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Floods Vulnerability Assessment in the Area of Rivers Ropotamo and Veleka Southeastern Bulgaria

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Abstract: The present research observe the problems related to floods and flood vulnerability assessment in the area of rivers Ropotamo and Veleka, Southeastern Bulgaria. The main objective of the investigation is to identify the flood vulnerability zones in the area of Veleka and Ropotamo river valleys. The realization of this objective is connected with check and analysis of data availability, delineation of the floodplains in Veleka and Ropotamo river valleys, identification of the land use within the floodplains and flood vulnerability analysis of Veleka and Ropotamo floodplains.

Key words: Flood, floodplain, flood vulnerability

I. Introduction

Floods are among the most dangerous natural phenomena causing severe damage to various branches of the economy and in many cases lead to casualties. Flooding occurs when areas that are not normally under water are inundated due to rising river levels and/or the level of groundwater due to rainfall and/or snowmelt, due to breaking of embankments, the dam breaks, temporary blockage of the river bed etc. (Nikolova and Nedkov, 2012). The risk of flooding is determined by the frequency (probability) of their occurrence and exposure of the affected areas in terms of potential damage they may suffer. Damages in turn depend on the degree of hazard of the corresponding flood, as well as the vulnerability of exposed people and objects. Exposure to floods is assessed on one hand through flood hazard zoning and on the other it is an important factor for vulnerability assessment. There are different systems (economic, social, ecological etc.) that can be exposed to flood hazard in particular area. Furthermore their exposure is different according to the flood risk zones where they belong to. Vulnerability depends on the degree of flood hazard as well, but it also depends on many other factors such as the urbanization and buildings density, the type of threatened infrastructure, population characteristics such as density, age structure, mobility and health status, presence or absence of protective equipment in hazardous areas and early warning systems etc.

The study area in this research includes basins of the rivers in Southeastern Bulgaria which drain into Black sea on the South of Burgas. It includes the river basins of Ropotamo, Dyavolska, Karaagach, Veleka, Rezovska, Silistar as well as some small basins drained directly to the Black sea. It comprises an area of 184611 ha. The biggest basins in the area are Veleka (79192 ha) and Ropotamo (24645 ha) therefore these two basins were chosen as a main focus in this research. This area corresponds to the Project Unit XV South-Burgas rivers, Veleka and Rezovska in the National Plan of Flood Risk Management. According to the Preliminary flood risk assessment in Black Sea region for water management (2012) there were registered 135 floods for the period 1979-2010 and almost half of them (64) were in the Basin of Veleka River. The location of 35 significant floods during this period is given in figure 1.

The main objective of this work is to identify the flood vulnerability zones in the area of Veleka and Ropotamo river valleys. The realization of this objective was accomplished through the following tasks:

- Check and analysis of data availability;
- Delineation of the floodplains in Veleka and Ropotamo river valleys;
- Identification of the land use within the floodplains;
- Flood vulnerability analysis of Veleka and Ropotamo floodplains.

