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Reducing Negative Flood Impacts in "Apatinski Rit" – Part of Special Nature Reserve "Gornje Pondunavlje" (Vojvodina, Serbia) Using GIS

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Abstract

During the history, the Danube valley was often devastated the northwest part of Bačka. However, the Danube river created also one of the most rich full wetland complexes in Serbia, Special Nature Reserve „Gornje Pondunavlje" (Upper Danube). Hunting-ground „Apatinski rit" is located within borders of SNR „Gornje Podunavlje". The people from this region constructed river embankments and other fortification objects to protect themselves from the floods, but still there are spacious areas that are not protected. In those areas, many floral and animal species (including game) face floods every year. High water level of the Danube River is the most dominant factor of change of habitat conditions in hunting ground „Apatinski rit". About 60% of the territory of „Apatinski rit" are in the zone of floods. During the extreme high water level, game animals suffer serious losses. The purpose of this paper is to present possible application of geographic information system (GIS) in flood prediction in hunting-ground „Apatinski rit" in order to reduce negative flood impacts. GIS technologies are used in many aspects of flood identification, prediction, and hazard mitigation. In this paper a 3D model is introduced to realize the flooded areas. The flooded areas are estimated based on the Danube water levels and topography of the surrounding terrain. The estimated flooded areas based on several water levels are shown in the paper. During the flood some parts of hunting ground are under water, and some higher courts remain dry. By using 3D model, all the isolated „islands" with trapped game can be located during the floods, which is crucial for rescue intervention priorities and decision making during the flood.

Key words: GIS, floods, game, Apatinski rit, Gornje Podunavlje

Introduction

Hunting-ground „Apatiski rit" (6.579 ha) is located in the northwest part of Vojvodina, between 45° 32' and 45° 43' North and 16° 33' and 16° 46' East, and it is an integral part of Special Nature Reserve „Gornje Podunavlje" (19.648 ha). Hunting-ground „Apatinski rit" spreads along Danube's river bank, from 1.400 river kilometer in the North, to 1.367 river kilometer in the South, all the way to Bogojevo bridge (Figure 1). Hunting-ground „Apatinski rit' is located 160 km from Belgrade airport and 100 km from Novi Sad.

This is a lowland type of hunting-ground with height terrains between 82 and 89 meters above sea level. The Danube created alluvial silt that makes the geological substrate of this area. The climate in this area is moderate continental, with warm summers and cold winters. The average annual air temperature is 11,1°C. The warmest month is July, with average monthly temperature of 21,7°C, and the coldest month is January with average monthly temperature of −0,6°C. The average temperature of a vegetation period is about 17,6°C. The average annual rainfall is between 600 and 700 mm. „Apatinski rit" includes numerous channels, meanders, still water and water, marsh, meadow and forest ecosystems.

Aquatic and swamp vegetation, meadow and forest plant communities are main floral elements of hunting-ground. The forests cover 3.583 ha (54,46%); pastures and meadows 956 ha (14,53%); arable land and fields 137 ha (2,08%); water, reed

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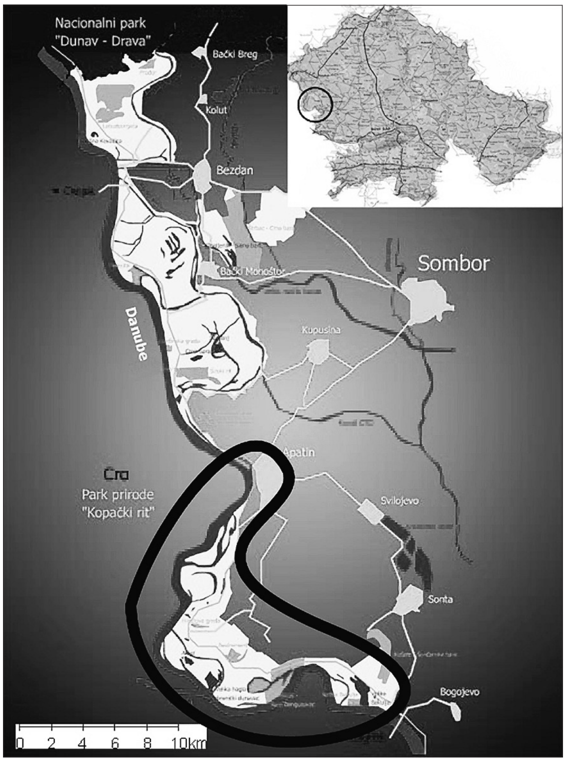

