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Natural Hazard Assessment for Land-use Planning in Serbia

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ABSTRACT: The territory of Serbia is vulnerable to various types of natural hazards and the risk is not equal across the entire territory; it varies depending on the type of hazard and the expected potential for damage. The first aim of this research was to determine the geographical distributions of the major types of natural hazards. Seismic hazards, landslides, rock falls, floods, torrential floods, excessive erosion, droughts and forest fires are the most significant natural hazards within the territory of Serbia. Areas vulnerable to some of these natural hazards were singled out using analytical maps; their area relative to the total area of Serbia was defined, along with the total surface area that is vulnerable to each type of natural hazard. Upper intensity values for single natural hazards were measured; these values represent the limiting factor for land-use planning at the given level. Based on these analyses, an integral map of the natural hazards of the territory was created using multi-hazard assessment. Hence, a recent state of the natural hazard vulnerabilities of the territory of Serbia was created and then an integral map was made. The integral map showed spatial distribution of the different types of hazards that are considered to be limiting factors for the highest level of land-use planning. The results presented in this article are the first multi-hazard assessment and the first version of the integral map of natural hazards distribution in Serbia for land-use planning, which is important both nationally and regionally.

Key words: Natural hazard distribution, Vulnerable areas, Multi-hazard assessment, Integral map, Spatial planning

INTRODUCTION

Each territory on the surface of the Earth (depending on the complexity of natural conditions) has characteristics and predispositions to certain natural occurrences and processes, resulting in a particular set of risks for various natural hazards. Seismic hazards, landslides, rock falls, floods, torrential floods, excessive erosion, droughts and forest fires are some of the significant natural hazards within the territory of Serbia; these natural processes can directly and indirectly endanger the environment, population and material goods.

Due to the geographical position of Serbia, with territory situated along the southern part of the Pannonian plain and the Balkan Peninsula and also due to the complex influences of various abiotic and biotic factors, diverse natural hazards are present. As the analysed area is bordered by eight independent states, the problem of natural hazard assessment in land-use planning exceeds the administrative borders and carries importance in a regional, SE European context.

The Republic of Serbia does not have a clearly-defined strategy for protection against natural hazards, but this problem has been solved in some sectors for some types of hazards, or as a component of various planning documents (Dragicevic *et al.*, 2009-b; Dragicevic *et al.*, 2010). There has not been any official and public data on the activities of natural hazards and on the consequences of their activities on a

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national level in Serbia. Therefore, such data has been excluded from many projects and studies that have been carried over the last 20 years.

Consequently, the basic objective of this paper is to provide a regionalisation of the territory of Serbia according to the level of vulnerability to different natural hazards. This analysis is especially important as an attempt to categorise countries according to their levels of the risk from natural hazards (Peduzzi *et al*., 2005), to identify the global distribution of exposure to the most significant natural hazards (Berz *et al*., 2001) and to form an available global database on the impacts of natural hazards (UNDP, 2004).

Knowledge of the susceptibility of a given area to natural hazards is important for spatial development, for proper planning of the purpose of space aiming at the protection of environment and for making frameworks for the application of the concept of the sustainable development. By understanding the nature and the spatial distribution of natural hazards in Serbia, treatments can be made to reduce the risks. The first aim of this research was to determine the geographical distribution of the major types of natural hazards in Serbia. Second, this paper provides an example of multi-hazard assessment of seismics, landslides, excessive erosion, flooding, forest fires and drought. Based on these analyses, the ability to create integral map of the natural hazards within the territory of Serbia will be achieved, identifying the areas prone to certain natural threats.

MATERIALS & METHODS

In most cases, the origin, scope and duration of a natural disaster cannot be predicted in advance. However, based on experience, statistical data and modelling methods and considering the location, it can be predicted that some number of events will occur. Therefore, the methodological approach encompassed an analysis of the territory of Serbia by considering the vulnerability to individual types of natural hazards. The overall review was made according to this method, showing the total surface and the degree of potential risk for the whole territory. Hence, the recent state of vulnerability of the territory of Serbia to natural hazards was shown using analytic maps and then a synthetic map was made. The integral map indicated the spatial distribution of the types of hazards that are considered to be limiting factors on spatial development or on land-use planning at the regional level, that is, on the level of the development strategy. Consequently, areas that were vulnerable to some natural hazards were singled out and their percentage of the total area of Serbia was defined, along with the total surface area that was vulnerable to natural hazards.

