Natural Hazard Assessment in Pčinja Catchment

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Abstract

A natural hazard has been defined by UNESCO as the probability of occurence within a specified period of time and within a given area of a potentially damaging phenomenon. It has been estimated that the natural hazards cost the global economy over $50000 million per year. The aim of this work is to analyse and determine the areas of potential natural hazards in Pčinja basin. Pčinja is large left tributary of Vardar River (135 km long, 2877,3 km^2 catchment's area), which drainages surface waters from northeastern Macedonia, and in smaller part (538 km^2 or 19%) from southeastern Serbia. Because of suitable physical-geographic factors (geology, terrain morphology, climate, hydrology, vegetation cover, soil composition, and high human impact), some parts of the catchment have significant risk of natural hazards. Given the well-known fact that they occur suddenly, independently of each other or in the mutual relationship (synergy), it is necessary to make assessment analysis of most significant natural hazards in the selected basin. Therefore, in this work analysis of vulnerability of the area to various geohazards, atmospheric and hydrologic hazards in Pčinja basin is performed, and then generalized map of the natural hazards is prepared. Assessment of geohazards is prepared by analysis of existing seismic maps, while landslide potential and excess erosion risk is estimate through appropriate methodology. Assessment of atmospheric hazards involves spatial distribution of extreme temperatures, intense rainfall (heavy rain), the average number of days with the hail and identification of areas vulnerable to drought. The hydrological hazards (hydro-hazards) involve determination of hydrological extremes, while the risk of bio-hazards involve identification of areas endangered by fires. Based on these analyses the ability to create generalized map of natural hazards in the basin Pčinja will be achieved, with areas vulnerable to certain natural treats, as well as the total area endangered from hazards.

Keywords: natural hazards, Pčinja catchment, vulnerable areas.

Introduction

Natural disasters are natural phenomena which distort the stability of the system of natural processes, recently significantly modified by anthropogenic influence. Suddenly arise independently each of other or in the mutual association. Their environmental impact is very large so that in the literature instead of „natural hazards" are increasingly using the term „environmental hazards". If they inflict enormous damage to society, or populated areas, natural disasters becoming catastrophes (Dragićević, S. and Filipović, D. 2009). A natural hazard has been defined by UNESCO as the probability of occurence within the specific period of time and within a given area of a potentially damaging phenomenon. It has been estimated that natural hazards cost the global economy over $50 000 million per year. Two thirds of this sum is accounted for by damage, and the remainder represents the cost of predicting, preventing and mitigating disasters. Hazards pose a threat to man, his proprety and the environment and so they are of more significance when they occur in highly populated areas (Bell, 1999). Natural Hazards can be divided into geologic, atmospheric, hydrologic, anthropogenic and other types of hazards. Also, they can be divided into rapid onset hazards, such as Volcanic Eruptions, Earthquakes, Floods, Landslides, Severe Thunderstorms, Lightening, and wildfires, which develop with little warning and strike rapidly. Slow onset hazards, like drought, insect infestations, and disease epidemics take years to develop.
The importance of knowing possibilities of some territory for causes and occurences of certain natural disasters, has priceless importance in the prevention of negative consequences for the population and material resources, developing strategies for spatial development, proper land use, prevention of environmental degradation (protection area), etc. In addition, this approach represents a realistic basis for the development of modern management of natural disasters.
Vulnerability refers to not only the possible physical effects of a natural hazard, but the way it affects human life and property. Vulnerability to a given hazard depends on (Nelson, A.S., 2009):

- Proximity to a possible hazardous event
- Population density in the area proximal to the event
- Scientific understanding of the hazard
- Public education and awareness of the hazard
- Existence or non-existence of early-warning systems and lines of communication
- Availability and readiness of emergency infrastructure
- Construction styles and building codes
- Cultural factors that influence public response to warnings

In general, less developed countries (like Serbia and Macedonia) are more vulnerable to natural hazards than are industrialized countries because of lack of understanding, education, infrastructure, building codes, etc. According to Nelson (2009) hazard assessment consists of determining the following:

- when and where hazardous processes have occurred in the past.
- the severity of the physical effects of past hazardous processes (magnitude).
- the frequency of occurrence of hazardous processes.
- the likely effects of a process of a given magnitude if it were to occur now.
- and, making all this information available in a form useful to planners and public officials responsible for making decisions in event of a disaster.

