



DE GRUYTER
OPEN

DOI 10.2478/pesd-2018-0034

PESD, VOL. 12, no. 2, 2018

ASSESSMENT OF PLUVIAL FLOODS POTENTIAL ON THE RIVERS OF THE REPUBLIC OF MOLDOVA

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Key words: Flash Flood Potential Index, Flooding Potential Index, Flood Propagation Potential Index

Abstract. Present study is dedicated to assessment and mapping of generation and propagation potential of flash flood and river floods on the rivers of the Republic of Moldova. Main methods applied in the research are Flash Flood Potential Index (FFPI) and Flooding Potential Index (FPI). Additionally, a new index for estimation of flood propagation potential (FPPI) is proposed in order to evaluate impact of main factors (natural and human) on propagation of flood wave through the floodplain of small and medium-sized rivers of Moldova. In total, assessment of FFPI an FPI was performed for 789 elementary river basins (basin area less than 200 km²) and also was considered for 983 elementary territorial-administrative units (communes). Estimation of FPPI was made for 50 main small and medium sized rivers of Moldova. All index parameters (7 for FFPI, 6 for FPI and 12 for FPPI) were integrated, analyzed and combined in GIS environment. As a results, it was found that the FFPI is average for mostly all basins and communes but is characterized by significant differences in spatial representation on local level. FPI is high in basins and communes situated in the floodplains of large and medium sized rivers, in flood-prone areas, and is low in those with high altitudes and steep slopes (Codri and Nistru heights). Flood propagation potential was estimated with average values for 56% of total number of rivers, high for 34% and very high for 6%. The results can be used for future estimation of flood generation and flood wave propagation processes and for improvement and optimization of flood management practices and strategies on rivers weakly studied from hydrology point of view.

Introduction

The Republic of Moldova is situated in a region with high flood frequency. Floods counted 50% of total number of disasters and caused 45% of losses and ~70% of victims

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which died because of natural calamities occurred during 1990-2014 (CRED, 2016). Extreme climatic conditions (heavy rains and/or snow melt) are the main factors which determine flood generation on the rivers of the Republic of Moldova. The most significant impact is caused by large rivers floods and, especially, by flash floods of the summer period (Hazardurile naturale, 2008). Occurrence of pluvial floods is caused by heavy rains but their potential effect depends on physical-geographical features, soils, vegetation as well as human factors. So far, flood protection is performed by a complex of structural and non-structural measures which are in continuous improvement process due to increasing frequency and magnitude of this hazardous phenomenon. According to Flood Framework Directive, to establish suitable flood management activities and for optimization of decision making processes it is necessary to evaluate "flood hazard maps and flood risk maps showing the potential adverse consequences associated with different flood scenarios" (2007/60/EC DIRECTIVE, 2007). Through the huge number of models that are developed for estimations of flood-prone areas the most important are those that can give an adequate hydrological answer regarding flood generation and propagation processes. Application of these models, as usual, depends on quality and quantity of hydrology data which often are absent or insufficient. In this cases, in order to estimate flash flood and flooding areas there have been developed indexes that can be easily and fast applied and can give a preliminary understanding of hydrology processes during these hazardous phenomena: Flash Flood Potential Index (FFPI) and Flooding Potential Index (FPI) that are being used worldwide and adapted to the local environmental conditions of different regions (Hapciuc et al., 2016; Minea, 2013; Shaban et al., 2001; Smith, 2003; Zaharia et al., 2015). These indexes are non-dimension and consider main basin features for assessment of flood generation and accumulation potential. Additionally, Flood Propagation Potential index (FPPI) can be used in order to evaluate impact of main factors (natural and human) on propagation of flood wave through the river floodplain. In this regard main aim of present study is estimation of flash floods, flooding and flood wave propagation potential for rivers of the Republic of Moldova. The results can be used for improvement and optimization of flood management practices and strategies on rivers weakly studied from hydrology point of view.

Study area

Estimation of FFPI and FPI was performed for the whole territory of the Republic of Moldova and particularly for 789 elementary river basins (basin area less than 200 km²) and 983 elementary territorial-administrative units (communes). Evaluation of FPPI was made for main tributaries of large rivers: Danube, Dniester as well as Black Sea, in total counting 50 small and medium sized rivers with a length over 20 km, permanent flow generated within the Republic of Moldova territory and river basin area over 200 km². Main geographical features that influence on flow generation, accumulation and propagation processes and are applicable for indexes estimation were assessed by runoff potential perspective. Their detailed description, analysis and classification is given in next chapters.