Upper values of intensity for each natural hazard were determined, as this value represents the limiting factor on surface use for the given level. For seismic activity, for example, areas in which the strength of the seismic hazard was above VIII on the MCS-64 scale were singled out, followed by areas at risk of excessive erosion, etc.

A state map of Seismic Regionalisation of the Republic of Serbia with a return period of 100 years and an approximately 63% probability of earthquake occurrence (Vukasinovic, 1987) was used to analyse the influence of seismic hazards as a limiting factor for land-use planning. The map was from an earthquake catalogue of historical and instrumentally registered data since 1909. Isolines were used to single out the areas in which a maximal intensity of earthquakes (according to MCS-64) has been expected for a return period of 100 years with an ~ 63% probability of occurrence. The standards of EUROCOD 8 have not yet been adopted in Serbia, so parameters for the estimation of seismic hazards in accordance with EC 8 were only defined for some locations.

The areas at risk from landslides in Serbia were selected in phases: analysis of the geologic maps, interpretation of the topographic maps (quantitative geomorphology analysis), field research and cabinet synthesis of the collected material.

After detailed analyses of the engineering geological and topographic maps (i.e., the maps of vertical dissection of the relief and the maps of the slope angle), the surfaces with different erosion potentials were singled out. Through the process of elimination, all of the surfaces with lithological structures that did not fulfil the conditions for the occurrence of landslides were excluded (Lazarevic, 2000; Jelinek and Wagner, 2007; Dragicevic, 2007; Dragicevic and Filipovic, 2009). Using a comparative analysis of the quantitative geomorphologic maps, the engineering geological map and the map of landslide events, the unstable surfaces were identified. If relief dissection is more expressed (with a more expressed slope of terrain) and the lithological composition and method of land use are such that there are real conditions for the occurrence of landslides, then all of the necessary factors for the possible manifestation on the topographic surface are fulfilled (Clerici *et al*., 2002; Dragicevic *et al*., 2007; Kanungo *et al*., 2008; Dragicevic *et al*., 2009-a). All of the areas within Serbia that exhibited the natural conditions for the occurrence of landslides were mapped according to the aforementioned preparations and a reference map was made of the unstable areas throughout Serbia (Lazic and Bozovic, 1995), as well as on the field research.

Fig. 1. Flood on the Kamisna River – Western Serbia (26.5.2007 - a) and gully erosion on Stara planina Mountain – Eastern Serbia (19.04.2010 - b)

Recent studies of floods in Europe have not encompassed the territory of Serbia, so this territory has been previously neglected for the most part (Barredo, 2007). Total length of water course on the territory of Serbia is 65980 km, i.e., density of river network is 0.75 km^{-2}. The potential floodable area, for the waters of a return period of 100 years, cover the surface of 16000 km^2, affecting 500 larger settlements, 515 industrial objects, 680 km of railroads and about 4000 km of roads (Petkovic and Êîstandinov, 2008). The most vulnerable area is northern part of Serbia (Vojvodina), where, in the coastal part of the Danube River (specifically, the Tisa, the Tamis and the Sava), there are about 12900 km^2 of potentially floodable land.

The greatest flood in Serbia in the 20^{th} century was in coastal part of the Danube River, during May and June in 1965, when more than 2.500 km^2 was flooded, affecting 16000 houses and 214 km of roads. However, the most vulnerable area is the coastal part of the water courses whose watershed surfaces are in the range of A=10–1000 km^2. Floods in Serbia have a mostly torrential character (17 people died from only 1994 to 2010) (Abolmasov *et al*., 2009).

The characteristics of the maximal discharge of torrential watersheds were studied using data processing of 102 control profiles (equipped by automatic water-level recorders), located at all of the important river systems in Serbia. The observation system was under the supervision of RHMOS (Republic Hydro-meteorological Office of Serbia). The study area comprised southern Serbia from the Sava River and the Danube River (66873 km^2). The magnitudes of the researched watersheds ranged from A=52 km^2 to A=1268 km^2. The frequency of the maximal discharge Q_{max} (for individual months), over the referential threshold (the average maximal discharge Q_{maxsr}) for all of the years of observations (ending with 2007) was analysed in this paper. The average maximal discharge Q_{maxsr} was determined to be the mean value for the recorded maximal discharges Q_{maxi} for all N ($N \geq 25$) years of observations. Historical records of the maximal discharges, reconstructed using "hydraulics flood traces" are presented.