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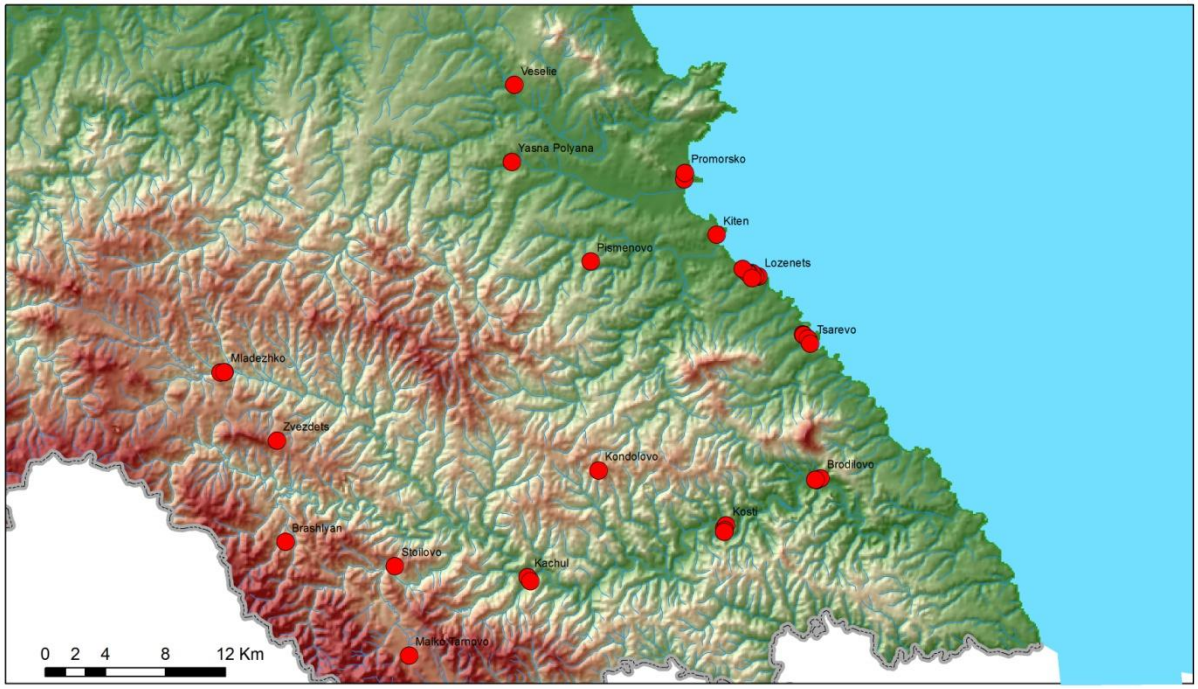

Figure 1. Location of the significant floods

II. Materials and methods

The necessary data for identification of flood vulnerability area include topographic maps, land cover data, data for hydrological objects in the area, topography data, infrastructure data, and information for flood events in the area. The analysis of data availability revealed that the objectives of the study could be achieved by using 1:25000 topographic maps, 50 m DEM, and land cover data from CORINE project.

The area of Veleka river basin is located within 19 topographic map sheets at scale 1:25000, while Ropotamo river basin covers 7 map sheets. Their distribution is given at figure 2 and 3. All topographic maps have been scanned and georeferenced in coordinate system UTM WGS1984 zone 35N. The river basins have been outlined using ArcGIS Hydrology tools. The procedure includes generation of flow direction and flow accumulation grids, and model of river flows which is used to define the outlets of the catchments (Tarboton et al., 1991).