Figure 1 The location of hunting-ground „Apatinski rit" in Upper Danube region
(Source: www.biblioso.org.rs)

and ponds 1,005 ha (15,28%); and other terrains cover 898 ha (13,65%) (www.vojvodinasume.rs).

Predominant large game animals are red deer and wild boar, whereas roe-game is an accompanying species. Marsh's habitat represents an ideal reserve for waterfowl. During winter, hunting-ground is inhabited by small game animals, such as wild ducks and wild geese. The main cultivated species are red deer (472), roe buck (24) and wild boar (191) (Internal document of J.P. „Vojvodinašume", 2005).

Public company „Vojvodinašume" manages with this hunting-ground. The main role of the hunting ground is growing a big, trophy game for hunting tourism. Approximately, 85% of the total hunting-ground (5.589 ha) is productive for hunting deer and wild boar (Hunting base of hunting ground „Apatinski rit", 1996).

Ministry of Agriculture, Forestry and Water Management proclaimed „Apatinski rit" as a hunting ground in 1995 (Delić, Dragin 2006). Because of the natural values, the area is included in the IPA (Important Plant Area) and IBA (Important Bird Area) areas. Within MAB (Man and Biosphere) program, the area was proposed as a Biosphere Reserve. Also, the area is proposed to be part of The Ramsar Convention (The Convention on Wetlands of International Importance, especially as Waterfowl Habitat).

In the recent years, floods made major damages in the territory of Vojvodina. A flood, loosely defined as an abnormally high discharge of water level, results from an unusually high meteorological input in the form of rainfall or snowmelt or from a rapid loss of storage such as a failure of a dam or a levee (Muzik, 1996). Floods are one of the most harmful and dangerous natural hazards. Floods cause human suffering, economic losses, and losses in flora and fauna.

High water level of the Danube is the most dominant factor of change of habitat conditions in hunting ground „Apatinski rit". About 60% of the territory of „Apatinski rit" is in the flood zone (Delić, Dragin, 2006). Danube affects the regime of a ground water, which comes to the surface. This indirectly reflects to the humidity in the forest area in the defended parts of hunting-ground.

The largest part of the hunting-ground (85%) is situated 83-85 m above the sea level. The areas with altitudes over 85 m (10%) are flooded, on average, eight days a year in the vegetation period. In order to reduce damages to the hunting ground, i.e. to reduce the mortality of wild animals, and to reduce and sanitary hunting (required measure after the flood), it is necessary to introduce the use of geographic information systems (GIS) in the everyday managing of this hunting ground. The central focus in this field revolves around delineation of flood zones and preparation of flood hazard maps for the vulnerable areas (Sanyal, Lu, 2004).

Background of Research

The changes of habitat conditions and damages to the game animals at high water level of the Danube River

After World War II the control recording of zero „0" was made on all the water meters in Serbia. Near Bezdan „0" was revised to 80,64 near Apatin to 78,84 and near Bogojevo to 77,46.

The duration of high water level is measured in days, and it implies a situation when the Danube water flows from the riverbed over the levee. When the water level is +500 water starts to overlap the levee. When the water level is over +500, near Bezdan, and over +600 near Apatin, regular defense is declared. The longest duration of high water near Bezdan is shown in Table 1.

The Danube water is in contact with bog through a numerous swamps and canals, so at the low water level (200-250 cm) water penetrates only in the lowest parts of bog. At the higher water level (400-550 cm) low beams are flooded; while at the high water level (550-700 cm) the entire bog is under water (Panjković, 2005).