Excessive erosion of the land surface can have limiting consequences on the use of natural resources, but it can also represent a natural risk in some regions. Serbia is covered with hard erosive processes and about 86% of its area is at some risk of erosion. Stronger categories of erosion cover 35% of the southern territory of Serbia (Lazarevic, 1983), from the Sava River and the Danube River (hilly-mountainous part of Serbia).

By analysing the most important indicators and parameters (the annual amount of precipitation, pluviometric regime, lack of water in the soil, as well as the temperature and air humidity during the vegetation period) that determine the duration, frequency and intensity of drought, four regions were singled out (due to their dryness) within Serbia (Ràêicåvic, 1988; Dragicevic *et al*., 2009-b). To identify which regions are at the highest risk for drought, spatial analysis was carried out using trends of some climate elements that exert a primary influence on drought.

It is well known that forest fires mostly occur in dry years, when the air temperature is high during the summer periods and the atmospheric precipitation is minimal. According to data from the national forest inventory, forest covers about 40% of the area of Serbia, out of which, 27% consists of broadleaf forests. The analysis of the Corine Land Cover database in 2006 clearly indicates a recent 1975 ha increase in the area of land covered by forest; this increase is the result of afforestation of agricultural land and an increase of surface of conifer and mixed forests. The Deliblato sand and Eastern Serbia are at a particular risk for forest fires (Dragicevic *et al.*, 2009-b).

RESULTS & DISCUSSIONS

Serbia belongs to a region that features moderate seismic activity, according to both the number and frequency of earthquakes, as well as to the magnitude (Richter scale) and intensity (MCS-64 scale). During the period from 1956 to 2009, 7407 earthquakes were registered with an intensity of IV on the MCS-64 scale, 284 earthquakes with an intensity of V, 115 earthquakes with an intensity of VI, 20 earthquakes with an intensity of VII and only 4 earthquakes with an intensity of VIII on the MCS-64 scale (Àbolmasov *et al.,* 2010). Out of the total area of Serbia, 38% of the territory is at risk of maximally expected intensity of earthquake VII–VIII ÌCS, 14% of the territory is vulnerable to an earthquake with an intensity of VIII–IX ÌCS and only 0.3% of the territory is at risk of an earthquake in the zone of IX–X ÌCS of in-ten---sity (these figures are all according to a 100 y return period with a 63% probability).

Recently, earthquakes in the territory of Serbia have had different magnitudes, but in the densely populated area, there has not been any increase in the stronger earthquakes. An extremely strong earthquake was registered in 1922 in Lazarevac (M_L=6.1) and then in 1980 in Kopaonik (M_L=5.8).

After that, a strong earthquake hit the region of Valjevo (western Serbia) on 30th September 1998. This shock (M_L= 5.4, or an intensity of VIII MCS-64 at the epicentre) was one of the four strongest earthquakes in Serbia over the last century. The objects were damaged by the earthquake within a diameter of 31 km from the epicentre and the earthquake was even felt in Hungary. It was observed that the earthquake totally or partially damaged over 24000 objects. The damage from this earthquake was estimated at around 400 million euros. The most recent strong earthquake in Serbia was registered on 10th March 2010, with M_L=4.7 and an intensity of VI–VII on the MCS-64 scale.

According to previous studies (Lazic and Bozovic, 1995), 25% of the territory of the Republic of Serbia is potentially at risk for landslides and rock falls. The zone at a considerable risk for the development of landslides consists of a terrain with developed, complex and mainly active landslides. These are mostly slopes of Neogene basins built from heterogeneous sediment complex, with frequent unfavourable interactions between the lithological compositions, complex hydrologic characteristics and unfavourable morphologic conditions. The terrains built from the rocks of the diabase-chert formation also belong to this zone. The landslides cover the slopes over a large area; they are very deep with frequent secondary activity in the older parts of the sliding mass. The dynamics of a landslide can vary, with slow to fast movement of the sliding mass during the period of activity. The regions that are highly susceptible to landslide are those areas in which mass movement occurs frequently. This characteristic is especially important during spring period and it occurs in accordance with the precipitation regime throughout Serbia.

