FACTA UNIVERSITATIS
Series: **Working and Living Environmental Protection** Vol. 13 , N° 1, 2016, pp. 53 - 62

FLOODS PREVENTION IN THE SOUTHERN REGION OF SERBIA USING GIS TECHNOLOGY

UDC 627.51:004.91(497.11)

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Abstract. *Flood management represents the strategy to reduce flood damages, both in terms of property and people's lives. There is a large number of intelligent integrated systems for flood prediction and prevention. GIS is powerful information system with an ability to collect, analyze, and visualize information based on location. It provides real-time planning and mapping in order to prevent and predict flood risk. The paper presents an analysis of flood affected areas in Leskovac, in the spring of 2014. The analyzed data were imported into GIS database, and critical areas were mapped. The obtained results can be used for the analysis of conducted activities, assessment of incurred damage and improvement of emergency response services.*

Key words: *GIS, flood maps, flood mitigation, risk assessment, decision making.*

1. INTRODUCTION

The resulting impact of disasters on society depends on the affected country's economic strength prior to the disaster. The larger the disaster and the smaller the economy, the more significant is the impact. Irrespective of size, there is a need for coordinated efforts in efficient and effective countermeasure selection based on the evaluation of pre- and post-event strategies [4].

Floods are major contributors to personal injury and to property damage, and can strike with little warning. Problems related to flooding have greatly increased over recent decades because of population growth and the subsequent development of extensive infrastructures in close proximity to rivers. Increased frequency of extreme rainfall events, characteristics of a changing climate, can also potentially contribute to this problem. An effective real-time flood modelling and prediction system that generates simple maps of

Received September 2, 2015 / Accepted May 27, 2016
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potential flood water distribution could help to mitigate the worst effects of flood disasters through the rapid dissemination of information regarding threatened areas [1].

Higher levels of rainfall in the wet season often lead to extensive flooding in the low-lying areas of the country. In recent years, Serbia is faced with a major problem of flood control. There have been many severe flooding events which have led to significant damage to livestock, agricultural produce, homes and businesses [3].

The problem stems from inappropriate use of lands that are vulnerable to erosion, and inadequate watershed and sewer maintenance equipment. Lack of maintenance of the above mentioned elements made soil increasingly exposed and therefore more susceptible to being washed away during periods of heavy rainfall and subsequent runoff [7]. This ultimately leads to flooding. In addition, the lack of vegetative cover leads to much shorter lag times between rainfall and the water reaching the waterways. It makes already reduced channels to overflow which causes massive floods [5].

Inappropriate land use is further aggravated by several problems including the absence of relevant information on the level of vulnerability of different areas to damage due to these usages, the lack of political will to address the problems and the lack of adequate resources for the relevant authorities to enforce the laws of the country [2].

2. OBJECTIVE

This paper utilizes geographic information systems to map the extent of the flooding, and to estimate the extent of the affected area during the floods in the Leskovac surroundings in the period from March to April 2014. In addition, this paper can assisst in development of a watershed management plan and a flood control plan for the region.

The paper provides a detailed description of the methodology used in the GIS component of the study to generate estimates of soil erosion and to identify flooded areas needing conservation and the type of conservation appropriate for these areas.

The goal of flood forecasting is to provide a reliable prevention mechanism to eliminate disasters and reduce the negative consequences of a hazard [3].

3. STUDY AREA

Leskovac is located in south-east part of Serbia in Jablanica district and it comprises a significant portion of the arable lands available in the region (see Fig. 1).

In the north it borders with Niš District with the municipalities Doljevac and Gadžin Han, in the east with the municipalities of Vlasotince and Crna Trava, while in the west it borders with the municipalities of Lebane and Bojnik and in the south with Pčinja District or municipality of Vladičin Han and to a lesser extent with the municipality of Kosovska Kamenica.

The total area of the city territory is 1025 km^2, of which urban settlement Leskovac covers about 25 km^2, three larger settlements Grdelica, Vučje and Predejane about 20 km^2, and the other 140 inhabited areas approximately 980 km^2. The average length of the territory of the city in north-south direction is about 40 km and width in east-west is approximately 32 km. Central and western part of the territory makes Leskovac field which is in the east bordered with Babička gora (1059 m), from the southeast Ostrozuba (1546 m) and Čemernik (1638 m), and to the south with Kukavica (1442 m). In the south

of the territory it stretches through Grdelica canyon, with a length of 15 km and further to the municipality of Vladičin Han.