Methodology

Assessment of potential for generation and propagation of floods was done by combining the natural and human factors classified according to runoff potential and application of the FFPI, FPI and FPPI indexes. Pioneer in application of FFPI was of G. Smith (2003), which assessed the flash flood potential in the Colorado River Basin, USA. The proposed methodology consisted of identification, classification and combination of main factors that determine the flood runoff. In the simplified form, FFPI formula is characterized by the function of interrelationship of three factors: soil, slope, vegetation, classified according to runoff potential (from low to high). This concept has been used and adapted by other authors for different regions of the globe (Prăvălie & Costache, 2014; Shaban et al., 2001). Subsequently, the number of factors increased and methods for estimation of weighted effect of each factor were identified and applied (Zaharia et.al., 2015). Later, basing on the logic applied for FFPI assessment, the Flooding Potential Index (Costache et al.; 2015, Hapciu et al., 2016; Shaban et al., 2001, Zaharia et al., 2015) has been developed that estimates the factors contributing to stormwater accumulation in the floodplain.

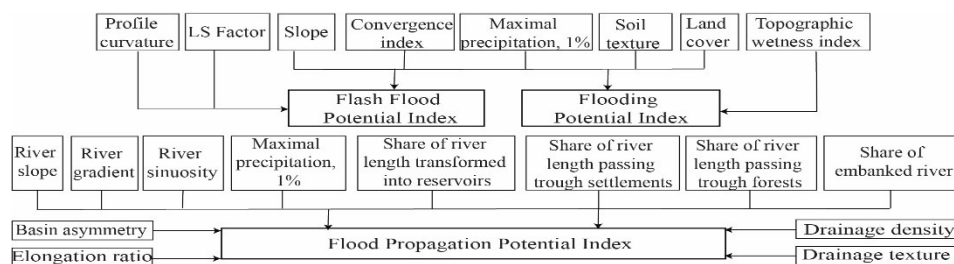


Figure 1: GIS database for assessment of FFPI, FPI and FPPI

In present study, for modeling FFPI, FPI, FPPI 19 factors that reflect flood generation and propagation processes were used (Fig. 1). Factors classification was performed according to their characteristics and the impact on the surface runoff generation by attribution of a score from 1 (low potential) to 5 (high potential). Assessment of FFPI and FPI was performed using spatial data distributed on entire river basins. On the other hand, evaluation of FPPI was made by using data describing riverbeds state. Mapping, calculation and derivation of factors needed for indexes' estimation were performed in ArcGIS and SAGA environment. Elevation model was extracted from SRTM (2014), soil cover and river network - from Moldova's national geospatial data fund (Harta texturii solului, 2016). Spatial structure of land cover was estimated using FAO land cover map (Harta FAO, 2005). FFPI, FPI, FPPI modeling was made in ArcGIS using Weighted Sum function. Weighted values of each factor were evaluated basing on Decision

Making Matrix in Microsoft Excel (Cojoc et al., 2015; Decision Matrix, 2017; Romanescu et al., 2014, 2017, 2018a, 2018b).

Results and discussions

For estimation of potential for flash flood generation on the territory of the Republic of Moldova, the Flash Flood Potential Index was used which consists in integration of natural and anthropogenic factors with spatial distribution on entire river basin: slope, LS factor, convergence index, profile curvature, land cover, soil, and maximum precipitations for 1% probability. Classification and weighted values of all factors are presented in table 1.

Main flood generation factors are maximal precipitations, that are specific for summer period (Hazardurile naturale, 2008; Normativ în construcții, 2013). The precipitations considered for present study are of 1% probability (Normativ în construcții, 2013). These data were integrated in ArcGIS environment and interpolated from points - meteorological stations and posts of the monitoring network of the State Hydro-meteorological Service of Moldova - to raster format. It was estimated that extreme precipitations have a high spatial variability, however the highest values are specific for central and northern part of the country being over 150 mm and the lowest - for the southern part with values less than 70 mm.