Over the past 120 years, several huge landslides were registered that exerted significant social-economic influence: Landslide “Zavoj” in 1963, Landslide “Jovac” in 1977 and Landslide “Bogdanje” in 2006. The largest rock fall recorded in Serbia took place in Ovcar Banja in 1896. Apart from these landslides, the biggest problems have been active landslides on the right bank of the Sava and the Danube rivers: Umka, Duboko, Čortanovci, Vinča, Karaburma, Grocka, Smederevo and others (Abolmasov *et al.*, 2009).

Floods and torrential floods are the most frequent phenomena of the “natural risks” in Serbia. Their frequency, intensity and diffusion across the territory make them a continual threat to the ecological, economic and social spheres (Kostadinov, 1988; Ristic *et al.*, 2000; Ristic *et al.*, 2006).

Analyses of the frequency of maximal discharges over the referential threshold (which was defined as the average maximal discharge Qmaxsr) indicate that the critical periods occur at the end of spring (May to the first half of June) and at the end of winter (February to the first half of March). The period from May to the first half of June was identified as the primary maximum for most of the watersheds (Velika, Juzna and Zapadna Morava, Ibar, Kolubara, etc.). High water levels during this period were the results of intensive rains that lasted for a few hours. The daily and monthly maximums of precipitation were recorded during the period from May to June at the rain-gauge stations across most of Serbia. The period from February to the first half of March was identified as the secondary maximum. The absolute maximal values of discharge Q_{maxa} were recorded during the periods of expressive frequencies at most of the profiles (Ristic, 2002). However, some of the Q_{maxa} were recorded during the periods of expressive low frequencies at some profiles, due to the specific climate and hydrological conditions.

Some interesting historic cases of torrential floods are presented in Table 1. along with their main characteristics. The specific maximal discharges are plotted on a diagram with the “curves of specific maximal discharges” (Fig. 2). Hydrological practice in

Serbia uses a control model (to compute the maximal discharge), which is known as “curves of specific maxi-mal discharges”, for watersheds in which A=10–100000 km^2 (Jankovic and Malosevic, 1989).

Common characteristics of presented historical cases include the following: the steepness of the river beds, with an absolute slope I_a=5.74–13.45%; huge parts of the watersheds under bare lands, degraded forests and agricultural land; shallow, skeletal soil with a low infiltration-retention capacity; excessive erosion processes; a short duration of rain events, 90–180 minutes, with intensities from I=0.75–1.17 $mm \cdot min^{-1}$. The consequence of these characteristics was the sudden occurrence of torrential floods, a high content of the hard phase and strong destructivity. Maximal discharge on the Timjanicka River (city of Negotino, in neighbouring Macedonia) was an extreme event on the regional level (Blinkov *et al.*, 2002) that was used for comparison with similar events in Serbia.

Table 1. Main characteristics of reconstructed torrential floods

Water course	Profile	Date of appearance	Magnitude [km^2]	Q_{max} [$m^3 \cdot s^{-1}$]	q_{maxsp} [$m^3 \cdot s^{-1} \cdot km^{-2}$]	Duration/ Intensity
Lestarska Valley	Vladicin Han	25.07.1982	2.64	16.16	6.12	90 min; 1.17 $mm \cdot min^{-1}$
Timjanicka River	Negotin	1995	17.80	220.0	12.36	165 min; 1.06 $mm \cdot min^{-1}$
Kalimanska River	Vladicin Han	Summer 1929	16.04	149.0	9.3	/
Sejanicka River	Grdelica	02.07.1983	12.51	62.75	5.02	90 min; 1.01 $mm \cdot min^{-1}$
Manastirica	Brezdje	13.06.1996	29.5	154.9	5.25	180 min; 0.75 $mm \cdot min^{-1}$
Ribnica	Pastric	13.06.1996	104	418.08	4.02	180 min; 0.75 $mm \cdot min^{-1}$

