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Assessing drought and drought-related wildfire risk in Kanjiza, Serbia: the SEERISK methodology

Vladimir Marković[1] · Imre Nagy[1,2] · Andras Sik[3] · Kinga Perge[3] · Peter Laszlo[3] · Maria Papathoma-Köhle[4] · Catrin Promper[4] · Thomas Glade[4]

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Abstract Climate changes alter the frequency and magnitude of a range of physical processes that often have negative consequences on life and property. Decision makers, local authorities and other end users are in need of tools and methodologies for assessing the risk of natural hazards in order to be able to design strategies for reducing it. The SEERISK project is an EU project that aims at the harmonization of risk assessment methodologies in southeast Europe. For this reason, a common risk assessment methodology has been developed and was applied in six case study areas. One of them is Kanjiža municipality in Serbia. Major environmental concerns in Kanjiža municipality include the occurrence of drought and drought-related wildfires. Between 2001 and 2012, 12 drought periods were registered, and between 2007 and 2012, 210 wildfire incidents were recorded. The direct and indirect estimated damage of these events exceeded 200 million Euros. Apart from the monetary loss related to these incidents, there were one victim and one injured person related to a wildfire event in this period. This study demonstrates an application of the SEERISK methodology for drought and drought-related wildfire risk assessment. The results show that more than 80 % of the area under study belongs to the very high and high-risk categories. The SEERISK methodology and its application provide a useful tool for wildfire risk assessment. Given the high priority on protecting human life, crops and environment, the methodology we present here could have wide application across Serbia as well as in other countries facing similar hazards.

✉ Vladimir Marković
vladimir.markovic@dgt.uns.ac.rs

[1] Department of Geography, Tourism and Hotel management, Faculty of Science, University of Novi Sad, Trg Dositeja Obradovića 3, Novi Sad 21000, Serbia

[2] Department of Regional and Environmental Studies, Kaposvar University, Guba Sandor u. 40, Kaposvar 7400, Hungary

[3] Ministry of Interior, National Directorate General for Disaster Management, Mogyoródi Street 43, Budapest 1149, Hungary

[4] Department of Geography and Regional Research, University of Vienna, Universitaetsstrasse 7, 1010 Vienna, Austria

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1 Introduction

There is no universal definition for drought due to differences in hydrometeorological variables and socioeconomic factors, or to the stochastic nature of water demands in various areas. Belal et al. (2014) distinguish the drought definitions in the two categories: conceptual and operational, and list them. A broad definition of drought according to UNISDR (2009) is "a deficiency of precipitation over an extended period of time, usually a season or more, which results in a water shortage for some activity, groups or environmental sectors." Droughts are classified in the following types: meteorological, agricultural, hydrological and socioeconomic (UNISDR 2009). In the present paper, the focus is on agricultural droughts.

Drought risk assessment involves the analysis of the drought hazard and the vulnerability of exposed elements at risk and provides information on the exposed population property, services and livelihoods (UNISDR 2009). However, drought risk assessment is a challenging task and a complex process that includes many influential factors (Belal et al. 2014). Drought risk analysis is a suitable approach in order to design ex ante measure able to anticipate effects of drought on agricultural production (Hao et al. 2012).

As far as droughts are concerned according to the IPCC (2012, 13) SREX report: "There is a medium confidence that droughts will intensify in the twenty-first century in some seasons and areas due to reduced precipitation and/or increased evapotranspiration." However, the confidence is "medium" and not "high" due to definitional issues, lack of data and inability to include all the factors that influence droughts (IPCC 2012). Climate change predictions suggest that wildfires may become more frequent and more intense with global climate change (Prior and Eriksen 2013; Westerling et al. 2006) and became emphasized around the world constantly (Liu et al. 2012). The higher temperatures recorded globally might affect directly the population and the agriculture, but they may also cause secondary effects that have also catastrophic consequences for the environment and the communities such as wildfires. Wildfires present a particular challenge for nature conservation because they are temporally and spatially highly variable (McKenzie et al. 2004). Prolonged drought combined with extreme weather conditions such as high air temperature, wind and low relative humidity often leads to the occurrence of wildfires (Moritz 2003; McKenzie et al. 2004; Keeley 2004) and can have devastating impact on regional agriculture, water resources and the environment (Sheffield et al. 2012; Scott et al. 2012). Drought indices, but also fuel in vegetation (Gibbons et al. 2012), are one of the long-term factors that intensify the occurrence of wildfires through the year (Wotton and Flannigan 1993; Bradstock et al. 2009) and can contribute to the initiation and spread of severe wildfires (Yongqiang et al. 2010). Suburban communities in fire-prone regions are at increasing risk from wildfires due to population growth and climate change (Bradstock et al. 2009; Gibbons et al. 2012). Large wildfires can have important environmental, social and economic consequences such as death and injuries, population mobility, destruction of buildings, crops and infrastructure (Keeley and Fotheringham 2001; Gill 2005; Bradstock et al. 2009; Potop and Soukup 2009; McLeman et al. 2010; Gray and Mueller 2012; Potop et al. 2013).

As a general trend in southeast Europe (SEE), the frequency and severity of extreme climatic events are increasing due to climate change (NMI 2013). In the southeastern Balkans and the wider Mediterranean region, an increase in the frequency and intensity of droughts has been recorded (MWSDR 2007). A similar trend is expected in the coming decades. Meteorological observations suggest that intense droughts occur in the Republic of Serbia, especially in the northeastern, eastern and southern parts. These were recorded in the last two decades (RSOG 2011). In 1990, drought was particularly intense in the wide area of southwest Serbia and in the northeastern part. In 2000, the drought in all parts of Serbia was catastrophic, especially in the northern part of Vojvodina (Kanjiža), Timočka Krajina and the southeastern areas (Spasov 2003). More recently, droughts have been recorded in 2000, 2001, 2007, 2008, 2011 and 2012. Moreover, Serbia was particularly affected by the heat wave in 2012, with temperatures of up to 40 °C, damaging crops and triggering hundreds of wildfires (SEERISK 2014).

In particular in the Kanjiža municipality (Serbia), the occurrence of drought and drought-related wildfires is of major environmental concern. Drought may have significant adverse impact on agriculture and related activities, which are the basic economic source of the municipality. However, apart from economic losses droughts also cause negative physical and ecological impacts. Between 2001 and 2012, 12 drought periods were registered with an average of 30-day duration. The latest drought event in 2012 was the most severe, lasting for more than 90 days. Its direct estimated damage exceeded 20 million Euros, and indirect estimated damage was ten times greater (SEERISK 2014). In Kanjiža, wildfires mostly occur on pastures, meadows and natural grasslands, frequently along the highway, regional and local roads and near settlements. Between 2007 and 2012, 210 wildfires caused one death and one injury as well as damages of about 65.000 Euros (SEERISK 2014).