Exceptionally high water level of Danube is usual, after long and snowy winters. If the snow cover in the Alps remained to the beginning of

***Table 1** The longest duration of high water levels near Bezdan from 1876 to 2000.*

Place	WATER LEVEL											
	> +500		> +550		> +600		> +650		> +700		> +750	
	day	year	day	year	day	year	day	year	day	year	day	year
1.	149	1878	108	1965	61	1965	52	1965	28	1965	14	1965
2.	130	1965	83	1896	46	1926	22	1926	6	1954		
3.	124	1896	70	1879	38	1881	13	1940	5	1975		
4.	118	1897	69	1878	31	1876	10	1975				
5.	116	1910	69	1881	31	1940	10	1954				
6.	110	1944	67	1926	26	1887	9	1967				
7.	107	1881	65	1880	25	1878	9	1883				
8.	105	1937	60	1907	21	1966	8	1881				
9.	99	1897	57	1924	17	1880	7	1944				
10.	95	1924	56	1876	16	1883	6	1897				

Source: Andrejev, 2004

summer, the melting of snow starts quickly. At the same time, it starts the rainy period. The rains are usually very intensive in this time of the year. The rains speed up melting of the snow, while wet surface does not allow intensive absorption.

During the extreme water level (over 700 cm), only defended part is not under water, and 70,5% of hunting productive area is under water (undefended, flooded part). These flooded areas are the best and richest habitats for red deer and wild boar. With the rising of water level, the last refuges for wild animals are flooded, and the game is forced to migrate.

During the extreme floods, there is increased concentration of wild animals in the protected parts, and therefore, there is greater possibility of spreading communicable diseases. But, it is still safer for the wild animal than flooded areas.

The undefended area occupies 57,47 % of the total area of hunting ground. During the extreme high water level, game animals suffer serious losses, which are reflected in following examples.

During the spring of 2006, at the end of March, the water level of Danube River started to rise. The average daily air temperature was 7°C. Young game animals (calves and pigs) were not able to survive high differences between body temperature and temperature of the air. Since the water level rose one meter a day, only adults, healthy and strong games animals could swim to safe ground. Recorded mortality was 6 heads of corvine, 79 wild boars (9 sows and 70 porkets) (Internal documents of P.C. „Vojvodinašume", 2005).

During the 2002, floods occurred in July, and August. The highest water level was 756 cm. The mortality recorded was two red deers, two roe bucks and 26 wild boars, of which 20 were porkets (Delić, Dragin, 2006). The reason of smaller mortality in flood in 2002, in comparison to 2006, lies in the fact that flood in 2002 occurred much later in the year, when the water and air temperatures were not hugely different and temperature shocks to the animal organism were avoided.

Floods with the largest negative effects to games occur in the winter months. The last extreme winter flood was recorded in 1999, at the beginning of January. Water level of Danube River was rising and due to low air temperature, water was frozen. Game animals were trapped on the higher parts of undefended areas. The lack of food, hypothermia, and drowning were devastated, not only for young animals, but also for adult wild boars and deers.

Great floods also affect game animal reproduction, which is particularly emphasized in case of wild boar. A sow, which lost her offspring, during the spring flood in March or April, after rehabilitation, is again ready for mating and for bringing offspring in July or August. In this way, sows permanently move their period of reproduction, and piglets do not have enough time to grow up to be ready for the winter.

Extremely high water level of Danube River has a direct impact on hunting and tourism. The loss of game animals due to floods, directly reduce total number of game animal available for hunting season. The consequences can be significant reflecting in declining of tourism incomes (Ristić et al, 2009), inability for applying necessary action in repairing fences, watching towers, feedings, veterinary interventions, intake of food in hunting ground, etc.

