TEKIC, Ivan, FUERST-BJELIS, Borna, DURBESIC, Anamarija (2015). ***The impact of aleppo pine afforestation on the structure and dynamics of landscape in mediterranean Croatia.*** The overarching issues of the european space: spatial planning and multiple paths to sustainable and inclusive development. Porto. FLUP. pp. 207-221

THE IMPACT OF ALEPPO PINE AFFORESTATION ON THE STRUCTURE AND DYNAMICS OF LANDSCAPE IN MEDITERRANEAN CROATIA

Ivan TEKIĆ
University of Zagreb
ivan.tekic5@gmail.com
Borna FUERST-BJELIŠ
University of Zagreb
bornafb@geog.pmf.hr
Anamarija DURBEŠIĆ
Hrvatske šume d.o.o.
anamarija.durbesic@hrsume.hr

Abstract

Unlike the rest of Europe, the Mediterranean region is characterized by large biodiversity of floral species. Due to intensive human influences forest cover of autochthonous Holm oak (*Quercus ilex*) is reduced to small dislocated patches of stands. This deforestation has led to massive erosion and loss of soil which prompted widespread afforestation efforts throughout the Mediterranean region. Because of its resistance to drought and capability to grow on highly degraded soils, as well as its fast growing and the ability to gradually rejuvenate soil on which it grows, Aleppo pine (*Pinus halepensis*), a pine species native to western Mediterranean, was the most commonly used specie. Rejuvenation of soil on which it grows is one of the main goals of afforestation in order to create the conditions for the growth of autochthonous Holm oak. However, the invasive spreading of Aleppo pine, its negative effects on floral biodiversity and susceptibility to fires have started to raise questions regarding the possibility of success. The case study in Dalmatia, the littoral part of Croatia, has shown that Aleppo pine is becoming the most dominant element of littoral landscape due to combined effects of afforestation and natural rejuvenation. Still, its ecological effects are yet to be truly understood.

Keywords: Aleppo pine (*Pinus halepensis*), afforestation, Mediterranean, Geographical Information System - GIS.

Résumé

Contrairement au reste de l'Europe, la région méditerranéenne est caractérisée par une large biodiversité des espèces locales. Sous une influence humaine intense, les forêts autochtones de chênes verts (*Quercus ilex*) n'occupent plus que de petites surfaces localisées. Une telle déforestation a engendré érosion et perte de sol massives qui ont entraîné l'élaboration de projets de reboisement sur toute la région méditerranéenne. En raison de

sa résistance à la sécheresse, de sa capacité de prospérer sur des sols dégradés et d'une croissance accélérée avec faculté de s'étendre rapidement en renouvelant progressivement le sol sur lequel il pousse, la pin d'Alep (*Pinus halepensis*), est l'espèce autochtone de Méditerranée occidentale la plus utilisée à cette fin. Le renouvellement du sol est en effet un des objectifs principaux du boisement visant en dernier lieu à créer les conditions de développement de l'espèce autochtone du chêne vert. Cependant, le caractère invasif de la croissance du pin d'Alep qui a une influence négative sur la biodiversité ainsi que sa vulnérabilité aux incendies rendent contestable le succès de cette méthode pour restaurer la végétation autochtone. L'étude des différents cas en Dalmatie et sur tout le littoral de Croatie a montré que le pin d'Alep est devenu l'élément dominant du paysage grâce à l'effet combiné du boisement et de la rapidité de son extension naturelle. Les implications écologiques de ce processus sont évidemment beaucoup plus complexes.

Mots clés : Pin d'Alep (*Pinus halepensis*), reboisement, Méditerranée, Système informatique géographique SIG.

1. Introduction

The Mediterranean floral species and vegetation structure emanate from glacial and interglacial periods that have had profound impact on European living organisms. While most of the middle and northern parts of Europe were covered with thick ice cover, warm, maritime air masses have enabled life to bloom on the shores of what is today known as the Mediterranean sea (Grove and Rackham, 2001). As a result, the Mediterranean nowadays, with its area of 2.3 million km², provides a habitat for nearly 25 000 species in contrast to non-Mediterranean Europe that encompasses 8 million km² with approximately only 6 000 floral species (Quézel, 2005; Harriet, 2009). Even though such floral diversity can be attributed to climate conditions, vegetation composition is heavily impacted by human activities ranging back as far as 6 000 years BP. Along with the warming of climate around 10 000 years BP, species accommodated to cold climates retreated and Holm oak (*Quercus ilex*) gradually started to dominate the Mediterranean forest vegetation. Its spatial distribution was so widespread that it is to this day usually regarded as the climax vegetation type of the Mediterranean. However, several millennia of human activities decimated Holm oak forests (mainly through clearing forests for agricultural areas and obtaining wood) to such extent that in some of the Mediterranean countries they can only be found in the form of degraded vegetation types such as *macchia.* As Holm oak forests gradually disappeared, newly induced ecological conditions allowed the wider spread of other tree species, among others Aleppo pine (*Pinus halepensis*) (Grove and Rackham, 2001; Quézel, 2005).

