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Forest fires in Dalmatia

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Abstract. Every year the Republic of Croatia, especially in its south part in Dalmatia, faces forest fire risks. The weather is exceptionally conducive to fires, so the main period of fire occurrences is between June and October, characterized by long lasting dry and warm weather with temperatures over 30°C. Research carried out by the authors in 1997 and 2012 have pointed to the fact that human impact is the main cause of ignition. This paper presents an overview of the total number of fires in the period from 1998 to 2012, with the emphasis on forest and woodland fires in the Croatian region of Dalmatia. Data on the situation in Dalmatia refer to the situation in the areas of responsibility of four Dalmatian Police Administrations. Analysis is based on official data of the Croatian Ministry of the Interior and the report of the National councillor for managing and controlling forest fires. The authors have analysed the frequency of forest fires in Dalmatia in a period of fourteen years (1998-2012) comparing it with the previous period, 1989-1996. The results that the authors have obtained reveal how forest fires most commonly (2/3) break out during the warm part of a day, from 09.00 until 18.00 hours in the warm period of the year. Particularly vulnerable are the forests of Aleppo pines and maquis being mostly thermal forests, whilst in the south of the country the forests of Holm oak (*Quercus ilex*) and English oak (*Quercus robur*) are at the highest risk. Reforesting of burned areas is very slow and Croatia has been far behind in reforesting in the continental part of the country.

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1. Introduction

Wildfires have been an integral part of the Earth's ecosystem in the last 350 million years. We obtain data about wildfires from numerous sources like geochemical processes, layers of charcoal, growth rings on stumps, and archaeological sites (Iglesias et al., 2015). Deposits of charcoal present a valuable source of information due to the mechanism of their formation during incomplete combustion of fuel in reduced conditions. Pieces of charcoal are dispersed in wildfires and deposited in lakes, where they form sediments which are preserved until the present day (Iglesias et al., 2015). Natural causes (lightning, volcanic eruptions) of wildfires are common in many parts of the world and are an integral part of many ecosystems, but 0.6 - 4% of all burned areas in the Mediterranean were caused by lightning, making it the primary cause (Naveh, 1975). Wildfires today are in 95% of all cases due to anthropogenic activities. Having started to use fire in the Palaeolithic, the Neolithic man turns it into a tool for transforming the natural landscape of the Mediterranean (Naveh, 1975). Even though Mediterranean vegetation dates from the Pliocene, only a small number of species survived the glacial era. The Mediterranean has more than 25 thousand plant species, while the rest of Europe has a mere 6 thousand. The reason for this state is that the Mediterranean was devoid of ice in the glacial and the interglacial eras (Quézel, 2000; Harriet, 2009; Tekić, 2013).

Around 11 thousand BC, the climate in the Mediterranean becomes drier, and species more adapted to this climate appear; this is when the holm oak (*Quercus ilex*) becomes dominant. In the early Holocene more fire activities were recorded in the Mediterranean, in the Pyrenees around 10,000 BC, and in Italy around 9,500 BC. The Holocene temperature maximum dominates in the northern hemisphere in the period from 8,000 to 5,000 BC (Vanniere et al., 2011). The analyses of charcoal deposits in Lake Malo on the island of Mljet (southern Dalmatia) indicates an expansion of forest of *Q. ilex* in the 7th millennium BC (6,400-6,200 BC), while to the north around Lake Vransko (central Dalmatia) the expansion began much later (5,200 BC) and is linked to climate change, i.e. to frequent occurrences of dry summers and increased anthropogenic activities (Colombaroli et al., 2009).

As the summer temperatures decreased and the precipitation, i.e. the moisture of the soil, increased, the fire activities became less common, reaching the lowest level of occurrence in the period from 4,700 – 3,300 BC (Feuerdean et al., 2013). The Croatian coast experienced the transition from deciduous to evergreen forests of *Q. ilex* around 6,400 BC, while for three millennia (until 3,500 BC) the fires played a significant role in the changing of the vegetation cover (Colombaroli et al., 2009)

2. Material and research methods

Human activities on agricultural land are the most common causes of fires (Aleksandrian et al., 1998). The traditional rural socio-economic system has drastically changed in the past 50 years. Key changes in economy and the landscape of the Mediterranean countries start in the 1950s, particularly in Dalmatia. Traditional activities are abandoned and the rural areas are affected by population migrations towards coastal cities. Vineyards and olive trees are grown on plots of land where dry stone walls are used for terracing; the numbers of sheep and goats otherwise common in Dalmatia are reduced as terraces and pastures are abandoned (Rego, 1992; Arianoutson, 2001).

When the intensive industrialization of the country began towards the end of the 1960s, vineyards and olive groves were common in the limestone area of Dalmatia, yet by the end of the 1990s agriculture in these areas was gradually abandoned. This process is not characteristic only for Dalmatia, but for the whole Mediterranean area (Arianoutsou, 2001). At the same time, the number of fires and the size of burned areas increase in this period (Pausas, Vallejo, 1999).

The changes that occurred in the traditional use of land showed that much agricultural land was abandoned and uncontrolled growth of secondary vegetation became apparent, all of which brought about an increase in accumulated fuel material (Rego, 1992).

Mass tourism, erection of hotels, apartments and summer houses demanded more free land surfaces.

Fires have been the means by which previously agricultural, and nowadays abandoned land is transformed into terrain for the construction of tourist and residential facilities. Woodfires in plots near forests often cause fires in the lowland part of Dalmatia.

In summer, tourism brings Dalmatia numerous tourists from various ecological systems quite different from those that are characteristic for the Mediterranean area. Carelessness and lack of knowledge and awareness about the area where they are on holiday causes activities that lead to wildfires. Illegal rubbish dumps, sometimes located near forests and containing combustible materials, are also potential causes of forest fires.

The Mediterranean eco-climatic zone is classified as the most risky area with more than 10 fires per 1,000 km² surface. The Mediterranean with its 50,000 fires per year and 700,000 to 1 million burned areas is considered one of the world's regions with the highest risk of fires (Vannier et al., 2011). Most of the fire-affected area is left to natural succession. However, planned restoration of burned areas is based on indigenous plant species (Pausas, Vallejo, 1999).

Mediterranean pine – Aleppo pine – has been used in reforestation since the 19th century (Pausas et al., 2004), together with increasing numbers of deciduous forests of holm oak, kermes oak and downy oak (*Quercus ilex, Quercus coccifera, Quercus pubescens*, Riera, Mogus, 2004). The authors have analysed the frequency of wildfires in the region of Dalmatia in the decade from 1998 to 2012 and compared it to an earlier period from 1989 to 1996.