Some of these aspects will be analyzed on the area of P**č**inja catchment, which lay between Macedonia and Serbia and is characterized with significant vulnerability of some natural hazards. From appropriate maps, area of category or degree of vulnerability to some hazards is calculated, and on the end, comprehensive map of vulnerability to several natural hazards is presented.

General characteristics of Pčinja catchment area

Pčinja River is one of the largest left tributaries of Vardar River, which drainages northeastern part of Republic of Macedonia and southeastern endless part of Serbia. According to digitalized topographic maps data, river length is 135 km, divide length is 366 km, and catchment area is 2877,3 sq km. From whole area, 2339,3 sq km (81%) lye in Republic of Macedonia, and 538 sq km (19%) belongs to the Republic of Serbia. Because of large drainage basin in the Republic of Macedonia (9,1% of country area), Pčinja has great significance for many aspects (water supply, irrigation, water balance) (Milevski, I., Dragićević, S. and Kostadinov, S. 2007). It is important that in the area of Pčinja catchment living about 200 000 inhabitants, most of them in municipality of Kumanovo (105 480), then Lipkovo (27 058), Staro Nagoricane (4 840), and part of Petrovec (8 255) in Macedonia, as well as Presevo (8 009), Bujanovac (10 864) and Trgoviste (3 369) in Serbia.

Table 1. The general morphometric characteristics of catchment area

drainage basin area, A	2877.3 km^2
drainage basin perimeter, O	366 km
drainage basin length, L	135 km
drainage density, G	1.3 km/km^2
local erosion basis, Be	195 m
mean elevation, Nsr	773 m
mean altitudinal difference, D	578 m
mean slope of drainage basin, Jsr	13º
stream bed slope, Jt	10.8‰

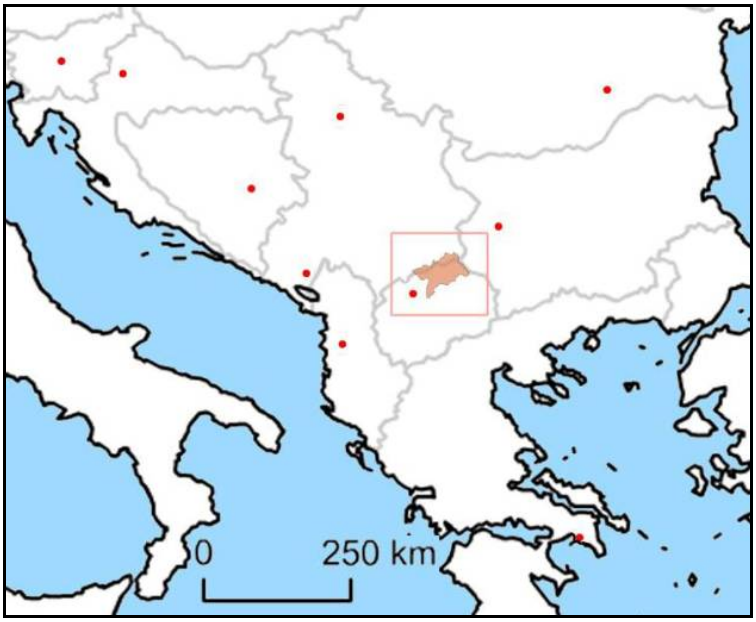

Figure 1. Location map of the Pčinja catchment on Balkan Peninsula

Methodology

The emergence, scope and duration of natural disasters in most cases can not be predicted in advance, but for certain phenomena, based on experience, statistical methods and data modeling, and considering the place of occurrence, can assume that it will come to them. Methodological approach involved the analysis of watershed Pčinja in terms of individual vulnerability to some types of natural disasters, and with their compensive presentation, assessment of the total area and the degree of vulnerability of the entire space. For this reason, areas endangered by particular natural disasters singled out, then is determined their percentage in respect to the total watershed area, and the total area of Pčinja catchment endangered by natural disasters.
Recent state of the basic parameters is shown via analytical maps, and then is made syntetized map of vulnerability of this area by natural disasters. Rating vulnerability of Pčinja catchment is represented through the assessment of risk (vulnerability) from natural disasters, which also defines the areas with restrictions based on:

- seismic vulnerability of the terrain (seismic hazard);
- engineering-geological conditions and possibilities of terrain for building (landslides and un-stable slopes, excessive erosion, torrent flows);
- climatic characteristics (intense precipitation, hail, drought);
- hydrological characteristics of terrain (areas affected by floods);

Assessment of geohazards is prepared by analysis of existing seismic maps, while landslide potential and excess erosion risk is estimate through appropriate methodology. Assessment of atmospheric hazards involves spatial distribution of extreme temperatures, intense rainfall (heavy rain), and average number of days with the hail and identification of areas vulnerable to drought. The hydrological hazards (hydro-hazards) involve determination of hydrological extremes, while the biohazards involve identification of areas endangered by fires. Based on these analyses the ability to create generalized map of natural hazards in the territory of Pčinja catchment will be achieved, with areas vulnerable to certain natural treats, as well as the total area endangered from hazards.

Analysis of geohazards in Pčinja catchment

Planning and arrangement of the area from the standpoint of securing the protection of the earthquake is part of the spatial and urban planning. Seismic hazard is part of natural hazards and represent the likelihood of occurrence of earthquakes with appropriate characteristics, in a certain period of time and at a certain place that will be manifested in a specific way to the observed location.

In order to properly estimate the field seismicity, seismic regionalization of defining conditions of seismicity was performed which get ideas about site of appearance and strength of future earthquakes. Except for the use of planning area, the expected strength of the earthquake is of great importance for the modification of intensity of erosion processes. Thus, unless human casualties and material losses, earthquakes can cause changing of the existing natural conditions marked by the appearance of other natural disasters (synergy effect). Namely, they can cause the appearance of slumps, landslides, collapse of a topographic surface, river flooding, etc.
The maximum intensity of earthquakes in the Pčinja catchment according to the classification belongs to moderately (7°) and a significantly (> 8°) vulnerable areas, which is the limiting factor of its spatial development. Of particular importance is the fact that a seismic risk areas are densely populated, and therefore are very large risks for the population, settlements and buildings.

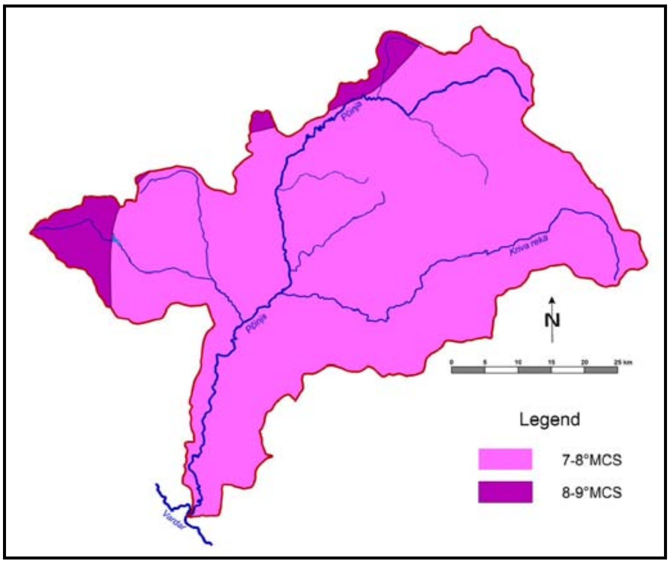

Figure 2. Seismic map of Pčinja catchment for reverse period of 100 years (according to Vukasinovic M., 1987)

Table 2. Areas endangered with different degree of seismic activity in the Pčinja catchment for reverse period of 100 years

Seismic risk (°MCS)	Area [km^2]	From total area (%)
7-8	2707.16	94.09
8-9	170.14	5.91
Total	***2877.30***	***100,00***

Defining the vulnerability of landslides and other forms of mass movements is based on knowledge of the engineering-geological characteristics of terrain, and then the knowledge of the effects of external factors on the geological environment. In defining of possibilities for the emergence of landslides, determination of initial geological materials (parent rocks) was performed, then quantitative geomorphologic analysis of the field, biological indicators, anthropogenic activities, etc. As we now, a perfect assessment method for landslide susceptibility does not exist (Ercanoglu and Gokceoglu 2002). For this purpose, within the Pčinja river basin, we define a "landslide hazard zone" (LHZ) as the area of possible (or probable) short-term evolution of an existing landslide, or a group of landslides, of similar characteristics (Reichenbach et al. 2005), identified from the topographical and geological maps or observed in the field. The proposed method complies with the existing and widely accepted definitions of landslide hazard (Varnes 1984; Guzzetti et al. 1999a, 1999b). Landslide hazard zone were identified based on the local topographic, morphological and geological settings, and the existing and past landslides that can be identified in the study area.

