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ORIGINAL PAPER

Vulnerability to natural disasters in Serbia: spatial and temporal comparison

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Abstract The frequency of natural disasters and the extent of their consequences at a global level are constantly increasing. This trend is partially caused by increased population vulnerability, which implies the degree of population vulnerability due to high-magnitude natural processes. This paper presents an analysis of vulnerability to natural disaster in Serbia in the second half of the twentieth and the early twenty-first century. Vulnerability changes were traced on the basis of demographic–economic indicators derived from statistical data for local government units (municipalities) provided by the Statistical Office of the Republic of Serbia. Calculations were performed in the geographical information system environment. The results of the study show that spatial and temporal vulnerability variations are causally correlated with changes in the selected components. Significant rise of vulnerability is related to urban areas, while lower values are characteristic for other areas of Serbia; this is primarily a consequence of different population density.

Keywords Natural disasters · Vulnerability · Demographic–economic indicators · Serbia

1 Introduction

Natural disasters are sudden events caused by high-magnitude natural processes which affect regular human activities, cause casualties, loss or damage of property to an extent surpassing the capacity of a community to cope with them. Numerous similar definitions can be found in relevant scientific and expert literature (UNISDR 2009a; Wisner et al. 2004; Đarmati and Aleksić 2004). Since its beginnings and through all stages of its development, the human community was exposed to devastating effects of natural disasters

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and their grave consequences, involving large numbers of casualties, significant material loss as well as great efforts and vast investment to overcome them. As their distribution is global—meaning that they occur in almost all inhabited areas of the world—natural disasters may affect any country regardless of the level of its economic or social development or the type of political system. However, the consequences of natural disasters show that the mentioned characteristics of a society directly determine their scope and extent, and, most commonly, the former is reversely proportional to the latter. Therefore, the casualties from natural disasters are the most numerous in undeveloped or developing countries, which are, along with an unstable political and economic situation, additionally burdened with a huge population, low level of infrastructure capacity, education and awareness of natural disasters, a degraded environment, etc. (Alcántara-Ayala 2002). The extent of natural disaster consequences is lesser in developed countries (Kahn 2005; Raschky 2008) with an established natural disaster management system, which includes a set of activities undertaken before a disaster with the aim of preventing and mitigating potential consequences, as well as activities implemented after a disaster in order to recover and overcome the consequences.

According to the International Emergency Disasters Database (EM-DAT), between 1975 and 2008, 8,866 natural disasters (not including epidemics) occurred, killing 2,286,767 people; out of that number, 1,786,084 disaster victims were from undeveloped or developing countries (UNISDR 2009b).

2 Theoretical framework

Natural disasters have always attracted great attention. Accordingly, over time, a great body of knowledge based on various experiences has been built up and constantly developed and enhanced. In some periods, the evolution of that knowledge gave rise to various interpretations of natural disasters. These interpretations are marked by changing understanding of disaster genesis, their consequences and disaster mitigation measures.

Smith and Petley (2009) and Smith (2013) give an overview of various phases through which the attitude toward natural disasters has developed. In the past, the great natural catastrophes were interpreted as inevitable, external events which, due to their magnitude, occasionally brought about the displacement of human settlements. On the other hand, the current approach treats the natural disasters trough a complex interaction between nature and society, which enable long-term hazard management in accordance with the needs and capabilities of the local communities.

When dealing with natural disasters, it is essential to understand that they are a result of collisions between natural and socioeconomic processes (Wisner et al. 2004), whereby the issue of the relationship between natural disaster risk components (hazard, vulnerability, resilience) often arises, as well as the dilemma which of the three components is more important in that relationship.

There is apparently a strong two-way and multi-level relationship between natural and social processes. On the one hand, a natural process of some magnitude affects the human community, whereas on the other hand, the human community with its activities, various development processes and actions (urbanization, population density, state of environment, the state of natural resources conservation, etc.) shapes an environment that may contribute to an increased frequency of occurrence of that natural process and various degrees of vulnerability to its effects. The vulnerability as component of disaster risk is the factor which largely determines the level and scope of consequences of a natural disaster.

Accordingly, the control over this component may have influence on the expected effects. Research has shown that the number of victims is considerably smaller when a community is aware of the risk and educated what to expect and how to react in such situations, and particularly when it has timely information about the type and intensity of a disaster expected in a particular territory (Morrissey 2004). Kovačević-Majkić et al. (2014) wrote about the current state and importance of risk education in Serbia. Examples of children's reaction during the earthquake in Serbia (November 2010) confirm that risk awareness is necessary (Panić et al. 2013).

At about the same time when numerous definitions were formulated, the pressure and release model (PAR) was devised; it is considered to be the key concept of the sustainable development of a community (Wisner et al. 2004). It focuses on the existing relations between the effect of a natural hazard on the human community and a great number of social factors and processes which shape (generate) vulnerability, which are classified in the "root causes," "dynamic pressures" and "unsafe conditions."

The concept of natural disaster vulnerability was firstly introduced with the intention to focus on vulnerability of buildings and infrastructure, but subsequently it was significantly expanded and primarily directed toward the vulnerability of human communities. It was defined so as to include spatial and temporal changes within a society, as well as to show the attitudes of various social groups toward the risk from the occurrence of particular types of natural disasters and methods to mitigate their impact (Bohle et al. 1994). Over time, the concept was further expanded to include the environmental issues. The current understanding of vulnerability includes various aspects grouped into four areas, which are in constant interaction. The division of vulnerability to natural disaster into four main types—physical, social, economic and ecological—is based on that understanding (UNISDR 2004; Wisner et al. 2004; Cutter et al. 2003; Kumpulainen 2006). Answers to the question what makes someone or something vulnerable have highlighted various aspects of the phenomenon and have resulted in various interpretation of disaster vulnerability. For example, along with many other characteristics which contribute to the vulnerability of risk elements, age (elderly and children), gender, race/ethnicity and socioeconomic status are generally accepted and most commonly analyzed characteristics which define the population vulnerability and social vulnerability (Cutter et al. 2003; Wisner et al. 2004; Cutter and Finch 2008; Donner and Rodríguez 2008). Numerous studies highlight the differences in the degree of vulnerability between various age groups—e.g., the vulnerability of children (Wisner et al. 2004; Anderson 2005; UNISDR 2007; Ronan et al. 2010) and elderly people (Ngo 2001; Powell et al. 2009; Wang and Yarnal 2012), genders (Fothergill 1996; Enarson and Meyreles 2004; Neumayer and Plümper 2007), and various ethnic groups (Pulido 2000; Bolin 2007), as well as the differences in the degree of vulnerability depending on the socioeconomic status of the population (Fothergill and Peek 2004).