Flash floods regime depends on characteristics of the surrounding environment. The topography of the country represents a hilly plain, average elevation is equal to 148 m and varies from 429 m. and -4 m. The highest elevation is specific for central part of the country - Codri Heights - and leads to generation of fast slope runoff, while the lowest - in large rivers floodplains Dniester and Prut - determines flow accumulation (Fig. 2). Country average slope is 3.78 degree, maximum and minimum values were distributed as in case of elevation - the steepest being in the central part and the lowest in the south-east and south part of the country. The slope - a governing factor in the slope runoff - was grouped according to the surface type and morphodynamics, the steep slopes were assigned the value 5 and gentle slope - value 1 (Bilasco, 2008). In general, slope is enclosed into low and very low potential class with a share of about 70% of the territory (Fig. 3). Approximately the same regularity is observed in the case of LS factor analysis, the maximum values are specific to the central part of the country, but ~ 70% of the country's territory is characterized by very low and low runoff potential according to this indicator. The profile curvature was classified according to the runoff potential as follows: the concave slopes influencing the formation of the deceleration runoff and the convex ones leading to the accelerated runoff. The share of concave and convex profile curvature is about 50/50, but it was observed a slightly larger abundance of concave slopes in the northern part, and of convex slopes in the central part of the country. The estimation of the divergent (on convex

slopes) and convergent (on convex slopes) runoff basing on the convergence index showed equal values for both (~50/50). The distribution of this index is well highlighted even in small rivers and shows great runoff potential on the slopes and low in the floodplain. The same law was also observed in case of the Topographic Wetness Index analysis which allowed a much clearer detection of surface runoff. On the one hand, there are well defined the floodplain of the rivers Prut, Nistru, Raut, Ialpug, Cogylnic, Botna, Byc, where the stormwater accumulates, and on the other - the minimum values are spread on the slopes characterizing the maximum slope runoff (Fig. 4).

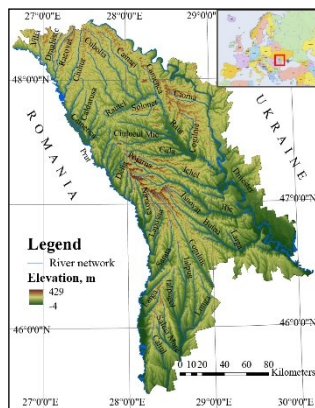


Figure 2: Elevation model

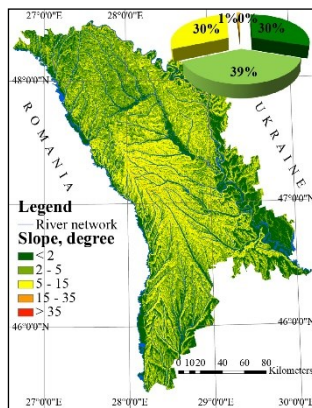


Figure 3: Slope, degree

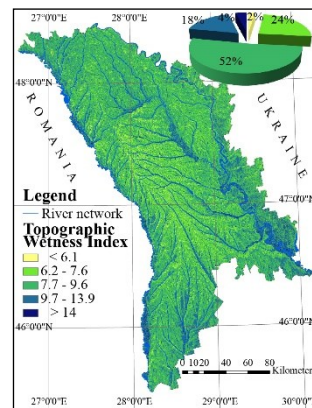


Figure 4: TWI

Soil classification was performed according to its textural characteristic and runoff rate. Thus, the soil with clayey texture and high runoff potential was assigned a value of 5 and of a sandy texture and a low runoff potential - value 1. The soil cover is mostly characterized by low infiltration rate and high runoff potential due to the fact that 60% of country soil cover is clayey loam.

The land cover was analyzed from the perspective of water retention capacity. The greatest contribution to reduce the maximum runoff is caused by forest (with a share of 12% of the country territory) through the ability to retain considerable volumes of water from the heavy rains. On the other hand settlements (with a share of 10% of the country territory) create favorable conditions for heavy rains to be virtually transformed into surface runoff without the possibility of being retained by vegetation or being infiltrated by soil. In case of lack or inefficiency of pluvial sewerage systems in the cities, the torrential flow damages the infrastructure and may paralyze economic and social activity of the human being. Compared with settlements and forest, the largest part of the country territory is covered by arable area, and even if it has a lower impact on flash flood generation than urban area, its

high share, over 55%, make it one of the most important factors in maximal slope runoff generation. Forest, grassland as well as orchards are predominant for central part of the republic so even if here the topography is hilly and slope are steep, vegetation retention capacity reduces flood runoff. On the other hand, the northern and southern parts of the country are covered mainly by arable area that leads to a higher FFPI.