The analyses included a number of components:

1. Natural factors which influence the occurrence and spread of wildfires (climatic elements, combustible material), geological characteristics of the terrain, type of vegetation
2. Burnt areas according to dominant economic activities: agricultural land – vineyards, olive groves, forests, abandoned and uncultivated land
3. Burned forest vegetation was analysed
4. Causes of wildfires were established
5. Damage to the landscape and the economy was assessed
6. Ultimately, the authors have dedicated a part of the research to the process of reforestation which they determined to be mostly by natural self-regeneration, while intentional reforestation is poorly represented.

Apart from analysing statistical data, the methodology in this research included field work in areas affected by wildfires, as well as interviews with local residents. The authors used the data supplied by the police departments in Dalmatia, by Croatian Forests, and the Canadian system of risk assessment (FWI) in this paper.

Dalmatia is a part of the Croatian Adriatic coast (from Istria to Konavle), from the island of Pag in the north to the border with Montenegro to the south (Fig. 1), looking from east to west. It is divided into three regional centres: the islands, the coastal belt and the interior (Dalmatian hinterland and Bukovica). The climate is Csa (hot summers – Mediterranean climate) and Csb (warm summers – Mediterranean climate), whose characteristics are hot dry summers and mild wet winters.

The Mediterranean coastal area has forests of Aleppo pines and holm oak, and forests of Oriental Hornbeam (*carpus orientalis)* and downy oak, while in the Mediterranean mountain belt the most common forest stands are Ostry (hop-hornbeam) and downy oak, together with forests of Pinus nigra subsp. dalmatica and forests of holm oak and hop-hornbeam (Trinajstić, 1998).

Analysis of fire activity in the area of Dalmatia is based on data from Police Administrations of the four counties that form this area. The study deals with the period from 1998 to 2012 compared to the previous period from 1993 to 1996.

The authors used data from police administrations as they are institutions that have the most accurate information on all wildfires in the Republic of Croatia, and the data are processed by regional police administrations that correspond to the political structure of the counties. Apart from the Police Administrations, data are collected by the State Directorate for Protection and Rescue and in the Central Bureau of Statistics. Given that the data vary in these institutions, the authors have opted for data provided by the Interior Ministry.

In the period from 1998 to 2012, Croatia registered 125,150 wildfires, with 31.7% (38,907) being in the region of Dalmatia. Most of the wildfires were recorded in PA Split – Dalmatia, while PA Dubrovnik-Neretva (Mamut, 2011) in the period from 1998 to 2008 never had more than 400 wildfires (Fig. 2).