Due to a very broad theoretical and temporal framework, there are numerous definitions of natural disaster vulnerability which vary depending on research perspective (Cutter 1996; Brooks 2003). Some of them are focused on a single factor, such as exposure to natural disasters or social aspects of a community (gender, age, etc.), whereas others highlight the combination of several factors. Birkmann (2005) has traced how the concept of vulnerability has changed and expanded. McEntire (2011) has presented a classification of vulnerability concepts based on the perception of vulnerability to natural disaster. According to that classification, one group of authors defines vulnerability as the *conditions determined by physical, social, economic and environmental factors or processes, which increase the susceptibility of a community to the impact of hazards* (UNISDR 2004, p. 16), i.e., as the *potential for loss* (Mitchell 1989, as cited in Cutter 1996, p. 531), and we could name it sensu stricto vulnerability. Another group of authors, including Wisner et al. (2004, p. 11), defines vulnerability as *characteristics of a group or individual in terms of their capacity to anticipate*, *cope with*, *resist and recover from the impact of a natural hazard* (*an extreme natural event or process*). There is also a third group, in which the authors integrate the previous two definitions of vulnerability (Birkmann et al. 2006; Pelling and Uitto 2001; Hufschmidt 2011). Cutter and Finch (2008) have pointed out that according to some authors, vulnerability is viewed as a dynamic process that involves coping capacities. Accordingly, such an approach, supported by the second and third groups of authors, could be named sensu lato vulnerability.

Diverse interpretations of vulnerability also lead to diverse interpretations of the vulnerability of poor and rich communities. Densely populated areas are indeed more vulnerable, and this is a matter of general consensus among authors on disaster vulnerability. However, as far as poor communities are concerned, vulnerability may be viewed from two perspectives. On the one hand, the property of such communities has lesser value compared to the property of the economically more developed communities. In that respect, the poorer may be considered less vulnerable, speaking in absolute numbers, and not proportions. On the other hand, there is another concept/interpretation that also takes into consideration coping capacities. Accordingly, wealthy communities are less vulnerable because they have more resources for disaster recovery, while poor communities encounter greater difficulties while recovering from a disaster. Therefore, taking into consideration recovery capacity, the poorer the community, the more vulnerable it is. (Fothergill and Peek 2004; Masozera et al. 2007; Donner and Rodríguez 2008).

Although there are authors who look critically upon the multitude of similar concepts and definitions of vulnerability, suggesting that in order to measure vulnerability, it is necessary to define it correctly and precisely (Birkmann 2006), it is still possible to single out the key elements of vulnerability that include the process (stress) to which a community is exposed, its sensitivity and, in some cases, the community's capacity to recover after a crisis (Adger 2006). Quantification of vulnerability is a complex problem because it involves a transfer of theoretical knowledge into exact vulnerability assessments, which must rely on mathematical models and satisfy the applicability criteria. It usually implies the incorporation of a significant range of qualitative and quantitative parameters which should enable to recognize and identify various processes and predict consequences that could arise from the assessed vulnerability (Adger 2006). According to the Fuchs et al. (2012), there are two current approaches in vulnerability assessment: deductive and inductive.

The approach to the study of vulnerability presented in this paper is based on the theory that the risk from natural disasters is a result of three main components (hazard, vulnerability and the capacity to recover) (UNISDR 2004). Therefore, among the vulnerability concepts presented by McEntire (2011), we have selected the one that does not include the capacity to recover, but treats vulnerability as susceptibility of a spatial element to being damaged by a natural process. Among the concepts described by Birkmann (2005), who has outlined the widening of the concept of vulnerability, we have decided to use the first one, where vulnerability is seen as an internal risk factor (intrinsic vulnerability), and not as a dualistic, multiple or multidimensional concept. A similar approach has been applied by Holand et al. (2011), who view vulnerability as *an inherent property of human system before a potential event and independently from hazard exposure*. Another reason for this lies in the fact that we have tried to quantify vulnerability. Therefore, it was necessary for measurement purposes, as Cutter and Finch (2008) would say, to analyze all components of risk separately in accordance with sensu stricto concept of vulnerability. From that point of view, the economic indicator is independent from the capacity to recover and it is, consequently, directly proportional to the vulnerability index, i.e., lower values of the indicator correspond to lower vulnerability and vice versa. Furthermore, considering Fuchs et al.'s (2012) classification, we have used deductive vulnerability assessment, meaning we have identified, compared and quantified vulnerability of chosen areas using different indicators.

3 Methodology

3.1 Study area

Vulnerability of Serbia to natural disasters is a result of its geographical position (Southeast Europe, Balkan Peninsula), natural and socioeconomic characteristics. During the observed period (1971–2002), Serbia experienced many types of natural disasters, the most common being floods, earthquakes, landslides and forest fires (National Assembly of the Republic of Serbia (NARS) 2011; Milošević et al. 2012; Gavrilović et al. 2012; Ristić et al. 2012; UNICEF and UNISDR 2011; Aleksić and Jančić 2011). They have usually been medium in intensity, with consequences most commonly limited to material loss and only rarely involving human victims. According to the National Strategy of Protection and Rescue in Emergency Situations of the Republic of Serbia (2011), about 5,000 natural disasters were recorded in Serbia in the observed period (1971–2002).

Due to its frequency, flood as a natural disaster poses the greatest risk to the territory of Serbia (Gavrilović et al. 2012; UNICEF and UNISDR 2011). Torrential floods are the prevailing type (Ristić et al. 2012). During the past 50 years, a great number of floods have been recorded in almost all watercourses; particularly severe among them were those of 1965 and 2006. Floods threaten 18 % of Serbia's territory along large rivers (1.6 million ha), as well as 512 large settlements, a great number of industrial facilities, 4,000 km of roads and 680 km of railroads (Spatial Plan of the Republic of Serbia 2010–2014–2020 2010). According to data provided by the Directorate of Water of the Republic of Serbia, the material damage caused by floods over the past several years is estimated to be 25 million euros a year. Although floods are the most frequent natural disaster in Serbia, the available flood protection capacities are not satisfactory. The region exposed to the greatest flood risk is the Autonomous Province of Vojvodina. Torrential floods occur both in urban and rural areas, threatening people and property. Over the past 60 years, floods killed more than seventy people and caused material damage estimated to be eight billion euros (Ristić et al. 2012).

Seismic activity is also very common in the territory of Serbia, where about 50 % of the territory is potentially vulnerable to *M* 7 earthquakes and <20 % to *M* 8 earthquakes (UNICEF and UNISDR 2011). The majority of earthquakes occur in Central Serbia: Kopaonik, Mionica, Rudnik, Trstenik (Radovanović 2008) and south Serbia (NARS 2011). In many countries, data related to victims and damage are not systematized and up-to-date (Abolmasov et al. 2010). However, it should be pointed out based on published data that the earthquake that hit Kraljevo in November 2010 (*M* 5.3 earthquakes) caused great material damage and took two human lives (Seismological Survey of Serbia 2010).

About 25 % of the territory of the Republic of Serbia is affected by landslides: 3,137 active or potential landslides have been recorded. Landslides threaten inhabited places and buildings (about 3,727 buildings and about 7,755 people), as well as traffic infrastructure—most commonly local and regional roads (NARS 2011).

Drought has various negative effects on agriculture, water supply, energy and health management, environmental protection and other human activities. In the Balkan Peninsula, as well as in the broader Mediterranean region and Southeast Europe, an increase in frequency and intensity of draughts due to climate change has been observed. A similar trend is expected to continue in decades to follow. Meteorological observation data show that the most severe droughts in the territory of Serbia have been recorded during the past two decades, particularly in northeast, east and south areas (NARS 2011; Spasov 2003).

Fires are frequent and widespread in the territory of Serbia particularly during summer months, as a result of high temperatures and low precipitation. The most severely threatened are the forest areas in east and southeast Serbia (Aleksić and Jančić 2011).