Table 1: Classification of factors for estimation of FFPI

Factors, weight	Parameters/values				
Maximal precipitations, 1%, mm, W=1.8	<50	50-80	80-100	100-150	150-180
Slope, degree, W=1.0	≤ 2	2.1-5	5.1-15	15.1-35	≥ 35
LS factor, W=0.8	0 - 2	2 - 4	4 - 6	6 - 8	> 8
Convergence index (derived in SAGA) W=1.5	(-100) - (-6)	(-6) - (-1)	(-1) - 1	1 - 6	6-100
Profile curvature (derived in ArcGIS) W=1.4	43-2.5	2.5-0.1	-0.1-0.1	(-2.5) -(-0.1)	(-31)-(-2.5)
Soil, texture, W=1.8	Loam sand, sandy	Sandy loam	Loam	Clayey loam	Clay Loamy clay
Land cover, W=1.6	Forests	Orchards, vineyard, shrubs	Grassland	Arable area	Settlements (cities, towns, villages)
Score for parameter/ value	1	2	3	4	5
Total score	< 19.8	19.9-26.5	26.6-33.3	33.4-40.0	> 40.0
FFPI class	Very low/null potential	Low potential	Average potential	High potential	Very high potential

On the basis of the summing up of all the FFPI factors and their weighted values (Table 1), a grid with the values between 13.6-46.7 was obtained, which was classified according to the equal intervals method into 5 classes to which flash flood potential classes from very low to very high were assigned. As a result, it was calculated that a low and very low flash flood potential is characteristic for approx. 11% of Moldovan territory, on the other hand 29% of the country's surface is subject to high and very high flash floods potential. Most of the territory of the Republic of Moldova is characterized by an average flash flood potential, approx. 60% (Fig. 9). Based on the FFPI raster, the average values for elementary river

basins and administrative-territorial units (communes) have been extracted (Fig. 13, 14). Finally, it was estimated that for most communes and river basins, FFPI is characterized by average values and only for 7 (0,9%) basins and for 4 (0.41%) communes is low and for 36 (4.56%) small basins and 50 (5.1%) communes the FFPI is high. Basins and communes with high FFPI values are located mainly in the central and northern parts of the country where the value of 1% maximum precipitation is more significant than in other regions and the degree of anthropogenic impact on landscape systems is higher. The FFPI value in the Codri Heights is average due to the presence of a proportion of sandy soil and large forest areas, which reduce flood runoff.

Estimation of the flooding potential index was made on the basis of the principle: summing up the factors that lead to stormwater accumulation in the river floodplains: maximum precipitation of 1% probability, slope, convergence index, topographic wetness index (TWI), soil, land cover. Attribution of score to soil, precipitation and land cover was performed according to the approach described above for FFPI. The slope and convergence index were classified according to the principle of the concentration of flood wave in the floodplain, respectively, the score was assigned in reverse order as in case of FFPI. The topographic wetness index was classified in accordance with the maximum values, distributed in the floodplains of large and medium sized rivers (up to 27), which were attributed to 5 values class, and the minimum values, estimated for the areas of the highest altitudes (less than 2), which were assigned to 1 (low potential). Finally, based on the combination of mentioned weighted factors (Table 2), a grid of 13.3-49.5 values was obtained which was classified in equal intervals and grouped in 5 classes. The most important classes that characterize the accumulation of flood water in the floodplain are those with high and very high potential. The share of these classes areas is 28% of the total country area. 2/3 of the total is attributed to average FPI surfaces and 15% to those with low and very low FPIs (Fig. 10). Estimation of FPI for small basins and communes resulted in the fact that the FPI is low and very low for 22 basins (2.79%) and 33 communes (3.36%) situated in Codrii Heights, high for 111 (14.1%) basins and 99 (10.1%) communes situated in the river floodplains, and average for the other areas (Fig. 15, 16).

According to the same principle applied for the estimation of FFPI and FPI the index that describes the potential of the wave propagation through the river bed has been developed. For the estimation of the FPPI, the natural and anthropogenic factors characterizing the main riverbed were considered: river slope, sinuosity, fall, share of embanked river, the share of river lengths passing through forests and settlements and the river length converted into reservoirs, as well as the maximum precipitation of 1%. Classification of river slope was performed on analysis of local maximal and minimal values and divided into classes using equal interval

method (Table 3). Thus, a low and very low propagation potential was assigned to 21 rivers, situated mainly in northern part of the country and a high and very high potential - for 22 rivers, which flow through central part of the Republic of Moldova. The highest values of river fall (>250 m) is also specific for the river from the central part: Byc, Botna, Lapusna, etc., and the lowest (<100 m) for Prut tributaries: Gyrla Mare, Sovatul Mare and others.