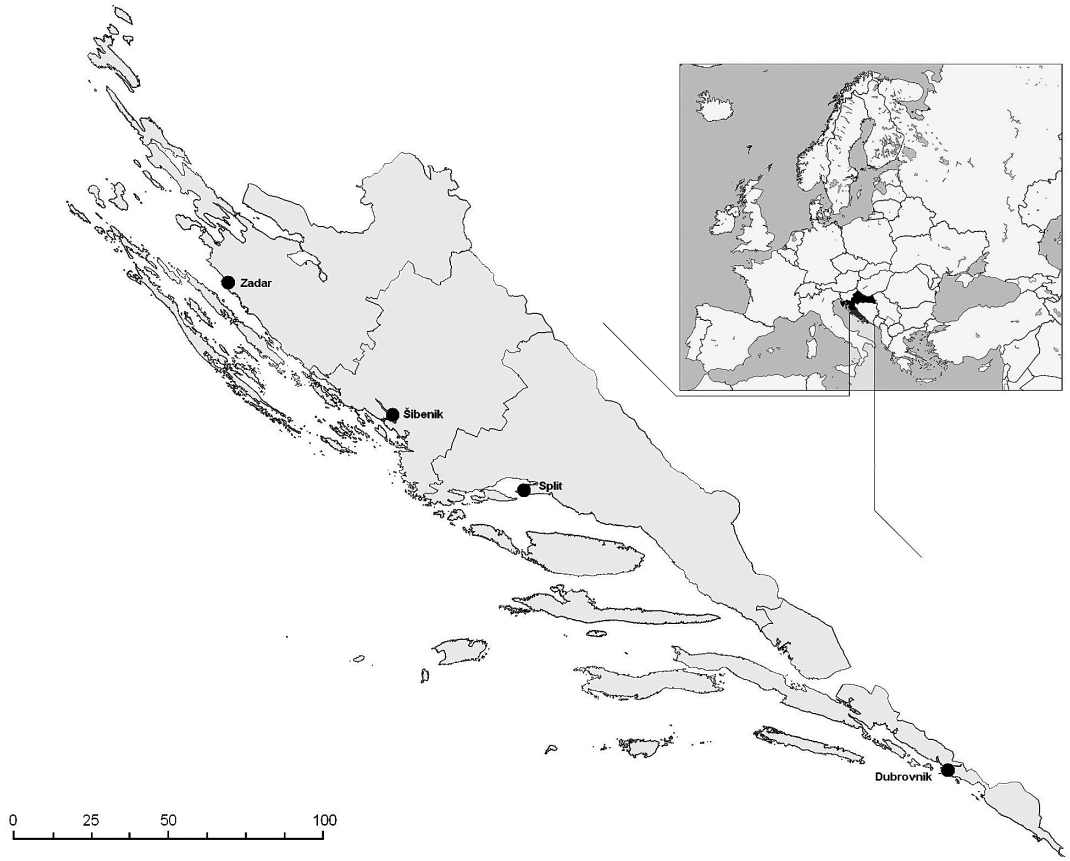

Fig. 1. Geographical location of Dalmatia

Source: Authors' own work based on Croatian Ministry of the Interior data, 2014

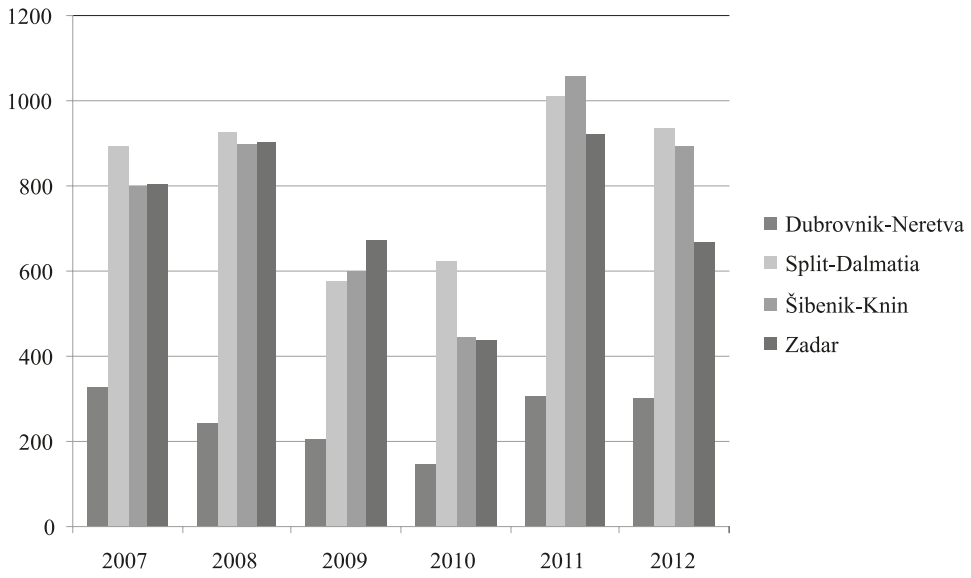

Fig. 2. Fires registered by the Police Administrations in Dalmatia in the period 2007 - 2012 (own calculations based on data of the Croatian Ministry of the Interior)

Source: Croatian Ministry of the Interior, 2014

Earlier studies from 1993 to 1996, show that the highest concentration of fires with the largest burnt areas were in the PA region of Zadar and Šibenik – Knin. Part of the territory of these two PA (interior – Bukovica and the Dalmatian hinterland) was occupied during the Homeland War (1991-1995) and numerous fires were intentionally caused by the occupation forces. Large areas in the hinterland were mined in the war preventing fire fighters from working from on land. Data on burned open space show a disparity in the number of fires and the size of burned areas (Fig. 3).

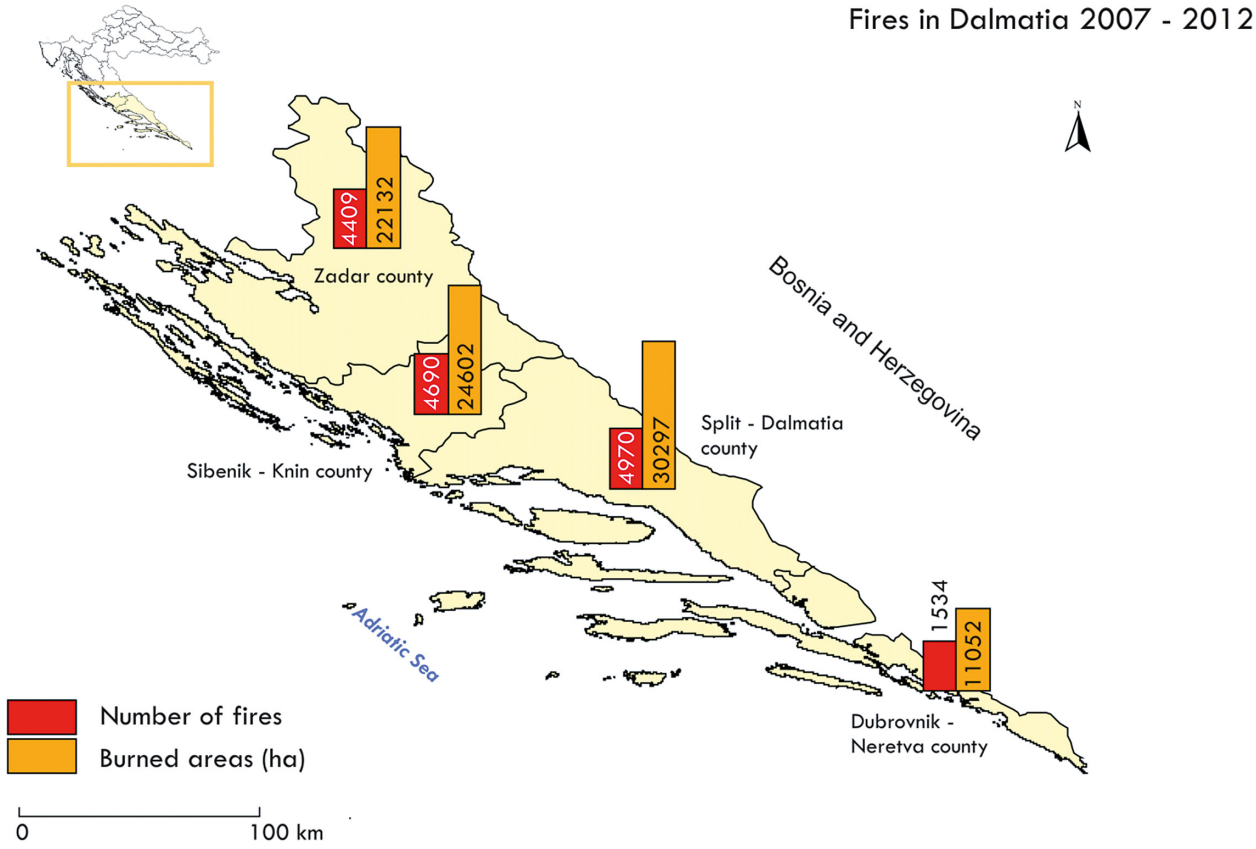

Fig. 3. Fires in Dalmatia (2007 – 2012)

Source: Authors' own work based on Croatian Ministry of the Interior data 2014.

In the past fifteen years PA Šibenik-Knin had the largest fire-affected zone (84,193 ha), followed by PA Split-Dalmatia (76,119 ha), PA Zadar (70,808 ha), and PA Dubrovnik-Neretva (48,871 ha). The size of the burned areas in Dalmatia changed over the years, depending on climatic conditions. Long-term drought, high temperatures and lack of rainfall in the summer months were all factors that enabled the spread of wildfires. The size of burned areas in the Dalmatian territory ranged from 4,311 ha (2005) when 103 ha of open space was burned in the zone of PA Dubrovnik-Neretva up to 73,676 ha (2000) when a staggering 24,959 ha of open space got burned in the region of PA Šibenik -Knin. In the same period, fires caught 766,365 ha of open space, out of which 280,078 ha (36.55%) of open space in Dalmatia.

According to its dominant vegetation community, open space is categorized as the following: forest area, forests, pastures and natural meadows, agricultural land and landfills. The Republic of Croatia is rich in forest areas; as much as 24,900 km², or 44%, of the national territory land is covered by forests. Most of it (59%) is high forest – seed plants; 24% is

low forests – stump or coppice forests; 16% is maquis, garrigue and shrub; and an insignificant 1% is plantations (Šiljković, 1997).