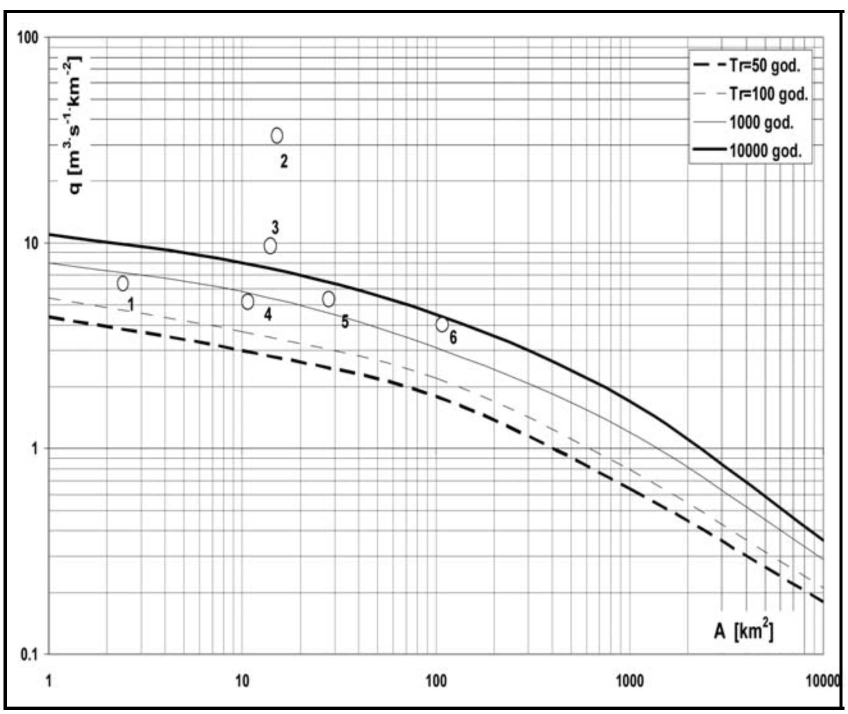

Fig. 2. Specific maximal discharges for extreme torrential floods (1-Ljestarska Valley; 2-Timjanicka River; 3-Kalimanska River; 4-Sejanicka River; 5-Manastirica; 6-Ribnica)

Other than hail (for which there is no referent map), drought is the atmospheric disaster with the largest consequences on the territory of Serbia. The basic problem is to define a criterion for establishing natural disasters caused by drought. With the analysis of the most important indicators and parameters (annual quantity of precipitation, pluviometric regime, lack of water in the soil, as well as temperature analysis and air humidity during the vegetation period) that determine duration, frequency and intensity of drought, four regions were singled out (due to their dryness) within the territory of Serbia (Rakicevic, 1988). The regions of Serbia at the highest risk of drought are the following: Niško-Leskovaèka ravine with Dobrièka, Belopalanaèka and Aleksinaèka ravine, Vranjska and Gnjilanska ravine, Kosovo polje with Drenica, Metohija, Negotinska krajina and northeastern Baèka with northern Banat.

The longest drought in Serbia was observed in Vranje and it lasted 61 days. This extreme drought began on 22nd June and ended on 21st August 1928. The hottest recorded day in Serbia was on 24th July 2007; all July maximums were exceeded at 22 stations and at 20 stations, the former absolute maximums were exceeded as well. The air temperature in Smederevska Palanka was 44.9ºC. It became the absolute maximum for Serbia and even exceeded the former maximum registered in Kraljevo on 22nd July 1939, when the air temperature was 44.3ºC.

The penetration of extremely warm air from Africa began within the Balkan Peninsula in the middle of July 2007. Strengthening of the thermobaric reef in the southwestern height stream caused further advection of warmer air and, because of atmospheric heating, the temperature in Serbia continued to rise higher each day (Àndjelkovic, 2007). It should be noted that the highest temperature in Europe that day was only slightly higher, measured in Demir Kapija in Macedonia, 45.7ºC.

Fires represent a considerable risk of natural disasters within the territory of Serbia. In accordance with climate changes, during the high-temperature summer months, the number of fires in the territory of Serbia has been increasing from year to year, causing large amounts of damage to the forest fund of the Republic. However, there is currently no map of forest fire hazards for the territory of Serbia.

During the period from 1990–2005, around 43000 ha of Serbian forest and overgrown forest soil were ruined in forest fires. Within this period, the largest number of fires was registered in 2000, as 13201 ha of forest and overgrown forest soil burnt in 339 fires. In 2007, there were 482 fires that destroyed 34000 ha of forests and forest soil; this incidence represents an extreme increase of fire frequency relative to 2003, when 51 fires caught and destroyed 324 ha of forest and forest soil (Petkovic and Êostadinov, 2008). During the period from 1948–2007, 258 fires were registered just in the Deliblato sand, affecting 11921 ha. One of the biggest fires in this region took place in 1996, when 3815 ha of land was destroyed. The last fire occurred in 2007 and burned 547 ha.