Present measures during the flood

During extremely high water level of Danube River, boats and sledges are used for bringing food to higher courts where game can survive. The direct measures of rescuing wild animals are also undertaken. During the flood in 2006, 30 deer heads and 77 heads of wild boar were rescued in three days (Documentation P.C. „Vojvodinašume", 2005). Selective hunt is usually undertaken after the flood. Sick animals, which cannot be helped by veterinary intervention, represent positional transmitters of infectious diseases.

Because of the financial situation, the design standard of flood control is not high enough. It has been proved in the practice of flood control that it is impossible to control damages of great floods by depending only on present measures.

The state of the scientific research on the investigated problem

Hydrology is a geosciences linked to processes occurring at the earth's surface. Application of GIS is a predictable set in the evolution of hydrology (Muzik, 1996). For many flood planners the advantages of GIS are not considered of fully understood. Benefits of GIS and automated information are seen as negligible because flooding seldom occurs twice (Francis, 2008)

GIS technologies are used in many aspects of flood identification, prediction, and hazard mitigation. When combined with data on land cover, topography, and flood frequency, these inundation maps are used to estimate flood hazards. Or, in combination with such data as precipitation, soil moisture, vegetation, and channel geometry and roughness, the flood stage data are used for runoff modeling. Topographic data from are manipulated with GIS to derive characteristic channel shapes for a drainage basin, and these data are then used for hydrological modeling (Whol, Oguchi, 2004).

GIS technology has been used in supporting surface-water modeling and flood-hazard exposure analysis by providing the ability to integrate modeling results with other layers of information to enhance the decision-making process (Boyle et al, 1998). The main advantage of using GIS for flood management is that it not only generates a visualization of flooding but also creates potential to further analyze this product to estimate probable damage due to flood (Hausmann et al., 1988; Clark, 1998).

Flood hazards can be assessed by field survey, remote sensing, during or after an event or by computer modeling (Su, 2005). Spatially explicit flood models can play an important role in natural hazard risk reduction. A key element of these models that make them suitable for risk reduction is the ability to provide time-series inundation information about the onset, duration and passing of a hazard event. Such information can be critical for land use planning, for mapping evacuation egress routes, and for locating suitable emergency shelters (Zerger, Wealands, 2004).

3D GIS models have now become a reality due to advances in computer graphics such as fast graphics processing units and efficient terrain visualization algorithms (Brooks & Whalley, 2008). 3D models are very useful to help analysts and decision makers to form a vision to the real situation and make correct decisions (Zhou, et al, 2004). The applications of effective GIS visualizations are vast and include environmental analysis and modeling, flood models, geological models and urban planning (Brooks & Whalley, 2008). Among many other applications, flood uilding in 3D GIS is believed to be beneficial (Stoter & Zlatanova, 2003).

Directive 2007/60/EC, even sugest establishing a framework for Community action in the field of water policy requires river basin management plans to be developed for each river basin district in order to achieve good ecological and chemical status. Member States shell, at the level of the river basin district, prepare flood hazard maps and flood risk maps, at the most appropriate scale for the areas (Official Journal of the European Union, 2007).

Methodology

The process of making of digital physical map of hunting „Apatinski rit" followed several stages: the collection of data, scanning, georeferencing, digitization, database development, and creating of a 3D model. The projection of maps is Gauss–Krüger (Greenwich Meridian, Bessel modified). All maps were printed in 1976. To create digital map model authors used folloving scanned topograhical map sections; Apatin 43, 44; Bogojevo 2, 3, 4, 12,13, 22, 23, 24, 25, 26, 32, 33, 34, 35, 36, 37, 38 All topographical maps were created by Faculty of Geodesy in Zabreb (Croatia) with scale 1:5000. The authors used ArcGIS 9.3 software.