The relationship between fire occurrence and drought has important implications for fire prediction under current and future climates. Karin et al. (2013) evaluated correlations between drought and fire-danger-rating indices representing short- and long-term drought, to determine which had the strongest relationships with large fire occurrence at the scale of the western USA during the years 1984–2008. Calkin et al. (2011) described options for assessing alternative investments to mitigate wildfire risk, suggesting the use of comparative risk assessment as a rigorous basis for analyzing the ignition, spread, suppression, duration, costs, and ecological and economic impacts of wildfires.

National-level alerts and available data often do not reach the relevant local authorities responsible for the intervention, and even more typically, the ones suffering from the consequences. The perception of citizens and the local authorities regarding the impacts of climate change varies by country and region, but it is generally inadequate (Hungarian Academy of Sciences et al. 2013; National Directorate General for Disaster Management et al. 2013). Due to the regionally varying social awareness and preparedness, the same climatic event may result in different consequences within the SEE region. This study focuses on the impacts of drought and drought-related wildfire, the associated risk, as well as, on existing and potential adaptation strategies.

Due to the significant impact of drought and drought-related wildfires in the area, the effects of climate change would require systematic integration of risk assessment results in territorial planning. In order to assess the risk from drought and drought-related wildfires, we apply the SEERISK common methodology for risk assessment and mapping (Papathoma-Köhle et al. 2013). The methodology was developed within the SEERISK project. The project aims at the development of a methodology for risk assessment, the analysis of risk awareness and the development of suggestions on how to incorporate climatic aspects into existing territorial and sector-specific planning regimes to enable communities to make harmonized, strategically elaborated actions to deal with the new challenges. The main purpose of SEERISK is to improve coherence and consistency among risk assessments and emergency preparedness of society undertaken by the countries at national and local level, and especially in case of disasters intensified by climate change. A description of the SEERISK methodology is given in the following chapter.

2 SEERISK common risk assessment methodology

The Ministry of Internal Affairs of Serbia provides national guidelines which contain a methodology for risk assessment, protection plans and rescue in emergency situations caused by natural and man-made disasters at the national level. However, the SEERISK common methodology for risk assessment and mapping may be used at different scales (national, regional and local or site specific). It has been developed under the consideration of the "EC Guidelines for Risk Assessment and Mapping" (EC 2010) and offers alternatives in order to overcome common obstacles such as the lack of data and lack of documentation of past events. The methodology has been developed as a neutral framework (Fig. 1), but within the SEERISK project it has been adapted for five climate change-related hazard types: flood, drought, heat wave, wildfire and extreme winds. The methodology for wildfire and drought has been adopted due to the high number of annual wildfires during severe droughts and is shown in Figs. 1 and 2. The impact, in the case of drought hazard rating, was the affected crop type and its associated value, while in the case

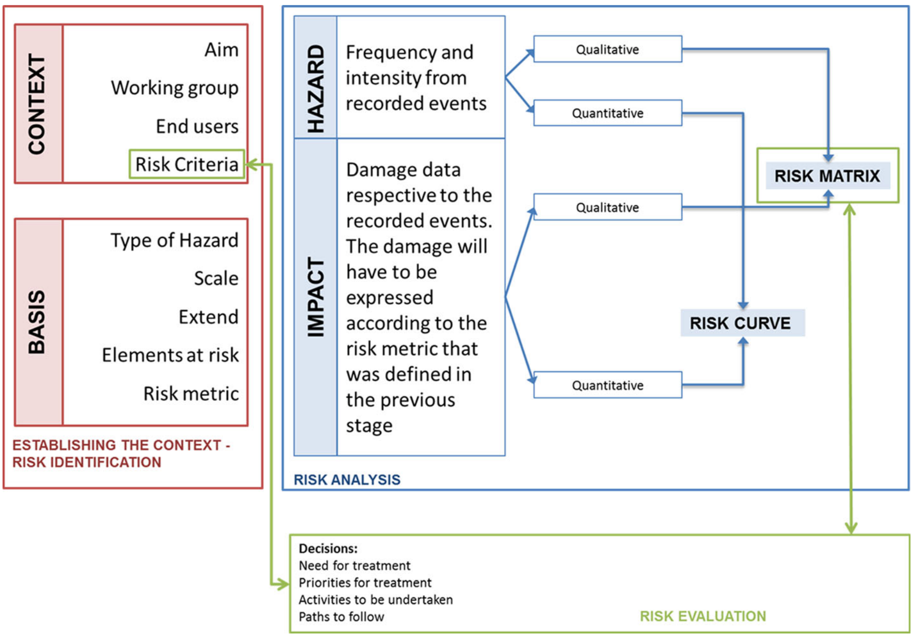

Fig. 1 SEERISK methodology (Papathoma-Köhle et al. 2013)

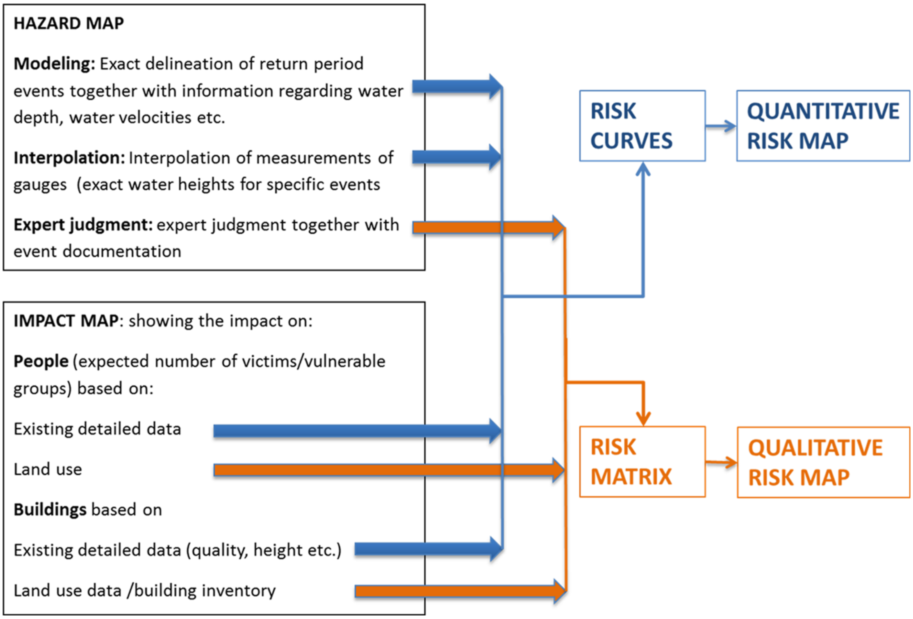

Fig. 2 SEERISK common risk assessment methodology modified for droughts (Papathoma-Köhle et al. 2013)

of the wildfire, the impact was data on land cover type, based on its value but also on its importance from a civil protection viewpoint.