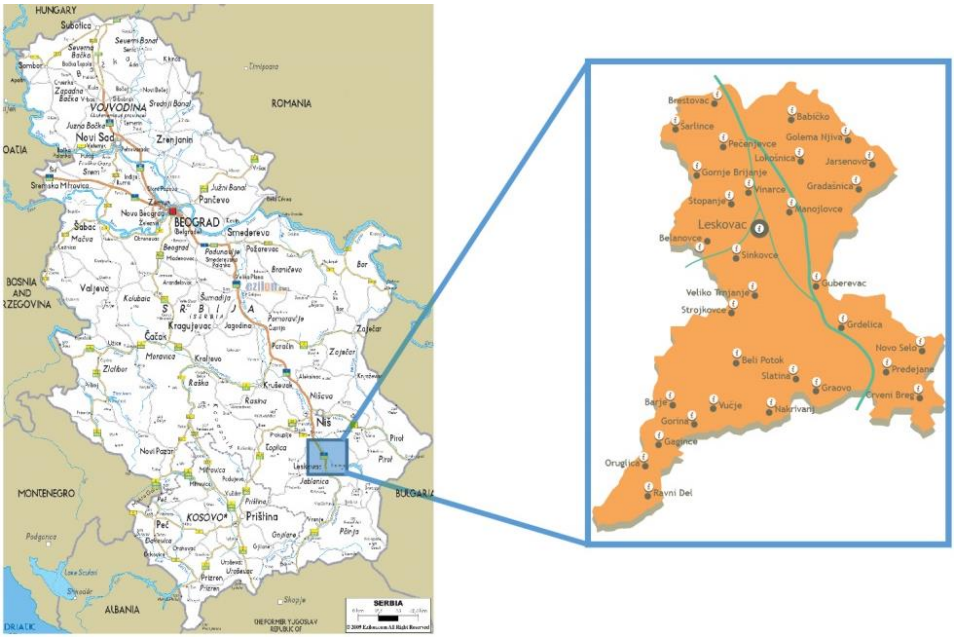

Fig. 1 Location of study area

Major land use in this region includes commercial activities and active agricultural activities. As such activities in the region increase, the natural protective cover of the land is reduced causing more flooding and erosion. This has led to extensive damage and loss of valuable raw materials and resources.

The problem is therefore quite significant in this area. To avoid future loss, it is necessary to identify the causes of the problem and attempt to address them urgently [6].

4. METHOD

With global climate change and the expected increase in extreme climatic events, the possibility of severe dry spells and heavy rainstorms is also likely to further worsen the situation, especially in the most vulnerable areas. There is therefore an urgent need to introduce mitigation measures to ensure that these areas are protected so that erosion and flooding is minimized. The first step in achieving this is to identify the nature and extent of vulnerability of the areas under consideration. Next, determine the most appropriate mitigation measures that should be used to address the problem. Finally, these measures must be implemented and maintained [1].

One of the best possible approaches for identifying vulnerable areas is to use spatial analysis tools available in geographic information systems (GIS). GIS analysis is developed to examine spatial and temporal patterns and to find relationships between various geographical factors.

Software which is used for identifying vulnerable areas during floods and mapping flooded areas in the study is *Global Mapper v16*. Global Mapper is an affordable and easy-to-use GIS application that offers access to an unparalleled variety of spatial datasets and provides just the right level of functionality to satisfy both experienced GIS professionals and beginning users.

Since flooding is a spatial phenomenon and is a consequence of a number of factors (including soil type, vegetation cover and type, rainfall intensity, rainfall frequency, etc.) the GIS will allow the user to handle, manage and analyze the spatial data sets to determine which factors have what effect and to foresee the resulting consequences. In addition, GIS has the ability to carry out temporal analysis, which is essential for flood prediction. By storing data on previous floods, soil types, river channel size, etc., it is possible to create a model of peak flow, discharge and runoff. In terms of the impacts of land use/cover on flooding, GIS can be used to detect changes as well as to identify trends, both visually and statistically, resulting from land use changes and flooded areas [8].