To create link to real-world coordinate system, maps are georeferenced. The georeferencing process establishes the relationship between image pixel locations and real-world locations. The georeferencing is accomplished by first selecting points on a scanned raster map with known coordinates for the real-world surface location. These real-world coordinates are then linked to the corresponding pixel grid coordinates in the raster source image (Galati, 2006). After the georeferencing, selected geographical objects are digitized. Digitization is the process of transfer of information from scanned maps into digital (vector) form (Stankov, et al, 2007). During digitizing, geographic elements are represented with geometric primitives as following: contour lines, embankment, wire fences with polylines; Danube, flood area, backwater with polygons; height points, fortification uildings with points. During the transformation from analogue to digital maps, the large number of map elements was digitized comprising: 939 contour lines, one embankment, one wire fence, one river, one flood area, 6282 height points and five fortification uildings.

Each layer contains a table of attributes (database), which are filled by the names and types of columns, depending on which geographical object it describes. Fields for data entry can be text or number. The spot-shape objects are digitized in its center, for example, a church or an elevation spot. The lines are digitized along its center, and the surface characters (polygon) are digitized by the edge of an object.

In this paper a 3D model is introduced to realize the flooded areas, based on the research of M. Mori (2007). A three-dimensional river flood model was used for estimating flooded areas on the left side the Danube River. A 3D model required the geometric description of river inundation extent. Creating surface representations of river flood systems is a challenging task because of issues associated with interpolating river water level, and then integrating this water level with surrounding topography. The flooded areas are estimated precisely, based on river water levels, and can be used for flood hazard maps. Estimated flooded areas based on several water levels are shown in the paper. Flood hazard maps cover the areas that could be flooded according to the following scenarios: (a) floods with a low probability; (b) floods with a medium probability; (c) floods with a high probability

Since the control zero “0” near Apatin is 78.84 m, according to the first scenario which indicate water level up to 250 cm, only the lowest parts of the ground (lower than 81.34 meters) will be flooded. At the higher water level, like 400 cm, the ground lower than 82.84 m will be flooded. In that situation, reducing of the habitat area will endanger game. Game will move to higher holms. The third scenario, with water level higher than 550 cm, represents the situation when most of the terrain is under water. Game animals are forced to migrate in the defended part of the reserve, where is also endangered due to the excessive density of other animals.

Results

The main result of this research is preparation of flood hazard maps for different water levels of the Danube River and identification of the vulnerable areas. After digitization, a 3D model was created based on the database. The surface is represented by TIN (TIN - Triangulated Irregular Network) model which is obtained by converting contour lines and trigonometric points using Mass Points method.

In order to make flood assessment according to 3D model, some critical criteria expressed in water level of the Danube River and geomorphology of the terrain were established. During the floods some parts of hunting ground are under water, and some higher courts remain dry. Dry parts are than becoming refuges for the game, with high concentration of wild animals on relatively small areas. Apart from the lack of space, game is faced with a lack of food and peace, and limited life habits (Figure 2).

For formulating any flood management strategy the first step should be identifying the areas that will remain dry, at certain water level. The digitized maps of the hunting ground „Apatinski rit" have equidistance between contour line of 0.5 meters and the differences between the high points are shown in decimeters (sometime even centimeters). Thus, it is possible to display small daily difference (even 10 centimeters) in a water level of the Danube River.

It is very useful to have information about parts of hunting ground that will be flooded if water level riches certain level (Figure 3). The use of GIS 3D model allows navigation through the virtual hunting ground, so that the natural terrain features such as relief or hydrology can be seen without a need for going on the field. This is a much simpler and cheaper way for collecting necessary data.

In 1973, Institute for the Development of Water Resources „Jaroslav Černi“ identified maximal high water level probability. Results shows that near Bezdan water level of +774 can be expected every 100 years, and one water level of +798 in eve-