2. Aleppo Pine in the Mediterranean

Aleppo pine is the Mediterranean pine species which was first described and classified in 1768 by Phillip Miller on the basis of trees that were grown from seeds originating from Aleppo area in Syria. As a result, its name, *Pinus halepensis*, led to misconception about its natural distribution area. Aleppo pine's distribution is dominantly west-Mediterranean, and not east-Mediterranean as it is commonly believed (Trinajstić et al., 2011) (Fig. 1). Archeological, botanical, palynologycal and historical research has shown that Aleppo pine could barely be found in vegetation composition of Israel by the beginning of 20th century, while its present share of 50% in Israelian wood cover is a result of intensive afforestation efforts (Liphschitz and Biger, 2001). In France, mostly in its Mediterranean part, Aleppo pine forest areas have also increased from 360 km² in 1878 to 1050 km² in 1900 while today they encompass more than 2000 km² (Grove and Rackham, 2001), that is altogether an increase of 455 %. Situation is similar in Spain, country with largest Aleppo pine forests as their area has increased by 75% in the last 50 years (Chirino et al., 2005).

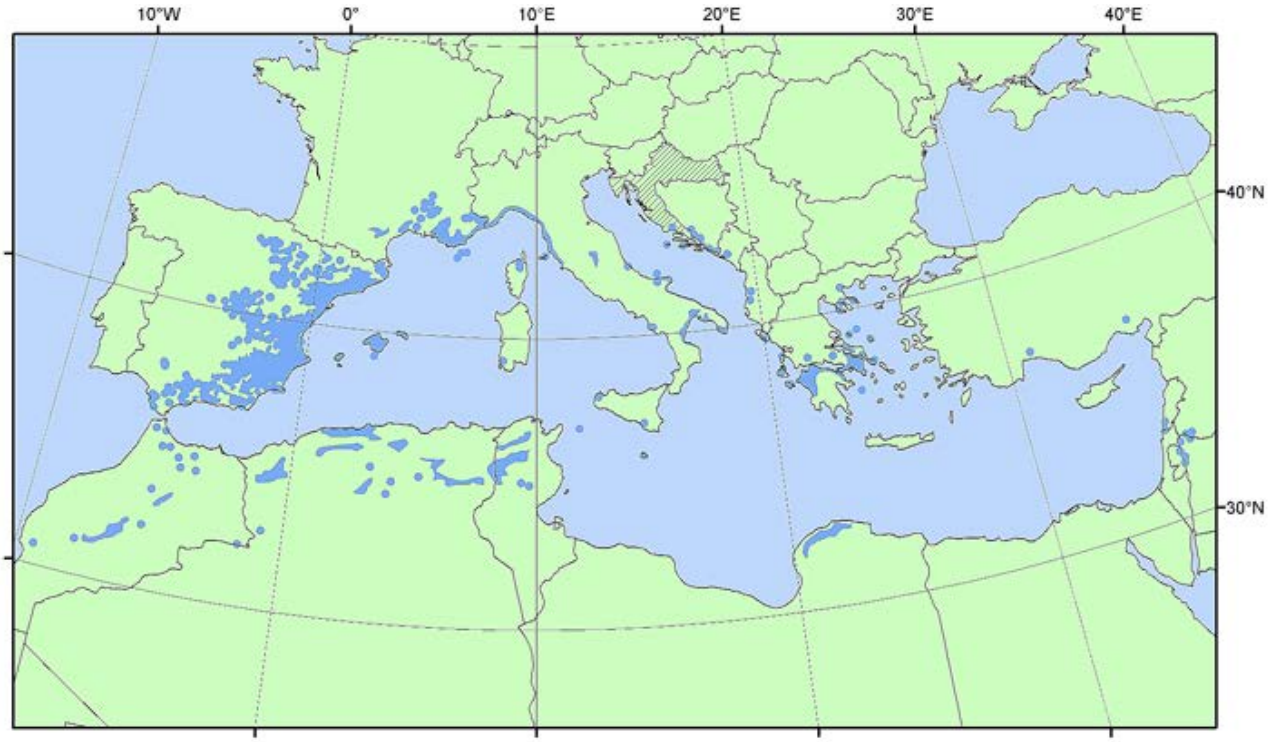

Fig. 1. Area of natural growth of Aleppo pine in the Mediterranean
Source: EUFORGEN, 2009.

