FIRE RISK INCIDENCE OVER THE LAST 200 YEARS: CASE STUDY IN THE MEDITERRANEAN CROATIA

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Abstract

Humans have controlled the fire within the subsistence economy and manipulated the landscape in the Mediterranean for millennia. The research has pointed out to the strong correlation between the anthropogenic impact, landscape change and rising fire risk incidence since the 19th century in the Mediterranean Croatia. The research has been conducted on the southern slopes of the Svilaja Mountain, situated in the interior part of Mediterranean central Dalmatia, Croatia. The research was based on a number of various data covering the period of 200 years. Data encompass the original cadastral plans from 1830 to 1846, forest vegetation maps (1975), satellite imagery data (since 2004) and fieldwork data. Fire risk assessment for each of all these periods was estimated according to the methodology provided by the Fire risk assessment measures within the official Regulation on the Forest Fire Protection issued by the Ministry of the Internal Affairs of Croatia (2003). Methodology is based on a number of parameters such as land cover, climate, orography, vegetation type and forest arrangement, as well as anthropogenic factors. The analysis of the landscape vulnerability to fire has shown that the most vulnerable and endangered landscape types are degraded and coniferous forest and pastures. Taking into account the overall landscape change over 200 hundred years and the prevalence of degraded forest clearly points to the importance of the human impact on landscape change by means of degradation and extensification and also inevitably points to the increase of the fire risk incidence.

Keywords: Croatia, fire risk incidence, GIS, landscape change, Mediterranean.

Résumé

Depuis de millénaires, les hommes ont contrôlé l'incendie dans une économie de subsistance et manipulé le paysage Méditerranéen. Le présent recherché souligne la corrélation étroite entre l'impact humain, la transformation du paysage et le taux de risque d'incendie depuis le XIXe siècle en Méditerranée croate. La recherché a été effectué sur le versant sud de la montagne de Svilaja, située dans la partie intérieure de Dalmatie centrale en Croatie. Elle est basée sur un nombre considérable des données couvrant le période de 200 années. Les données englobent des plans cadastraux originaux datant de 1830 à 1846, des cartes de végétation forestière (1975), des données images satellite (depuis 2004) et des données de terrain. Evaluation des risqués d'incendie pour chaque période a été estimé en fonction de méthodologie fournie par des Mesures réglementaires officielle (2003). La méthodologie est basée sur un nombre des paramètres tels que la couverture terrestre, le climat, l'orographie, le type de végétation et l'arrangement de forets ainsi que les facteurs anthropiques. L'analyse de vulnérabilité du paysage aux incendies a relevé que les forêts et pâturages dégradées et de conifères sont les types les plus vulnérables de paysage.
La transformation globale du paysage pendant des 200 dernières années et la prévalence des forets dégradées indique clairement l'importance de l'impact humain sur la transformation du paysage – par dégradation et extensification - et mène inévitablement à l'augmentation du taux de risque d'incendie.

Mots-clés : Croatie, taux de risque d'incendie, SIG, transformation du paysage, Méditerranée.

1. Introduction

Considering the fire risk, Mediterranean is the one of the most endangered areas on Earth, apart from North American pine forests and African savanna, primarily due to climate features, regular and often long drought periods, and a lot of dry and flammable material in the landscape. Some of the authors argue that Mediterranean ecosystems are the most aromatic and among the most flammable ecosystems in the world (Keeley et al., 2012; Pausas et al., 2015; Thompson, 2005), while within Europe the region that is mostly affected by fires (Tedim et al., 2015). Although natural fires are rare, human impact on the occurrence of fire, due to the environmental features of the Mediterranean is extremely large. The Mediterranean region accounts for the larger proportion of human-caused fires in the world (Leone et al. 2009; Tedim et al. 2015). Men have controlled the fire within the subsistence economy and manipulated the landscape in the Mediterranean for millennia.