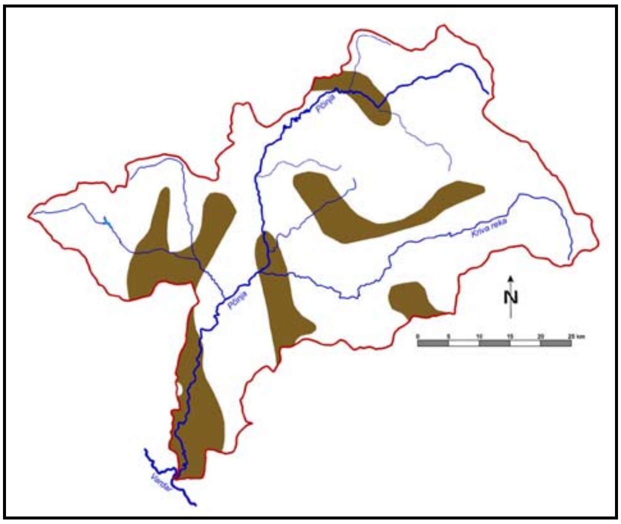

Figure 3. Landslides hazard zones in the Pčinja catchment

Based on the analysis carried out revealed that landslides affect vulnerable area 595.47 km^2, or 20.70% of the total area of Pčinja catchment.

Accelerated (anthropogenic) soil erosion, can have significant effects on limiting the use of natural resources and represent a serious risk in certain areas. Stronger categories are affected by erosion is more than 35% of the territory of Serbia (VOS, 2001) and 38% of the territory of Macedonia (Djordjevic et al., 1993). As is known, Pčinja catchment is always indicated as an example of excessive erosion which includes a substantial part of the border region of Serbia and Macedonia. Due to the fact that Pčinja catchment is one of the basins with the strongest intensity of erosion in the region, this area was the subject of numerous investigations and modeling of the intensity of erosion (Rakićević T., 1975, Andonovski T., 1982; Andonovski T. and Kolčakovski D., 1989; Milevski I., 2001, 2005, Djordjevic et al. 1993; Milevski I. et al., 2007). After conducting extensive protection measures during the last 30 years of 20th century, the intensity of erosion in the Pčinja catchment is significantly reduced.

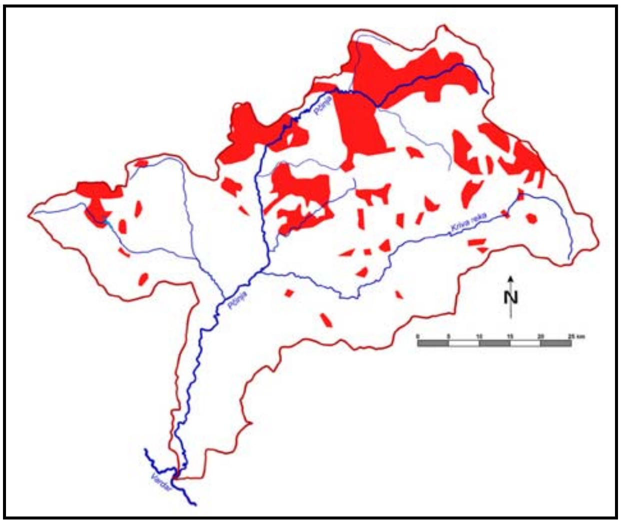

Figure 4. Areas of excessive erosion in Pčinja catchment
(according to: VOS, 2001 and Djordjevic et al., 1993)

In addition to water supply, problems of erosion, flood and sediment affects the other branches of the economy. Torrents and deposits threaten settlements, transport infrastructure (roads, railways, bridges, etc.) and agricultural land. It is, therefore conclude that 516.23 km^2 or 17.94% of Pčinja catchment is endangered by stronger categories of torrential and erosion processes, and this is a limiting factor of its development. It is important to stress out that downstream part of Pčinja River (from mouth of Kriva River) is largely endangered by excess deposition of eroded material, especially near v. Šupli Kamen and south of v. Pčinja. These deposits are also highly polluted by disposal waters from Kumanovska River and city of Kumanovo, representing a high treat to agricultural production and humans in this region.