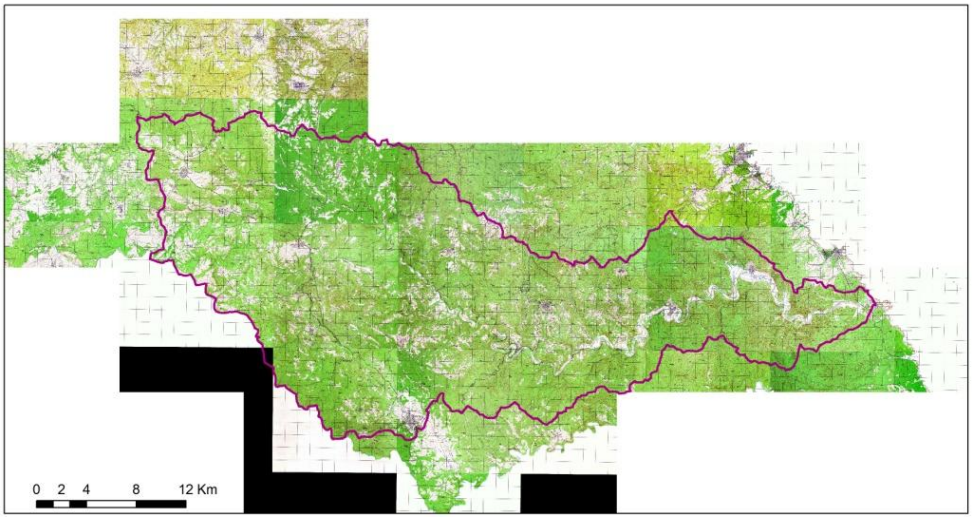

Figure 2. Topographic maps in the area of Veleka river basin

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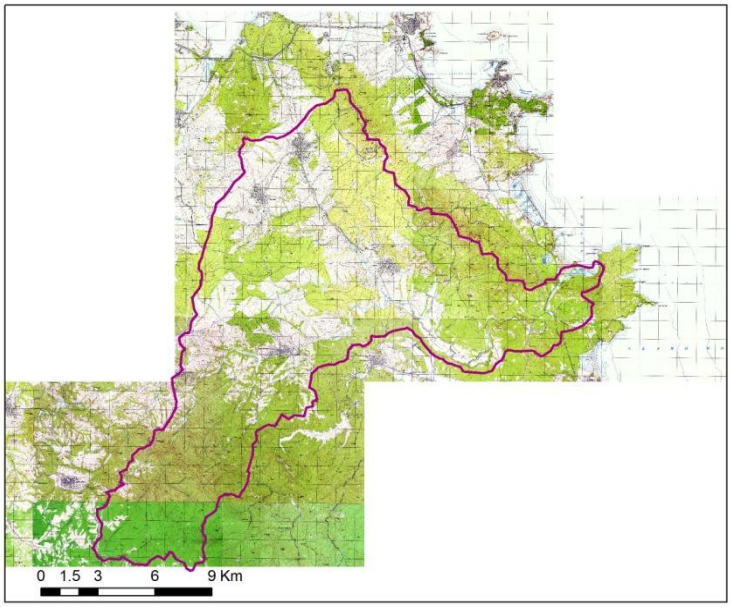

Figure 3. Topographic maps in the area of Ropotamo river basin

The hydrological objects were digitized from the topographic maps using the Heads-up_digitizing method and the results were in form of vector GIS layers of rivers, water bodies and channels. The floodplains of Veleka and Ropotamo rivers were delineated using two steps algorithm. At the first step 50 m DEM have been used to derive slopes in the basins. Then, the slope layer was reclassified and flat surfaces were extracted. The areas around the rivers were identified by intersection with rivers GIS layer. Thus the potential floodplains were identified. At the second stage the results from the previous procedure were compared with the topographic maps and the contours of the floodplain were checked and corrected. The results from this procedure are vector polygon GIS layers that contain the floodplain area of Ropotamo and Veleka rivers.

Land cover data were extracted from CORINE database which is available for three time series – 1990, 2000 and 2006. The latest version of CORINE 2006 was used in the present study. The aim of the CORINE program of the European Union is to compile information on the state of the environment with regard to certain topics which have priority for all member states of the community (EEA 1994). CORINE includes 44 land cover classes altogether grouped in a three-level nomenclature into 1) artificial surfaces, 2) agricultural areas, 3) forests and seminatural areas, 4) wetlands and 5) water bodies. These classes represent all land cover types in Europe and they are clearly defined in the nomenclature provided by the project. The CORINE data for Veleka and Ropotamo river basins were extracted from the main database and transformed into separate vector polygon layers. Then, an overlay analysis was performed between the floodplain and CORINE layers in order to identify the land cover classes within the floodplain. The results of this procedure are vector polygon layers that contain all land cover classes within the floodplains of Veleka and Ropotamo rivers.

The floodplains delineated from topographic maps represent the area exposed to floods. They are used as a basis to assess the flood vulnerability in the studied areas. Each land cover class was assessed in order to define its vulnerability against floods. Then, they were categorized using three-level scale including the following classes: 1) High vulnerability; 2) Middle vulnerability; 3) Low vulnerability; 4) No vulnerability. Land cover classes with high vulnerability are from the first level of the CORINE classification especially class 112 Discontinues urban fabric. The potential losses in such areas include all kinds of damages that could be caused by flood e.g. destroyed buildings, cut transport network and communication, casualties etc. Middle vulnerability is assigned to arable lands which may also badly suffer from flood that can destroy plants, remove or inundate soil etc. Low vulnerability is assigned to other agriculture areas including pastures, vineyards, agriculture with natural vegetation etc. Very low or no vulnerability was assigned to natural land cover classes such as forest, natural grasslands, water bodies etc.

III. Flood vulnerability areas in Veleka river basin

Veleka river has its sources in Turkish territory of Strandzha Mountain. It is 147 km long and its basin covers 99500 ha, while in the Bulgarian part of the basin is 79192 ha. The river valley in it upper part has typical mountainous character with narrow bottom and limited disconnected floodplain. The river banks are covered predominantly by forests and there are no urban or agricultural areas, therefore there is no flood risk and this part was not included in the analysis.