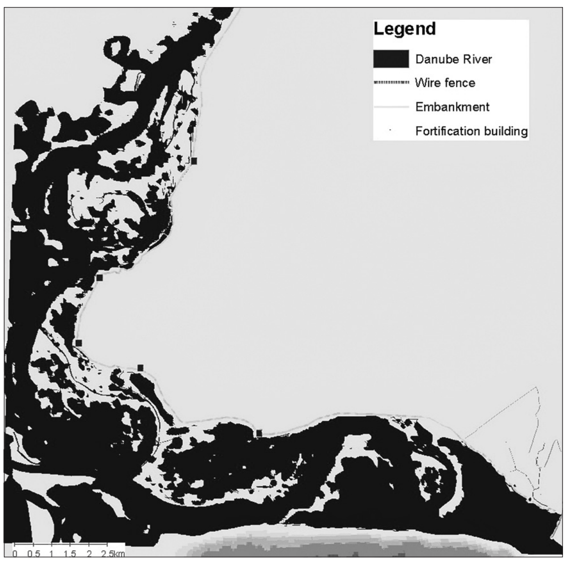

Figure 2 Flood prof parts of the hunting ground during the high level of the Danube
(Source: Marković, Stankov, 2009)

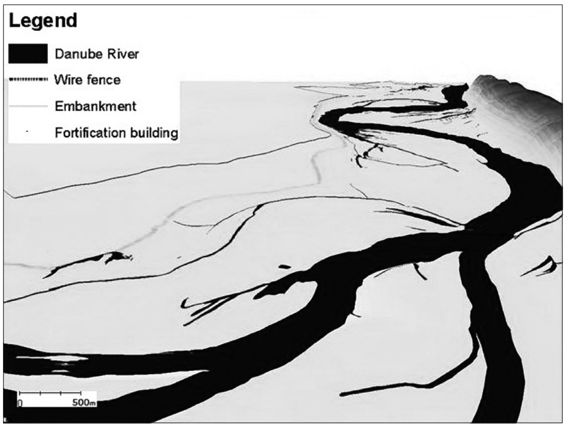

Figure 3 A 3D model of ,,Apatinski rit"
(Source: Marković, Stankov, 2009)

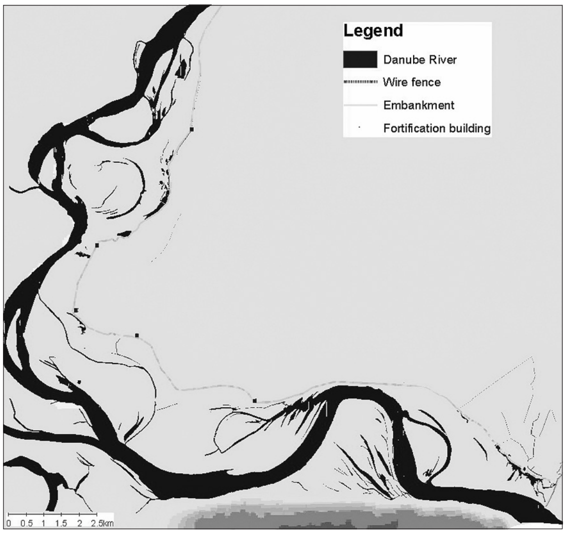

Figure 4 The view of hunting-ground „Apatinski rit" during the middle level of the Danube
(Source: Marković, Stankov, 2009)

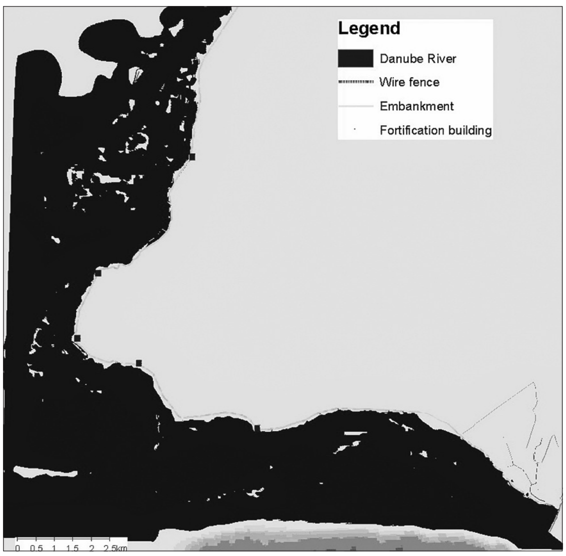

Figure 5 The view of hunting ground „Apatinski rit" during the extreme water level of the Danube
(Source: Marković, Stankov, 2009)

ry 1000 years (Andrejev, 2004). During extremely high water level of the Danube, when the first level of defense against floods is declared, wild animals are most endangered. High water level can last a several months (Table 1). During that time, it is very important to find a game animals remained at the isolated „islands" surrounded by the water.