Numerous researchers deal with the fire regime and ecology (Naveh, 1999; Nodilo, 2003; Tekić et al., 2015*)*, enhancement of the flammability in Mediterranean (aromatic) plants (Dimitrakopoulos, 2001; Massari & Leopaldi, 1998; Pausas et al. 2015), fire regime in relation to the meteorological parameters and their impact on flammability of the Mediterranean species (Bonora et al., 2006; Pereira et al., 2005; Rosavec et al. 2013) as well as with climatic and other environmentally relevant factors such as relief, exposure or vegetation in fire risk zones (Netolicki et al. 2012) or "piro-climatic areas" assessment and fire risk predictions (Masala et al., 2013). All these researches have the common goal to understand the fire mechanism and regime and the factors that enhance and facilitate the ignition and spread of the fire. Few researchers have related the selectivity of burning to the land cover by identifying preferred land cover types to fire incidence (Bajocco & Ricotta, 2008; Lloret et al., 2002; Moreira et al., 2001; Nunes et al., 2005) for the recent period of the turn of the century, yet without analysing the temporal trend.

The aim of this research is, however, to understand more clearly the correlation between the human impact, landscape change and fire risk incidence in the Mediterranean environment. The hypothesis is that changes in the livelihood and lifestyle affect the environmental and landscape change and eventually lead to the change of the vulnerability to fire as well. Mediterranean Croatia has experienced a massive socio-environmental change in the course of two last centuries. The main turning point in recent environmental change of Mediterranean Croatia is related to the strong population shift around 1970 as a direct consequence of the process of littoralization, being the trend well recognized in the whole European Mediterranean. Behind the economic and demographic growth of the littoral, there is population and economic decline in the hinterland, leading to a considerable environmental change, mostly defined by the processes of extensification and reforestation (Fuerst-Bjeliš & Durbešić, 2013). The paper will present the most important socio-environmental relations relevant for traditional lifestyle and

livelihood and landscape development, as well as key processes of their subsequent change. Furthermore, the approach and the applied method of fire risk incidence estimation in the frame of two hundred years will be elaborated and the main results will be discussed.

2. Socio-environmental setting

The research has been conducted on the southern slopes of the Svilaja Mountain, situated in the interior part of Mediterranean central Dalmatia, Croatia (Figure 1).

Figure 1 - Study area

The area is a typical Mediterranean karst environment, with considerable human impact in human-environment interrelations. Karst environment of Mediterranean Croatia is marked by rock permeability and scarcity of water and soil and restricted, highly localized arable, with regular summer droughts. Coping with these constraints throughout the centuries, population has adopted pastoralism as the most adaptable economic activity and lifestyle. Excessive pastoralism in the conditions of Mediterranean climate, thin soil cover and especially steep slopes eventually led to the deforestation. Narrative (travel accounts) and graphic (cadastral and cartographic) sources dating as early as 18th century, have documented the image of the Dalmatian karst hinterland generally as rocky, dry and desert land, whilst more humid mountain environment of Svilaja was perceived as a green island in the midst of that rocky desert (Fuerst-Bjeliš et al., 2011). Mean annual temperature is 12,9 °C, while mean annual precipitation reaches 1261 mm with fall - winter maximum and less dry summers in comparison to

surrounding lowland. The effects of mean humidity rate of the area (70%) is considerably reduced by the dominating cold and dry N and NE wind *Bora,* which can drop the humidity rate in winter months down to 9%. However, mountain environment was more favorable for animal grazing than surrounding dry and rocky lowland. Consequently, the 19th century Svilaja mountain was dominated by pastures (67%) in the landscape structure (Fig.2). However, abandoning of land due to the socio-economic changes i.e. the process of littoralization in the second half of 20th century, initiated the process of natural succession and reforestation. For interior Mediterranean Croatia, the littoralization process means primarily the loss of population. Mountain areas are especially affected by depopulation all around the European Mediterranean. Population mostly permanently abandoned land and left to the growing cities – working centers in the littoral zone. Thus, dissolution of traditional lifestyle based primarily on pastoralism and localized tillage zones in the karst hinterland, started the natural process of vegetation succession. As a consequence, there has been a considerable change in landscape structure and vegetation cover. At the beginning of 21st century, the share of the pastures decreased to 37%, whilst the new category of degraded forest and shrublands (*macchia*[1] and *garrigue*) reached the same surface share (35%) (Figure 2). The research has pointed out to the strong correlation between the human impact, landscape change and rising fire risk incidence since the 19th century in the Mediterranean Croatia. Previous research has shown so far that the risk of wildfire is closely related to landcover at one hand (Bajocco & Ricotta, 2008), and, at the other hand, that it is linked to some societal factors, such as the loss of traditional knowledge of fire management due to depopulation (Tedim et al., 2015).