Risk assessment according to the EC guidelines for risk assessment and mapping (EC 2010) involves the assessment of the probability of occurrence of an event and the assessment of its impact on elements at risk. In other words, risk analysis addresses hazard and vulnerability analysis. In Fig. 2, the SEERISK methodology for droughts is demonstrated. It incorporates the development of a hazard and an impact map that will lead to a quantitative or a qualitative risk map according to the available data.

In the present paper, a qualitative risk map is developed following the methodology of Fig. 2. The steps of the risk assessment and mapping are described below:

1. The development of a risk matrix by implementing the following actions based on information on past events
   - Indicating the likelihood or probability of occurrence of drought events
   - Indicating the impact of droughts on crops
   - Setting the drought risk levels (low, medium, high, very high)
2. The development of a hazard map
3. The development of an impact map
4. Overlay of the above maps and development of a risk map showing the different risk levels as they have been rated in the risk matrix

The Standardized Precipitation Index (SPI) was used to express the drought intensity. The SPI is a widely used probabilistic drought index, which is simple and spatially consistent in its interpretation (Guttman 1998; Hayes et al. 1999; Shamsuddin and Behrawan

2008). It is official index of Republic Hydrometeorological Service of Serbia for assessing drought risk. An SPI based on precipitation data daily delivered from three stations (Kikinda, Palić and Bečej) was obtained for 12-month period from mean index for the interval 2000–2012, for the municipality of Kanjiža.

Drought-related wildfire risk analysis requires assimilation of physical information from many sites with a unique geographical location. Detailed database for wildfires in municipality of Kanjiža is available since 2007. The database consists of the date of the wildfire event, the exact location, the duration, the extend of the affected area, data on human causalities, damages and material loss of agriculture, damages and material loss of residential buildings and the maximum temperature during each event. Records for events before 2007 have many gaps. In more detail, before 2007 only information regarding the date of wildfire event, the total damages, the quantity of spent water for fire fighting and the description of the site without exact location (which is crucial for GIS analyzing and mapping) is available. From these reasons, we are using data for wildfires only since 2007. GIS maintains the spatial location of sampling points or area and provides tools to relate the sampling data contained through a relational database, by integrating data from different sources (Pandey et al. 2012). Therefore, GIS has been used in this study to induce levels of drought-related wildfires risk through the analysis of spatially distributed meteorological, land use and land cover data from the general plan of the municipality, i.e., from land use and land cover plan, settlement network, public services and infrastructure plan and natural resources, protection of natural and cultural resources and environmental protection plan.

The multi-hazard matrix rates the hazard based on the number of wildfires ranging from 0 to 14 events during two-class drought category. Based on that information, the risk matrix has been established. In both cases (drought and wildfire), the element at risk considered was the type of agriculture, in case of drought, the risk metric was their value in Euros/ha, while in case of wildfire the risk levels were formulated from a civil protection aspect (fire protection of people and inhabited areas).

The output is a qualitative risk maps for drought and drought-related wildfires at regional level. The maps may be used for the design of preventive and mitigation measures or emergency planning. Hazard, impact and risk maps were based on available data on the identified hazards for the Kanjiža municipality collected from municipal sector for emergency situations and Municipal Fire Brigade.

3 The study area

The territory of municipality of Kanjiža is situated in Vojvodina region (Serbia) and geographically extends from 45°55′ to 46°10′N latitude and from 19°48′ to 20°05′E longitude (Fig. 3). Kanjiža municipality consists of 13 settlements and is located in the North Banat District in Vojvodina by the Hungarian border at 78–108 m above sea level. It has a population of 25,950 people. Its administrative area covers 399 km^2. Tisa River flows East of Kanjiža and around 200 km of artificial channel network crosscuts the municipality.

The climate is moderate continental, with cold winters and warm and dry summers. In 2012, there were many warm days (mean $T > 25$ °C for 121 days and mean $T > 30$ °C for 62 days). In 2012, the mean annual temperature was 12.3 °C, insolation was 2517.8 h per year with an average precipitation of 434 mm per year (RHMZS 2012). The average annual precipitation in the period from 1949 to 2010 for meteorological station Palić is

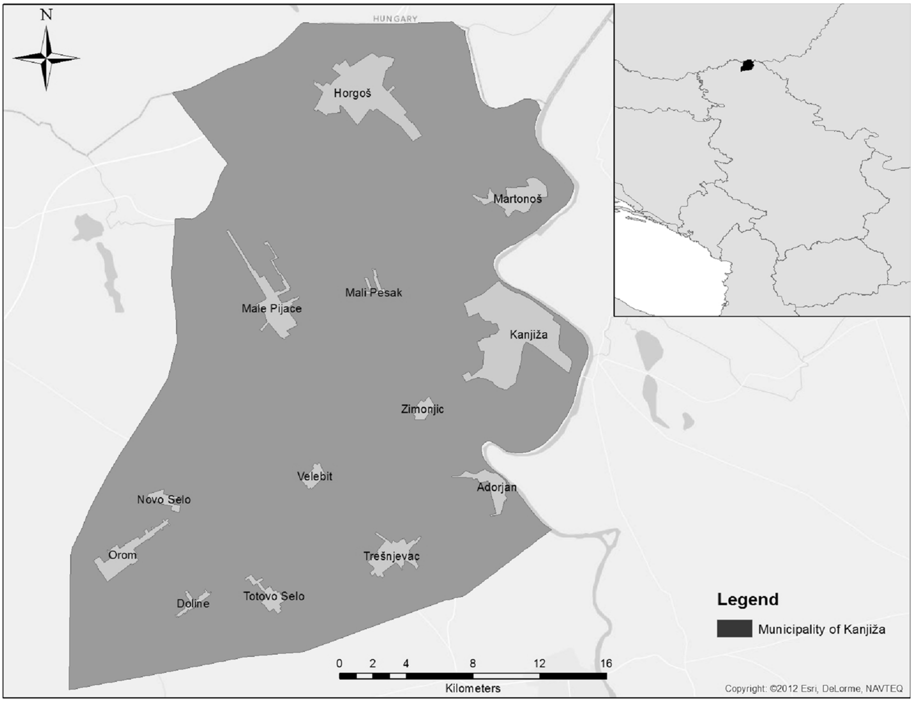

Fig. 3 Study area Kanjiža in the Vojvodina region (Serbia)

556 mm (Miloševic and Savic 2013), and in the period from 1971 to 2000 for the meteorological station Szeged 490 mm, and the average for the same period in the spring of 117 mm as compared to the average of the last 100 years means a reduction in about 30 % (HMS, 2000). Meteorological stations Palić and Szeged (Hungary) are two nearest meteorological stations to the study area. In the southeast border areas of Hungary and in the territory of Kanjiža, the number of days with precipitation decreased. Although a slight increase in the number of days with precipitation over 20 mm can be observed, the length of the dry period (the longest period when daily rainfall does not reach 1 mm) significantly increased from the beginning of the twentieth century. According to the National strategy for climate change of Hungary based on data for the period 1961–1990, projected growth of the average monthly temperature for the period 2021–2050 will be 1–2.5 °C (SNCCS 2013).