Assessment of floods hazards in the Pčinja catchment

Last years Serbia and Macedonia was threatened by floods caused by small watercourses i.e. torrent flows, and this is directly related to the intensity of erosion process. Endangered are the villages, roads, industry, agricultural areas, tourist centers. When it comes to torrential flows, it is necessary to emphasize that in Serbia, according to the cadastre of torrential flows prepared in the fifties and sixties of XX^{th} century, there are more than 12,500 registered torrential flows (excluding Vojvodina). This means that virtually the entire Serbia south of the Sava and Danube (highland part of Serbia) is threatened. However, it should be noted that the most vulnerable areas lay in the border area: Grdelica gorges and ravines Vranjska, Binačke Morava River Basin in Kosovo and Metohija.
In Macedonia, most of the rivers has torrential character, and this also applies to area of Pčinja catchment. Until the seventies of XX^{th} century, from torrents was endangered settlements in the whole Pčinja catchment, especially in the Kumanovska and Kriva River sub-catchments. Parallel with the construction of hydro-systems, the regulation of torrents was apply, and thus most of the torrents were regulated. Nevertheless today also has torrential floods, but are far less frequently. Potential flood areas in the basin Pčinja affect an area of 184.41 km^2, or 6.41% of its total area.

Figure 5. Huge quantity of deposits and vegetation debris in Pčinja River form dam-like barrier on the bridge, rising the river level upstream and leading to flood (19.02.2010). The bridge itself is in danger.

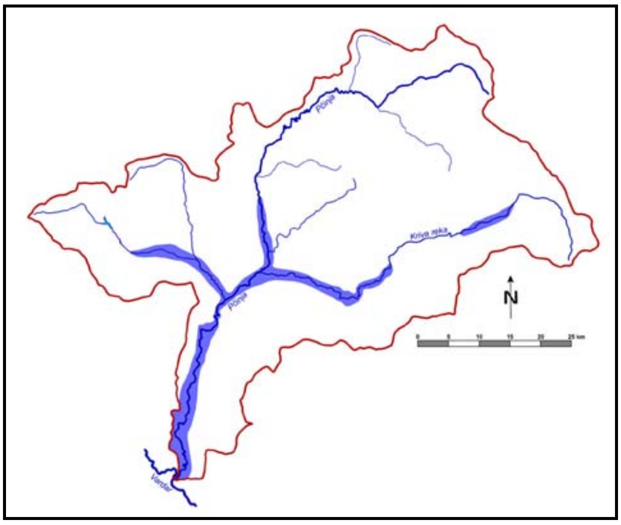

Figure 6. Potentially floods areas in Pčinja catchment

In last decades, largest flood in Pčinja catchment occur on 19th and 20th November 1979, when the peak flow was 350 m^3\sec. In this date is recorded higher transport of suspended sediments through the river profile Katlanovo, with 2800 kg\sec (Rakicevic T., 1975). Similar situation is with frequent floods of Kumanovska River, which until recently endangered lower parts of Kumanovo around the river. Anthropogenic factor here have indirect influence through reducing of discharge capacity of the riverbeds and channels (with waste and disposals), and lowering of wet profile and faster flooding. Large flood in Kumanovska River is recorded on 19th November 1979, when the peak flow reach 110 m^3\sec. causing severe damages. Because of frequent damages from floods, in recent years large regulation works in Kumanovska River were done, especially in the reach through Kumanovo. The river channel is cleaned from deposits and waste, while the banks are regulated. As a result, frequency of flash floods as well as consequent damages lowered significantly.

Assessment of atmospheric hazards in the Pčinja catchment

In addition to the hail (for which there is no reference map), drought is atmospheric hazard with the greatest consequences in Serbia and Macedonia. The main problem is the definition of criteria for determining the natural hazards caused by drought. Monitoring of drought has special attention while using a number of indices of humidity, ie. drought indices: standardized precipitation index (SPI) for the period from 1 to 24 months, which for operational purposes can be calculated daily, reserves of productive moisture in the soil water balance calculations, Palmer Z index, Palmer drought severity index, etc.