Forests are natural habitats for numerous communities of plants and animals and are one of the main sources of Earth's oxygen. Forests prevent erosion and floods; they protect against landslides and accumulate floodwaters. Their role as places for recreation and relaxation for people is also important as they protect against strong solar radiation at the same time increasing air moisture and cooling the earth. Mediterranean forests are hugely exposed to the risk of wildfire, which results in the degradation of biological and landscape diversity changing the physiological and chemical characteristics of soils. Fires disrupt their stability destroying, in a very short time, the entire forest ecosystem. According to their resistance to wildfire, plants are divided into three basic categories: Fire susceptible plants, which are highly inflammable and completely destroyed by wildfire; Fire tolerant plants able to withstand some types of wildfire and grow despite the damage since the energy for their future reconstruction is stored in the roots; and Fire-resistant plants have only small amounts of oils and resins in their leaves, smooth barks and a high moisture content in the leaves. Among the former stand out the evergreen plants Pinus nigra and Cupresuss, while the most resilient fire species are Nerium oleander and Acacia cyanophylle (Nayisci, 2014.). Since wildfires cause vegetation loss and damage to the forest floor, water retention is reduced and the risk of erosion increased. Fires destroy the soil structure and its aggregate stability affecting the chemical and physical characteristics of the soil and making it vulnerable to wind and rain. Therefore, post-fire erosion is frequent in Dalmatia. A wildfire that swept through the forest and agricultural land on Pelješac peninsula in July 2015 destroyed 3,028 hectares of forest and agricultural land, including 200 hectares of maritime pine, 80 hectares of Aleppo pine, 10 hectares of Pinus nigra and 236 hectares of maquis. A summer downpour that followed caused floods and erosion from the fire-affected areas destroying populated settlements by the sea, downhill of the area of the wildfire.

Soil erosion in fire areas makes restoring vegetation difficult long-term since it washes away and destroys the soil whose rehabilitation takes dozens of years. Wildfires cause transformation of the social, environmental and economic functions of forests, particularly the loss of wood mass (Miklić, 2013). After the fire, the burnt areas usually give rise to pioneering and most often less valuable tree species.

How many areas will be affected by the fires depends on many factors, from forest vegetation and combustible materials to climate and relief elements.

An important factor in the type of forest vegetation is the age of forest stands, i.e. combustible materials. Forest fuel is considered to be the entire quantity of the plant material, dead and alive, which is located above the part of the mineral soil (Španjol et al., 2008). Apart from by vegetation types and quantities of combustible materials, the flammability of fuel and spread are affected by air temperature, soil and air moisture and the amount of solar radiation, wind speed and direction and the vertical structure of the atmosphere (Vučetić et al., 2007).

In situations of high temperatures, low rainfall or prolonged drought periods when the soil is dry, there is a higher risk of wildfire, as well as its rapid expansion. Brücher (2014) believes that the increase in fire activity is primarily related to temperature variations, and only secondarily to variations in rainfall. The driest years are associated with heat waves and intense fire activity. A good example of this is the year 2007, when wildfires destroyed more than 226,000 ha of forest, olive trees and maquis in Greece (Vannier et al., 2011). The warm season from June to October marks the period when coastal Croatia, especially its southern part (Dalmatia), is exposed to wildfires of forests and agricultural lands. It is a long-term season of dry and hot weather with temperatures above 30°C.

Previous studies (Šiljković, 1997) show that the warmest time of the day, from 12.00 to 18.00 is the period when wildfires most often occur (40.8 %).

The wind continually blowing spreads combustible particles influencing the expansion of the wildfire and spreading the wildfire's burning front. Fires can result from natural factors (lightning, volcanic eruptions), but are most commonly the result of anthropogenic activities (carelessness, arson, clearing agricultural land, attempts at re-assigning areas for civil construction purposes, activities related to tourism and recreation, cast-away cigarette butts, fireworks, demining fields).

Over the decade of 1998-2008, on the territory of Croatia, 189,985 hectares of forests and woodlands were burnt, out of which the majority was in the zones of Dalmatian Police Administrations, as much as 64.3% or 122,241 ha (Mamut, 2011). Similar trends were detected in previous research (Šiljković, 1997) revealing that in the period from 1989-1996, out of 101,680 ha of Croatia's burned woodlands, 80,350 ha (79.02%) were in the coastal zone and on the islands. Especially large woodlands were burned in 1998 (21,531 ha), in 2000 (32,661 ha), in 2003 (15,694 ha) and in 2007 (20,341 ha). The PA Šibenik-Knin registered the highest rate of burned woodlands. With regard to the ratio of temperature and the amount of precipitation, the highest number of fires, as well as the largest burned areas, were recorded in the dry years of 2000, 2003, 2007 (Fig. 4.).