By using a 3D model, all the „islands" with trapped game can be located during the floods, without terrain searching. By simply entering a given level of the Danube in the query, the display shows a detailed 3D view of the hunting area. Higher areas of hunting ground surrounded by water can easily be spotted. When the „island" is located, it is necessary to catch the game and transfer to the safer parts of the hunting ground. For that purposes a GPS device can be used. When the map of flooded area is inserted into GPS device, terrain surveying is very simplified. The process of searching for the endangered game can be much shorter, cheaper and efficient. Following the instructions of the receiver, rescue teams will avoid the wandering and losing time.

One of the main benefits of using GIS model is the possibility to calculate the size of all isolated parts of the hunting area that are surrounded by the flood. The information of the size of isolated „islands" can be used for estimation of the density of the game. This is the critical information for an estimation of the outbreaks of infectious diseases.

On the other hand, knowledge about the size of the area and biogeographically characteristics can be used for estimation of the duration of food recourses on „islands". Based on that information, the list of rescue intervention priorities can be easily created.

Conclusion

A detailed assessment and mapping of the Danube River with surrounding terrains should be based on establishing, developing and applying the geographic information systems, particularly created for this purposes. The basis of this approach is an extensive database that will provide wide opportunities for manipulation, intersection and overlapping of the content and elements of the geographical space (Marković, 2009).

The monitoring of the flooded terrain would include collecting, storing, analyzing and providing guidance for the successful management of the endangered areas. The distribution of a spatial and tabular attribute data over the Internet and GPS can be powerful and efficient method that overcomes the communication features of the classical approach.

The use of GIS can provide important information for decision making during the floods in the hunting ground. GIS allows the user to set queries and to retrieve useful information to satisfy the specific requirements of decision makers. The most important function of GIS is the ability to predict what will occur at a location, at another point in time, and under certain conditions (Hammersmark, et al, 2005). It can be difficult or impossible to obtain by using some traditional methods when it comes to the prediction and understanding of the flood damage. GIS can be regarded as a vital instrument for decreasing damages of floods.

The main goal of the use of GIS is to provide users of the hunting ground (and other organizations) effective and powerful tool for monitoring floods and reducing negative impacts of the floods. This will significantly contribute to the improving of the action plans for flood protection and reduce the damages. Selective hunting, as very invasive consequence of floods, can be avoided using detailed maps for timely organized rescue actions.

Reference

Andrejev, N. 2004. Waters of the Danube and the development of water resources in the Apatin and Sombor Danube region. Cultural Center, Apatin, 198 pp.(in Serbian)

Boyle, S.J., Tsanis, I.K., Kanaroglou, P.S. 1998. Developing geographical information systems for land use impacts assessment in flooding conditions. *Journal of Water resources Planning and Management* 124, 1, 89-98.

Brooks, S., & Whalley, J. 2008. Multilayer hybrid visualizations to support 3D GIS. *Computers, Environment and Urban Systems* 32, 4, 278-292.

Clark, M. J.1998. Putting water in its place: A perspective on GIS in hydrology and water management. *Hydrological Processes* 12, 823–834.

Craciunescu, V., Stancalie, G., Constantinescu, S., Ovejanu, I. (2007). Web-based geo-information system for transboundary flood management. *Geographia Technica* 2, 20- 32.

Delić, J., Dragin, A. 2006 . The impacts of extremely high water levels on the Danube river habitat and the hunting of the game „Apatinski rit". *Tourism* 10, 206-209. (in Serbian)

Directive 2007/60/EC of the european parliament and of the council of 23 October 2007 on the assessment and management of flood risk, Official Journal of the European Union.