The floodplain of Veleka river has an area of 2286.9 ha. The greatest part of it is occupied by agricultural lands which comprise about 77% of the whole area. Most of them are represented by the mixed class 243 Land principally occupied by agriculture with significant areas of natural vegetation (table 1). Arable lands occupy 514 ha (22.5%) which are located mainly in the lower part of the river valley around the largest floodplain areas near Kosti, Brodilovo and Sinemorets. Small patches of Complex cultivated patterns (59 ha), Vineyards (16.5 ha) and Pastures (6.1 ha) are also presented in the Veleka floodplain. The natural and seminatural land cover classes are presented by Broad-leaved forests with 392.3 ha (17.2%), Transitional woodland-shrub with 85.1 ha and small patches of Mixed forests with 11.9 ha (0.5%). The artificial surfaces cover limited areas but they are the most vulnerable to floods therefore should be studied more precisely. Discontinuous urban fabric class covers 18 ha (0.8%),

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which are located in two villages. Brodilovo has 9.6 ha located within the floodplain which is about 15% of the whole village while Kosti has 8.3 ha which is about 10% of it area. There is also Sport and leisure facility class located in the mouth of the river with 9 ha, which is used mainly for summer tourism. There are also limited urban lands around Kachul locality which are represented by some small buildings and yards used mainly for recreation.

Table 1. Distribution of CORINE Land Cover classes within Veleka floodplain

CORINE class		Area (ha)	%
243	Agriculture with natural vegetation	1174.2	51.3%
211	Non-irrigated arable land	514.6	22.5%
311	Broad-leaved forest	392.3	17.2%
324	Transitional woodland-shrub	85.1	3.7%
242	Complex cultivation patterns	59.3	2.6%
112	Discontinuous urban fabric	18.0	0.8%
221	Vineyards	16.5	0.7%
313	Mixed forest	11.9	0.5%
142	Sport and leisure facilities	9.0	0.4%
231	Pastures	6.1	0.3%