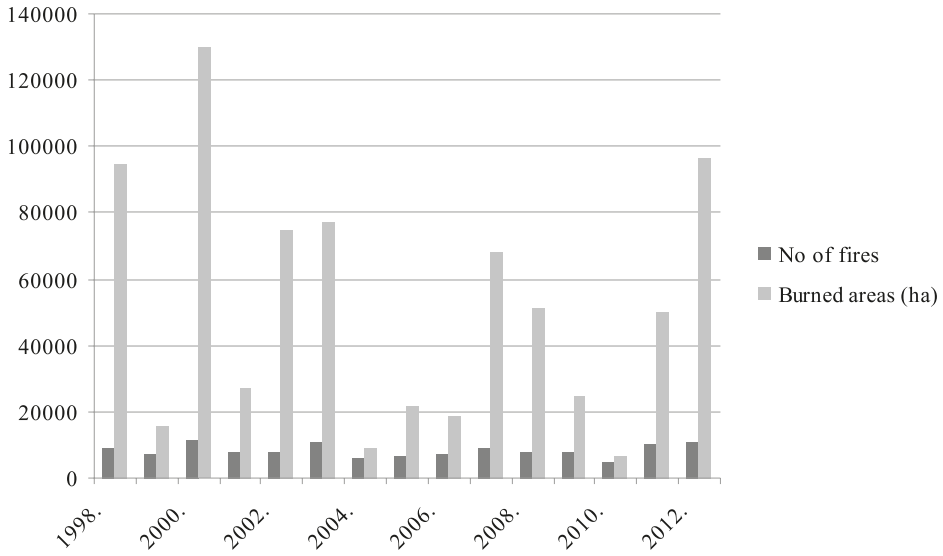

Fig. 4. Fires and consequences in the period 1998 – 2012 in Croatia per year

Source: Croatian Ministry of the Interior, 2014

In the period from 2009-2011, 66,843 hectares of forests and woodland were affected by fire on the Croatian territory, especially during the extremely dry summer of 2011, when the major part of woodland, scrub and maquis left a charred landscape. Coastal forest communities are more flammable than continental woods because of the dry climate and their xenomorphic composition of vegetation. Since the Mediterranean vegetation is abundant in resin (conifers) and essential oils, it is obvious that coastal forests are more subject to fires than deciduous forests of the continental part of Croatia, which are less flammable and do not support fires. The Mediterranean forest ecosystem of conifers and deciduous forests is also called a 'Pyrophytic eco-system' due to its effect on fires. This group includes the species from the families of *Pinus, Quercus, Cistus, Calicotome* and from the families of *Ericacea* (Španjol et al., 2008). The forests of Aleppo pine (*Pinus halepensis*) and numerous types of maquis (Juniper) are mostly subject to fires. Except for autochthonous plants in the karst Dalmatian area, artificially cultivated allophonic sorts can be found, planted for the needs of reforesting and melioration of degraded areas. Increased flow of people (tourists) influences the frequency of forest fires in the Mediterranean area, especially during summers when forests are mostly exposed to fire risk (Fig. 5). Very often uncultivated and neglected allophonic and autochthonous pine forests can be found in tourist destinations, increasing the possibility of fires due to carelessness. Sometimes even constructed anti-fire corridors may present a possible threat because their poor maintenance may cause overgrowth of easily combustible plant species.

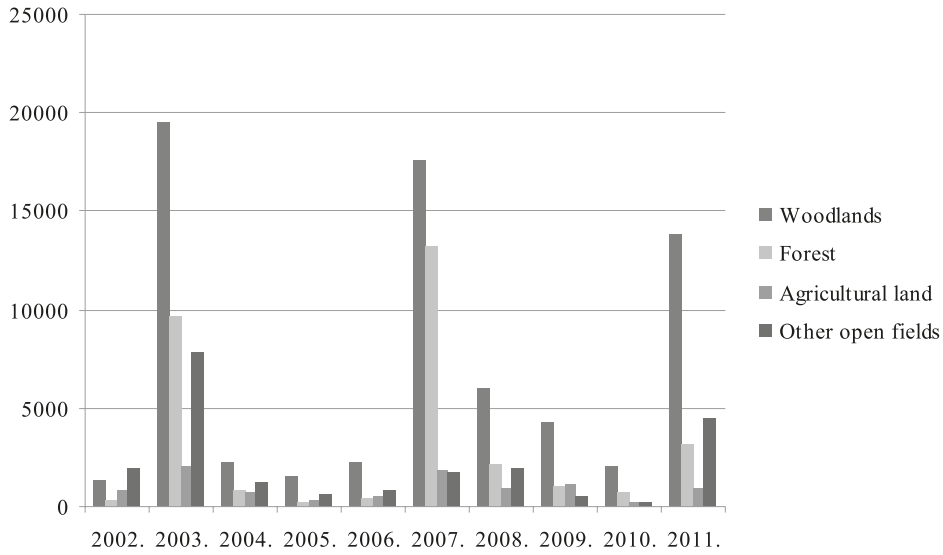

Fig. 5. Burned areas in the Adriatic region in the period from 2002 – 2011

Source: Croatian Ministry of the Interior, 2014

Apart from the type of vegetation that endangers the Mediterranean forests more than the continental ones, it is necessary to stress the climate and geological elements of the Mediterranean area (Mamut, 2011). The most important climate elements referring to the flammability of open spaces are certainly humidity and water, i.e. precipitation. Thus, dryness conditions play a vital role in fire protection and also in the rehabilitation of burned space. Wind should be added to these climate factors, being a strong trigger for causing and especially for spreading forest fires. Wind acts mechanically, spreading flames and sparks and destroying exceptionally large forested lands in wildfires and fires in the conifers' crowns when the blaze spreads from one treetop to another causing what has been dubbed a 'flying fire'. In Dalmatia, along the coast, in the hinterland and on the islands, the wind regimes change very often, especially in summertime, explaining a high rate of burned spaces under the Dalmatian Police Administrations' responsibility. A serious threat is Bora, a strong and dry wind that aggravates fires and prevents their successful extinguishing, often making it impossible. Wildfires particularly break out at the time of a strong Bora. More than 30 years ago, an American scientist Richard Rothermel made a semi-empirical mathematical model of the spreading of fire which was dominant in all analyses of fire behaviour. He claimed that the speed of the wildfire's burning front depended on the type of vegetation, angle of terrain and the speed and direction of the wind (Rothermel, 1972). On the other hand, Stipaničev (2008) thinks the situation in the field is more complex. The speed of the spreading of the burning front at the foot of the hill is greater than the speed with which the wildfire had started up the hill. The wildfire does not move at a continuous speed up a hill but speeds up. In the equation to calculate the spread of the wildfire Stipaničev (2008) thinks it is necessary to add another component – time. According to him, the speed of the spreading of the burning front depends on the terrain, vegetation, meteorology and time.

The size of burned space depends on the terrain topography, especially on the steepness of the terrain and the exposition of slopes. Spreading of fires is faster on up-hill than on down-hill slopes and also the elevation increases the fire speed. On an elevation of 30 - 40°, fire expansion could be 20 times faster than in lowlands (Bodrožić et al., 2005). Geological features and the lithological and pedological composition are other essential factors in causing fires and their spreading.

The orientation of the slope has an impact on the occurrence of wildfires since northern slopes are shady and less exposed to sunlight, as opposed to

southern slopes that receive greater amounts of radiation and longer exposures. Therefore, most wildfires occur on southern slopes.

Pedological conditions refer to the forest floor being the main part of the combustive material. As a rule, craggy and rocky areas are convenient for fires. Forest fires adversely influence not only the natural landscape but also the composition of the soil since over 10-13 years the proportion of humus has downsized by 11-30% and nitrogen by 7-25% (Španjol et al., 2008). Depending on the soil type and the elevation of terrain, the composition of clay in the soil also changes in burned areas.