Because natural disasters occur suddenly and either independently from one another or in mutual connection (synergy effect), it is necessary to carry out a complete analysis of the natural hazards within the territory of Serbia. In addition, it is also important to provide a multi-hazard assessment showing the comprehensive vulnerabilities and the hazard areas. Fig. 3 indicates the preliminary multi-hazard map of the study area. Using a multi-hazard approach is crucial because the occurrence of one hazard may trigger another one.

Fig. 3 indicates that the territory of Serbia (with its population, material and other natural and achieved goods) is prone to natural hazards. The risk is not uniform across the whole territory but varies depending on the type of hazard and the potential damage. However, there is enough of a risk to lead to consequences for the population, to damage the health and the lives of the people and to cause material damage of a higher scope.

There are neither clearly defined maps nor criteria for seismic hazards in Serbia. Until a map adapted to the EUROCOD standard can be made, an official seismologic map of Serbia is in use (Vukasinovic, 1987), which indicates the expected maximal intensity of earthquakes for a return period of 100 years (therefore, it is capable of long-term forecasting). Its territory is on this oleate, located in the zone of VII, VIII and IX of MCS-64.

For landslide hazard assessment and a mitigation plan for Serbia, it is necessary to map an inventory of landslides, the elements at risk and the vulnerability. Landslide susceptibility maps only indicate the spatial distribution of landslides; therefore, they have limited use in landslide management and mitigation strategies. Floods and torrential floods, as the most frequent phenomena among the “natural risks” in Serbia, need serious treatment. This treatment is accomplished through the following activities:

- identification of the flood zones (whole watersheds or particular sections of rivers);
- monitoring in real time (the water level in the river bed and the amount of precipitation), along with a forecast and warning system;
- short-term protection;

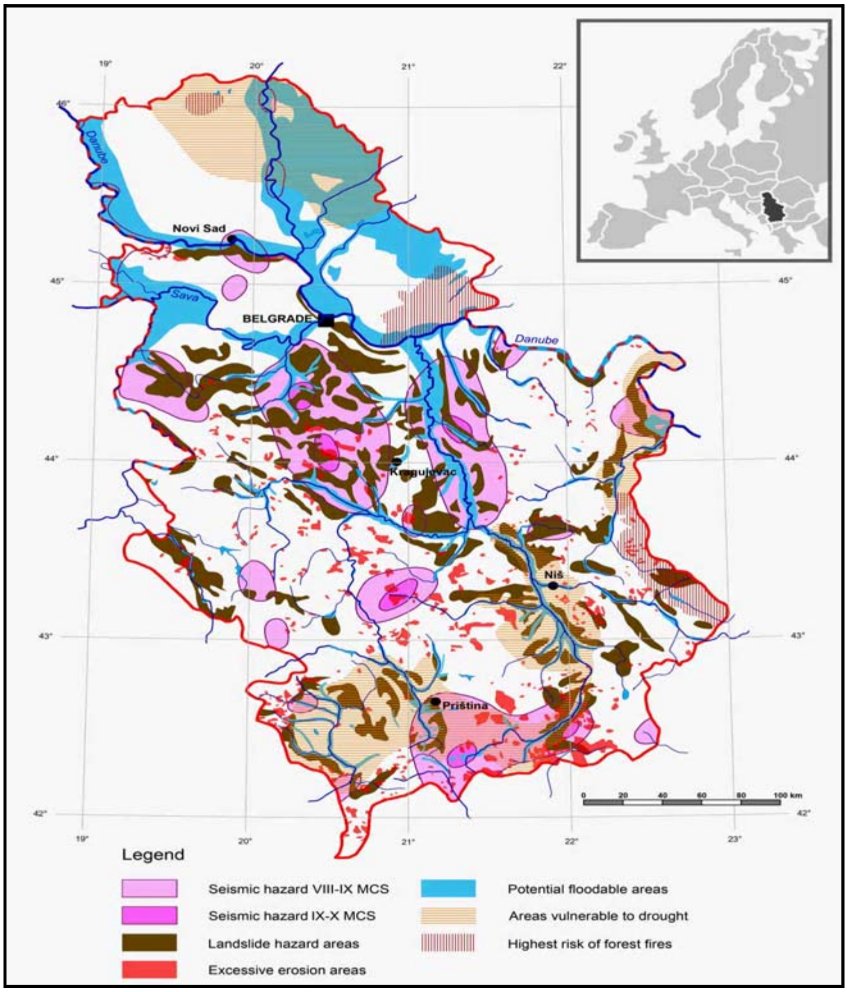

Fig. 3. Integral vulnerability map of the natural hazards in the territory of Serbia