5. Results and Discussion

Hydrographic network in municipality of Leskovac is well developed (see Fig. 2). In most natural waterways, the dimensions of the river channels and their capacities are not in accordance with flow rates of high water, which is the principal cause of the phenomenon of flooding. Such is the case with all of torrential streams in the region of Leskovac.

Fig. 2 Hydrographic network in the territory of Leskovac

Besides the South Morava, all other streams in this area fall into the category of torrential flows, and by categorization they belong to the waters of II class (see Table 1).

Table 1 The largest rivers that flow through the territory of Leskovac municipality

No.	Name of the major river	Tributary of river	The river length through Leskovac (km)	Built length dikes (km)
1	The South Morava	The Great Morava	55	8 km
2	The Vlasina	The South Morava	2,2	-
3	The Veternica	The South Morava	74	33 km
4	The Jablanica	The South Morava	27	12 km
5	The Pusta river	The South Morava	-	-

In recent period of high water, spills from the riverbed of the South Morava, the Veternica, the Jablanica and their tributaries were common occurrence, which caused great damage to the population, agriculture, municipal economy and industrial buildings.

The upper portion of catchment areas of most torrential streams belong to mountainous areas, with relatively large declines of catchment areas and riverbeds. On the other hand, the lower flows are typical for lowland zones (river valleys).

The length and width of the river valleys are variable, depending on the geomorphological and geological conditions. Within the morphological factors of watercourses, special importance has longitudinal fall. The longitudinal fall of the riverbed is determinant factor of the hydraulic flow regime.

In most natural watercourses, the dimensions of the riverbeds and their throughputs are not in accordance with discharges of high water, which is the basic cause of the flooding phenomenon.

In most cases, the dimensions of the basin are minimal - width at the level of the river banks vary from 2 - 4 m and a maximum depth (the distance between the bank and the thalweg) is 1 - 2 m.

Important torrential streams, creeks and canals which threaten and endanger the outpouring of Leskovac are (see Fig. 3):

1. The Šaranica Channel-Čekmin stream
2. The Šaranica River
3. The Babička River
4. The Jelašnica River
5. The Rudarski Channel
6. The Rajnopoljska River
7. The Tulovska River
8. The Sušica River
9. Grčki stream
10. The Šainovac Channel
11. The Kozaračka River
12. The Nakrivanjka River
13. The Slatinska River

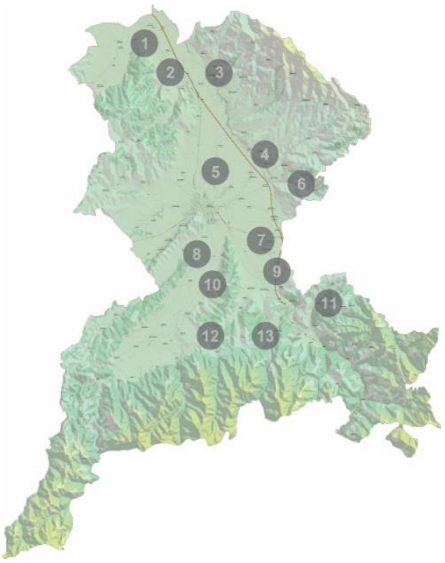

Fig. 3 Map of flooded zones in the territory of Leskovac

1. The Šaranica Channel - Čekmin stream

The Channel of Šaranica-Čekmin stream runs through the village Čekmin and through Lipovica and Brestovac and flows into the South Morava on the territory of Doljevac. In this part of its course, there is a Čekmin stream.

Flooded zone covers the section of the flow channel Šaranica in Čekmin, from settlement Čekmin to Lipovica districts on left and right riverbank. Surface of flooded zone comprises approximately 20 ha of agricultural land and along the section of the channel in the Lipovica, from Čekmin districts through Lipovica on the right side of the channel. Surface of flooded zone is about 20 ha of agricultural land in the zone west of the railway line (agricultural land and several residential buildings). Channels from Lipovica towards Brestovac near railway lines are also affected by floods. (see Fig. 4).