3. Scope and method

In order to establish and to explain the correlation between the environmental and landscape change and fire risk incidence, the fire risk assessment is estimated for three comparative periods in the last two hundred years, according to the methodology provided by the official regulation measures (2003).

The landscape change research carried out by Durbešić (2012) and Fuerst-Bjeliš & Durbešić (2013) covered three comparative periods in the course of the last two hundred years: 1830 to 1846 , 1975 and 2004 to 2010. The research was based on a number of various data, encompassing the original cadastral plans from 1830 to 1846 from the Chart collection for Istria and Dalmatia of the State Archives in Split, forest vegetation maps of the Institute for Adriatic Cultures and Karst Melioration in Split (1975), the satellite imagery data of CORINE Land Cover Croatia, as well as field work data for the period since 2004. For each of these three periods prevailing landscape types were defined, as well as types of landscape change and landscape

[1] Term regionally differs. Italian variant is *macchia*; French *maquis;* Spanish *matorral;* Greek *phrygana;* Portugese *mato.* Shrubland biome in the Mediterranean, typically consisting of densely growing evergreen shrubs. Further degradation leads to the less dense vegetation of *garrigue*.

change trends. Land cover has been the main criterion used in classification of the landscape types.

Landscape types obtained by this research were the basis for the fire risk assessment. It was estimated according to the methodology provided by Fire risk assessment measures within the official Regulation on the Forest Fire Protection issued by the Ministry of the Internal Affairs of Croatia (2003). Methodology is based on a number of parameters such as land cover, climate, orography and exposition, vegetation type and forest arrangement, as well as anthropogenic factors. Every parameter is evaluated according to the potential fire risk. Among the most risky qualities of parameters are, according to the above mentioned Fire risk assessment measures, coniferous and degraded forests, forests close to arable land and recreational areas, areas with high mean annual temperature, low mean annual precipitations and humidity, sands, limestone and dolomites, southern exposition, low altitude and low forest arrangement. The fire risk assessment is estimated for each of all three comparative periods in the course of two hundred years, based on the aforementioned sources (cadastre, forest vegetation maps, satellite imagery and field-work) and defined landscape types, according to the methodology of parameters evaluation. The territory of Republic of Croatia is classified into four levels of forest fire risk: very high, high, medium and low. The whole study area of the interior Mediterranean Croatia, enters only the higher risk classes (from medium to very high risk), along with the increasing component of very high risk in recent period (2004-2010).

4. Results and discussion

4.1. Environmental change

Due to the pastoralism as the most adaptable economic activity and lifestyle, main environmental feature of the 19th century Svilaja mountain are pastures with the share of 67% of the total study area. The autochthonous deciduous forest covers 17%, while the arable land and vineyards takes less than 15% of the area.

By the turn of the 20th – 21st century, the majority of the area covered by pastures, arable and mountain deciduous forest has been reduced and replaced primarily by various forms of degraded forest and shrubland such as *macchia and garrigue*, mostly due to the massive depopulation and abandonment of the land and subsequently the traditional livelihood and lifestyle that involved pastoralism, localized tillage and vinegrowing. Pastures and arable land are reduced 50% in relation to the 19th century and all in favor of degraded forest as a new landscape category (Figure 2).