In Serbia, disaster fatalities are not frequent (usually, 1–2 persons a year are killed in floods or fires), whereas economic damage is considerable. Unfortunately, there is no systematic database available on economic damage; therefore, it is very difficult to compile data and almost impossible to compare them.

3.2 Mathematical model and analytical process

The conceptual model used in the study of natural disaster vulnerability in Serbia is shown in Fig. 1. Although there are numerous studies and classifications of vulnerability of places (Cutter 1996; Wisner et al. 2004; Wolf 2012), not a single study dealing with any component of vulnerability at a local level has been done for the territory of the Republic of Serbia. Accordingly, the aim of the research presented in this paper is to establish the vulnerability to natural disaster of Serbia based on the indicators that describe it best. In abundant literature on disaster vulnerability, a "vulnerability index" is commonly used as a measure of vulnerability. Various methods are used to calculate it, and authors use various terms to designate it. According to Cutter et al. (2003), 42 variables could be used to calculate vulnerability. Depending on available data, it may be the Composite Vulnerability Index, according to Briguglio (2003; 2004 cited in Villagrán 2005), and it is calculated based on four components. Kumpulainen (2006) lists 16 potential indicators that are used to calculate the vulnerability index. However, within the ESPON Hazard Project, only four indicators were fully available and the term "Vulnerability Index" was used. Within the IADB-ECLAC-IES Programme, one of the four indices in the devised Risk Management model was the Prevalent Vulnerability Index (Villagrán 2005). Depending on the type of vulnerability, it includes the social, economic and ecological components and uses related indicators. When it focuses on the society and the social component, it is usually designated as the Social Vulnerability Index (Vincent 2004; Cutter et al. 2000, 2003; Cutter and Finch 2008). The here presented study has been conducted through an analysis of the vulnerability index calculated from selected parameters, followed by a spatial and temporal comparative analysis of the vulnerability index.

In the analysis of demographic–economic vulnerability, municipalities in the territory of Vojvodina and Central Serbia were taken as spatial unit. Due to the lack of data, the territory of Kosovo and Metohija was not covered by the analysis.[1] At the time of the 2002 Population Census, Serbia (without Kosovo and Metohija) consisted of 161 municipalities (Fig. 2). Such a detailed administrative division has enabled a spatial analysis and an insight into specific differences among municipalities. The study of vulnerability covers the period between 1971 and 2002, and analyses were made for census years: 1971, 1981,

[1] Territory of Autonomous Province Kosovo and Metohija is under UN protectorate, Resolution 1244, UNMIK.

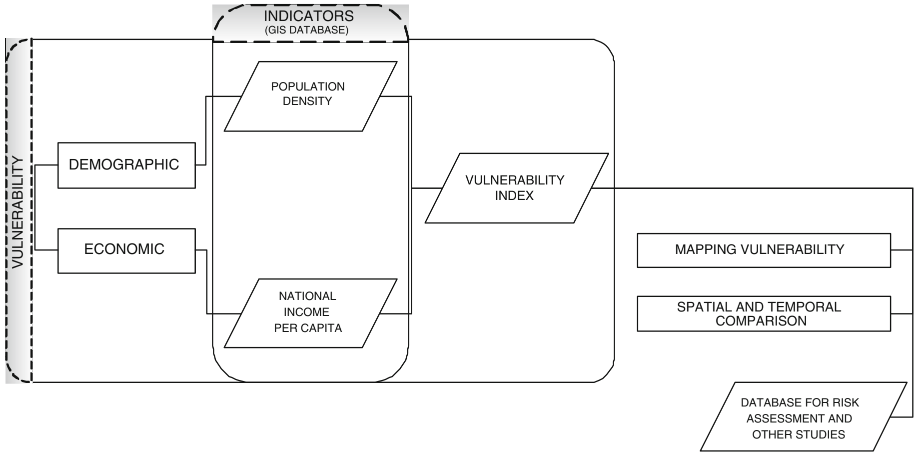


Fig. 1 Conceptual model of vulnerability analysis

1991 and 2002. The results of the 1948, 1953 and 1961 Censuses of population are not substantially compatible with other data and were not taken into consideration. Data of the 2011 Population Census were also included in the study, but the economic indicator we have used (national income per capita; by the Statistical Office of the Republic of Serbia) has chronological series only until 2005. Due to these causes, we do not have comparable data for 2011. However, in order to show a more contemporary situation, instead of the national income per capita, we have used average net salaries and wages per employee. Data relevant to the study of natural disaster vulnerability were collected, organized, processed, analyzed, interpreted and presented in a GIS environment using the *Geomedia* software.

As it can be observed in Fig. 1, the vulnerability measurement was carried out through several phases:

1. selection of vulnerability indicators (Fig. 3);
2. data collecting;
3. redistribution of data into equivalent territorial units—this was necessary because municipality boundaries changed;
4. data normalization aimed at calculating the vulnerability index;
5. calculation of the vulnerability index.

1. The selection of vulnerability indicators was a comprehensive and complex task which had to fulfill several requirements. In order to meet the first requirement, it was necessary to select such indicators which not only describe the phenomenon well, but are also available for municipalities and can be chronologically traced. Few indicators could meet the requirement of being available at the municipal level. Most commonly, data were available only at the national or regional levels. Another requirement implied that data covered the entire period from 1971 to 2002. In other words, data had to be available for each of the years in that period and had to be mutually comparable. The problem of data comparability was most commonly related to economic indicators. The reasons for this lie in changing methodologies for data collection, processing and presentation.

Among numerous social and economic indicators commonly used in studies of vulnerability and tested in the selection procedure presented in Fig. 3, two indicators were

Fig. 2 Geographical position and administrative divisions of Serbia

selected: population density, as an indicator of demographic vulnerability, and national income per capita, as an indicator of economic vulnerability.

Population density has often been used as an indicator of vulnerability, and due to Wisner's PAR model, it belongs to root causes of risk. This is one of the first demographic

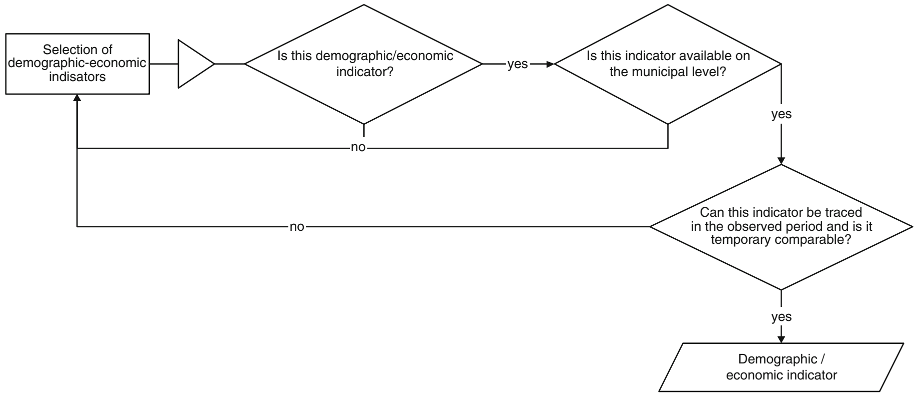


Fig. 3 Algorithm showing the selection of vulnerability indicators

indicators that we tested in our study. National income per capita was selected as an indicator of economic vulnerability and is one of dynamic pressure causes due to PAR model. In international studies dealing with vulnerability, national income is used merely as one of many indicators in measuring economic vulnerability. It is gross domestic product (GDP) that is most commonly used as an economic indicator. There are several reasons why it could not be used in our study. Mutually comparable data related to GDP for each year were available only for larger territorial units: Serbia (national level), Central Serbia, Autonomous Province of Vojvodina, Autonomous Province of Kosovo and Metohija (macro-regional level), and only recently (from 2009) for the NUTS 2 level.