The analysis of the major indicators and parameters (the annual amount of precipitation, precipitation regime, the analysis of temperature and humidity in the vegetation period, the lack of water in the soil) to determine the duration, and intensity of droughts frequency, singled out four areas in Serbia (Rakićević T., 1988). The greatest absolute length of the drought was observed in Vranje and it amounted to 61 days. This extreme drought began on 22 June and ended on 21st August 1928th year. In Macedonia, droughts are more prominent. During 1956. in Gevgelija, Bitola and Prilep are recorded the extreme drought that lasted 88 days, in Demir Kapija and Strumica 87 days, and in Kumanovo, Kocani and Stip 86 days (Lazarevski A., 1993). It is characteristic that in last decades, frequency and length of drought are more prolonged, which is attributed to the effect of global warming (Bergant, K., 2006).

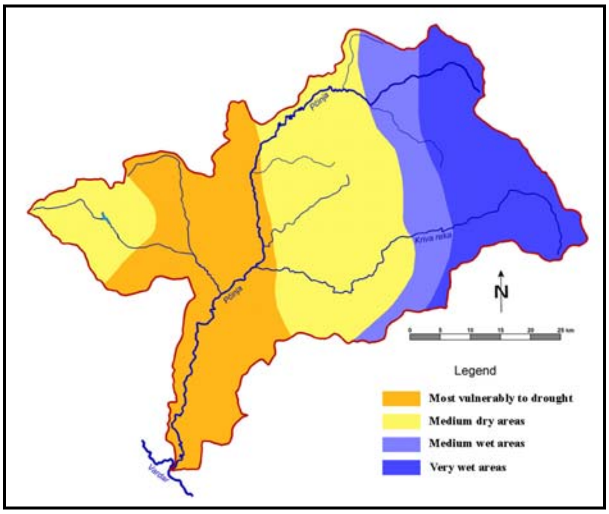

Figure 7. Map of the areas vulnerabile to drought

Table 3. Areas endangered by drought in Pčinja catchment

Category of vulnerability	Endangered area [km^2]	Part of the total area [%]
Most vulnerably to drought	886.61	30.81
Medium dry areas	1090.96	37.92
Medium wet areas	341.28	11.86
Very wet areas	558.45	19.41
Total	2877.30	100.00

Conclusions

Each territory on the Earth's surface depending on the complex physical-geographical conditions has its own peculiarities and natural predisposition for certain phenomena and processes, and thus for a certain kind of natural disaster. What is the vulnerability of natural spaces is an important factor in choosing the location and land use planning purposes, to determine the degree of concentration of physical structures and infrastructure facilities. Natural conditions most often represent the potential and limitations in disaster planning, organization and development of a space, and require adequate analysis before planning its development.

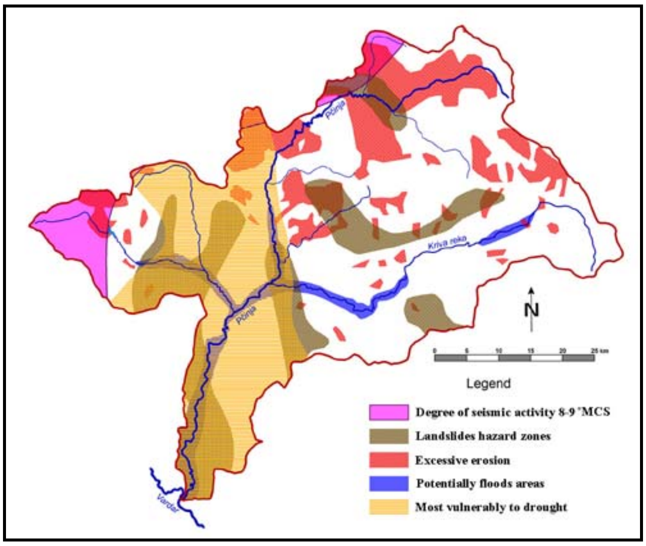

Figure 8. Comprehensive map of Pčinja catchment vulnerability to natural hazards

To be able to make proper assessment of the degree of vulnerabilities of space, i.e. restrictions on its use and development, it is nececery to accessible toward cadastral drafting vulnerability of space in the function of natural spatial and urban planning. On the basis of such knowledge and research, it can be made the list of points (zones) of potential hazards probability occurrence, extent and consequences based on the definition of risk. Logical consequence is the development of protection plans and priorities for care in planning the border region of Serbia and Macedonia. The risk from natural hazards, while it cannot be eliminated, can, in some cases be understood in a such a way that we can minimize the hazard to humans, and thus minimize the risk. To do this, we need to understand something about the processes that operate, and understand the energy required for the process. Then, we can develop an action to take to minimize the risk. Such minimization of risk is called hazard mitigation.

