

SPATIAL ANALYSIS AND MAPPING OF FIRE RISK ZONES AND VULNERABILITY ASSESSMENT – CASE STUDY MT. STARA PLANINA

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Abstract: During the turn of the century, the current data of registered fires in Stara planina were insufficient to up date and incomplete, which directly conditioned unintended purpose of prevention and fire protection. With the advent and development of new technologies (remote sensing, GIS, GPS, etc.), since 2010 various data patterns of fire have been collected, recorded, processed and analyzed. Based on the collected and processed data since 2010 preventive measures against fire and better management of natural resources of protected areas have been implemented. The aim of this paper is spatial analysis and mapping of risk zones of fire in Stara planina, consisting of different vegetation cover, the complex structure of the terrain and heterogeneous composition of the soil. In Stara planina, a total of 44505 fires in the open space, in the period from 2010 to 2012, was registered. Cartographic locating, plotting the recorded "hot spots" and analyzing topography (aspect, slope, etc) and collected data for this period, the authors identified and zoned endangered belts of Stara planina.

Keywords: risk zones, GIS, remote sensing, fire, Stara planina, Serbia

Introduction

Forests are a major natural resource and play an important role in preserving the environment. However, the emergence of forest fires creates a major environmental problem and the fire is the greatest enemy of vegetation. In Stara planina, fires are one of the largest natural problems and dangers. In most cases, the cause of the fire is the human factor. However, a long drought, high temperatures, vegetation composition, terrain, lightning phenomena and etc. probably can in certain circumstances cause and dictate the development of forest fires (Radovanović & Gomes, 2008).

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GIS (Geographic Information Systems) is a way of useful analysis of forest fires which enables spatial analysis of large areas and can easily be integrated with remote sensing. GIS and remote sensing represent a remarkable and effective tool for emergency management, particularly forest fires. These technologies are of great importance and interest to all institutions dealing with space, disaster management (monitoring the situation, simulating natural disasters in order to come up with better forecasting models, preparation of spatial data, etc), including emergency services.

For the prevention and preventive action, GIS and remote sensing are used to manage large amount of data needed to assess the vulnerability and danger during disaster, this tool is used to design evacuation routes, emergency response centers. In the post stage of the affected natural disasters, these techniques are used to organize information on the damage, inventory data after disasters and estimate update locations (Kumar, Joshi, Parkash & Krishna, 2009).

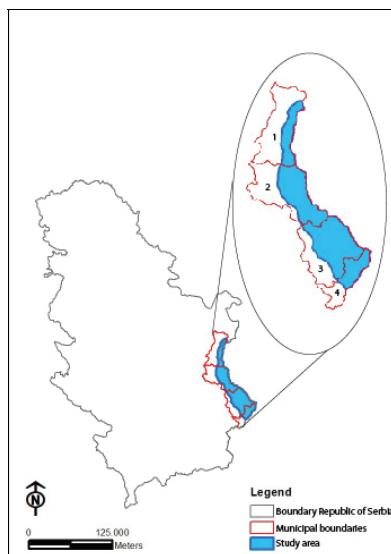


Figure 1. Location of study area: 1- Zaječar municipality, 2 - Knjaževac municipality, 3 - Pirot municipality, 4 - Dimitrovgrad municipality

Technique of overlapping thematic layers increases the information content of the map, its readability and flexibility of semiotic choices. GIS technique opens up the possibility of spatial analysis, assessing distance and setting different query for the selected theme. All this makes to the implementation of different variables to give complete geographic analysis (Robigliol, Mala & Diaw, 2003).

This paper presents an analysis of fire in Stara planina and linking environmental factors with the help of GIS and remote sensing. Model of variables of vegetation index (NDVI), angle, exposure, altitude, the land use, that are integrated with data from the Department for Emergency Situations of the Republic of Serbia for the period 2010-2012.

Remote sensing and GIS provide the information and tools necessary for modeling of forest fires and maps in order to identify, classification and mapping of the area fire zones (Pradhan, Suliman & Awang, 2007). Cartographic data of fire are statistics and correlated with physical and human factors (Cutter, Yenilmez & Kuter, 2011). This paper analyzes the components that affect different aspects of fire presented with thematic maps:

Aspect - position of the sun in relation to relief. Takes into account the different sensitivity of the fire in relation to exposure, which specifically refers to the effects of drying.