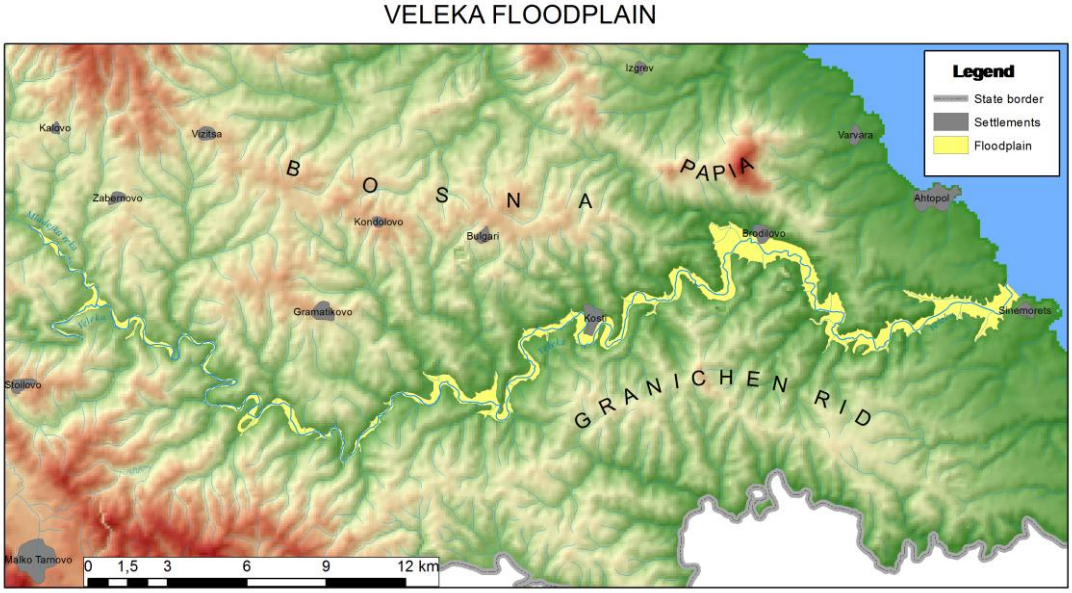

Figure 4. Map of Veleka floodplain

The flood vulnerability analysis of Veleka river shows that the areas of high vulnerability cover 1.2% of the floodplain area (table 2). They are located in the lower part of the river valley where floodplain is wider and most suitable for agriculture. They represent the above mentioned villages and recreation areas. The areas of middle vulnerability cover about quarter of the floodplain (25.1%) which is localized in four areas. The first one is situated in the floodplain downstream of Brodilovo and covers about 415 ha (fig. 5). This is the largest agricultural area comprising almost 80% of all arable lands. The second one is around the village of Kosti and covers 110 ha. They are presented by both arable land and complex cultivation pattern classes. The third one is located on the South of Gramatikovo village and covers about 23 ha of arable land. The fourth one is located on the North of Stoilovo village and covers about 21 ha of arable land. The zone of low vulnerability covers almost half of the floodplain area. It is presented mainly by small agricultural lands surrounded by natural vegetation and some small patches of pastures and vineyards which are located all over the floodplain. The areas of no vulnerability cover 21.4 ha and are represented mainly by broad-leaved forests. They are located mainly in the upper part of the valley and around the mouth of the river where large patches of riparian vegetation are present.

Table 2. Distribution of Veleka floodplain land cover according to their flood vulnerability

Vulnerability	Area (ha)	%
High	27.0	1.2%
Middle	573.9	25.1%
Low	1196.7	52.3%
No	489.3	21.4%

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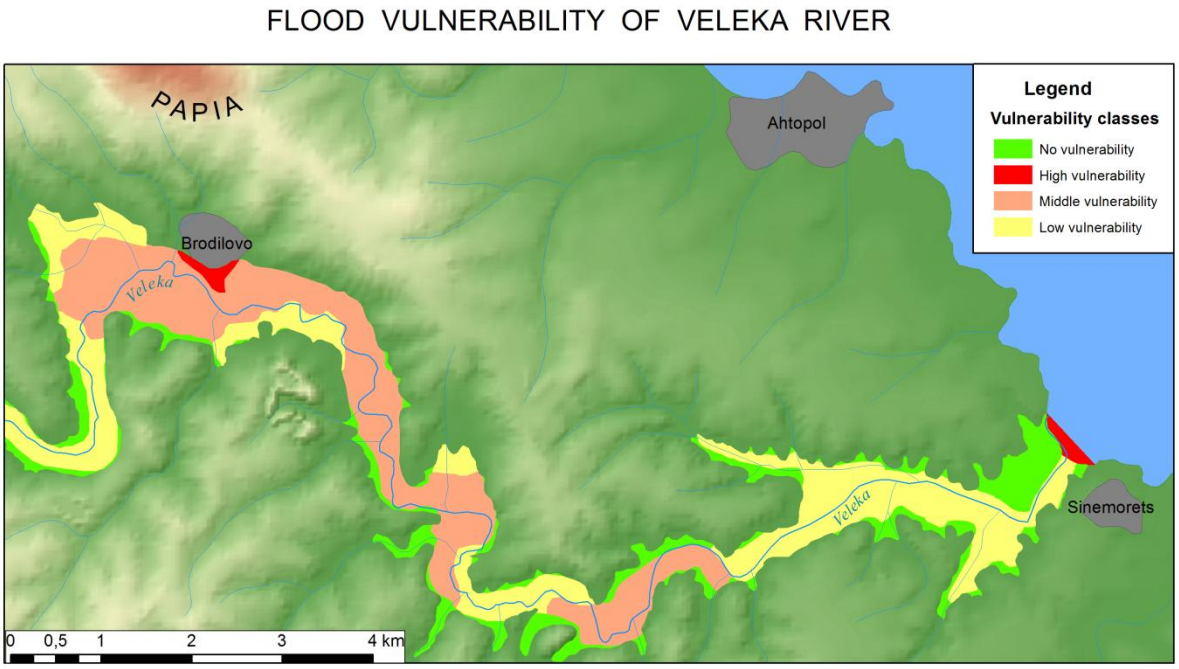

Figure 5. Flood vulnerability of the lower part of Veleka river valley

IV. Flood vulnerability areas in Ropotamo river basin

Ropotamo river has its sources in the Northeastern slopes of Bosna ridge. It flows through narrow and deep valley to Northeast until Novo Panicharevo village. After this village the river turns to the East through wide plain valley and flows into Black Sea forming large marsh and liman. It is 48.5 km long and its basin comprises 24645 ha. Its main tributary is Rosenska river, which flows from Medni Rid ridge into South until its infuse to Ropotamo river. The river valley in its upper part about 10 km from the sources has narrow bottom and limited disconnected floodplain. The river banks are covered predominantly by forests and there are no urban or agricultural areas, therefore there is no flood risk and this part was not included in the analysis.