2. The Šaranica River

The Šaranica river flows through several urban areas Dušanovo, Podrimce, Kaštavar, Pečenjevce and empties into the river Jablanica.

Flooded zone covers the lower course of the Šaranica river from the village Pečenjevce to flows in the river Jablanica. The length of river flow is about 3000 m. It is threatened from the left and right sides of the wider riverbank, in the territory of Pečenjevce and Čekmin. Surface of flooded zone is about 150 ha (agricultural land, a few houses and an access asphalt road toward to the village Čekmin) (see Fig. 4).

3. The Babička River

The Babička river is of typical torrential character, and in its course it collects atmospheric water from the slopes of Babička gora.

Flooded zone covers the lower course of the Babička river in the area around 1000 m upstream flows into the South Morava on the territory of Donja Lakošnica. Surface of flooded zone is about 20 hectares (agricultural land) (see Fig. 4).

4. The Jelašnica River

The Jelašnica river is the right tributary of the South Morava river which flows in Jelašnica village. Its watershed includes parts of Jarsenovo, Gornje and Donje Kupinovce, Velika Biljanica and Jelašnica.

Flooded zone covers riverbank strip in the lower course of the river, near the confluence with the South Morava on the territory Jelašnica. Surface of flooded zone covers about 6 ha of agricultural land (see Fig. 4).

5. The Rudarski Channel

The Rudarski channel drains water from the hillside of Kukavica and Rudarsko brdo from the village Šainovac to the confluence of the river Veternica in Bogojevce.

Flooded zone covers a wider area of riverbank land along the river channels in Rudare, Leskovac, Mrštane, Bratmilovce and Bobište (especially compromised right-hand side of the riverbank area through these settlements) and Navalin. The total surface of flooded zone is about 400 ha (agricultural land, several residential buildings and roads) (see Fig. 4).

6. The Rajnopoljska River

The Rajnopoljska river has typical torrential character which in its course collects atmospheric water from the slopes of Babička gora. The total length of the river is about 8 km. It flows through Rajno Polje and Manojlovce where it joins the South Morava.

Flooded zone covers part of the Rajnopoljska river flow in the length of 200 m downstream from the bridge in the village Rajno Polje and consolidating partition. Surface

of flooded zone is about 1,5 ha (agricultural land, housing and economic facilities, access road for households and agricultural plots) (see Fig. 4).

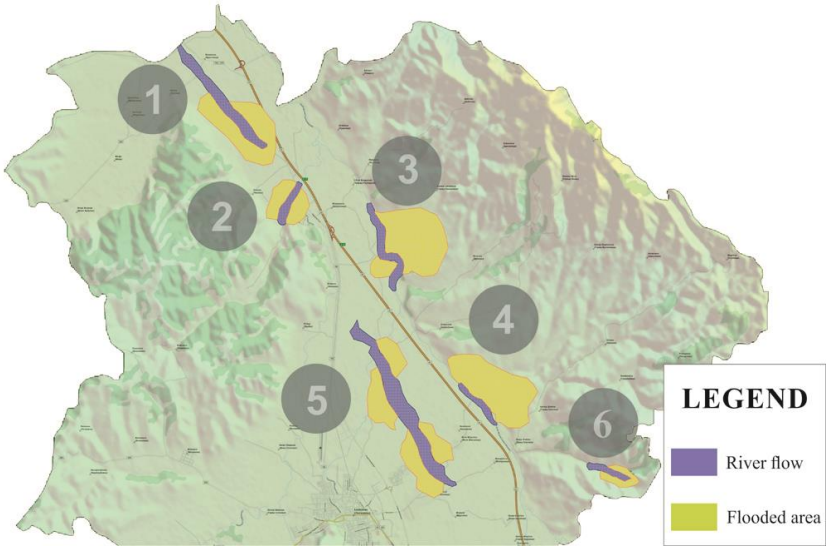

Fig. 4 River flow and flooded area in north part of Leskovac

7. The Tulovska River

The Tulovska river is regulated in its upper course only (through the village of Tulovo), while its downstream to the inflow in South Morava is not.