Due to various limitations (changing methodologies and components used in calculating GDP, changing values of the national currency, etc.), redistribution of raw data in order to obtain data at the local level and ensure their comparability throughout the period covered by the study could lead to multiplication of errors. This could compromise their relevance. Having in mind that one of the aims of this study has been to establish changes in spatial vulnerability over time, due to data availability and comparability, national income per capita (originally got at a municipal scale) was selected as one of the basic indicators of development at various levels of territorial administration. Although it is expressed in the national currency, whose value significantly varied over the observed period, through proportional transformation (calculating an index relative to the average national income, the value 100 has been assigned), these data became spatially and temporally comparable. We have selected net salaries and wages per employee as an economic indicator for 2011. It was multiplied by the number of employees per municipality. The value of the net salaries and wages per capita was thereby obtained, and it was transformed so as to make it relative to the average national income (to which the value 100 was assigned).

2. While collecting data, it was necessary to rely on the same type of data sources. We selected the following publications of the Statistical Office of the Republic of Serbia: comparative review of the number of population 1948–2002 (Statistical Office of the Republic of Serbia 2004a), 2011 Census of population (Statistical Office of the Republic of Serbia 2012a), municipalities in the Republic of Serbia 1971–2002 (Statistical Office of the Republic of Serbia 1973, 1983, 1993, 2004b) and municipalities and regions in the Republic of Serbia 2011 (Statistical Office of the Republic of Serbia 2012b). The data on municipal boundaries were provided by the Official Register of Administrative Units (Statistical Office of the Republic of Serbia), as of 2002.

3. As municipal boundaries changed over the observed period, it was necessary to redistribute data into equivalent territorial units. The boundaries as of the last year covered by the study (2002) were selected. All changes can be divided into three groups:

a. creation of new municipalities, this was the case in four municipalities: an area of 14 km^2 that formerly belonged to the Municipality of Merošina was annexed to the Municipality of Niš; Niška Banja (145 km^2) was excluded from the territory of the Municipality of Niš; Batočina (55 km^2) was excluded from the territory of the Municipality of Lapovo, whereas Sremski Karlovci (50 km^2) was excluded from the territory of the City of Novi Sad; they were given the status of independent municipalities.
b. parts of the territory of some municipalities were annexed to the neighboring municipalities; these areas did not exceed 6 km^2, i.e., they did not exceed 15 % of the territory of a municipality.
c. illogical changes were treated as incorrect data resulting from erroneous data entry, rounding errors or survey differences.

Territorial changes described under (b) and (c) were not taken into account because of their small size, whereas significant changes resulting from the creation of new municipalities were taken into consideration when determining the national income of these areas for the years when they were not independent municipalities.

4. As the data for the selected indicators were diverse (wide value ranges and different units used to express them), they had to be normalized, i.e., transformed and reduced to values between 0 and 1 in order to calculate the vulnerability index. This was done using the following equation Eq. (1):

$$\mathrm{Vi} = \frac{\{\ln(x) - \ln[\mathrm{Min}(x)]\}}{\{\ln[\mathrm{Max}(x)] - \ln[\mathrm{Min}(x)]\}}, \tag{1}$$

where Vi stands for the vulnerability indicator and x for variables (population density and national income per capita/net salaries and wages per capita).

5. The vulnerability index was calculated by summing demographic and economic vulnerability, and both indicators were equally weighted as is expressed by Eq. (2).

$$V = V_{\mathrm{d}} + V_{\mathrm{e}}, \tag{2}$$

where V stands for the vulnerability index, V_{d} for the demographic indicator and V_{e} for the economic indicator.

Expressed through the selected indicators, the vulnerability index is calculated using the following Eq. (3):

$$V = \rho + \mathrm{NI}, \tag{3}$$

where V stands for the vulnerability index, ρ for population density (demographic indicator) and NI for national income per capita (economic indicator).

For 2011, a "proxy" vulnerability index was calculated using Eq. (4):

$$V = \rho + \mathrm{NS} \tag{4}$$

where V stands for the vulnerability index, ρ for population density (demographic indicator) and NS for national net salaries and wages per capita (economic indicator).

After the vulnerability indexes had been calculated for all municipalities and all selected years (census years), a spatial and temporal analysis was carried out and the obtained values of the vulnerability indexes were compared (except for 2011), i.e., the spatial and temporal vulnerability variation was determined. The vulnerability indexes were divided into five categories of equal intervals; these values are presented in Table 1.

Having in mind that temporal changes in vulnerability may go in two directions (it may increase or decrease), two categories were established and within each of them a group of municipalities with a significant change in vulnerability was identified. Groups with significant change were determined with quartile division of the occurrence probability. The first quartiles (in the positive and negative direction) were labeled as extreme (with significant change), and the second, third and fourth quartiles were labeled as mean (those with less significant changes).

Finally, it was also necessary to establish whether the used indicators were good enough to measure vulnerability. Having in mind that data related to fatalities and damages were not available, we made correlative analyses with hazard indicators using data related to the most typical disasters in Serbia—and these are floods. In the analysis of floods, the quantitative method and data related to flood zones (Jaroslav Černi Institute for the Development of Water Resources 2013; Gavrilović et al. 2012) were used. Earthquakes and extreme temperatures have been correlated with vulnerability using qualitative methods and based on data on social (demographic and education) structures, the state of infrastructure, quality and age of buildings. The applied model does not discriminate forest fires because the most vulnerable municipalities are located in central city zones, where forested areas are small or negligible, while the most densely forested municipalities are the least vulnerable because they are the least populated, i.e., depopulated.

4 Results

The analysis of the vulnerability index for 1971 (Fig. 4a) shows that the most of the municipalities belonged to the second (118) category, which means that they had low vulnerability index values. The municipalities falling into these categories were evenly distributed in the territory of Serbia. In the territory of AP Vojvodina, the municipalities belonging to the third category (moderate vulnerability) prevailed. The fifth category with very high vulnerability index included 3 municipalities: the Belgrade city municipalities (the city of Belgrade consists of 17 municipalities) which are not only the administrative, but also economic centers. The municipalities with a moderate vulnerability index (13) included those within the sphere of influence of Belgrade, Novi Sad (the administrative center of the Autonomous Province of Vojvodina) and other large regional centers (Niš, Jagodina, Sombor). The category with a very low vulnerability index included 27 municipalities mostly in mountain areas marked by population decline. Some inhabited places in Burela, Vlasina, Krajište and the border areas between Central Serbia and the Autonomous Province of Kosovo and Metohija were left without population, or were

Table 1 Categories of the vulnerability index

No.	Vulnerability category name	Interval of the vulnerability index values
1	Very low	0.0–0.2
2	Low	0.2–0.4
3	Moderate	0.4–0.6
4	High	0.6–0.8
5	Very high	0.8–1.0