Table 2. Areas vulnerable to natural hazards in the territory of Serbia

Natural hazard	**Area [km^2]**	**Percentage of total Serbian area [%]**
Seismic hazard VIII–IX MCS	16388.59	18.55
Seismic hazard IX–X MCS	1109.71	1.26
Excessive erosion areas	3320.80	3.76
Landslide hazard areas	13327.60	15.08
Areas vulnerable to drought	18306.93	20.72
Potential floodable areas	15198.07	17.20
Highest risk of forest fires	3154.95	3.57
Vulnerable areas in Serbia	50659.87	57.33

- long-term protection;
- land use;
- risk management;
- public participation, education and media.

It is important to define the high-risk zones and to establish a system for early warnings that is sensitive to the characteristics of torrential flood waves: sudden appearance, destructivity, short duration and seasonality. Analysis of the frequency of maximal discharges is able to define the critical periods: the end of spring (May to the first half of June) is the primary maximum in most watersheds and the end of winter (February to the first half of March) is the secondary maximum. Occurrences of the absolute maximal discharges Qmaxa correspond to the periods that feature the most expressive frequencies of discharge, with a few deviations.

Short-term protection comprises all of the measures that can be quickly realised (from one month to one year): an administrative ban on building in the flood zone, maintenance of the regulated and natural river beds and a ban on forest clear-cutting of extremely steep slopes. Long-term protection comprises the following methods: the formation of reservoirs and retentions for the reception of flood waves, the relocation of residential and infrastructure objects out of risk zones, erosion control management of watersheds and river training works in torrent beds. The risk of fast surface runoff could be significantly decreased by land-use changes that reduce erosive material production and ameliorate soil infiltration and retention capacity: afforestation, reclamation of meadows and pastures, contour farming and terracing. Defining the risk zones and observing the seasonality of the torrential flood waves would aid in the formation of a real-time warning system (Ristic *et al.*, 2000) that would serve to decrease damages and protect local dwellers.

One important problem with droughts is that there is still no operative method to defend against artificial influences on time for precipitation stimulations in Serbia. There are many unexplored possibilities here. To identify the regions that are at the highest risk of drought, it is important to conduct spatial analyses of the trends of various climate elements with a primary emphasis on drought. Zero or slightly positive precipitation trends have been observed across the territory of Vojvodina, as well as in the areas surrounding Leskovac and Nis. A negative trend has been observed in the region of Negotinska Krajina and a positive trend has been observed in the western parts of Serbia, especially in the Loznica-Valjevo-Zlatibor-Sjenica region.

According to the statistical data on forest fires, people are responsible for inciting over 98% of fires in Serbia; these incidents are mainly due to ignorance or carelessness, but others are deliberate. To change this behaviour and the habits of the population, propaganda and education serve as basic preventive measures to inform people of the necessity to protect the forests from fire. There has still not been any referential map that indicates which areas are at risk for fires within the territory of Serbia.

CONCLUSION

Recent errors during space planning in Serbia (which can often involve excessive material damage due to natural disasters) were the result of insufficient dedication to this problem and ignorance of the natural limitations of space, along with a lack of both clear data and clearly defined risk zones.

The study presented here is the first version of the Map of Major Serbian Natural Hazards. For the previously discussed reasons, Serbia has been excluded in most of the recent studies examining natural hazards within Europe and globally (Barredo, 2007; Mosquera-Machado and Dilley, 2009). Therefore, it was first necessary to create a preliminary multi-hazard map of the study area. This work will be valuable to support the government mitigation program and helpful for developing a natural hazard and risk assessment model for the area.

To accurately assess the vulnerability of a space (i.e., the limitations for its use), the next step should be to create a cadastre of the natural hazard risks for spatial and urban planning. This cadastre would allow an acceptable level of risk to be defined for all levels and in all phases of planning. Then, the system of preventive, organisational and other measures and instruments could serve to lessen the consequences from disasters to an acceptable level.

In creating further spatial and urban plans, protection from natural hazards will represent a very important segment of planning the purpose of land and land use, especially in vulnerable regions. Considering this, specific spatial planning will be applied to potentially risky zones, with regionalisation of the surfaces according to the degree of risk.

Involvement of the local community, such as with a public education program, will help people understand the hazard characteristics. It is also important to empower the community with the promotion, planning and management of indigenous disaster response activities.

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