The floodplain of Ropotamo river has an area of 1466.7 ha. The greatest part of it is occupied by agricultural lands which comprise about 67% of the whole area. Most of them are represented by class 243 Non irrigated arable lands (table 2). They are located mainly in the lower part of the river valley to the east of Yasna Polyana village. Land principally occupied by agriculture with significant areas of natural vegetation have 436 ha (29.8%). Small patches of Complex cultivated patterns (2.4 ha) and Pastures (13.8 ha) are also present in the Ropotamo floodplain.

The artificial surfaces cover limited areas but they are the most vulnerable to floods therefore should be studied more precisely. Discontinuous urban fabric class covers 19.2 ha (1.3%), which are located in two villages. Novo Panicharevo has 18.1 ha located within the floodplain which is about 25% of the whole village while Rosen has 1.1 ha. The natural and seminatural land cover classes are presented by Broad-leaved forests with 221.7 ha (15.1%), Transitional woodland-shrub with 80.9 ha and small patches of Mixed forests with 1.3 ha (0.5%). There are also Beaches and dunes that cover 4.2 ha, Water bodies with 33.3 ha and Water courses with 85 ha which are located in the mouth of Ropotamo river.

Table 3. Distribution of CORINE Land Cover classes within Ropotamo floodplain

CORINE class		Area (ha)	%
211	Non-irrigated arable land	532.2	36.3%
243	Agriculture with natural vegetation	436.5	29.8%
311	Broad-leaved forest	221.7	15.1%
511	Water courses	85.0	5.8%
324	Transitional woodland-shrub	80.9	5.5%
411	Inland marshes	36.2	2.5%
512	Water bodies	33.3	2.3%
112	Discontinuous urban fabric	19.2	1.3%
231	Pastures	13.8	0.9%
331	Beaches, dunes, sands	4.2	0.3%
242	Complex cultivation patterns	2.4	0.2%
313	Mixed forest	1.3	0.1%

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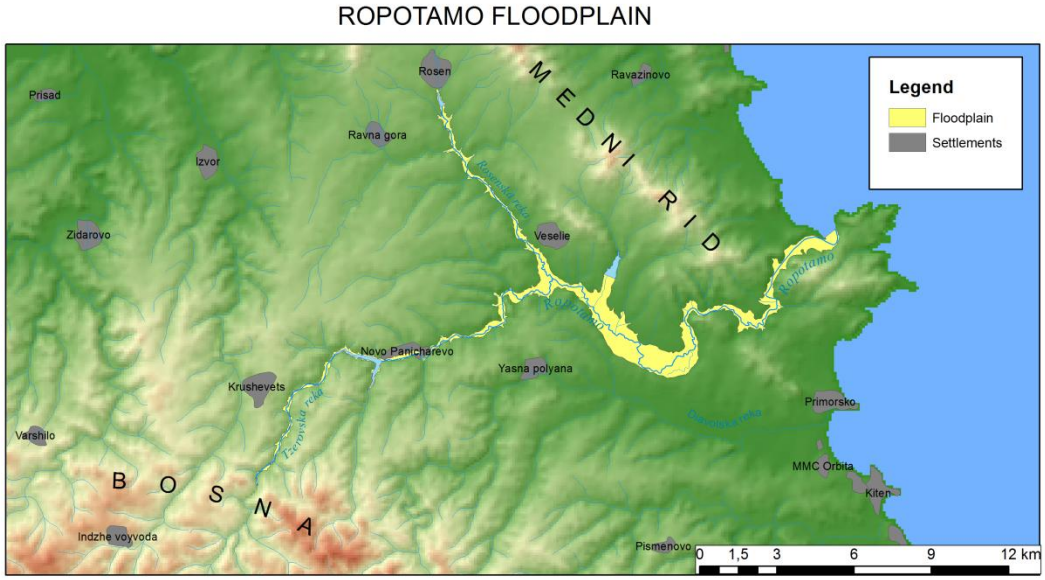

Figure 6. Map of Ropotamo floodplain

The flood vulnerability analysis in Ropotamo river shows that the zones of high vulnerability cover 1.3% of the floodplain area (table 4). They are located mainly in the middle part of the river valley where floodplain is wider and most suitable for agriculture. Most of them are located in the village of Novo Panicharevo which can be identified as the most important object of flood management in Ropotamo basin.