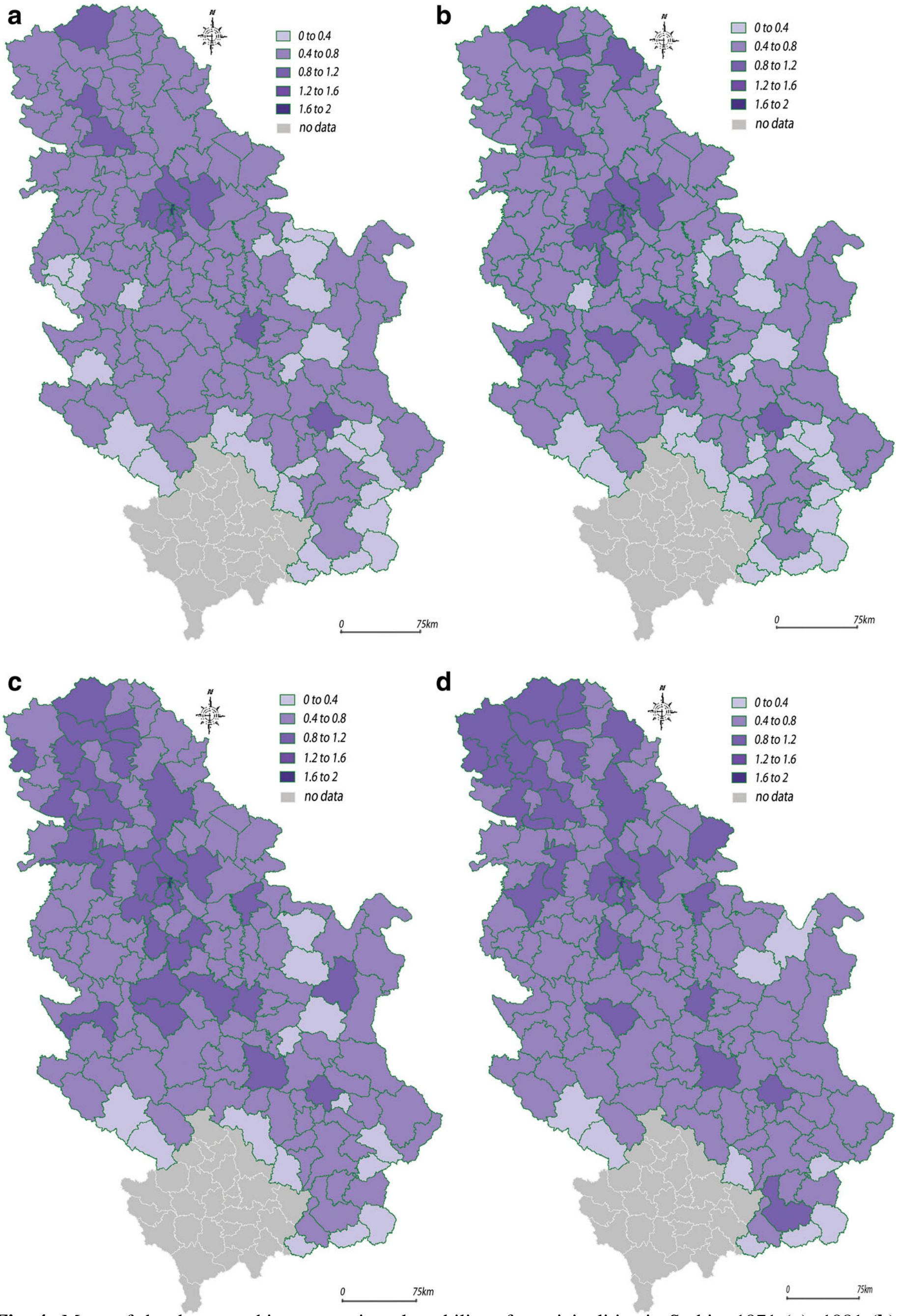
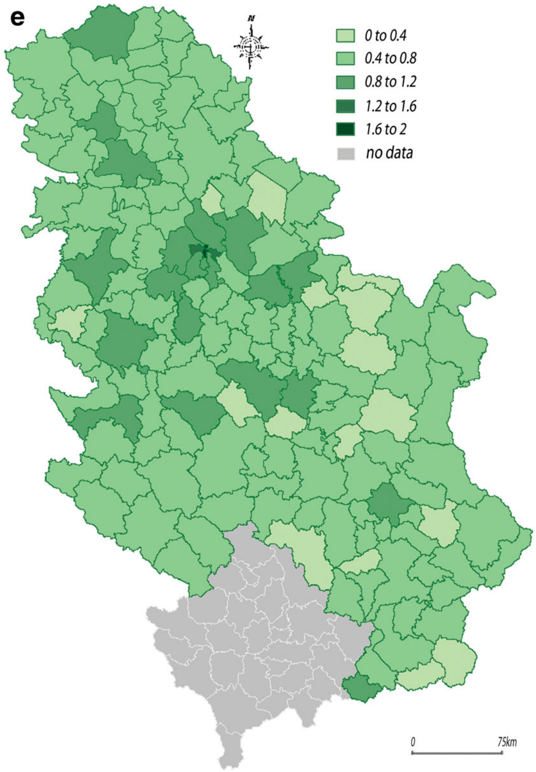


Fig. 4 Maps of the demographic–economic vulnerability of municipalities in Serbia: 1971 (**a**); 1981 (**b**); 1991 (**c**); 2002 (**d**); 2011 (**e**)

Fig. 4 continued



caught by depopulation (Statistical Office of the Republic of Serbia 1973; Milošević et al. 2010).

According to the analysis of the vulnerability index in 1981 (Fig. 4b), very low values were recorded in 26 municipalities (the same as those in 1971). The second category was the most numerous, including 110 municipalities which formed a continuous area in the territory of Serbia. The third vulnerability category included 22 municipalities: Some were located in the territory of the Autonomous Province of Vojvodina, in the contact area toward the Belgrade region, or were dispersed in Central Serbia. Three municipalities belonged to the fourth and fifth categories; they were same as in 1971.

The vulnerability index analysis for 1991 (Fig. 4c) shows that 14 municipalities in south Serbia belonged to the first vulnerability category. The municipalities belonging to the second category (107) were grouped in the territory of Central Serbia; their spatial continuity was disturbed by an increased number of municipalities which fell into the third category (36). The municipalities which belonged to the third category prevailed throughout the AP Vojvodina and the central part of Central Serbia. The municipality of Novi Beograd (Belgrade city municipality) was also among the most vulnerable municipalities (4). Stari Grad, Voždovac and Vračar—central Belgrade municipalities remained the most vulnerable municipalities.

The analysis of the vulnerability index for 2002 (Fig. 4d) shows a small decrease in number of municipalities belonging to the first category (9). The second category included 115 municipalities concentrated mostly in Central Serbia. The municipalities belonging to the third category (32) prevailed in the Autonomous Province of Vojvodina and in the territory of Central Serbia including regional urban centers and central Belgrade municipalities. Belgrade municipality of Zvezdara fell into the most vulnerable category. Thereby, the most vulnerable category became larger and included five municipalities.