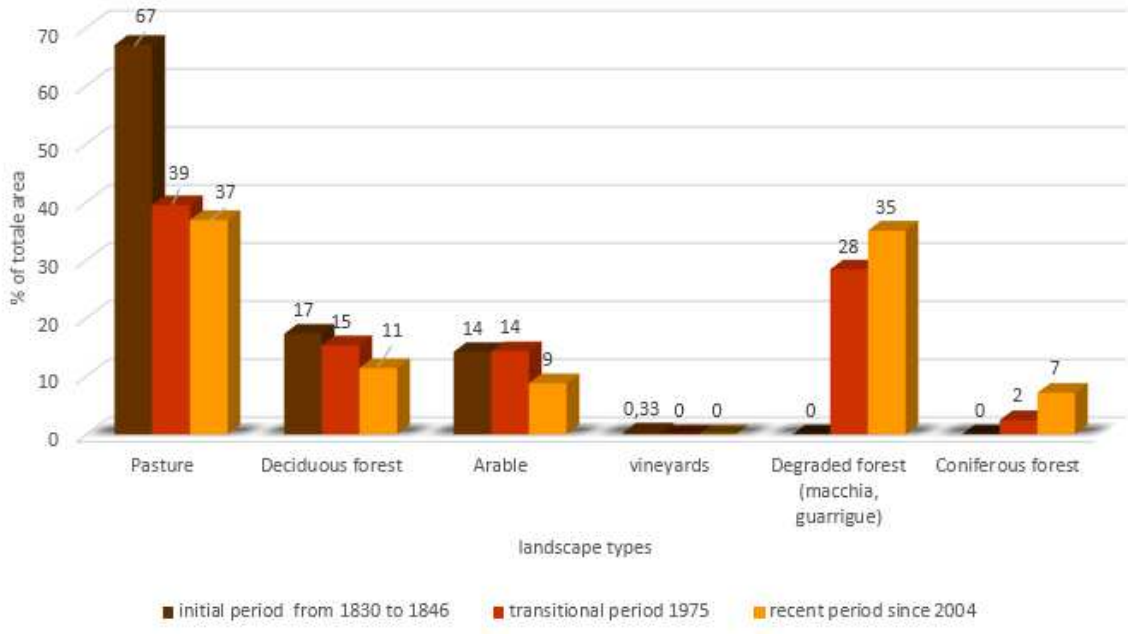

Figure 2 - Landscape change of the Svilaja mountain from 19th to 21th century

Such a massive landscape change in the course of two hundred years reveal main processes of change: forest degradation and extensification of agricultural, mainly pastoral activity due to the depopulation. Half of the whole study area can be defined by extensification (37%) and autochthonous deciduous forest degradation (13%) in environmental and landscape change. Both of the trends are leading to the outspread of degraded forests. The trend of extensification turned the arable and pastures to degraded forest, while dominant trend in more than 65% of deciduous forests is transition to degraded types of forests, i.e. *macchia, garrigue* and pastures (Fuerst-Bjeliš & Durbešić, 2013). Taking into account the overall landscape change over two hundred years and the prevalence of degraded forest clearly points to the importance of the human impact through the degradation and extensification on the landscape change and, as research has shown, inevitably to the increase of the fire risk incidence.

4.2. Fire risk assessment

All the parameters of fire risk assessment were evaluated according to the methodology of the official Fire risk assessment measures (2003). Climatic, pedologic and orographic parameters are constant for all three comparative periods, while anthropogenic and vegetational (landscape) represent changing variables and directly influence the changing fire risk vulnerability. Landscape types, defined by previous research (Durbešić, 2012; Fuerst-Bjeliš & Durbešić, 2013), were used as a basis for the assessment.

The 19th century pasture landscape of mountain Svilaja was estimated as dominantly (87,7%) under a moderate fire risk (Figure 3).