Table 2: Classification of factors for estimation of FPI

Factors, weight	Parameters/values				
Maximal precipitation, 1%, mm, W=1.8	<50	50-80	80-100	100-150	150-180
Slope, degree, W=1.9	≥ 35	15.1-35	5.1-15	2.1-5	≤ 2
Convergence index W=1.4	6-100	1 - 6	(-1) - 1	(-6) - (-1)	(-100) - (-6)
Topographic wetness index (derived in SAGA), W=1.4	1.8 - 6.1	6.1 - 7.6	7.6 - 9.6	9.6 - 13.9	13.9 - 26.9
Soil, texture, W=1.8	Loam sand, sandy	Sandy loam	Loam	Clayey loam	Clay Loamy clay
Land cover, W=1.6	Forests	Orchards, vineyard, shrubs	Grassland	Arable area	Settlements (cities, towns, villages)
Score for parameter/value	1	2	3	4	5
Total score	<23.0	23.0-30.0	30.0-37.0	37.1-43.0	>43.0
FPI Class	Very low/null potential	Low potential	Average potential	High potential	Very high potential

An important element determining the flow velocity and propagation is river sinuosity. The higher this values is, the more meandered the river is and flood flow passes more slowly the distance through the river bed. River regulations performed intensely in a second half of the 20th century determined the decrease of rivers length and respectively the diminution of the coefficient of sinuosity. At present, its value for almost all study rivers is less than 1.3, which characterizes them as relatively rectilinear rivers. The most meandered river are Camenca (Prut tributary), Rautel, Raut, and almost rectilinear are Delia, Cula and others (Fig. 5).

Flood wave propagation regime is highly influenced by human activity. Form one hand, there are constructed hydro-technical structures (embankments, reservoirs, etc.) for protection people and economical features from floods, from the other, almost all settlements are situated in the floodplain near water sources,

and floodplain themselves are used as agriculture land, in most of the cases disregarding river protection zones. Classification of flood protection measures was performed considering the impact on flood wave movement through the riverbed. Thus, reservoirs were built mainly to accumulate water and decrease flood wave propagation. The share of the river length that was modified into reservoirs with a dam across the river was considered as main classification criteria. If this indicator is less than 10% the river is weakly regulated so the assigned value is 5. In contrast, if the share is more than 50% flood regulation capacity is high and propagation potential is low so the value is 1. Share of river length that is transformed into reservoirs for almost all rivers is less than 10% except Camenca river basin (Prut tributary) where the value rises over 30% (Fig. 6). Another factor - embankments - cause longitudinal disconnection of the river with the floodplain. During flood events, the river flood is not distributed in natural floodplain but flow through an