The analysis of the "proxy" vulnerability index for 2011 (Fig. 4e) shows that the first category with a low vulnerability index included 16 municipalities. They were located in east Serbia and the boundary areas of southeast Serbia. The municipalities falling into the second category (119) predominated, and they were evenly distributed in the territory of Serbia. The third category included 21 municipalities with a moderate vulnerability index: municipalities in the central Belgrade area with neighborhoods in the peri-urban belt, as well as a number of municipalities in the suburban areas of Belgrade, Novi Sad, Niš and Subotica. They were mostly located in the valleys of major rivers (Danube, Sava, Velika Morava, Zapadna Morava, etc.), i.e., along the main axes of industrial development. This category of the vulnerability index also included the municipality of Preševo in the south of Serbia. However, due to the incomplete coverage of the 2011 population census, reliable data about the population in this municipality were not available, which also affected the reliability of indicators used in the analysis. Although different economic indicators were used for 2011, the most vulnerable municipalities still included the same five central municipalities in Belgrade as in 2002.

Temporal variations of vulnerability were given through an analysis of vulnerability index variations in 10-year intervals, but they were also traced throughout the observed period (1971–2002) (Fig. 5).

In the first decade, between 1971 and 1981 (Fig. 5a), prevail municipalities in which vulnerability index increased and they were distributed evenly in the territory of Vojvodina and west, south and southeast part of Serbia. Significant variations of the vulnerability index were recorded in 12 municipalities: In nine of them its value increased, whereas in three municipalities it decreased. The municipalities where the vulnerability index significantly decreased were concentrated in Mačva and lower part of the Danube basin in Serbia. The vulnerability index increased in municipalities within the Belgrade macro-region (Matijević 2009), as well as in some municipalities in west Serbia and Banat (eastern part of AP Vojvodina). Such a situation is a result of the rapid industrial development, due to which cities became zones attracting workers and investment (Derić and Perišić 1995; Stojanović 2003).

In the next decade (1981–1991), the situation radically changed toward a significantly increased number of municipalities with high positive change in vulnerability index (Fig. 5b). In this period, such municipalities (147) prevailed throughout the territory of the Republic of Serbia as a result of economic development (a growing impact of the economic indicator). The increased vulnerability index in the municipalities of south Serbia (Bujanovac, Preševo, Trgovište, etc.) may be explained as a result of incomplete demographic data. On the other hand, in 14 municipalities, the vulnerability index decreased.

Between 1991 and 2002, the number of municipalities with decreasing vulnerability index was smaller than in the previous decade (Fig. 5c). There were 107 municipalities with an increasing vulnerability index and 54 municipalities with a decreasing vulnerability index. They were evenly distributed on the territory of Serbia. Some of the municipalities with decreasing vulnerability index were concentrated along the border areas of Serbia and marked by depopulation. Also, this group included medium and large urban centers where industrial production decreased (Rakovica—Belgrade, Kragujevac, Bor, Priboj, etc.). Some parts of the Belgrade macro-region and certain parts of the Autonomous Province of Vojvodina were marked by slightly decreasing values of the vulnerability index, which does not mean that they were less vulnerable.

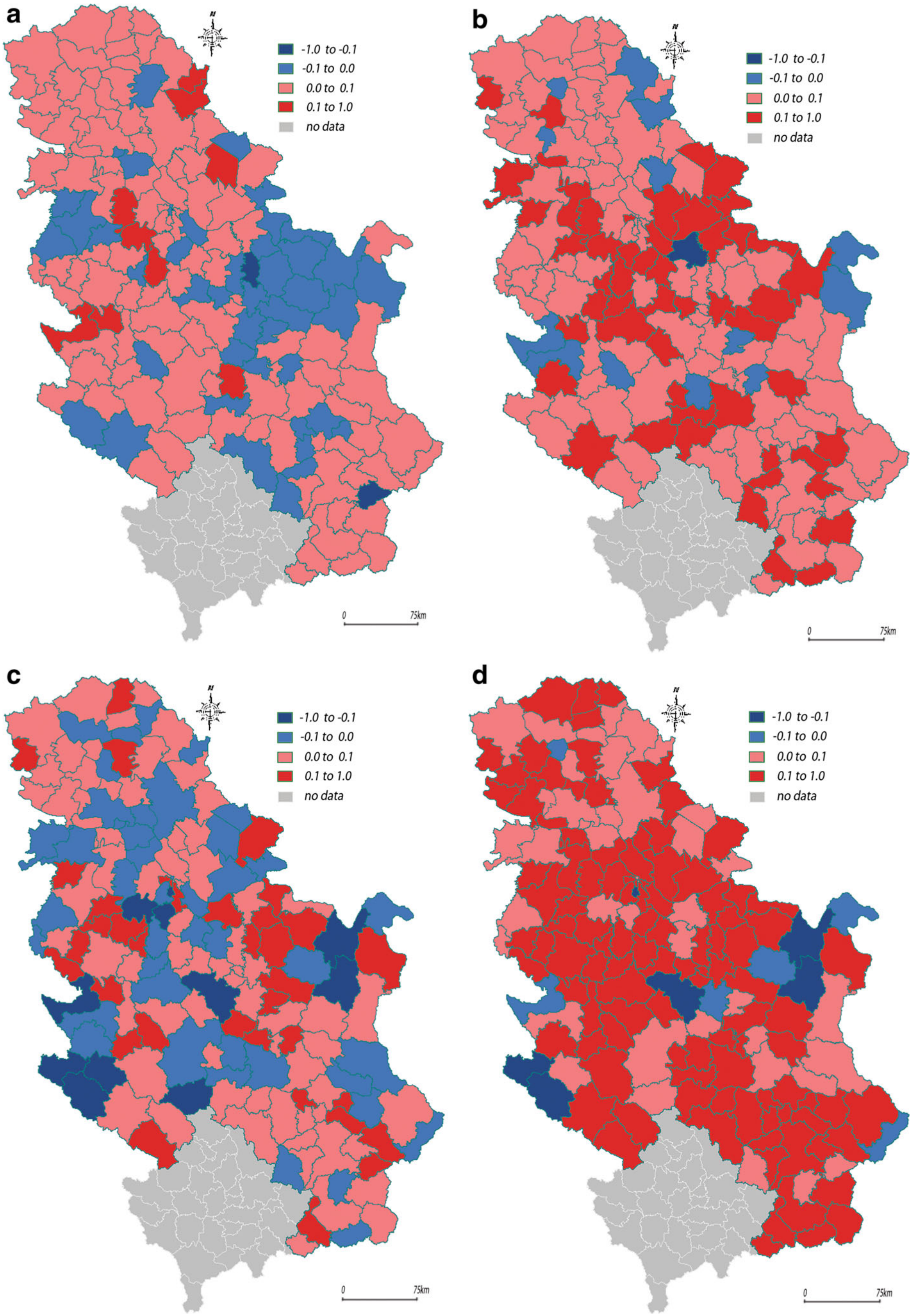


Fig. 5 Maps of demographic–economic vulnerability variations in municipalities in Serbia: 1971–1981 (**a**); 1981–1991 (**b**); 1991–2002 (**c**); 1971–2002 (**d**)

The analysis of the vulnerability index variation in the entire period between 1971 and 2002 shows that for the majority of municipalities (149), the index values were positive (Fig. 5d). They were evenly distributed in the territory of Serbia. Quite oppositely, municipalities with negative variations of the vulnerability index (12) were the result of the decline of industrial production in the 1990s. The municipality of Rakovica (Belgrade municipality) also belonged to this group. The analysis shows a decreasing vulnerability index compared to the value calculated for 1971. Such a situation is explained by an extremely low value of the economic indicator, i.e., the lowest national income per capita in Serbia.