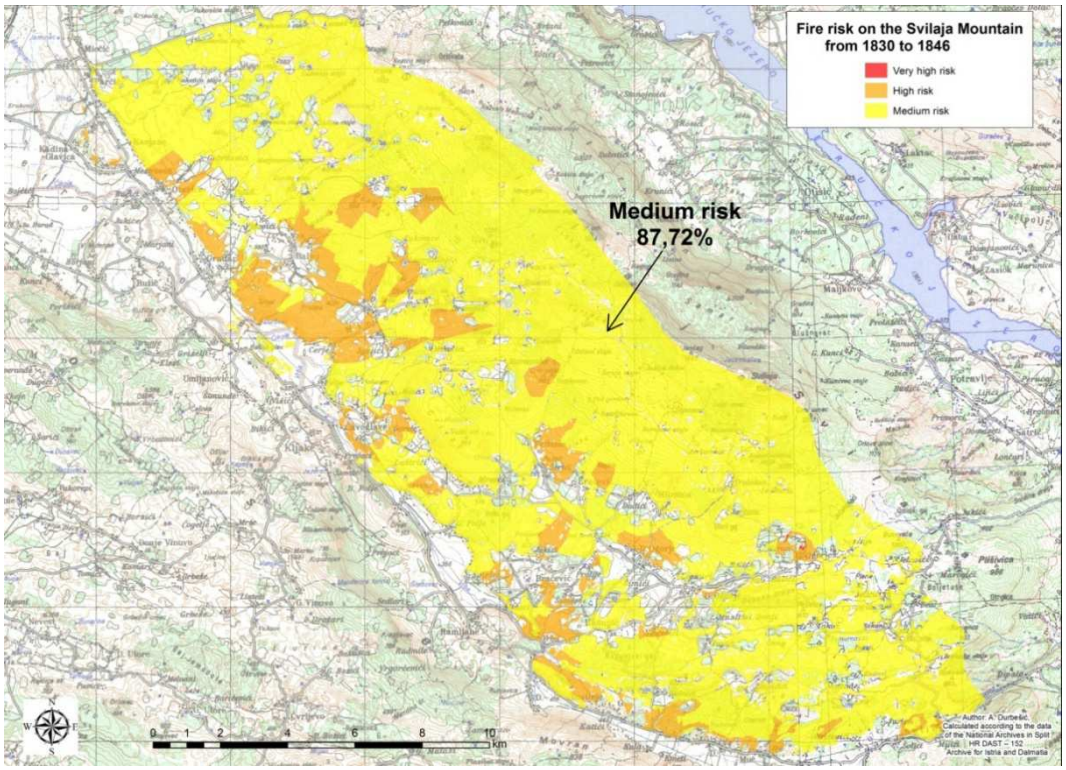

Figure 3 - Fire risk assessment in 1830 - 1846

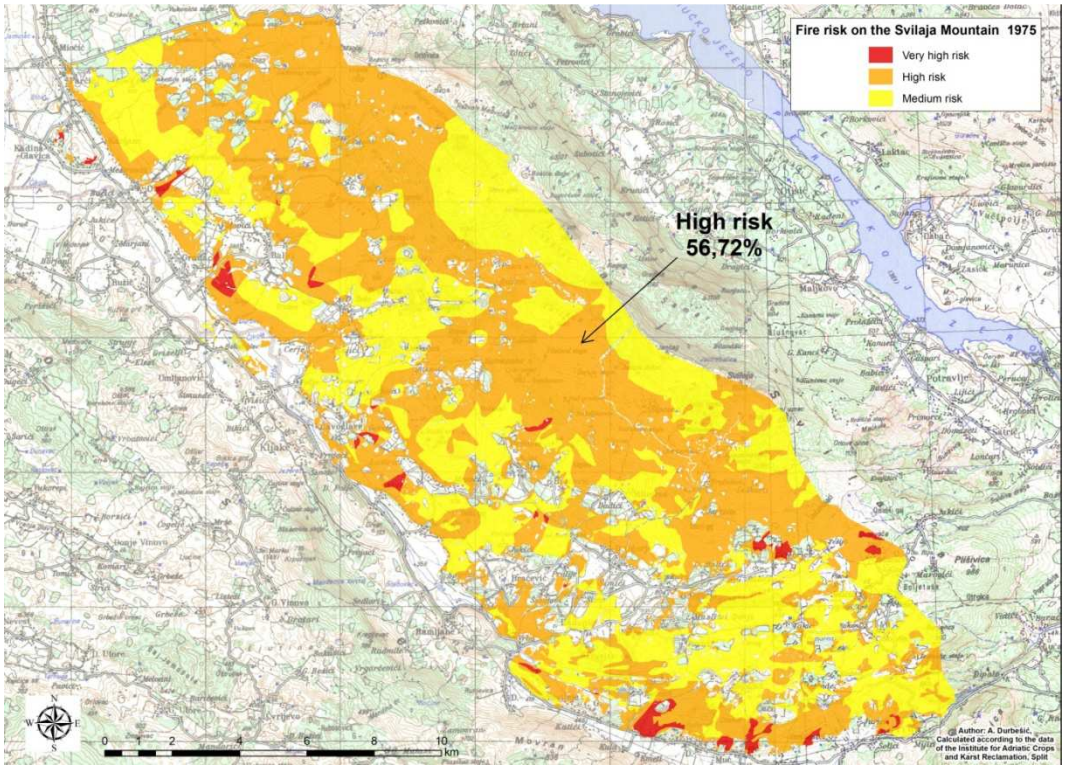

Figure 4 - Fire risk assessment in 1975

In the second half of the 20th century the medium fire risk was considerably replaced by high and very high fire risk over the almost 60% of the territory that shows an increase of 40% in relation to the initial state in 19th century (Figure 4). Moderate risk was, at the same time, reduced from 83% to 42%. The trend of fire risk change is very well in accordance with the landscape change, i.e. the replacement of pastures with the new category of degraded forests types such as *macchia* and *garrigue* (Figure 2).

In recent period (2004-2010) very high risk is showing dramatic increase of almost 5 times (Figure 5). It is, however, mostly related to the increase of the pine forest (*Pinus nigra*) as a consequence of reclamation works on highly eroded slopes. The ratio of moderate and high risk is slightly changed in favour of moderate risk (less than 10%) due to the progression of deciduous forest in the top area as a consequence of missing human impact for already 20 years in the mine suspected area (Homeland War in the 90s).

The analysis of the recently burnt area according to the database for the period from 2004-2010, shows that the affected area enters the category of moderate (58%) to high and very high fire risk (42%), in almost equal ratios.

The analysis of the landscape types on recently burnt area, clearly shows that all the fires took place in the higher parts of the mountain at the distance from the settlements, where dominating landscape types are degraded forests and shrublands i.e. *macchia, garrigue* and pastures which make 75% of the total burnt area (Figure 6).