Slope - taking into account the steepness of the surface affects the rate of fire spread.

Land cover - takes into account land cover, regardless of the origin of fire (natural or anthropogenic), factors affect the characteristics (nutrients, physical and chemical composition, moisture, temperature, fertility) of land.

NDVI (Normalized Difference Vegetation Index) - takes into account the vulnerability of vegetation cover from fire.

The classification of these factors is carried out with the help of GIS analysis and based on recorded and current data of Emergency Situations of the Republic of Serbia for the period 2010-2012.

Study area

The study area of this paper includes the south-eastern part of the Republic of Serbia, the corresponding Carpathian - Balkans system. Along the ridge of Stara planina there is natural border with Bulgaria. The highest peak of the mountain is Midžor (2165 m), which is one of the highest peaks of the Republic of Serbia, while the lowest point is located at the exit of the valley of Prlitski stream."

Northernmost point is situated in the valley of the Prlitski stream and southernmost point is Nišava in the valley on the border between Serbia and Bulgaria. The westernmost point is situated at the confluence of Trgoviški and

Svrljiški Timok, while the easternmost ridge of Stara planina – is top Silver Head (1933 m)." (Milovanović, 2010). Analyzed field covers an area of 1964,7 km², which is 2,22% of the total area of the state.

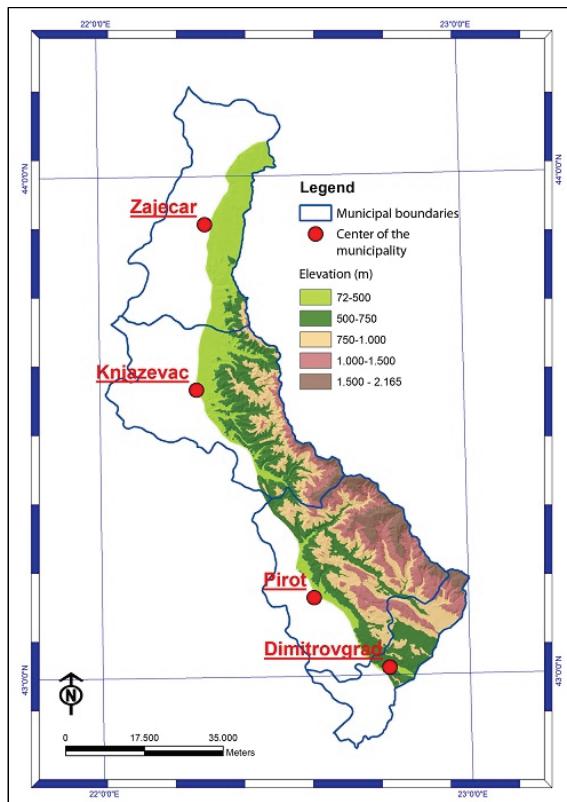


Figure 2. Map of municipal centers of study area and height dissection

Based on the data collected for the period 2010-2012 there burnt more than 1500 hectares of vegetated in the open space. The largest fire with over 300 hectares of vegetation burned per located place was struck by municipality of Zaječar and Knjaževac in 2012, and it of places Vrška Čuka, Prlita, Grljan and Vratarnica. From this year, larger fires (200 ha) occurred in the village Ravno Bučje while in 2011 the largest fire was in Crni Vrh with burnt area of 150 ha.



Figure 3. Map of fire places in study area

In Pirot district for analyzed period not registered fire of large-scale in comparison to the fires of municipalities Zaječar and Knjaževac. The largest fire occurred 2011 in the place Babin Zub and in the village Krupac, where the fire engulfed an area of 100 hectares. During the 2012 the fire of a medium scale, compared to the other mentioned places engulfed an area of 80 hectares in the village Jelovica.

Analysis topography of study area and its impact of the fires

For the period 2010 - 2012 there was total of 44505 fires in the territory of Stara planina, of which the forest vegetation (deciduous, coniferous and mixed forest) make 2309 fires. Area affected by the fires in the period from 2010 to 2012 is 18,3 km², which is 0,93% of the total area of the analyzed territory.