The typical vegetation types in the region include crops, bulrush, pastures, meows and shrubs, all of them are very prone to wildfires. Vojvodina is one of the European regions with poorest forest areas in terms of spatial extent—only 6.5 % of the territory is covered by forest (Sekulić et al. 2012). Moreover, forest cover in study area is only around 2 % (SORS 2008), while agricultural land covers 75 % of the territory. The remaining areas are characterized by pastures, meadows and wetlands.

The spatial plan of municipality of Kanjiža does not contain information about climate change scenarios, projected temperatures and future risk scenarios. However, it emphasizes the priority of the development of natural disaster protection system. The regional spatial plan of Autonomous Province of Vojvodina addresses the topic of risk management and assessment for droughts and on the hazard map of this chapter municipality of Kanjiža appears to be (threatened by drought) in the high hazard area. The municipality of Kanjiža has local headquarters for emergency situations. The municipality has a vulnerability assessment and emergency situations rescue plan, which is aligned with other official (structures) plans of the Republic of Serbia (RSOG 2011). This plan states that the land-use planning in the territory of Kanjiža for specific purposes must be in accordance with law on environmental protection and the law of the fire protection, to conserve natural resources and minimize the risk to human health. However, these plans are not hazard specific.

4 Application and results

Risk matrices were developed separately for drought and in combination with wildfires. The first risk matrix describes the drought risk levels based on SPI (Standardized Precipitation Index) classification and the associated impacts (Fig. 4). SPI was analyzed for the time period 2000–2012.

As there are only two SPI values in the pilot area, the drought risk-level rating uses a two-category hazard classification, where SPI score between −1.282 and −1.645 means high hazard (severe drought), while bellow −1.645 score represents very high hazard (extreme drought) (RHMZS 2010). The impact level is basically determined by the value of the affected crop type during a drought period. Very low SPI score associated with high-value crop type represents the highest drought risk level in the matrix. The risk levels change depending on crop value types and SPI scores. Very high-risk-level (red color code) cases need more intensive and frequent irrigation and have priority in building of irrigation systems. The other risk levels are ranging from orange and yellow to green accordingly. High risk (orange color code) includes building of alternative water supply, while medium risk (yellow color code) means investments in public awareness. Low risk level (green color code) means the least drought intensity where local authorities operate in a conventional manner. The insignificant risk level (white color code) relates to the geographical locations such as urban areas, water areas and wetlands where drought has no consequences.

The second risk matrix describes the drought-related wildfire risk levels, which represent the combination of hazard and impact levels (Fig. 5). The multi-hazard level is a combination of the drought index and the wildfire hazard. The impact rating is based on the type of elements at risk, where the land cover type ranges from residential area and forest with very high impact, orchard and vineyard with high impact, crop and vegetable with medium impact, grassland with low and finally water bodies and wetlands with insignificant impacts during very high multi-hazard level. Apart from the agriculture damage, we took in consideration civil protection point of view because for whole analyzed period

