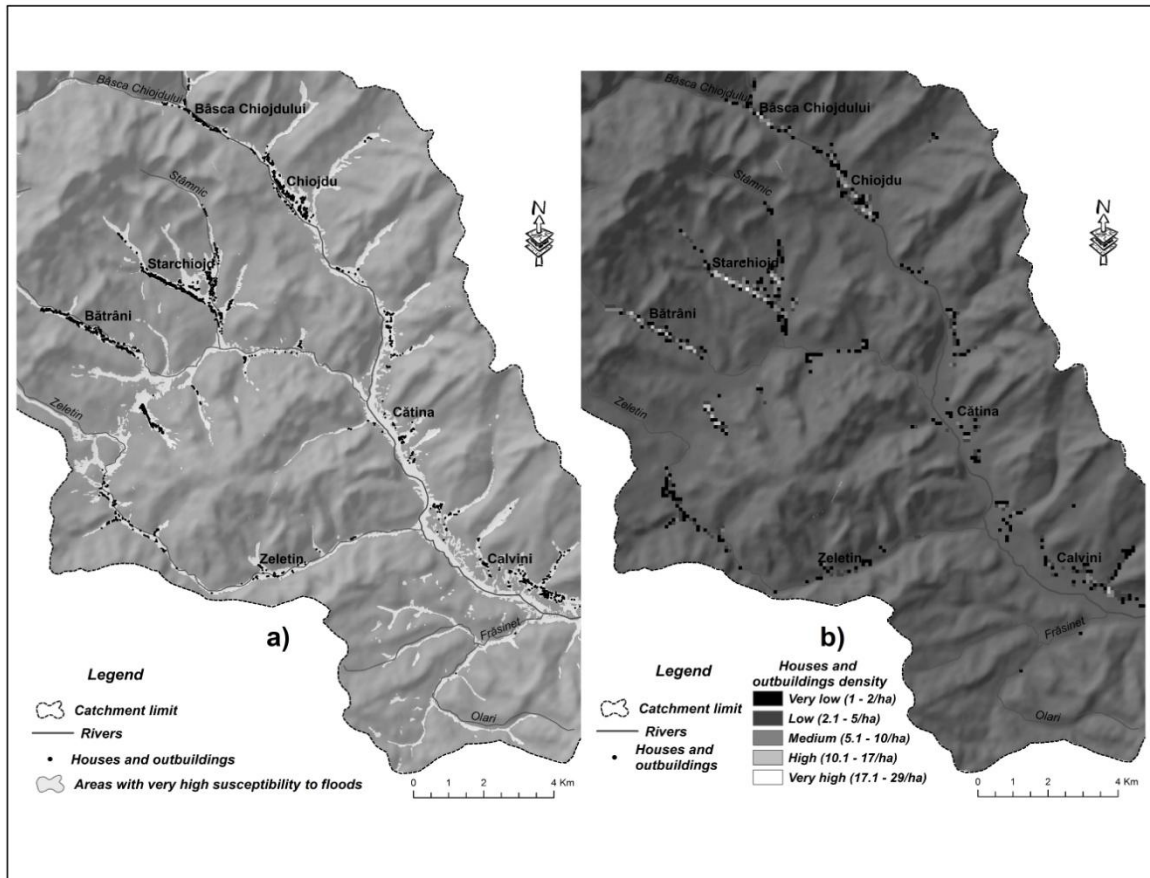


Figure 5. Spatial representation of houses and outbuildings at risk of flooding (a) and their density values (b)

It should be noted that, at spatial level, the vulnerability of socioeconomic elements at risk decreases in some cases in the context of improvement works in the minor riverbed. One of the cases is the improvement made between the villages of Chiojdu and Cătina on the course of the Bâsca Chiojdului river in 2010. The regularization of the river course aimed at protecting and consolidating the riverbank, in all areas of active erosion, on the overall length of about 8 km. Although over 50% of the road network is located in areas with high flood occurrence potential, there is a sector of the county road DJ 102L, that connects Chiojdu and Cătina, whose vulnerability was diminished to some extent by the left bank protection works.

CONCLUSIONS

The analysis of the vulnerability of socioeconomic elements to hydrological risk phenomena such as floods has a great importance because it allows the prevention of human and material

damages. The current analysis has revealed that the Bâsca Chiojdului catchment area is highly vulnerable in terms of the socioeconomic elements considered for the case study (houses and outbuildings, road infrastructure, agricultural areas). Vulnerability was identified mainly along the main valleys of the catchment area, which correspond to the “highly susceptible to flooding” segment.

Thus, it was found that the most important socioeconomic components considered in the analysis - houses and outbuildings - are highly vulnerable to flooding, given that 24% (nearly 2,500 household structures) of the total of more than 10,000 structures fall within the limits of the critical flooding potential area. A similar situation of high vulnerability was also found in the case of agricultural land (about 450 ha of arable / agricultural land overlap the critical flooding sector) and road infrastructure (approximately 50% of the length of the main roads intersect the very high flooding potential sector).