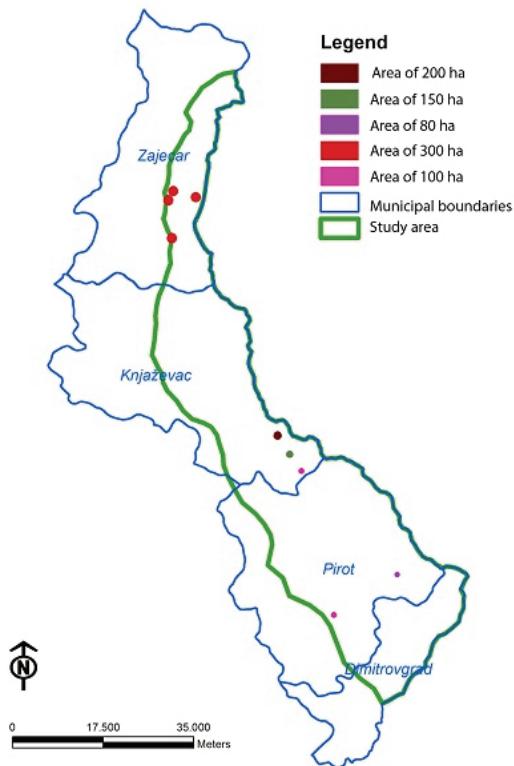


Figure 4. Review areas affected by fires

In the paper used for the analysis of Landsat 8, SRTM-DEM (Shuttle Radar Topography Mission - Digital Elevation Model) and CLC (Corine Land Cover) data. These data are free and have easy access to the network over the website United States Geological Survey (science for a changing world), NASA (The National Aeronautics and Space Administration) and EEA (European Environment Agency). Satellite images were processed to obtain thematic maps (slope, aspect, land cover, NDVI) in the purpose of the digital classification and fire hotspots threatened vegetation.

Remote sensing allows the possibility of a comprehensive analysis of the different ecosystems in all geographic latitudes and longitudes. And GIS also has extensive capabilities developed for analyzing the available information, provides a way to overlap and combine the data for analysis. Both techniques provide a key technology marrow for the detection and evaluation of forest fire management situation.

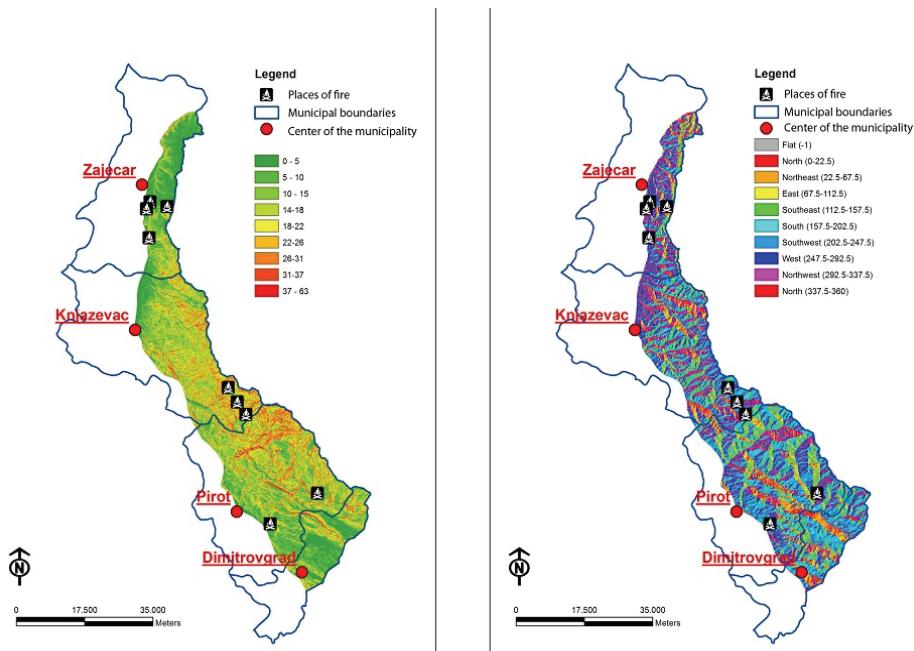


Figure 5. Slope and aspect map of Mountain Stara planina

Aspect (direction insolation) - southern slopes receive more direct solar energy and heat during the day compared to the slopes that are oriented to the north, which has two effects on the spread of fire. The northern slopes more helping development of plant mass more and hence in these areas tend to fire off. In the southern slopes the temperature is much higher due to increased solar radiation, vegetation and soil have tendency to dry up before and during the fire season. The slopes oriented towards the south sides, in addition of higher temperatures and under strong influence of wind, are causing lower up humidity, which is reflected in the moisture biomass, and influence its combustion. The northern slopes are cooler in the shade, which is why dry vegetation is much lower than on the southern slopes. As a result, the southern slopes are already at elevated temperatures and require less energy for their spontaneous burn up. While the slopes oriented towards the north side have fewer opportunities for the development of more severe fires.