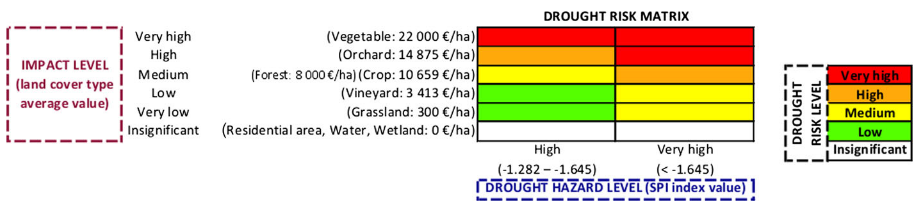

Fig. 4 Drought risk matrix

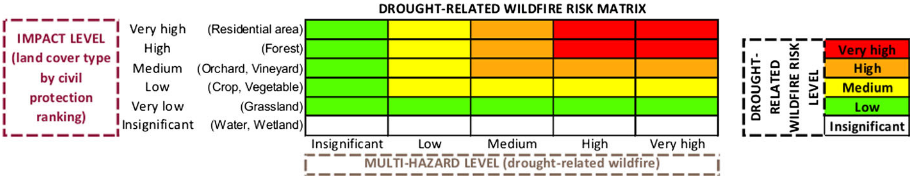

Fig. 5 Drought-related wildfire risk matrix

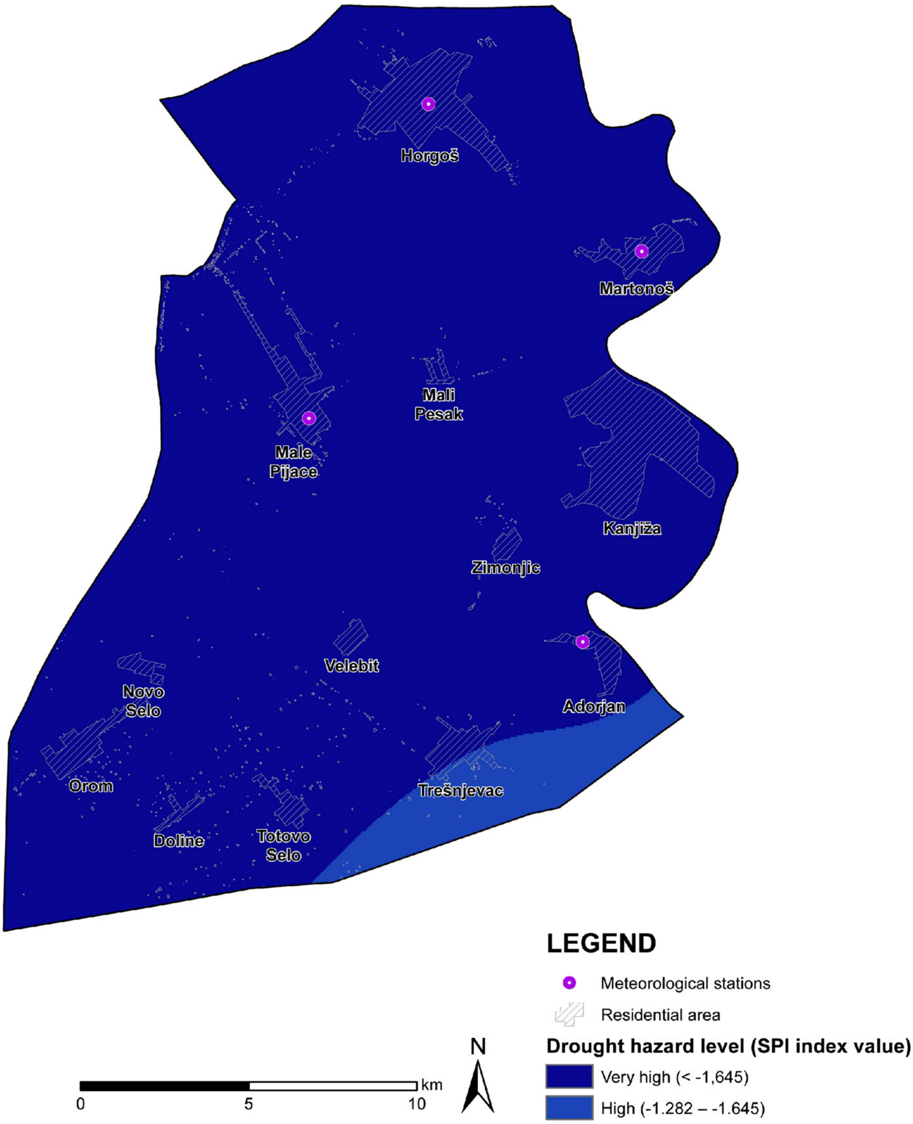

Fig. 6 Drought hazard map

(2007–2012) drought-related wildfires caused one victim and one injured. Very high-risk levels (red color code) represent situations with the highest frequency of wildfire occurrences in residential areas or forests. These cases need the most urgent emergency actions as preparedness for evacuations and fire extinguishing. High risk (orange color code) includes more extensive and frequent presence of fire brigades, while medium risk (yellow color code) means investments in public awareness. Low (green color code) risk level

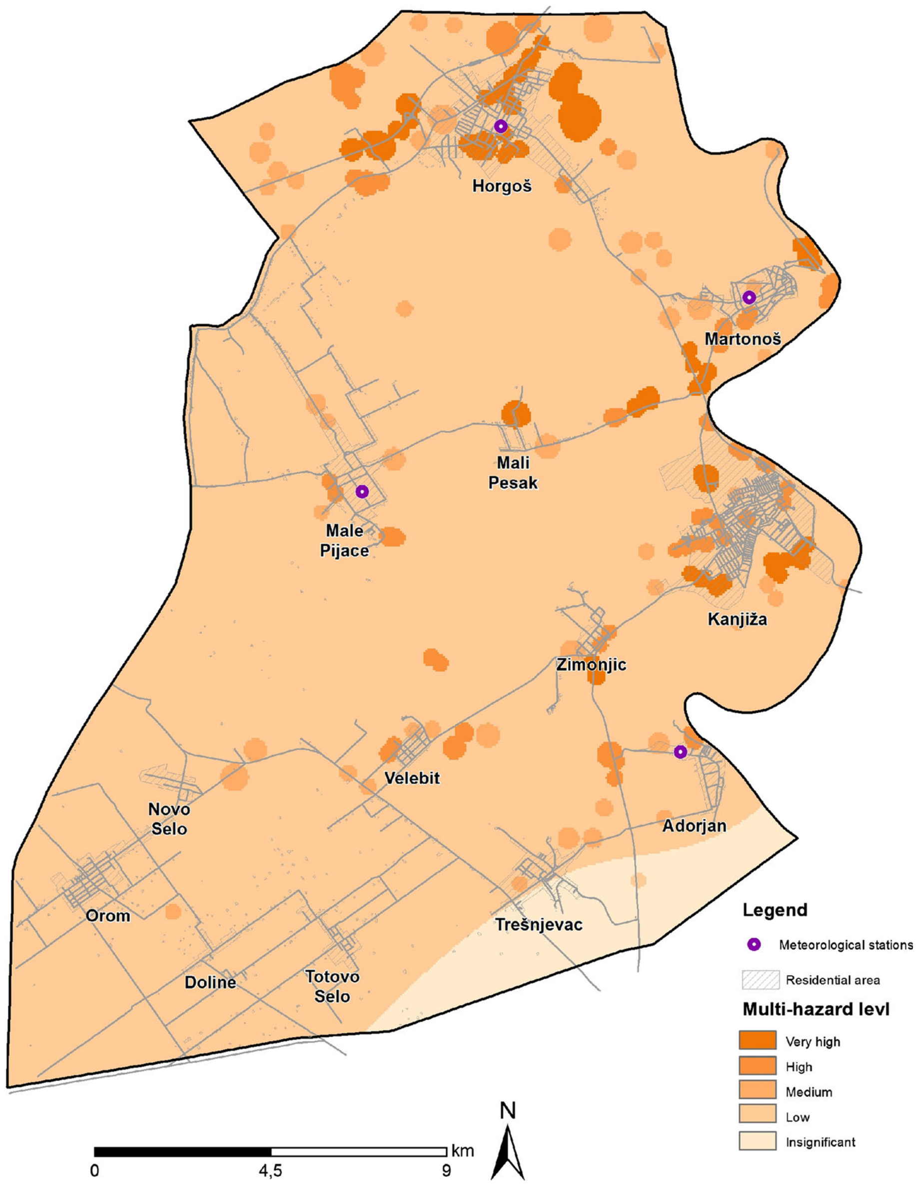

Fig. 7 Drought-related wildfire hazard map

means the least frequent wildfire occurrence, i.e., the lowest significance for civil and fire protection where local authorities operate in a conventional manner.

4.1 Risk mapping for droughts, wildfires and drought-related wildfires

Risk mapping The risk mapping process started with the calculation and interpolation of drought data (SPI) based on provided precipitation data (Fig. 6) and the number of occurrences of wildfire, placed on the map, with a 200-m buffer zone. The drought-related wildfire multi-hazard map was created by combination of these two above-mentioned factors (Fig. 7).