Documentations of P.C. „Vojvodinašume" 2005. Report on damages caused by floods in the game. F.A. Apatin, Apatin. (in Serbian)

Francis, H., 2008. A Primer of GIS: Fundamental Geographic and Cartographic Concepts, The Guilford Press, New York, University of Novi Sad, Faculty of Science, Department of Geography, Tourism and Hotel Management.

Galati, S. 2006. Geographic information systems demystified. Artech House. Norwood.

Hammersmark, C., Fleeno, W., & Schladow, G. 2005. Simulation of flood impact and habitat extent for a tidal freshwater marsh restoratio. *Ecological Engineering* 25, 2, 137-152.

Hausmann, P., Weber, M. 1988. Possible contributions of hydroinformatics to risk analysis ininsurance. In Proceedings from 2nd International Conference on Hydroinformatics, Zurich, Switzerland, Balkema, Rotterdam.

Marković, V. 2009. Application of geographic information technologies in hunting tourism in Vojvodina (Ph.D. thesis – manuscript; in Serbian)

Mori, M. 2007. GI Gis Analysis of River Flooding by High-Resolution (2m) Dem. URL: www.ceg.ncl.ac.uk/rspsoc2007/papers/110.pdf (Retrieved on 01.02.2009).

Muzik, I. 1996. Lumped Modeling and GIS in Flood Prediction. In Singh, V. and M. Fiorentino (eds), Geographical information systems in hydrology, Kluwer Academic Publishers, Dordrecht.

Panjković, B. 2005. Aquatic and semiaquatic vegetation of Apatin and Monoštor fen (PhD thesis). University of Novi Sad, Faculty of Science, Department of Biology and Ecology, Novi Sad. (in Serbian)

Ristić, Z., Marković, V., Dević, M. 2009. Development of hunting tourism in Vojvodina. *Geographica Pannonica* 13, 3, 105-114.

Sanyal, X.X.Lu, 2004. Application of Remote Sensing in Flood Management with Special Reference to Monsoon Asia: A Review. Natural Hazards33, 2, 283-301.

Stankov, U., Dragićević, V., Drakulić, N. 2007. Fundaments of digitization of TK25 map for use in tourism sector. *Turizam* 11, 149-150.

Stephen, G. 2006. Geographic Information Systems Demystified. Artech House, Norwood.

Stoter, J., & Zlatanova, S. 2003. 3D GIS where are we standing? Joint Workshop on spatial, temporal and multi-dimensional data modeling and analysis. Quebec, Canada.

Su, M., Kang, J., Chang, L., Chen, A.,. 2005. A grid-based GIS approach to regional flood damage assessment. *Journal of Marine Science and Technology* 13, 3, 184-192.

Whittington, T. 2008. Using GIS to Identify Social Vulnerability in Areas of the United Kingdom That Are at Risk from Flooding. In Wise, Stephen, Craglia Max (eds), GIS and Evidence-Based Policy Making, CRC Press, Boca Raton.

Whol, E., Oguchi, T., 2004. Geographic information systems and mountain hazards. In Bishop, M. and J. Shroder (eds), Geographic information science and mountain geomorphology, Praxis, Chichester.

Zerger, A., Wealands, S. 2004. Beyond modelling: Linking models with GIS for flood risk management. *Natural Hazards* 33, 2, 191-208.

Zhou, H., He, B, Zhu, L., Liang G. 2004. The application of Web GIS in emergengy flood control system. In International Association of Hydrological Sciences. GIS and remote sensing in hydrology, water resources and environment (Proceedings of ICGRHWE, Three Gorges Dam, China, September, 2003), 80-87.

http://www.biblioso.org.rs/images/eko/mapa01.jpg (Retrieved on 12.03.2009)

http://www.vojvodinasume.rs/indexnivo_en.php&nivo_1=9&nivo_2=27&nivo_3=36&naziv3=Apatinski20rit,20Apatin (Retrieved on 03.02.2009)