3. Results

According to their occurrences, wildfires of open spaces including all forest fires could be analysed as natural or caused fires, or according to their fuel type as ground fires (sub-terrain fires), surface fires (low-lying fires), canopy or crown fires and fires of isolated trees and bushes (Španjol et al., 2008). Ground fires destroy humus and peat layers of the land. They cause a great deal of damage when they destroy the roots of trees. They dry out the soil and destroy vegetation on the land where they occur. Ground fires commonly occur in all types of forests. Crawling or surface fires are the most common types of forest fires; they destroy the young trees, ground shrubs and the deciduous vegetation.

However, crown fires destroy the largest forested areas particularly if supported by wind when flying flames spread from one treetop to the next. Crown fires annihilate high-quality and economically valuable forest stands; they destroy the soil, water, and the ecosystem. Various types of fire often occur at the same fire site. Before fire destruction occurred, the majority of woodland space of 85,690 ha or 50.2% used to be covered with stump forests, maquis, garrigue, scrub and brushwood. According to its purpose, open space can also be divided by type as forests and woodlands, agricultural land, waste dumps and various other open spaces. The rate of these categories varies in the total rate of burned spaces in the Republic of Croatia from those in Dalmatia. In the territory of Croatia, the highest rate of burned open space refers to agricultural land, even 302,172 ha or 51.4%, (Mamut, 2011), whilst in Dalmatia burned forests and woodlands prevail. Perceiving the structure of burned open spaces under the Dalmatian PA-s responsibility, the proportion of forests and woodlands is as high as 53.5% (or 122,241 ha), agricultural lands constitute 11.1% (or 25,334 ha), waste dumps up to 1.8% (4,106 ha) and other burned open spaces 33.6% (Mamut, 2011).

Out of 91,705 fires registered in Croatia from 1998 to 2008, the greatest number (55,804) of fires was registered on the land of unknown ownership (Mamut, 2011). If the number of fires on private land (27,227 fires) is added to that number, it is evident how a majority of fires (83,031 or 90.5%) occur in the areas that are not under state management. Such a figure is the result of inadequate care and the lack of implementing preventive measures including clearing as well as building anti-fire corridors and the implementation of planting measures in forests. Changing the purpose of non-construction to construction land could often be heard as a possible reason for such a ratio of the fires on state and private ground. The law prescribes that the purpose of land may be changed five years after being burned. Data on the size of burned opened space as per ownership matches the number of fires. The majority of state estates burned was in the zones of Dalmatian PA-s, almost 70.2% or 54,890 ha out of totally burned state estates in Croatia (78,171 ha). The share of burned private open spaces in the zones of Dalmatian PA-s is slightly smaller but still with a high rate of 62.9% or 49,892 ha. It is important to stress that the ownership of the largest part of burned open space is usually unknown: in Croatia it is 73.2% or 430,829 ha and in Dalmatia 53.7% or 122,717 ha (Mamut, 2011). The first problem is when the owners of the land cannot be determined. The second problem is outdated land registers, i.e. the lack of harmonization between the cadastre and the actual field situation. There are many cadastre parcels of land with recently appearing forests but they are still registered as farmland and thus they do not fall under the fire protection programme. These forests are being cut and replaced with illegally constructed settlements especially in the vicinity of tourist destinations. Many opposite examples could be found, when a parcel of land had been registered as forest land in the cadastre, but the for-

ests disappeared many years ago. Apart from these, a considerable problem is keeping different data in the cadastre and the land registry for the same parcel of land.

The problem with analysis of fire causes, apart from open space fires, is that fires on facilities (constructed facilities and means of transport) are also often registered. From the geological point of view, that category is less interesting, yet from the socio-geographic and economic point of view it has been a significant indicator. Since the majority of fires are caused by people (deliberately, by negligence or in childish games), this analysis has mainly a socio-geographic character, so the fires on facilities are also included. It has been found that the majority of fires were caused by negligence, almost 75% (68,745 fires) presenting a distressing number. As per the place of fire, 30,470 fires occurred on facilities while 38,275 (55.7%) fires started in open spaces. Unsurprisingly, the majority of fires caused by negligence occurred on agricultural land (15,752 fires or 23%). Deliberately caused fires are a problem requiring the involvement of a range of different professions for their prevention (from the medical profession up to legislative authorities).

Forest fires destroy native communities of Holm oak (*Quercus ilex*) and Downy oak (*Quercus pubescens*) (Dubravec et al., 2006). If not rehabilitated, these areas become rocky lands. Forest fires harm olive and vineyards that need to be revitalized in one of the three systems: on stool, in the crown or by stronger cutting (Strikić et al., 2005). The rehabilitation is implemented by reforesting with black and Aleppo pine but also with native species. However, due to fast growth and abundant seed production, Aleppo pine is used for the reforesting of degraded karst areas on the majority of burned spaces (Matić et al., 2011).

Aleppo pine (*Pinus halepensis*) is one of the most important species in the Mediterranean area, where it covers an area of more than 25,000 km^2. It dominates in forest ecosystems in semi-arid and arid areas (Quezel, 2000). Spread over a wide area of the Mediterranean, it can be found from North Africa through Southeast Europe to Israel and Jordan at its eastern border (Španjol, 1996).

Aleppo pine was planted extensively in the western Mediterranean during the last century; as a pioneer species it was resistant to drought and could survive in a wide range of conditions (Quezel, 2000). Although this pine is a pyrophyte, it does not need fires for its reproduction. Proof of this are the firebreaks, clearings and abandoned and cleared agricultural fields that it covers (Španjol, 1997). The spontaneous expansion of pine on wide areas represents a potential for the spread of wildfire to large regions (Rosavec et al., 2013).

Afforestation of the Karst region is a tradition which is more than a century old, dating from 1852, when it was mandated by the Forest law in the former Croatian Military Frontier. The first afforestation was conducted in Senjska Draga valley in 1860 (Tikvić, Seletković, 2003), on an area of 1,317 ha, with Black Pine (*Pinus nigra*) saplings. Dalmatia is significantly subject to wildfires, so rehabilitation and reforesting of burned spaces are important here because of preventing erosion and renewing the ecosystem. Native species (*Holm oak and Downy oak*) are planted on burned areas. The rehabilitation is carried out by planting of container conifers and broadleaf and consists of several phases: preparation works (clearing of burned areas), planting, harvesting and caring. Over the past eleven years, the preparation works were carried out on 2,817.35 ha of burned forest spaces. The reforesting was implemented only on 44.89 ha mainly by Aleppo pines, pine-trees and cypress. Despite the dire field situation, i.e. a high rate of woodland loss, reforesting activities in Dalmatian Counties are in progress only in Split-Dalmatia County. However, these activities are very poor compared to the reforesting activities in other parts of Croatia, especially in its continental area. From the tourist point of view, the forest is seen as an important landscape element, a place in which leisure time or recreation can be enjoyed (Vuletić et al., 2007). Research on the island of Korčula (Vuletić et al., 2007) and in Catalonia (Riera, Mogas, 2004) has shown that tourists are even willing to pay additional fees for conservation and fire protection.