Nevertheless, it should be noted that a rigorous evaluation of the socioeconomic elements at risk of natural hazards such as floods is quite difficult, especially in terms of a static model, as in the case of the flood susceptibility analysis presented above. These hydrological risk phenomena present a very different pattern in time and space, so that comparing the results of the analysed static model with the results of other analysis models, mostly dynamic models, might be of use in order to obtain a complete view of the socioeconomic risks involved. In addition, a useful comparison could be made with results obtained by other static models, of hydraulic nature, that could be applied to certain sectors of the river which are located in areas with high flooding potential.

However, regardless of the employed methodology, in order to validate the results, a more detailed analysis is needed, one that would cover the mathematical relationship between the spatialized data on this hydrological risk and the concrete data on damages recorded locally, which can be made possible, for instance, through certain statistical correlations targeting administrative-territorial units.

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REFERENCES

- BALICA, S. F., DOUBEN, N., WRIGHT, N. G. (2009), *Flood vulnerability indices at varying spatial scales*, Water Science & Technology, vol. 60, no. 10, pp. 2571-2580.
- BARREDO, J.I. (2007), *Major flood disasters in Europe: 1950–2005*, in: Natural Hazards, vol. 42, no. 1, pp. 125–148.
- CONSTANTIN-HORIA, B., SIMONA, S., GABRIELA, P., ADRIAN, S. (2009), *Human factors in the floods of Romania*, in: Jones, J.A.A., Vardanian, T.G., Hakopian, C. (Eds.), *Threats to Global Water Security*, NATO Science for Peace and Security, Series C: Environmental Security, Springer, Dordrecht, The Netherlands, pp. 187–192.
- COSTACHE, R., PRĂVĂLIE, R. (2012), *The use of GIS techniques in the evaluation of the susceptibility of the floods genesis in the hydrographical basin of Bâsca Chiojdului river*, Analele Universității din Oradea, Seria Geografie, vol. XXII, no. 2, pp. 284-293.
- DANKERS, R., FEYEN, L. (2008), *Climate change impact on flood hazard in Europe: An assessment based on high resolution climate simulations*, Journal of Geophysical Research, doi:10.1029/2007JD009719.

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- GAUME, E., BAIN, V., BERNARDARA, P., NEWINGER, O., BARBUC, M., BATEMAN, A., BLASKOVICOVA, L., BLOSCHL, G., BORGA, M., DUMITRESCU, A., DALIAKOPOULOS, I., GARCIA, J., IRIMESCU, ANISOARA, KOHNOVA, SILVIA, KOUTROULIS, A., MARCHI, L., MĂTREAȚA, SIMONA, MEDINA, V., PRECISO, E., SEMPERE-TORRES, D., STÂNCALIE, G., SZOLGAY, J., TSANIS, I., VELASCOM, D., VIGLIONE, A. (2009), *A compilation of data on European flash floods*, Journal of Hydrology vol. 367, pp. 70–78.
- GRECU, F. (2009), *Hazarde și riscuri naturale* [Natural Hazards and Risks], 4th edition, with additions and amendments, Editura Universitară, Bucharest.
- GROISMAN, P.Y., KNIGHT, R.W, EASTERLING, D.R., KARL, T.R., HEGERL, G.C., RAZUVAEZ, V.N. (2005), *Trends in intense precipitation in the climate record*, Journal of Climate, vol. 18, pp. 1326–1350.
- IPCC (2007), *Climate Change 2007: The Physical Science Basis*, Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge.
- KUNDZEWICZ, Z.W., PIŃSKWAR, I., BRAKENRIDGE, G.R. (2013), *Large floods in Europe, 1985–2009*, Hydrological Sciences Journal, vol. 58, no. 1, pp. 1-7.
- LEHNER, B., DOLL, P., ALCAMO, J., HENRICH, T., KASPAR, F. (2006), *Estimating the impact of global change on flood and drought risks in Europe: a continental, integrated assessment*, Climatic Change, vol. 75, pp. 273–299.
- MUNICH RE GROUP (2003), *Annual review: natural catastrophes 2002*, Munich ReGroup, Munich, Germany.
- PRĂVĂLIE, R., COSTACHE, R. (2014), *The analysis of the susceptibility of the flash-floods' genesis in the area of the hydrographical basin of Bâsca Chiojdului river*, Forum geografic. Studii și cercetari de geografie și protecția mediului, vol. 13, no. 1, pp. 39–49.
- TRENBERTH, K.E. (1999), *Conceptual framework for changes of extremes of the hydrological cycle with climate change*, Climate Change, vol. 42, pp. 327–339.
- ZAREA, R. (2011), *Calitatea mediului în bazinul hidrografic al râului Bâsca Chiojdului* [Environmental Quality in the Bâsca Chiojdului Catchment Area], doctoral thesis, Bucharest,
- *** (2005), Orthophotomaps, Scale: 1:5000, the National Agency of Cadastre and Real Estate Advertising.
- *** (2006), CORINE Land Cover, raster data, the European Environment Agency, eea.europa.eu.