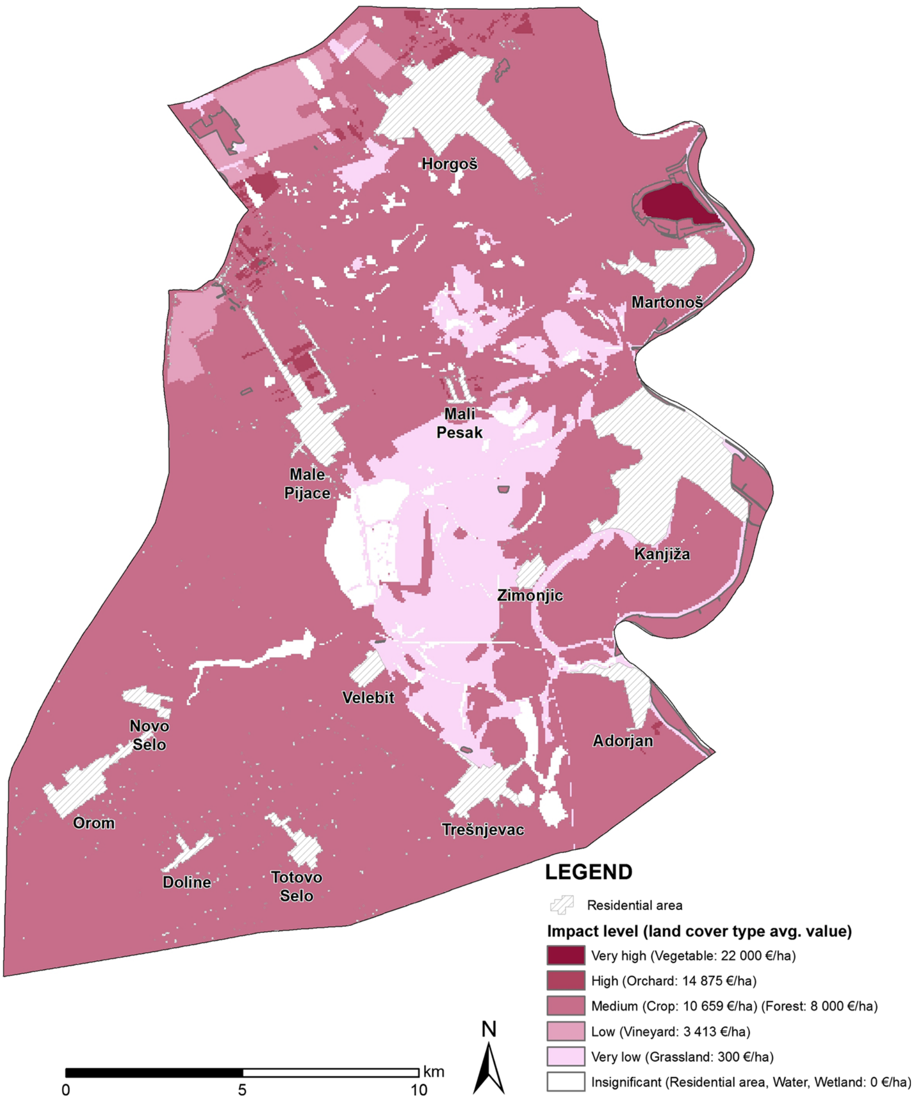

Fig. 8 Drought impact map

In the next step, the drought and the drought-related wildfire impact maps were created. The impact, in the case of drought hazard rating, was the affected crop type and its associated value (Fig. 8). In the case of the wildfire hazard ratings, the impact was data on land cover type, based on its value but also on its importance from a civil protection viewpoint (Fig. 9).

In the final step, a risk map for each hazard was created. The risk map was based on the intersection of the hazard and the impact maps. The hazard and impact value of each pixel led to a risk value based on the risk matrix. This value for each pixel is demonstrated in the

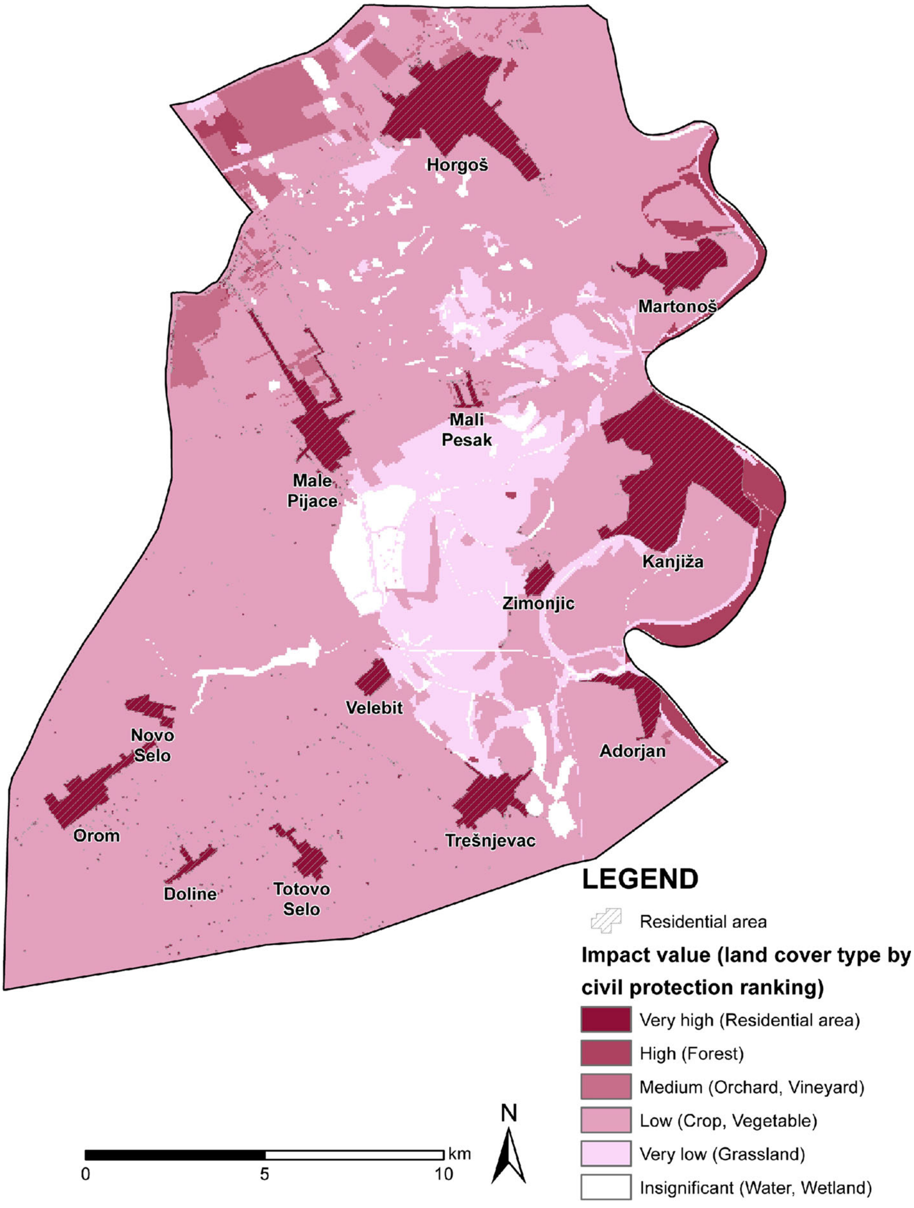

Fig. 9 Drought-related wildfire impact map

risk maps (Figs. 10, 11) where risks range from insignificant to a very high level. The cases with the highest number of annual wildfires during severe droughts represent very high-risk-level situation. In these cases, consequences are reflected in crop yield reduction (in