4. Conclusion

Dalmatia, the southern part of Croatia, is an area with the highest fire risk. On average, 2,645 fires break out annually, mostly during the summer sea-

son, destroying thousands of hectares of forests, maquis as well as agricultural land (vineyards and olive groves). In the period from 1989 to 1996, some 10,044 ha of forests and agricultural land were destroyed on average while in the period from 1998 to 2012, that rate was five times higher reaching 51,091 ha annually. Apart from weather conditions (longer dry periods, high temperatures) the causes of wildfires are primarily anthropogenic in character (an ever increasing number of tourists at the seaside, irresponsible behaviour, arson, and intentional fires aimed at shifting the purpose of landuse). With the aim of more precise assessment of the fire risk and better protection from forest fires the Canadian system of assessment of forest fire hazards (FWI-Forest fire weather index) is being applied to fire risk susceptibility including the analysis of several parameters: combustible material, weather conditions (wind), topography of terrain, altitude, longitude and latitude, season. According to FWI, Dalmatian forests are classified into four categories depending on the fire risk: I-exceptionally high risk, II-high risk, III-medium risk and IV-low risk. The results achieved by the authors show that wildfires occur most often (2/3) in the warmest part of the day, from 9-18, in the hottest season.

The most susceptible to fires are the Aleppo pine forests with the maquis making it a forest community which is extremely thermal, while at the very south of the country the most threatened are oak forests, particularly those of the holm oak. Research has shown that most wildfires are caused by unintentional activities, i.e. human carelessness

References

Alexandrian, D., Esnault, F. and Calabri, G., 1998: Forest fires in the Mediterranean area, Rome: FAO.

Arianoutsou, M., 2001: Landscape changes in Mediterranean ecosystems of Greece: implications for fire and biodiversity issues. In: *Journal of Mediterranean Ecology*, Vol. 2. pp. 165 – 178.

Bodrozić, L.J., Marasović, J. and Stipaničev, D., 2005: Fire modelling in forest fire management. In*: Proceedings of International Conference CEEPUS Spring School – Engineering for the Future*, Kielce, Poland 6-16. 06. 2005, pp.7-15.

Brücher, T., Brovkin, V., Kloster, S., Marlon, J.R. and Power, M.J., 2014 : Comparing modelled fire dynamics with charcoal records for the Holocene. In: *Climate of the Past,* Vol. 10, pp. 811-824. DOI: http://dx.doi.org/10.5194/cp-10-811-2014

Colombaroli, D., Tinner, W., Van Leeuwen, J., Noti, R.,Vescovi, E., Vannière, B., Magny, M., Schmidt, R. and Bugmann, H., 2009: Response of broadleaved evergreen Mediterranean forest vegetation to fire disturbance during the Holocene: insights from the peri-Adriatic region. In: *Journal of Biogeography*, Vol. 36, No. 2, February 2009, pp. 314–326. DOI: http://dx-.doi.org/10.1111/j.1365-2699.2008.01987.x

Dubravac, T., Vrbek, B. and Lalić, Z., 2006: Prirodna obnova u sastojinama alepskog bora (Pinus halepensis) nakon pozara (Natural regeneration of aleppo pine (*pinus halepensis mill.*) forests after forest fires – in Croatian). In: *Works of Forestry Institute,* Special edition, Vol. 9, Jastrebarsko: Forestry Institute, pp. 37 – 51.

Feurdean, A., Liakka, J., Vannière, B., Marinova, E., Hutchinson, S.M., Mosburgger, V. and Hickler, T., 2013: 12,000-Years of fire regime drivers in the lowlands of Transylvania (Central-Eastern Europe): a data-model approach. In: *Quaternary Science Reviews*, Vol. 81, No.1. December 2013, pp. 48–61. http://dx.doi.org/10.1016/j.quascirev.2013.09.014

Harriet, A., 2009: Vegetation and Ecosystem Dynamcis. In: Woodward, J. editor: *The Physical Geography of the Mediterranean*, Oxford: Oxford University Press, pp. 203-227.

Iglesias, V., Yospin, G.I. and Whitlock, C., 2015 : Reconstruction of fire regimes through integrated paleoecological proxy data and ecological modeling. In: *Frontiers in Plant Science,* Vol. 5., 22 January 2015, Article 785., pp. 1–12. DOI: http://dx.doi.org/10.3389/fpls.2014.00785

Mamut, M., 2011: Veza prirodnogeografske i sociogeografske osnove Dalmacije s ugrozenoscu otvorenog prostora pozarom (Ties between the geographical and social geographical features of Dalmatia with the endangerment of forest fires - in Croatian). In: *Sumarski list (Forestry Bulletin)*, Vol. 135, No. 1–2, pp. 37–50.

Matić,S., Anić, I., Orsanić, M. and Mikac, S., 2011: Njega i obnova suma hrvatskoga Sredozemlja (Tending and regeneration of forests in the Croatian Mediter-

ranean region – in Croatian). In: Slavko, M. editor, *Sume hrvatskoga Sredozemlja (Forests of the Croatian Mediterranean),* Zagreb: Croatian forests, pp. 375 – 386.

Miklić, B., 2013: Dinamika požara kod Selca 23. srpnja 2012. godine (The dynamics of fire in Selce in 2012 – in Croatian), In : *Vatrogastvo i upravljanje požarima (Fire Fighting and Management)*, Vol. III, No. 2., pp 32–43.

Naveh, Z., 1975: The evolutionary significance of fire in the Mediterranean region. In: *Vegetatio,* Vol. 29, No. 3, pp. 199-208.

Neyisci, T., 2014: Mediterranean forest ecosystems, wildland fires, cypress and fire tolerant species, In: *MEDLAND 2020,AGENDA Regional workshop for the networking on best case actor practices*, 17 –19 III., 2014. Camerino, Italy. Available at: http://www.medland2020.eu/, DoA: 25 June 2015.

Quezel, P., 2000: Taxonomy and biogeography of Mediterranean pines

(Pinus halepensis and P. brutia). In: Ne'eman, G. and Trabaud, L. editors, *Ecology, biogeography and management of Pinus halepensis and P. brutia forest ecosystems in the Mediterranean basin*, Leiden: Backhuys Publishers, pp 1–12.