Slope refers to the steepness of the terrain and has the greatest impact on fire behavior. The steepness of the slope affecting the speed and direction of spreading losses. Fires are usually move faster uphill than downhill and the steeper the slope the fire moves faster for a variety of reasons: on the hill, flame

is closer to plant mass which with at an angle (the slope) and can be catch fire faster than if it is on the level ground; wind usually moving uphill and it pulls heat and a new flame, on new plant mass, who has not torched; ardent ardor down the hill easily roll down in the lower areas and start new fires. By the combined effect with the presence of wind the intensity of the fire increases (Butler, Anderson & Catchpole, 2007).

Land is a key determinant of productivity of place and the state of its environment, which may be affected by the external factors (climate, topography, geology) - which affecting its long-term fertility, and internal factors (soil moisture - the ability to bind, productive potential, porosity of the soil that affect plant growth. (Grier, Lee, Nadkarni, Klock & Edgerton, 1989). Chemical properties of soils affected by fires, including organic materials nutritional elements as nitrogen, sulfur, phosphorus, cations (magnesium, potassium, calcium), pH (soil acidity). Many of these components affect nutrient availability interactions and play a key role in the composition and productivity of vegetation after fire (Erickson & White, 2008).

Generally, Fire - Rescue Unit of Republic of Serbia the fires in the open space in the period 2010-2012 the most intervened in extinguishing of the low vegetation and in 2012 with a total of 9960 interventions. Minimum of intervention has been during 2012 - total of 19 interventions in the areas of vineyards.

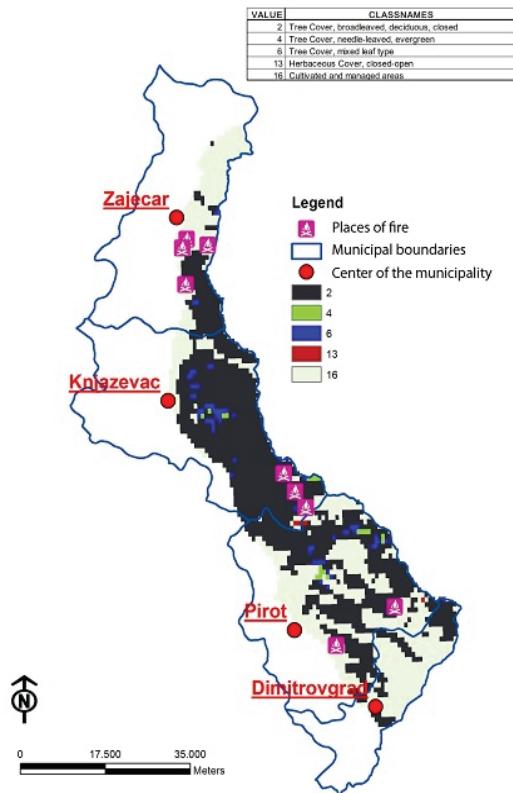


Figure 6. Land cover map of Stara planina: 2 – Tree Cover, broadleaved, deciduous, closed, 4 – Tree Cover, needle-leaved, evergreen, 6 – Tree Cover, mixed leaf type, 13 – Herbaceous Cover, closed-open, 16 – Cultivated and managed areas

$$\text{NDVI} = \text{NIR} - \text{VIS} / \text{NIR} + \text{VIS}$$

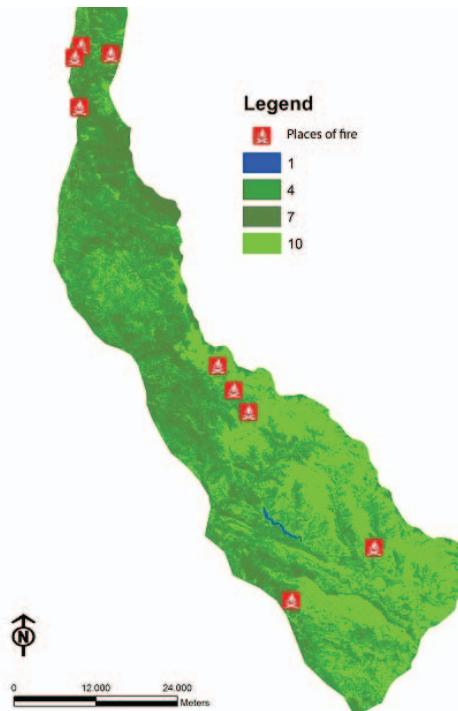


Figure 7. The classification of the NDVI of Mountain Stara planina: 1 – Water area, 4 - Grassy area, 7 - Grassed - forested vegetation, 10 - Forest vegetation