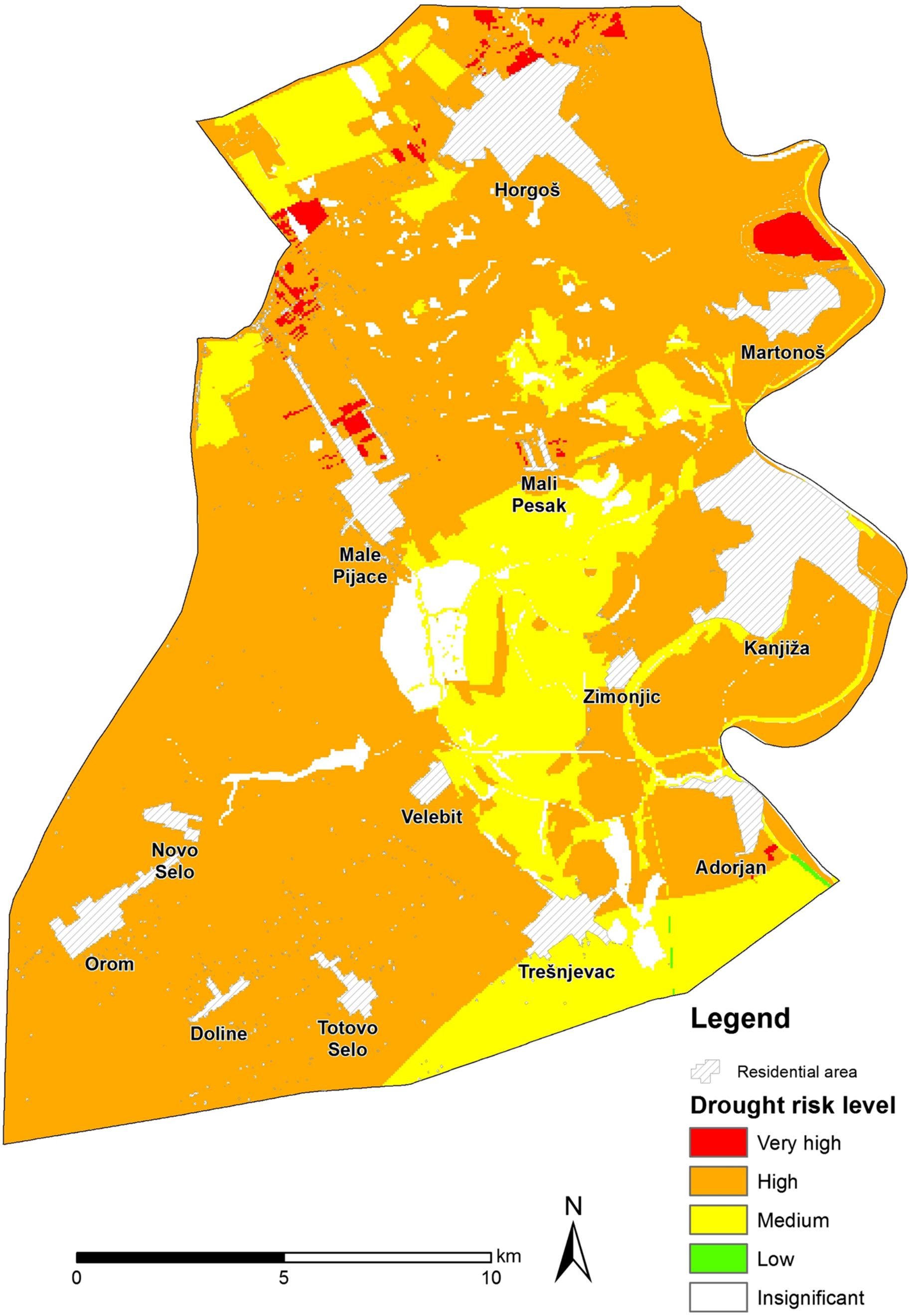

Fig. 10 Drought risk map

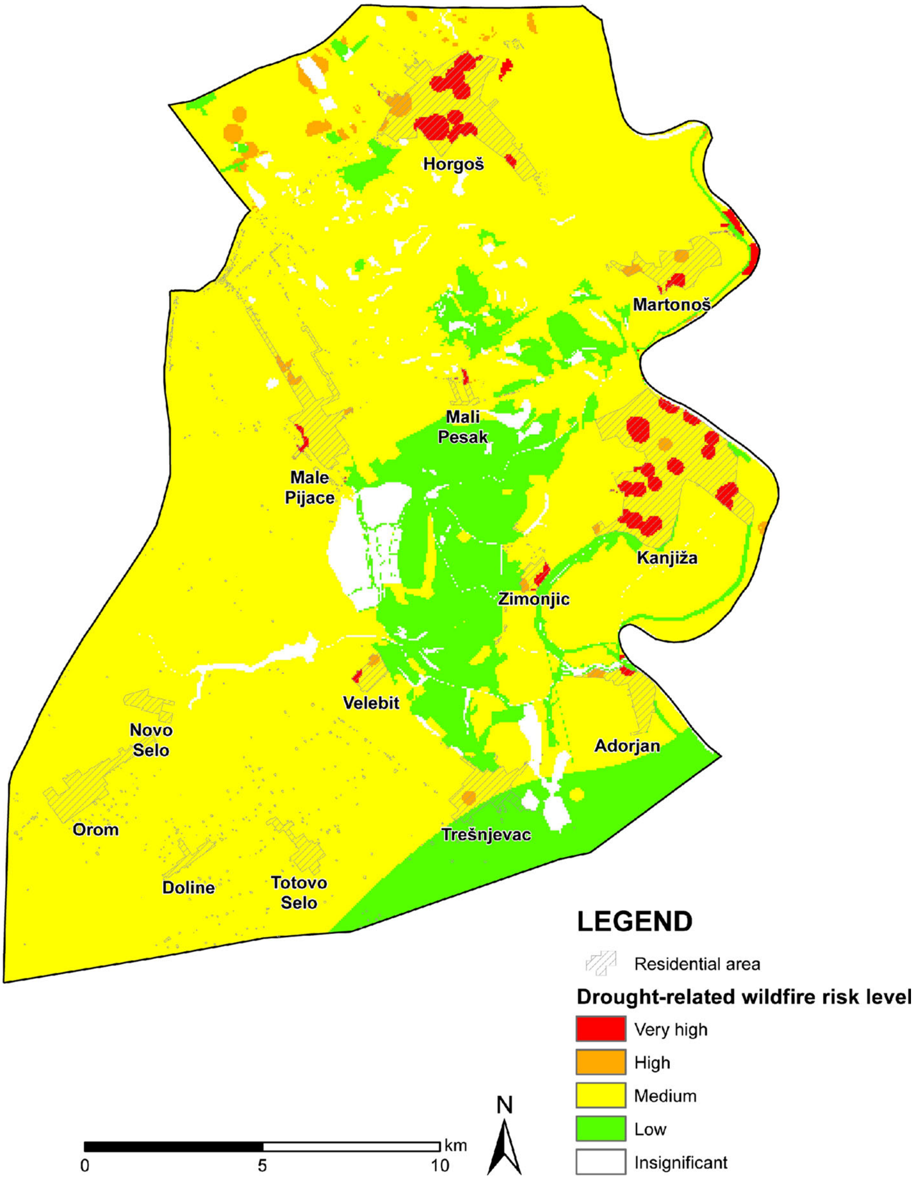

Fig. 11 Drought-related wildfire risk map

monetary terms greater than 30 million Euros of direct and indirect damage), health problems (from injury to death cases), wildlife habitat changing, livestock mortality and disruption of economic activity.

The analysis of the area percentage under different drought-related risk categories shows that 1.41 % of the area is exposed to very high risk, 0.82 % of the area to high risk, 77.97 % of the area to moderate risk, 14.89 % of the area to low risk and 4.91 % of the area to insignificant (Table 1).

Table 1 Percentage of area under different drought-related wildfire risk categories in Kanjiža municipality

Risk level	Percentage of the area (%)				
	Very high	High	Moderate	Low	Insignificant
	1.41	0.82	77.97	14.89	4.91

The wildfire hazard map (Fig. 7) clearly shows the occurrence of the wildfire events along the road network. It is an assumption that this hazard type (wildfire event) is in the majority of the cases a consequence of the human activity related to the glass garbage disposal and cigarette stubs (Mr. Laszlo Cikos, pers. communication, 2013).

Highest risk levels show places along the highway E-75 near the settlement of Horgoš, in the neighborhood of Kanjiža city, and the dumpsite located on the right side of the road between Mali Pesak and Kanjiža. Highest risks level, but in the lesser extent, show areas near settlements Martonoš, Zimonjić, Velebit, Adorjan, Mali Pesak and Male Pijace. The risk level is lower near other settlements or roads elsewhere in the municipality. In the low risk, categories belong to places situated far away from settlements (or roads). Typical land cover types within the highest risk areas include artificial surfaces, such as road networks, and associated grassland and seminatural areas (scrub and herbaceous vegetation associations).Water areas as rivers, fish pounds and wetlands risk have insignificant risk level.

5 Discussion

The present study's objective was to investigate impact and hazard of drought and drought-related wildfires in Kanjiža municipality and to assess and map the associated risk. As expected, high-risk areas correspond with areas characterized by high hazard and high impact. The areas of highest wildfire hazard correspond very well with the areas of high drought hazard and impact (high level of hazard due to droughts). On the other hand, this area also corresponds very well to the areas around settlements and the road network which indicate on direct human impact.

Human population patterns and environment have been influenced and modified by climatic variability, changes and extreme events. For areas affected by drought and wildfires such as Kanjiža municipality, risk assessment is very essential. Such investigations may assist in the design of mitigation measures and in the identification of potential points of intervention to moderate negative socioeconomic impact if and when they occur. As the assessment of risk is one of the main aspects of drought and wildfires mitigation and planning, we hope that these maps and the study in general will strengthen the operational responses of the authorities.

The application of the common risk assessment methodology in this case study can be the basis for the future regional planning in the Vojvodina province. It could be applied to neighboring municipalities that also belong to arid areas (Novi Knezevac, Kikinda, Subotica, Čoka, Senta).