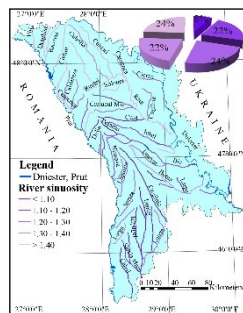


Figure 5: River sinuosity

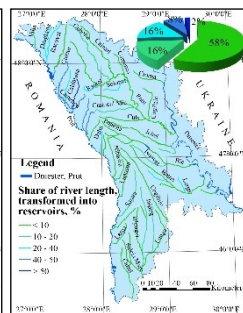


Figure 6: Share of river length converted into reservoirs

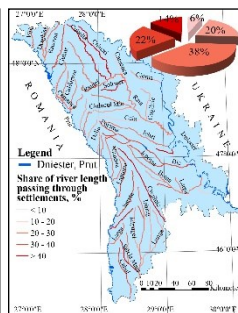


Figure 7: Share of river length passing through settlements

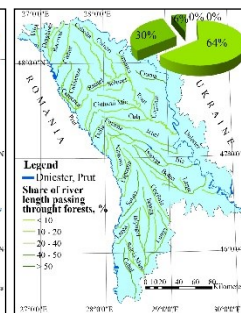


Figure 8: Share of river length passing through forests

artificial floodplain constrained by embankments which determines a higher propagation potential. In such a case, embanked rivers with a share over 50% have a very high propagation potential and those <10 - very low flood potential. Average share of embanked river lengths is 11 (on left side) -13% (on right side), maximal value being estimated for Botna river (~53% on right side and 68% on left side), no embankments on rivers: Vilia, Draghiste, Racovat, Sovatul Mic, Sovatul Mare, Caldarusa and others. Another two parameters that have a contrasts impact on flood wave propagation are settlements and forests. Urbanization process increases river flow and especially flood runoff, in comparison, forests establish contraries condition - reduce the slope runoff, and flood propagation potential. In this condition, classification of the share of river lengths which passes through settlements and forests was performed from maximum to minimum. If the share of river length passing through forests is <10 the potential of propagation is very high

and if this value is more than 50% - potential is very low. In case of settlements, classification is made in reverse order. Average share of river length passing through settlements is 26.5% which is almost 1/3 (Fig. 7). In contrast, average share of river length passing through forests is only 8.3% (Fig. 8).

Table 3: Classification of factors for assessment of FPPI

Factors	Parameters/values				
	<2.0	2.0-3.0	3.0-4.0	4.0-6.0	>6.0
River slope	<2.0	2.0-3.0	3.0-4.0	4.0-6.0	>6.0
River gradient, m	<100	100-150	150-200	200-250	>250
Sinuosity	>3	2.0-3.0	2.0-1.5	1.5-1.3	<1.3
Maximal precipitations, l%, mm	<50	50-100	100-115	115-130	>130
Drainage density, km/km ²	<1	1.0-2.0	2.0-3.0	3.0-4.0	>4.0
Drainage texture	<2	2-4	4-10	10-15	>15
Elongation ratio	<0.5	0.5-0.7	0.7-0.8	0.8-0.9	0.9 - 1.0
Basin asymmetry	0.1-(-0.1)	0.1-0.3/ (-0.1)-(-0.3)	0.3-0.4/ (-0.3)-(-0.4)	0.4-0.5/ (-0.4)-(-0.5)	0.5-0.7/ (-0.5)-(-0.6)
Share of embanked river, %	<10	10-20	20-30	30-50	>50
Share of river length passing through settlements, %	<10	10-20	20-30	30-40	>40
Share of river length regulated by reservoirs, %	>50	40-50	20-40	10-20	<10
Share of river length passing through forests, %	>50	40-50	20-40	10-20	<10
Score for parameter/value	1	2	3	4	5
Total score	<20	20-27	27-32	32-40	>40
FPPI Class	Very low/null potential	Low potential	Average potential	High potential	Very high potential

Optional features that were used in FPPI calculation, describe the basins characteristics: asymmetry, elongation ratio, drainage density and texture. An essential feature in the propagation of the flood wave is the basin shape. It was estimated that all of the basins are of a very elongated shape which means a lower potential of torrential regime. Drainage density plays an important role in the nature of the flood wave propagation. The torrential potential rises together with the increase of number of rivers from the basin. Average drainage density is 0.9, the highest being of 1.3 (Bratuleanca) and lowest - of 0.61 (Baltata). Drainage texture was classified from very fine (low permeability soft rocks) to very coarse (high permeability rocks). Average value for study area is 2 meaning a presence of coarse rocks which determine a low number of streams. Basin asymmetry was taken into account from consideration that as higher this coefficient is as faster storm-water will concentrate from the tightest part of the basin and accumulate in the river bed. In conditions of symmetric river basin time of concentration of flow will be equal to both sides and potential of propagation will be less than in previous

case. The estimation showed that about 70% are symmetric or nearly symmetric river basin.