5 Discussion

The share of the five vulnerability categories in municipalities in Serbia in the observed period (1971–2002) varied, and these variations are shown in Fig. 6. It can be observed that the greatest number of municipalities in the period covered by the analysis belonged to the second vulnerability category, where the index ranged between 0.4 and 0.8. This means that approximately 70 % of municipalities belonged to this category. The second most represented was the third category, including approximately 16 % of municipalities, while the first vulnerability category included 11 % of municipalities. The least represented categories were those with high and very high values of the vulnerability index. Less than 1 % of municipalities belonged to the fourth category, while the fifth category always included three Belgrade municipalities.

Apart from the share of municipal vulnerability categories, their (1) spatial distribution and (2) temporal variations in the observed period have also been analyzed.

1. The extreme vulnerability index values were related to border municipalities (the lowest vulnerability index values) and municipalities within large urban centers with a developed industry and higher population density (the highest vulnerability index values). Such a distribution of the extreme vulnerability index values was typical for the entire period covered by the study.

The lowest values of the vulnerability index were recorded in the border areas of south and southeast Serbia. Over time, the number of these municipalities only slightly varied.

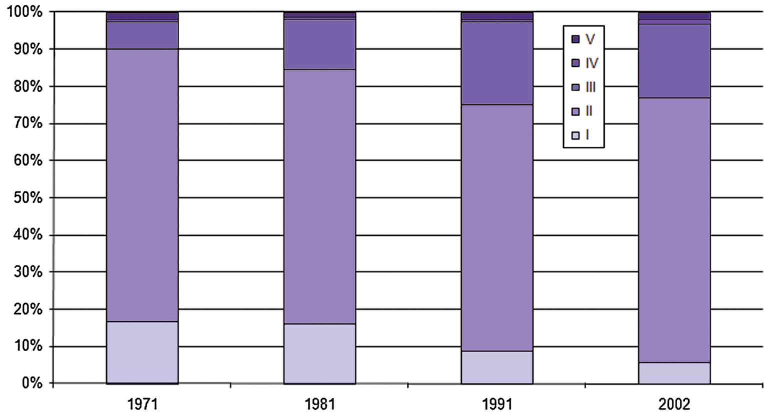


Fig. 6 Share of vulnerability categories of municipalities in Serbia between 1971 and 2002

Such a distribution is a consequence of the fact that the values of both vulnerability indicators (population density and national income per capita) were low due to the low population density, decades-long intensive migration processes, traditionally low levels of economic development and a low economic capacity of the population (Grčić 1991; Miletić et al. 2009; Tošić and Miletić 2002). Although we are familiar with studies which treat the poor as more vulnerable (Fothergill and Peek 2004; Masozera et al. 2007; Donner and Rodríguez 2008) and used the sensu lato concept of vulnerability, we have employed a sensu stricto approach and our results show that small communities have a smaller population at risk, speaking in absolute numbers.

During the first half of the observed period, the greatest part of municipalities belonged to the second vulnerability category. During that period, there were minimal fluctuations in their number. However, since 1991, the number of municipalities falling into the second category decreased, whereas the number of municipalities belonging to the third vulnerability category increased (by about 50 %).

The third vulnerability category mostly included municipalities grouped near large regional urban and industrial centers. Over time, their number increased due to their economic and demographic growth (Veljković et al. 1995; Tošić 1999). The third category mostly included large urban and industrial centers (Novi Sad, Subotica, Niš, Čačak, Jagodina, Kruševac, etc.).

The municipalities with extremely high vulnerability index were not numerous, and in terms of economic and demographic indicators, they significantly differed from other municipalities in Serbia. They were located in the very nucleus of Belgrade. The high vulnerability index is a result of a high population density, i.e., the municipalities' small size, as well as of the highly developed secondary, tertiary and quaternary sectors. The significant population influx during the 1970s and 1980s brought about the rise of population density in the municipality of New Belgrade, resulting in an increased vulnerability index, due to which this municipality fell into the fourth vulnerability category in 1991. Since 2002, the Belgrade municipality of Zvezdara has also belonged to this category. Numerous authors (Gencer 2013; Sanderson 2000) correlated an increasing urbanization and an increased risk. Cross (2001) has pointed out that megacities have a larger population at risk, but also greater disaster resilience. Having in mind that we have not taken into consideration the resilience, speaking in absolute numbers and not percentages/proportions, large cities are more vulnerable.

2. Based on the presented results, it may be concluded that in 67 municipalities, the vulnerability index was constantly rising, whereas in none of the municipalities, it was constantly decreasing. In most municipalities, the index varied, i.e., it was both increasing and decreasing. Having in mind the character of variations, three categories may be identified within this group:

- the first group, where vulnerability was prevailingly rising, though it decreased in one of the decades; the majority of municipalities (67) belong to this category;
- the second, where rising and falling trends were evenly distributed; this category includes 20 municipalities;
- the third category, where vulnerability was prevailingly decreasing, though it increased in one of the decades; 7 municipalities belong to this category.

The results of the study show that spatial and temporal vulnerability variations are causally correlated with changes in the selected components (population density and national income). Such socioeconomic changes and regional differences in Serbia are the consequence of development processes caused by many factors (historical, demographic, social, economic, political, ecological, etc.). Miljanović et al. (2010) have highlighted the polarization between macro-regional centers (Belgrade, Novi Sad, Niš, etc.) and traditionally undeveloped areas (rural, hilly and mountainous and boundary/peripheral) which have been formed over a long historical period; they have also identified new types of areas—municipalities ("devastated areas") that took shape in the period of economic transition ("transition poverty"). That kind of regional inequality in Serbia is seen as a development problem by mentioned authors, subsequently presents spatial distribution of vulnerability. These regional differences in Serbia, interpreted by the mentioned authors as a development problem, trace the spatial distribution of vulnerability. This means that the spatial and temporal distribution of vulnerability is a transformation of the development processes, which have caused regional differences. Winkler (2012) has found similar regional disparities between north and south parts of Serbia, between center and periphery and between urban areas with closer surroundings and rural areas dealing with socioeconomic pressure as their cause. The research was done at the level of municipalities with a number of indicators, but just for 1 year—2009.

Apart from the fact that the two selected indicators are almost regularly used in assessment of vulnerability index, in order to determine whether the calculated vulnerability index is able to reliably describe disaster vulnerability in Serbia, correlations have been established between the vulnerability index and hazard indicators. In countries where disaster fatalities occur almost daily, they may be used as a relevant vulnerability indicator. However, it would not be justified to incorporate disaster consequences (fatalities, damage, etc.) into the model as vulnerability indicators for countries like Serbia, where the scale of natural disasters is not so great as in countries where they are frequent and have considerable consequences. This is also confirmed by Birkmann (2007), who has pointed out that "major limitations regarding existing data are confronted with the approaches where mortality and losses are used as indicators of vulnerability." In countries like Serbia, fatalities and damage should be studied as consequences and separate analyses correlating vulnerability indicators and consequences should be made in order to assess the relevance of selected indicators for the analysis of vulnerability in particular territories. Eminent experts in this field (Cutter et al. 2003; Holand et al. 2011; Birkmann 2007) do not use fatalities and damage as vulnerability indicators. Therefore, it was necessary to find out characteristics different than mortality as defined by Birkmann (2007) and Pelling (2004, 2006).