Flooded zone includes parts of the river from the highway to the old road Leskovac - Grdelica in surrounding of Velika Grabovnica. Surface of flooded zone is about 5 ha narrow strip of mainly agricultural land.

Then, the river stretches 7,5 km downstream from the road Leskovac - Grdelica to the villages Badince, which includes the territory Guberevac, Gornji and Donji Bunibrod, Badince, Žižavica. Surface of flooded zone is about 600 ha (agricultural land, several residential buildings and roads) (see Fig. 5).

8. The Sušica River

The Sušica river is typical torrential river, which in its course also collects atmospheric water from the catchment areas of Igrište, Slavujevce, Drvodelja, Kukolovce, Gornja and Donja Jajna. The river carries a large amount of embankment and at the descent of the lowland part of the territory of Gornja and Donja Jajna this mound gets deposited which causes floods in the populated area (households) and greatly damages agricultural land.

Flooded zone covers the riverbanks in the lower course of the river, about 1000 m in length, upstream and downstream from the bridge in Donja Jajna and 1000 m upstream the tributaries of the river channel in the Donja Jajna to the inflow to the river Veternica. Surface of flooded zone covers about 12 ha of agricultural land and more households. Then flooded zone includes riverbank strip for the middle of the river, shorter sections (Drvodelja, Kukolovce, Šišince). The total surface of flooded zone is about 9 ha of agricultural land (see Fig. 5).

9. Grčki stream

In the lowland part of the flow Grčki stream, there is a characteristic section from the old highway through passage near the railway line, from the passage of the old road to Grdelica to the flows in the river South Morava. This section, in Velika Grabovnica and Dobrotin, has a high risk of riverbed leakage as well as risk of flooding about 80 ha of land, a few households and their housing and economic facilities.

Flooded zone covers stretch of the riverbed in part from omission at the railway Belgrade - Skopje, culverts on the old Grdelica road to the omission the new highway E-75. The total length of the troubled channel of the river is 800 m in Velika Grabovnica and Dobrotin. To the confluence with the South Morava riverbed meanders, which forms several sharp turns. In the shallow part of the riverbed there has been a discharge of water and flooding surrounding areas. Right bank of the river bed has been particularly endangered (see Fig. 5).

10. The Šainovac Channel

The Šainovac channel takes water from the slopes of Kukavica through the village Šainovac, intersect the road Leskovac – Vučje, thus draining water in the riverbed Veternica. It also collects water coming from the direction of Strojkovce. Through the village Veliko Trnjane, a number of households might be affected due to the backfilling of the old riverbed channel whose waters flow into the new riverbed.

Flooded zone covers riverbank land along the riverbed channel Šainovac and Veliko Trnjane. Surface of flooded zone is about 10 ha (agricultural land, building substations, several residential buildings and roads) (see Fig. 5).

11. The Kozaračka River

The length of the Kozaračka river channel is approximately 4,5 km, from the village Tupalovce to the confluence of with the South Morava, while the length of the flow through the village Grdelica is about 0,8 km, and through Grdelica town about 2 km. On the way from the village Tupalovce to the confluence of with the South Morava riverbed meanders, forming a series of sharp bends, which in the shallow part of the riverbed caused frequent overflowing and flooding the surrounding area. An additional problem is the lack of flow capacity of the bridge in Grdelica, as well as the reduced flow profile in place of the concrete sleeper (water intake "Textile industry Grdelica"), located near the confluence with the South Morava.

Flooded zone included the lower course of the Kozaračka river and the territories of Tupalovce and Grdelica. It is threatened by the left bank of river 4.5 km in length with surface of flooded zone about 20 ha (agricultural land and several buildings), as well as the left bank of the riverbed downstream from the bridge in village Grdelica in total length of 300 m (see Fig. 5).

12. The Nakrivanjka River

The Nakrivanjka flows through populated areas of Čukljenik, Nakrivanj and Strojkovce and flows into the river Veternica.

Flooded zone covers the right side of riverbank of the middle river course at the lenght about 50 m up to cascade in the village Nakrivanj. Surface of flooded zone is about 2 ha of agricultural land (see Fig. 5).