The main advantage of the methodology is comparability although amount of available data is limited. It offers a common platform to the involved parties so that individuals from different authorities (local authorities emergency services, etc.) and with different interests may work together and contribute their experience and knowledge for the development of a common risk map or risk assessment. The use of GIS enables the updating of the database helping in this way the decision makers to consider future changes not only concerning the climate but also the spatial pattern of the elements at risk. Using this methodology and GIS, field researches can identify with greater spatial precision places they seek to investigate. Last but not least the visualization of risk enabled through GIS alters the risk perception of decision makers and the public supporting in this way effective risk management.

However, many limitations are associated with the application of the specific methodology. Due to lack of data, many assumptions had to be made increasing in this way the level of uncertainty in the study. In more detail in the hazard assessment phase due to lack of relevant information regarding the probability of wildfire initiation, high hazard was assumed around settlements and the road network. Moreover, concerning the impact assessment, due to almost annually changes in land cover (planting different crops) the yearly update impact inputs every year are considered essential although it would increase the mapping costs.

As mentioned above, the main limitation of the methodology is the lack of reliable good quality data. Better event documentation in the future will lead to the collection of reliable good quality detailed data regarding the impact of drought-related wildfire, or other climate change-related hazards and, consequently, to an improved risk assessment and mapping.

Furthermore, more information on events and their location will contribute to reliable hazard maps demonstrating the probability of events in the area.

This article is a starting point for future investigation of drought and drought-related wildfires in Kanjiža municipality. The major outcome of this study is the production of a drought and drought-related wildfires risk maps. It is hoped that the study will be beneficial to a number of stakeholders, particularly disaster management, but also agricultural organizations, health centers, planning authorities, risk insurers and others to improve their understanding on drought and wildfire impacts.

6 Conclusion

The presented research illustrates the application of the SEERISK common risk assessment methodology on drought-related wildfire hazard in municipality of Kanjiža (Serbia). The risk maps developed can be used to give a quick estimate whether there is a high, medium or low risk in the affected area. Analysis of the presented map results may lead to an easier update of local action and development plans and legislation by taking into account the wildfire and drought hazards.

This methodology, represented with an integrated measure of drought-related wildfire hazard and impact, provides a useful tool for wildfire risk assessment. There is a potential for improvement in the way governments manage drought-related wildfire impacts. This research presents novel approaches to assess drought-related wildfire hazard. Given the high priority on protecting human life, crops and environment, the nature of analysis we present here could have wide application across the Serbia and other countries which face with similar natural hazard.

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