Due to lack of data related to fatalities and damages, we made correlative analyses with hazard indicators. The analyses of the correlation between the vulnerability index and the degree in which municipalities are affected by the flood zone have shown not high coefficient of correlation with the vulnerability index because the susceptibility of the model is low. Municipalities where more than 90 % of the municipal area is covered by the flood zone are located in alluvial valleys, i.e., in the lower watercourses of the largest rivers in Serbia—the Danube, Sava and Velika Morava. Furthermore, most of them are located in large urban centers with a moderate vulnerability index (Fig. 7). These very areas were affected by the floods of 2006, which caused vast material damage (Gavrilovic et al. 2012). As shown in Fig. 7, the municipalities in the very nucleus of Belgrade which have a high or a very high vulnerability index also make a distinct group. The municipality of Vračar (a Belgrade municipality) has a very high vulnerability index, but it is neither located in a flood-affected area, nor it has surface watercourses; accordingly, it is not threatened by floods. Another group of municipalities included areas which were not located in flood zones, and their vulnerability index varied between very low and moderate. The last two groups include the municipalities with less than 50 or more than 50 % of their area threatened by flood, while their vulnerability index ranged from low to moderate.

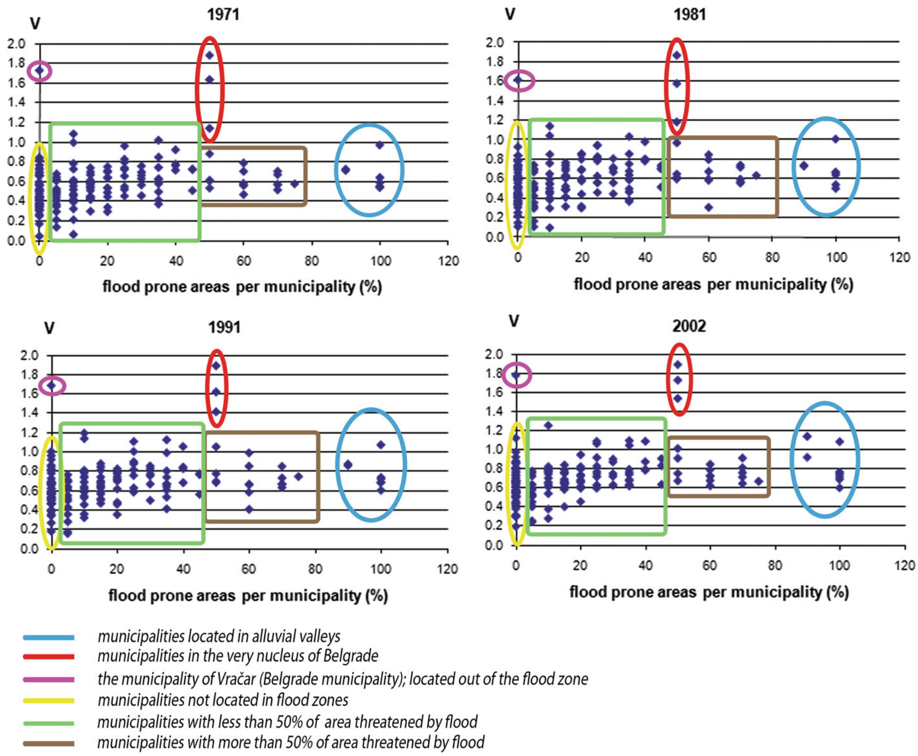


Fig. 7 Groups of municipalities by the vulnerability index correlated to flood areas

Earthquakes with large-scale consequences are not frequent in Serbia. Several significant earthquakes occurred in the observed period (Sjenica, 1977—M 5.2, Kopaonik, between 1978 and 1985—seven earthquakes—$M > 5.0$, Mionica, 1998—M 5.7 and Kraljevo, 2012—M 5.4) (Radovanović 2008). Extreme temperatures occur periodically; they have an annual frequency and affect large urban centers (heat islands) during summer (Unkašević and Tošić 2009a, b) and mostly result in health problems among the elderly population and problems in water supply. In winter, they affect both urban centers—resulting in traffic collapses, supply problems, death from freezing among marginal groups, health problems among the elderly, etc., and rural areas—resulting in difficult access or isolation and related consequences (in February 2010, a state of emergency was declared in 28 municipalities due to huge snow). Although, due to the lack of data, we did not use data about social (demographic) structures, quality of buildings and other socioeconomic indicators, it is clear that large urban centers (especially in the very nucleus of Belgrade) are even more vulnerable to earthquakes and extreme temperatures due to the old population (Devedžić 2007; Stojilković 2011), old building and houses or new structures of a poor quality built in the process of rapid urbanization (Goeler et al. 2012; Ratkaj 2012).

6 Conclusion

Having in mind that vulnerability is a result of individual and overall physical, social, economic and environmental conditions at a certain time period, it has an important role in all aspects of sustainable development (UNISDR 2004). Its significance is all the greater considering that it may be influenced, as opposed to hazards, which cannot be eliminated and may not always be controlled (Perrow 2007).

Regardless of the intensity of a natural process (hazard), changes in population parameters will influence the vulnerability from natural disasters. If the analyses were carried out at the level of settlements, demographic–economic vulnerability of the abandoned settlements (Stojanović 2003; Milošević et al. 2010) would be minimal or none, meaning that any natural hazard in such areas would remain merely a natural process, and not a natural disaster. The nonexistence of vulnerability in these settlements causes a decrease in vulnerability of the municipalities to which they belong. On the other side, megacities all over the world are already labeled as places prone to natural hazards (Braun and Aßheuer 2011; Cross 2001). Combination of rapid population growth and especially high pressure in suburban peripheral zones, where there are no developed infrastructural systems, results in increased vulnerability of large cities. This is the case with the large cities in Serbia, which are pull factors for population.

The analysis of population vulnerability has fundamental importance for all subjects involved in dealing with risks caused by natural disasters and other manmade and technological disasters (transport and industrial accidents, nuclear explosions, etc.). Due to lack of comparable data in the last 10 years, the data used in this study cover the period 1971–2002. The monitoring of economic indicators is a major problem that precludes temporal comparisons and may cause future vulnerability evaluations which are difficult or impossible to compare with previous ones. Nevertheless, the observed trends in vulnerability variations are still valid and there is significant regional variability of vulnerability, an increase in vulnerability at a national level during the past four decades and an increase in vulnerability differences between urban and rural areas. The data presented in this study may be used as the basis for estimating risk in Serbia, but also as a starting point for further research dealing with smaller territorial units (e.g., natural: river basins; complex: regions; administrative: districts, municipalities, etc.), individual disasters or the current situation. The purpose of this study is to identify municipalities that should have priority when making more detailed vulnerability studies; these shall certainly include major urban centers. This study is the first (quantitative and qualitative) analysis of natural disaster vulnerability in Serbia performed on the basis of selected parameters at a municipal level. The applied vulnerability model can be further improved toward analyzing the significance of the involved indicators, testing relevant operators and including a larger number of vulnerability indicators related to demographic and economic components (age, gender, robustness of the built environment, infrastructure and its quality, education, urbanization), as well as to other vulnerability parameters.

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