Pausas, J.G. and Vallejo, R., 1999: The role of fire in European Mediterranean Ecosystem, In: Chuvicco, E. editor, *Remote sensing of large wildfires in the European Mediterranean basin*, Berlin: Springer – Verlag, pp. 3–16.

Pausas, J.G., Bladé, C., Valderantos, A., Seva, J.P., Fuentes D., Alloza J.A., Vilagros, A., Bautista, S., Cortina, J. and Vallejo, R., 2004 : Pines and oaks in the restoration of Mediterranean landscapes of Spain: New perspectives for an old practice, In: *Plant Ecology*, Vol. 171, No. 1, pp. 209- 220.

Rego, F.C., 1992: Land use changes and wildfires. In: Teller, A., Mathy, P. and Jeffers, J.N.R. editors, *Responses of Forest Ecosystems to Environmental Changes*, London: Elsevier Applied Science, pp. 367 – 373.

Riera, P. and Mogas, J., 2004: Evaluation of a risk reduction in forest fires in a Mediterranean region, In: *Forest Policy and Economics*, Vol. 6, pp. 521 – 528.

Rosavec, R., Šikić, Z., Španjol, Ž., Barčić, D. and Vučetić, M., 2013: Ugroženost sastojina Alepskog bora (Pinus halepensis Mill.) požarima u stanišnim uvjetima jadranskog područja krša (Wildfire threats within the habitat conditions in Aleppo pine stands (Pinus halepensis Mill.) of Adriatic karst area - in Croatian). In: *Šumarski list (Forestry Bulletin),* Vol. 137, No. 9–10, pp. 461–471.

Rothermel, C.R., 1972 : A mathematical model for predicting fire spread in wildland fuels, Intermountain Forest and Range Experiment Station Forest Service U.S. Department of Agriculture Ogden, Utah, p. 48.

Stipaničev, D., 2008: Svaki požar može biti i eruptivni požar (Every fire can be an eruptive fire) - in Croatian). In: *Vatrogasni vjesnik (Fire Fighting Courier*), Zagreb: Hrvatska vatrogasna zajednica, pp. 18–21.

Strikić, F., Miljković, I., Vuletin Selak, G. and Bakarić, P., 2004: Regeneration models for old, neglected and burned olive trees. In : *Pomologia Croatica*, Vol.11, No.1–2, pp. 23–30.

Šiljković, Ž., 1997: Pozari kao oblik destrukcije geografske sredine, (Fires as a Form of Destruction of Geographical Environment - in Croatian). In: *Geoadria bulletin*, Vol. 2, No. 2, pp. 77–96.

Španjol, Ž., 1996: Prilog poznavanju šumskih požara u sastojinama alepskog bora (Pinus halepensis Mill.) (Contribution to the Knowledge of Forest Fires in Aleppo pine (Pinus halepensis Mill) stands – in Croatian). In : *Hrvatske šume (Croatian forest),* Zagreb: Hrvatske šume d.o.o., pp. 391-412.

Španjol, Ž., 1997: Amelioration of the burnt Allepo Pine (Pinus halepensis Mill.) forest area in the Makarska coastline region. In: *Glasnik za šumske pokuse (Annales experimentatis silvarum culturae provehendis),* Vol. 34, pp. 67.

Španjol, Ž., Biljaković, K., Posavec, R., Dominko, D., Barčić, D. and Starešinić, D., 2008: Forest fires and physical models. In: *Sumarski list (Forestry bulletin*), Vol. 132, No. 1-2, pp. 259–267.

Tekić, I., 2013: Prostorne promjene nastale pošumljavanjem alepskim borom na širem šibenskom području (Spatial Changes Caused by the Reforestation with Aleppo Pine in the Broader Area of Šibenik - in Croatian), Master Thesis, University of Zagreb, p. 77.

Tikvić, I. and Seletković, Z., 2003: Utjecaj posumljavanja krsa na hidrolosku funkciju suma, (The Effects of Karst Afforestation on the Hydrological Function of Forests - in Croatian). In: *Sumarski list (Forestry bulletin),* special edition: 125 godina od kraljevskog nadzornistva za posumljavanje krasa krajiskog područja – Inspektorata za posumljavanje krsa, goleti i uređenja bujica u Senju (1878- 2003), The 125th Anniversary of the Foundation "Royal Inspectorate for the Afforestation of Karst in the Krajina Border Region - the Inspectorate for the Afforestation of Karst, Bare Areas and Torrent Control" in Senj, the Oldest Croa-

tian Forest Karst Organisation, 1878 – 2003. Vol. 127, No. 1, Zagreb, pp. 30–34.

Trinajstić, I., 1998: Fitogeografsko rasclanjenje klimazonalne šumske vegetacije Hrvatske, (Plant-geographical Division of Climazonal Forest Vegetation of Croatia - in Croatian). In: *Šumarski list* (*Forestry bulletin*), Vol. 122, No. 9-10, pp. 407-421.

Vannière, B., Power, M.J., Roberts, N., Tinner, W., Carrión, J., Magny, M., Bartlein, P.,Colombaroli, D., Daniau, A.-L., Finsinger, W., Gil-Romera, G., Kaltenrieder, P.,Magri, D., Pini, R., Sadori, L., Turner, R., Valsecchi, V. and Vescovi, E., 2011: Circum-Mediterranean fire activity and climate changes during the mid-Holocene environmental transition (8500–2500 cal. BP). In: *The Holocene*, Vol. 21, No. 1, pp. 53–73. DOI: http://dx.doi.org/10.1177/0959683610384164

Vučetić, V., Ivatek-Šahdan, S., Tudor, M., Kraljević, L., Ivančan Picek, B. and Strelec Mahović, N., 2007: Analiza vremenske situacije tijekom kornatskog požara 30. kolovoza 2007, (Weather Analysis during the Kornat Fire on 30 August 2007 - in Croatian) In: *Hrvatski meteorološki časopis* (*Croatian Meteorological Journal*),Vol. 42, pp. 41–66.

Vuletić, D., Vondra, V., Szirovicza, Z. and Paladinić, E., 2007: Rezultati ispitivanja sklonosti turista za boravak u sumi i odnos prema ekoloskim i socijalnim uslugama suma, (Results of Investigation of Tourist Preferences for Visiting Forests and Their Attitude Towards Ecological and Social Forest Services - in Croatian). In: *Works* of *Forestry Institute*, Vol. 41, No. 1 – 2, Jastrebarsko, pp. 83–90.