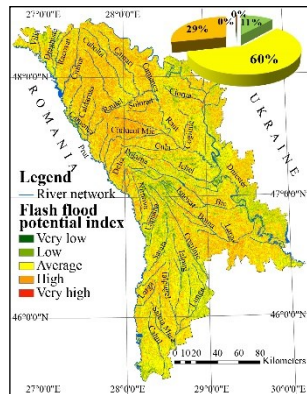


Figure 9: Flash flood potential Index

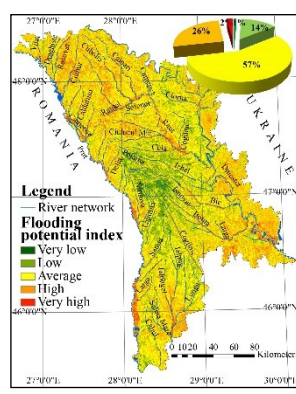


Figure 10: Flooding potential Index

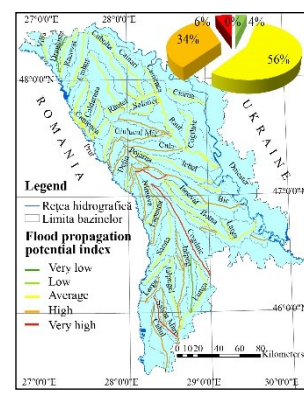


Figure 11: Flood wave Propagation Potential Index

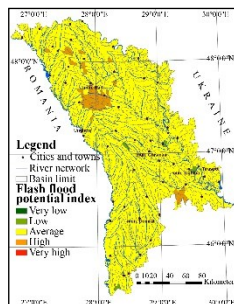


Figure 13: FFPI for small basins

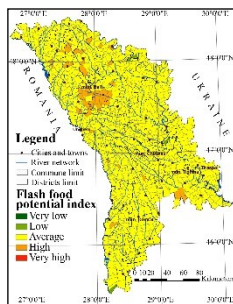


Figure 14: FFPI for communes

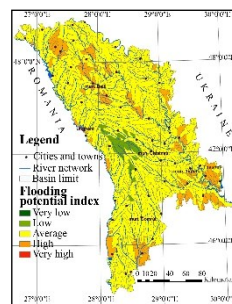


Figure 15: FPI for small basins

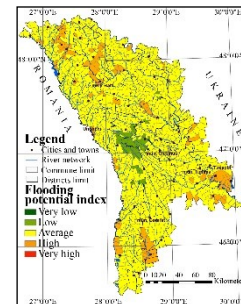


Figure 16: FPI for communes

As a result of combination of all factors for FPPI estimation and its classification in 5 classes, there was established that about 56% of study rivers indicates an average flood propagation potential, 34% are characterized by high, 4% - by low and other 6% - by very high FPPI (Fig. 11). Most of rivers with high FPPI are situated in plateau region, central and southern part of the country. The highest FPPI was estimated for Salcia Mare, Cogylnic and Bucovat rivers. Here, in first case, maximum values were assigned to basin asymmetry, share of river length passing settlements, forests and reservoirs. In case of Cogylnic highest score was given to river gradient and sinuosity, share of river length passing through reservoirs, settlements and forests. In case of Bucovat values of 5 were assigned to river slope and gradient, share of river length passing through settlements and

forests. The lowest values are assigned to Lunguta and Draghiste rivers. Here the maximum score was given only to lack of forests along the rivers.

Conclusions

Assessment of flash floods, flooding and flood propagation potential was performed basing on factorial analysis of general natural and anthropogenic features of the river basins and beds for the territory of the Republic of Moldova. Spatial distribution of factors classes is very nonuniform and respectively assessment of their impact on floods formation, accumulation and propagation processes varies from basin to basin or from river to river. Factorial analysis performed for estimation of FFPI, FPI and FPPI showed that rivers are exposed to impact of different number of factors, some of them being exposed to only one factor, some - to 7 or more. Understanding, assessment and modeling of their influence results in general knowledge about flood management practices that are performed in the basin and give and understanding of those that should be done. In addition to described factors, there can be applied other features that are considered important in flood potential estimation and increase the accuracy of modeling. As an example can serve estimation and classification of flood runoff basing on indirect methods. There can be also applied different scenarios which interpret human impact on flood processes like land cover, flood protection measures, river bed changes to estimate best or worst scenario of factors effects or to evaluate future flood management plans.

References:

- Bilasco, S.** (2008), *Implementarea G.I.S. în modelarea viiturilor de versant*, Casa Cărții de Știință, Cluj-Napoca, 212 pp.
- Cojoc, G., Romanescu, G., & Tirnovan, A.**, (2015), *Exceptional floods on a developed river. Case study for the Bistrita River from the Eastern Carpathians (Romania)*. Natural Hazards, vol. 77(3), pp. 1421-1451.
- Costache, R., Prăvălie, R., Mitof, I., & Popescu, C.**, (2015), *Flood vulnerability assessment in the low sector of Sărățel catchment. Case study: Joseni village*, Carpathian Journal of Earth and Environmental Sciences, vol. 10(1), pp. 161-169.
- Hapciuc, O.E., Iosub, M., Tomașciuc, A.I., Minea, I., & Romanescu, G.**, (2016), *Identification of the potential risk areas regarding the floods occurrence within small mountain catchments*, Proceeding of 2nd International Scientific Conference Geobalcanica, pp. 177-183;
- Minea, G.**, (2013), *Assessment of the Flash Flood Potential of Bâsca River Catchment (Romania)*, Based on Physiographic Factors Cent. Eur. J. Geosci., vol. 5(3), pp. 344-353