13. The Slatinska River

The Slatinska river is tributary to the South Morava river and is one of torrential flows. Its riverbed is not regulated, especially at the crossing with the railway tracks at Mala Kopašnica during of high water, there is a possibility of flooding of agricultural land, residential buildings and roads (rail and highway).

Flooded zone covers the lower course of the Slatinska river and the territory of Mala Kopašnica from flows into the South Morava to the road that leads to the Velika Kopašnica with surface of flooded zone about 10 hectares (agricultural land, several residential buildings and roads) (see Fig. 5).

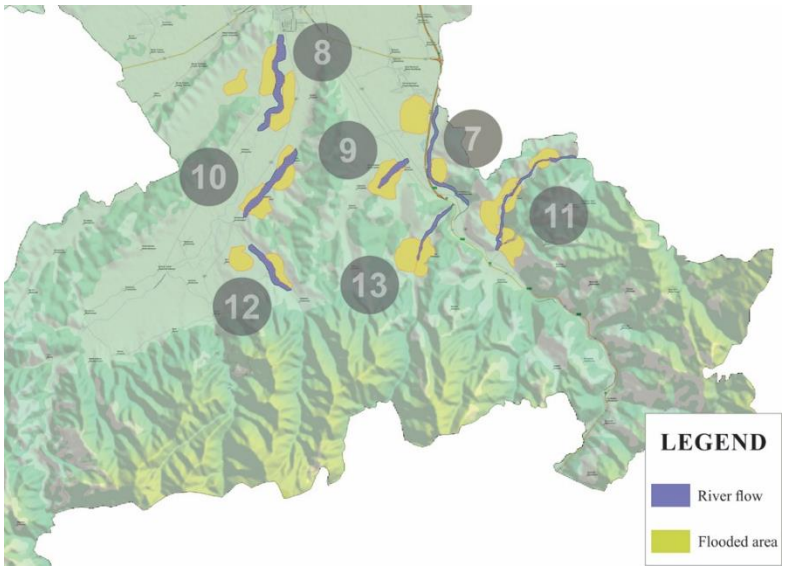

Fig. 5 River flows and flooded area in the south part of Leskovac

6. CONCLUSION

Flooding in the territory of Leskovac and its surrounding is caused by many factors, such as:

- Construction of residential and commercial buildings in the immediate vicinity of the riverbed;
- Construction of bridges over watercourses, with minimum flow capacity (often with columns in the riverbed);
- Construction of culverts at water courses and roads with insufficient capacity for large water;
- Installation of water pipes, electrical cables and other devices into the riverbeds.

For this study, GIS was successfully used to determine the scope of the problem. GIS application have facilitated identification of areas that needed conservation, the extent of soil loss, and the locations prone to flooding at different watershed sections. The analysis provided by GIS made it possible to expedite the development of mitigation strategies that

are most likely to provide necessary changes in the river basin. Flooding in the municipality of Leskovac may be mitigated if the recommendations provided are implemented in its entirety since the proposed strategies comprise many interdependent components.

The characteristics of these watercourses require constant flood defenses, torrential management and finding ways to use water for irrigation in agriculture.

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PREVENCIJA POPLAVA U JUŽNOM DELU SRBIJE KORIŠĆENJEM GIS TEHNOLOGIJE

Upravljanje poplavama predstavlja strategiju za smanjenje šteta od poplava, u pogledu gubitka imovine i ljudskih života. Postoji veliki broj inteligentnih integrisanih sistema za predviđa-nje i prevenciju poplava. GIS je moćan informacioni sistem za prikupljanje, analiziranje i vizuelni prikaz unetih podataka za određenu lokaciju. On omogućava mapiranje i planiranje u realnom vremenu u cilju prevencije i predviđanja rizika od poplava. U radu je izvršena analiza ugroženih područja poplavama u Leskovcu u proleće 2014. god. Analizirani podaci su ubačeni u GIS bazu i dobijene su mape kritičnih područja. Dobijeni rezultati se mogu koristiti za analizu sprovedenih akcija, procenu nastale štete i unapređenje službi zaduženih za reagovanje u ovakvim vanrednim situacijama.

Ključne reči: *GIS, mape poplava, ublažavanje poplava, procena rizika, donošenje odluka.*