References

Andonovski T., 1982: *Erosion areas in SR Macedonia. Proceedings from XI Congress of FRY geographers, Budva (in Macedonian)*

Andonovski T., Kolcakovski D., 1989: *Geomorphological characteristics of Kozjacia and Sredorek. Part of the project: Potential possibilities for development of Kozjacija and Sredorek. Institute of Geography, FNSM, Skopje 24-30 (on Macedonian)*

Bell F.G., 1999: *Geological hazards. Their assessment, avoidance and mitigation. E&FN Spon, London and New York.*

Bergant, K., 2006: *Climate change scenarios for Macedonia-review of methodology and results. University of Nova Gorica, Centre for Atmospheric Research. Nova Gorica, Slovenia*

Blinkov I., Mincev I., 2008: *Transnational methodology for development of risk maps, project RIMA-DIMA (Risk Management, Disaster Management and Prevention against Natural Hazards in Mountains/Forested regions)–code No.04MAC03/03/01/001/5D102; INTERREG IIIb Cadses project; 2006-08.*

Blinkov I., 2008: *Prevention and management of water related natural hazards, Regional conference of Balkan green parties, Sustainable management of water resources in the Balkan region", Skopje 1.10.2008*

Dragicevic S, Filipovic D., 2009: *Natural conditions and disasters in spatial planning and protection. Belgrade: Faculty of Geography.*

Djordjevic M., Trendafilov A., Jelic D., Georgievski S. & Popovski A., 1993: *Erosion map of the Republic of Macedonia-textual part, Water Development Institute, Skopje, 89 pp. (on Macedonian).*

Ercanoglu M, Gokceoglu C., 2002: *Assessment of landslide susceptibility for landslide-prone area (north of Yenice, NW Turkey) by fuzzy approach. Environ Geol 41:720–730*

Guzzetti F, Cardinali M, Reichenbach P, Carrara A., 1999a: *Comparing landslide maps: a case study in the upper Tiber River Basin, central Italy. Environ Management 25 (3): 247–363*

Guzzetti F, Carrara A, Cardinali M, Reichenbach P., 1999b: *Landslide hazard evaluation: a review of current techniques and their application in a multi-scale study, Central Italy. Geomorphology 31:181–216*

Milevski I., 2001: *Recent erosion in Kumanovo Basin and its treatment in space planning. Master thesis-manuscript, Institute of Geography-FNSM, Skopje*

Milevski I., 2005: *Characteristics of recent erosion in Kumanovo Basin. Bulletin for Physical Geography No 2, Institute of geography, Skopje, 25-45 (on Macedonian)*

Milevski, I., Dragicevic, S., Kostadinov, S., 2007: *Digital elevation model and satellite images in assessment of soil erosion potential in the Pčinja catchment. Bull Serbian Geogr Soc, 87 (2), Belgrade, 11-20.*

Nelson A.S., 2009: *Natural Disasters & Assessing Hazards and Risk. Lecture-text from the web-page http://www.tulane.edu/~sanelson/geol204/index.html*

Reichenbach P, Galli M, Cardinali M, Guzzetti F, Ardizzone F., 2005: *Geomorphological Mapping to Assess Landslide Risk: Concepts, methods and applications in the Umbria Region of Central Italy. In: Glade T, Anderson M, Crozier M (eds) Landslide Hazard and Risk, John Wiley & Sons, England, pp 429-468.*

Spatial Plan of Republic of Macedonia (2004)

Varnes DJ., 1984: *Landslide hazard zonation: a review of principles and practice. IAEG Commission on Landslides and other Mass-Movements, UNESCO Press, Paris.*

Vodoprivredna osnova Srbije, 2001.

Vukasinovic M., 1987: *Seismic map of Serbia for the reverse period of 100 years. Beograd: Community of seismology of SFRY, Seismic department of SR Serbia.*