- Romanescu, G., Zaharia, C., Paun, E., Machidon, O., & Paraschiv, V.,** (2014), *Depletion of watercourses in north-eastern Romania. Case study: the Miletin river*. Carpathian Journal of Earth and Environmental Sciences, vol. 9(1), pp. 209-220.
- Romanescu, G., Cimpianu, C.I., Mihu-Pintilie, A., & Stoleriu, C.C.,** (2017), *Historic flood events in NE Romania (post-1990)*. Journal of Maps, vol. 13(2), pp. 787-798.
- Romanescu, G., Hapciuc, O.E., Minea, I., & Iosub, M.,** (2018a), *Flood vulnerability assessment in the mountain-plateau transition zone. Case study for Marginea village (Romania)*. Journal of Flood Risk Management, vol. 11(S1), pp. S502-S513.
- Romanescu, G., Mihu-Pintilie, A., Stoleriu, C.C., Carboni, D., Paveluc, L.E., & Cimpianu, C.I.,** (2018b), *A Comparative Analysis of Exceptional Flood Events in the Context of Heavy Rains in the Summer of 2010: Siret Basin (NE Romania). Case Study*. Water, 216, vol. 10(2), pp. 216:1-17.
- Prăvălie, R., & Costache, R.,** (2014), *The analysis of the susceptibility of the flash-floods' genesis in the area of the hydrographic basin of Bâsca Chiojdului river*, Forum geografic. Studii și cercetări de geografie și protecția mediului, vol. 13(1), pp. 39-49.
- Shaban, A., Khawlie, M., Bou Kheir, R., & Abdallah, C.,** (2001), *Assessment of road instability along a typical mountainous road using GIS and aerial photos, Lebanon-eastern Mediterranean*, Bull. Eng. Geol. Environ, vol. 60(2), pp. 93-101.
- Smith, G.,** (2003), *Flash Flood Potential: Determining the Hydrologic Response of FFMP Basins to Heavy Rain by Analyzing Their Physiographic Characteristics*. http://www.cbrfc.noaa.gov/papers/ffp_wpap.pdf, 11 pp.
- Zaharia L., Costache R., Prăvălie R., & Minea G.,** (2015), *Assessment and mapping of flood potential in the Slănic catchment in Romania*, J. Earth Syst. Sci., vol. 124(6), pp. 1311-1324.
- ***, (2013), *Determinarea caracteristicelor hidrologice pentru condițiile Republicii Moldova. Normativ în construcții CP D.01.05-2012, ediție oficială*, Agenția construcțiilor și dezvoltarea teritoriului Republicii Moldova, Chișinău, 155 pp.
- ***, (2005), *Harta FAO „Acoperirea/utilizarea teritoriului Republicii Moldova”*, <http://canteav.blogspot.md/> (accessed on 3.04.2013).
- ***, *Harta texturii solului* www.geoportal.md (accessed on 3.07.2016).
- ***, (2008), *Hazardurile naturale. Colecția Mediul geografic al Republicii Moldova*, Compilat: Cazac V., Boian I., Volontir N. Chișinău, 207 pp.
- ***, (2017), *Decision Matrix* <http://blogs.msdn.com/mswanson/archive/2008/07/20/my-decision-matrix.aspx> (accessed on 22.03.2017).
- ***, (2016), *The OFDA/CRED International Disaster Database*, Université Catholique de Louvain-Brussels-Belgium www.emdat.be (accessed on 21.01.2016).
- ***, (2007), *2007/60/EC Directive of the European Parliament and of the Council of 23 October 2007 on the assessment and management of flood risks*; Official Journal of the European Union L 288(27), 8p. <http://eur-lex.europa.eu/LexUriServ/>.
- ***, (2014), *Shuttle Radar Topography Mission (SRTM)*, US Geological Survey, <https://earthexplorer.usgs.gov/> (accessed on 3.04.2017).