Number of interventions Fire - Rescue Unit of Republic of Serbia in fires of forest cover during 2010, 2011 and 2012 in the open space of Stara planina was the largest in the area of deciduous forest - 675 interventions. The minimum number of interventions occurred in 2010 in the area of conifers trees – 56. Total number of interventions during the period 2010 – 2012 of putting out the fire in the area of deciduous forest was 1191. In areas with mixed forest the total number of interventions was 668, while at the least interventions was in area of conifers trees.



Figure 8. Type of forest in relation of elevation:

- 1 – Area under the oak (> 500 m), 2 – Area under the beech (500 – 1000 m),
- 3 - Area under spruce (1200 – 1800 m), 5 - Sub-Alpine belt (1800 – 2000 m),
- 4 – Alpine belt (< 2000 m)

Vulnerability assessment for hazardous situations

Human factor when it comes to management and fire protection is one of the essential questions, considering that it was the effect of human factors, one of the most common causes of fire, like and the elements of the timely protecting and eventual of fire effects.

“People’s exposure to hazard is currently assessed in light of their vulnerability, so too is their resilience to deal with its effects increasingly regarded as dependent upon what is termed their capacity” (Bankoff, 2007, p. 32). The “capacity of individuals and social groups to respond to, that is, to cope with, recover from or adapt to, any external stress placed on their livelihoods and well-being” (Mc Entire, 2011). Social systems generate unequal exposure to risk by making some people more prone to disaster than others and these inequalities

are largely a function of the power relations (class, age, gender; and ethnicity among others) operative in every society (Phillips & Fordham, 2010; Mc Entire, 2011).

The variables leading to vulnerability include physical causes such as location of settlements, construction practices and the use of technology and equipment that indicates the effectiveness during response to disasters, as well as social causes, such as social behavior, politics in mean of possible support in emergency management, population characteristics in term that some groups (children and elders) are less able to deal with disasters effectively and economic conditions in terms that the lack in resources can indicate the less possibilities to prevent and cope with disasters.

Studied area includes area of Mt.Stara planina located in the area with strong long-term depopulation trends. In the area encompassed by this survey – Stara planina, there is a long-term tendency of demographic discharging. Although it is largely the cause of this adverse natural factor, caused by isolation of the larger settlements, poor infrastructure, series of social factors: high level of unemployment, low living standards, the lack of community infrastructure, and the lack health care and educational institutions, etc.

Lack of infrastructure, poor socio-economic capacities, lack of an educated and trained professional staff, lack of institutions that are involved of defense (fire stations, police, emergency medical help, etc) greatly affect the timely retrieval of information about the origin of fire, possibilities for reacting in emergency situation.

For this reason, GIS and remote sensing give the benefits in the sense of vulnerable zones and can provide the assessment of the best solutions in emergency situations management. A number of issues related to disaster management can be quickly identified and effectively addressed to the competent authorities to address this situation using by geo-spatial methods and tools like is GIS.

Therefore entering a multi-year data on the origin of fire direction of its expansion depending on many factors and the assessment of infrastructure, demographic and other factors using GIS tools can be in the short term to create a system for planning access of prevention, adequate protection and hazard management.

Conclusion

Remote sensing and GIS are powerful tool for the analysis, management, study and evaluation fires, in order to reduce their frequency and to avoid damage in huge proportions. GIS is an excellent tool for mapping the spatial distribution of forest fire danger. GIS makes it possible to improve our knowledge of locating potential "hot spots" and the danger of fire, which is essential for their control and development of regional plans of defense against fire. Analysis of the topography of Stara planina (aspect, slope, elevation, land use) and setting different query, mapping and incorporation into the GIS can determine the risk of serious forest fires.

Acknowledgements

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