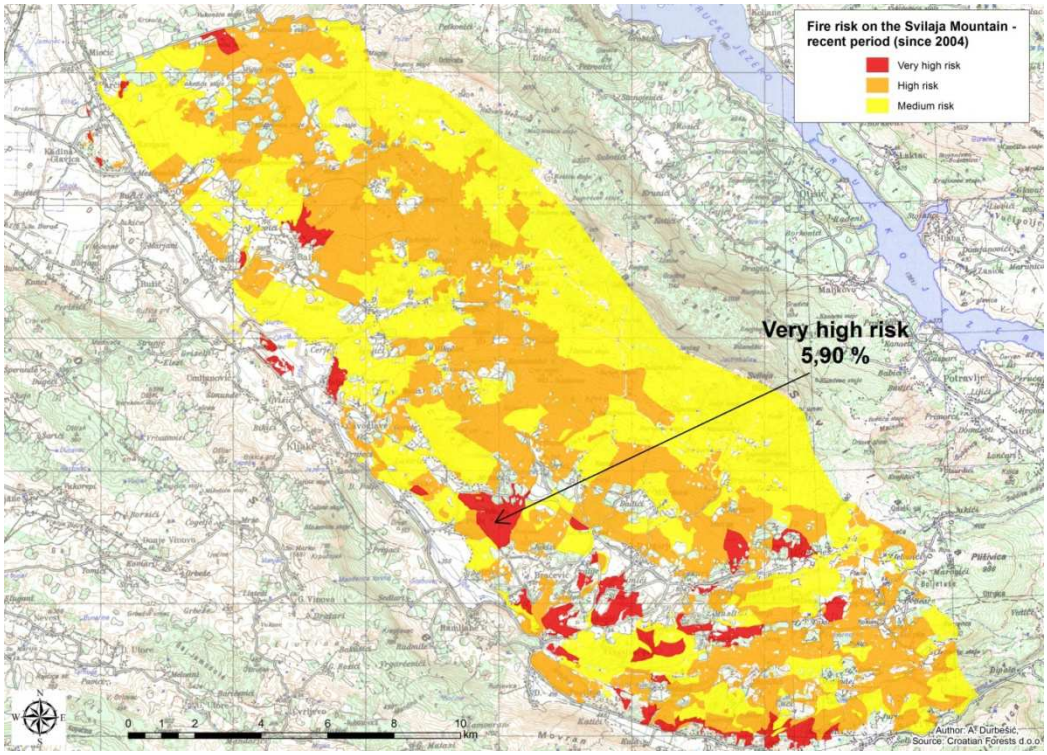

Figure 5 - Fire risk assessment in 2004 - 2010

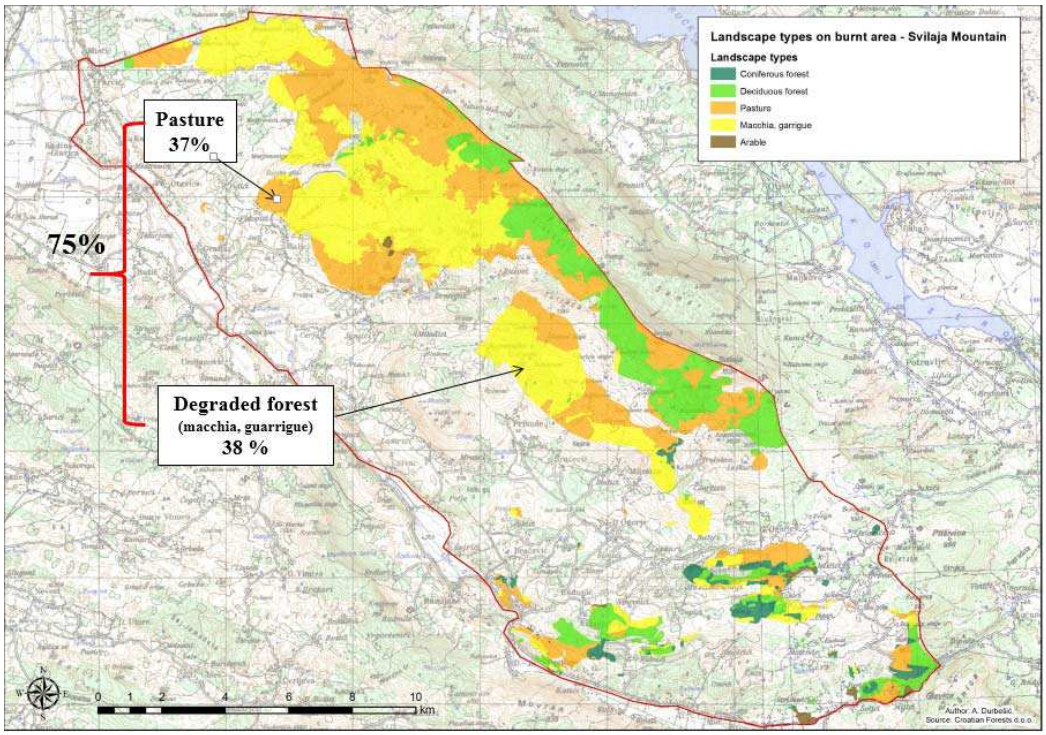

Figure 6 - Landscape types on burnt area in 2004 - 2010

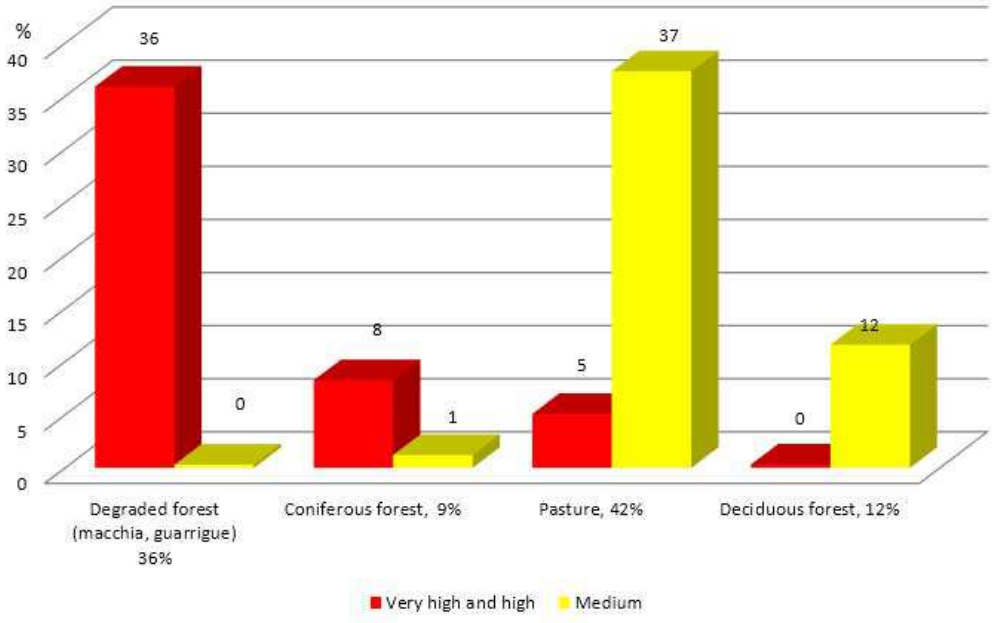

Figure 7 - Fire risk by landscape type in 2004 - 2010

The analysis of the landscape vulnerability to fire has shown that the most vulnerable and endangered landscape types are degraded and coniferous forests and shrublands and pastures (Figure 7). Previous researches on selective burning (Bajocco & Ricotta, 2008) also showed

that forests, shrublands and grasslands, where human pressure is not very intense, are generally characterized by large homogeneous patches of relatively high fuel load that favour rapid fire spread through the landscape. So, (coniferous) forests, natural grasslands and pastures and degraded forests, such as shrublands or *macchia* and *garrigue* are landscape types where the largest fires can be expected. Additionally, the results has also shown that variables such as shrubland vegetation, wetness in fall-winter and dryness in summer for prolonged periods are positively correlated to the burned area (Ganteaume & Jappiot, 2013; Tedim et al. 2015).

5. Conclusion

By the turn of the 20th – 21st century, the majority of the study area covered by pastures, arable and mountain deciduous forest has been reduced and replaced primarily by various forms of degraded forest and shrubland such as *macchia and garrigue*. Pastures and arable land are reduced 50% in relation to the 19th century and all in favor of degraded forest as a new landscape category. While in the 19th century moderate fire risk prevailed at more than 80% of the total area, more than 50% of the area was under the high risk at the end of the 20th century. At the beginning of 21st century, areas under the very high fire risk are introduced and rising up. The trend of fire risk change is very well in accordance with the landscape change, i.e. the replacement of pastures with the new category of degraded forests types and shrubland. While climatic, pedologic and orographic parameters are constant for all the research period of two hundred years, anthropogenic and vegetational (landscape) parameters represent changing variables and directly influence the changing fire risk vulnerability.

The analysis of the landscape types on recently burnt area, clearly confirmed that fire is selective to the landscape type. All the fires took place in the higher parts of the mountain at the distance from the settlements, where dominating landscape types are degraded forests and shrublands i.e. *macchia garrigue* and pastures, which make 75% of the total burnt area. It shows that the most vulnerable and endangered landscape types are degraded and coniferous forests, shrublands and pastures.

Taking into account the overall landscape change over 200 hundred years and the prevalence of degraded forest clearly points to the importance of the human impact on landscape change by means of degradation and extensification trends that inevitably points to the increase of the fire risk incidence. As both dominant trends, degradation, as well as extensification lead to the increase of the areas of degraded forest and shrublands, the abundance of fuel leads to the increase of fire risk potential.

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