Table 4. Distribution of Ropotamo floodplain land cover according to the their flood vulnerability

Vulnerability	Area (ha)	%
High	19.2	1.3%
Midle	532.2	36.3%
Low	452.7	30.9%
No	462.6	31.5%

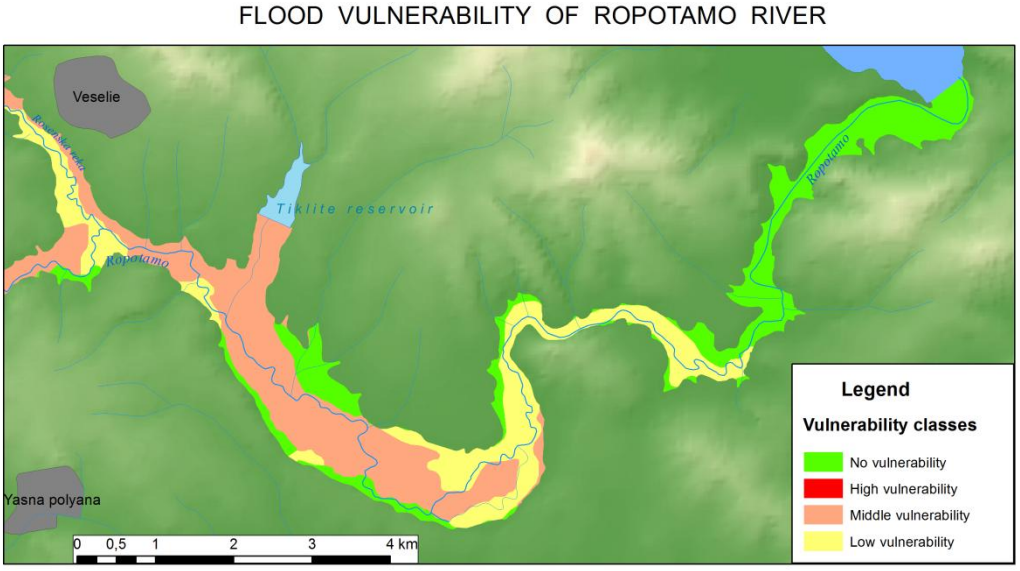

Figure 7 Flood vulnerability of the lower part of Ropotamo river valley

The zone of middle vulnerability covers about one third of the floodplain (25.1%) which are localized in three areas. The first one is situated in the floodplain downstream of the infuse of Rosenska tributary and covers of about 414 ha (fig. 7). This is the largest agricultural area comprising almost 80% of all arable lands. The second one is upstream of Rosenska river and covers 38 ha. The third one is located on the East of Novo Panicharevo village and covers about 78 ha of arable land. The zone of low vulnerability covers almost one third of the floodplain area. It is presented mainly by small agricultural lands surrounded by natural vegetation and some small patches of pastures and vineyards which are located all over the floodplain. The areas of no

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vulnerability cover 462.6 ha and represented mainly by broad-leaved forests. They are located mainly in the upper part of the valley and around the mouth of the river where large area of riparian vegetation is located.

Conclusions

Methods applied in the research provide opportunities for delineation of floodplains and areas of flood vulnerability in the systems of the rivers Ropotamo and Veleka. Emphasis is placed on the lower part of rivers where the flood plain is wider. Particularly important are certain areas with high and medium flood vulnerability. These are the regions around the mouth and south of Brodilovo village for Veleka river. The regions with medium flood vulnerability are situated east of Novo Panicharevo village, valley of influx Rosenska river and south of the dam Tiklite for Ropotamo river. Particular attention should be paid to cases where these areas are close to settlements, agricultural lands and important infrastructure.

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