This massive increase of Aleppo pine forest area is a result of intensive afforestation efforts in the Mediterranean countries that has begun in the mid-19th century after scholars acknowledged the devastating effects of deforestation. The species that would be chosen for afforestation had to be well adapted to the Mediterranean climate and soils and also had to grow reasonably fast in order for afforestation to be effective. Foresters and botanist chose several potential species, among which certain allochthonous species like eucalyptus could be found, but they predominantly used Aleppo pine for afforestation of coastal Mediterranean and Black pine (*Pinus nigra*) for sub-Mediterranean areas (Hughes, 2005). In Spain, for example, in the last 50 years pines have constituted 85% of all forest plantations (Chirino et al., 2005) while in the period from 1945 to 1986 Aleppo pine had a share of 55% of all afforested areas in Algeria, 71% in Greece, 86% in Portugal, and as much as 94% in Turkey (Pausas et al., 2004). In addition to afforestation efforts, the Mediterranean forests are also expanding because of the natural spreading due to changes in human activities which have occurred during the last century. Rapid industrialization and littoralization have led to reduced number of agricultural workers which in turn caused the abandoning of numerous agricultural areas and reduction in number of domestic animals, thus allowing the process of secondary succession that is now dominated by expansionist species such as Aleppo pine (Grove and Rackham, 2001; Quézel, 2005). Such combined effect of afforestation followed by natural spreading has more than doubled the natural growth area of Aleppo pine in the last century.

3. Aleppo Pine in Croatia

In the Croatian Mediterranean Aleppo pine is now widespread along the whole coast and most of the islands. Given the environmental conditions it is possible to differentiate three areas of its growth. In the north Adriatic Aleppo pine is successfully grown in forest plantations, but the seeds from those stands do not spread naturally and there is no new natural growth. On the coast of the middle Adriatic Aleppo pine is gradually spreading on abandoned farmlands from the stands that have resulted from intensive afforestation efforts. The ecological conditions of the south Adriatic, warmest part of Croatia, are facilitating the successful expansion of Aleppo pine and it nowadays occupies all the surfaces, and shows the characteristics of native species (Trinajstić et al., 2011). Although Beug (1967) argues that it is difficult to prove if the Aleppo pine is native to the Croatian coast, according to Trinajstić (2011), the composition of Croatian Aleppo pine forests is in no way different than the composition of the same forests from other parts of the Mediterranean, suggesting it to be partially native. The results of anatomical and physiological analysis of the structure of needles have shown that the populations of Croatian Aleppo pine are different from populations in other parts of the Mediterranean which indicates a long-term isolation from populations in other areas, thus supporting the idea of autochthony. However, most scholars agree that Croatian Aleppo pine is native in the areas where there are same environmental conditions as in other parts of the Mediterranean where Aleppo pine constitutes the basis of forest vegetation. This area

includes the coastal part of Dalmatian region south of the city Split and all islands south of the island Krapanj (Kajba et al., 2011; Prpić et al., 2011; Trinajstić, 2011) (Fig. 2).

Being a part of the wider Mediterranean region, Croatia shares its similar ecological conditions which means that Holm oak forests represent the climax vegetation. Holm oak indeed did cover vast areas of coastal Croatia until the beginning of the new era when the large scale wood exploitation by Romans and Greeks started (Šoštarić, 2005). Beug (1967) states that the Greeks, and later Romans, are the ones responsible for spreading and cultivating Aleppo pine in the southern parts of Croatia, while Meštrović (2011) supports this claim with evidence dating from the Classical period. Apparently, as Holm oak forests were being cut down for its quality wood, Aleppo pine was gradually spreading on the newly formed available terrain.

Period from the Middle ages to the 19th century saw the most widespread disappearance of wood cover in littoral Croatia which resulted in intensive erosion amplified by karst features of terrain. Rapid loss of quality soil, along with massive goat and sheep grazing, was alarming because it made impossible for vegetation cover to regenerate. This is one of the reasons afforestation efforts were carried out in minor extent in mid-18th century, with greater intensification from the end of the 19th century and onward. Aleppo pine was, like in the rest of Mediterranean, dominant species that was planted (Meštrović et al., 2011).

4. Ecology of Aleppo Pine

The choice of Aleppo pine for afforestation of the Mediterranean degraded areas can be attributed to its wide ecological amplitude, that is its good adaption to a variety of pedological, hydrological and climatic conditions. Aleppo pine is extremely xerophyl species, which means that it has developed adjustments by which it overcomes the lack of water during the year. Prpić et al. (2011) conducted an experiment which showed that Aleppo pine trees suffered no consequences even 121 days after the last watering. They grow with ease on highly degraded soils and their planting does not require a lot of effort and financial costs (Prgin, 1995; Maestre and Cortina, 2004). In addition, Aleppo pine's suitability for afforestation is magnified due to its very rapid growth and the possibility of natural expansion and rejuvenation (Vidaković, 1972).

The ground under the stands of Aleppo pine gradually becomes covered with pine needles and soil acquires properties which enable the growth of climatozonal vegetation (Maestre and Cortina, 2004; Matić et al., 2011; Prpić et al., 2011). Thus, over time, Aleppo pine's expansion over degraded areas creates the conditions for the re-growth of Holm oak and its chaperon vegetation. Being a climatozonal vegetation in Mediterranean, Holm oak has specific needs related to the properties of the soil that has been disturbed

by anthropogenic impact over the millennia so direct planting of its seeds in the ground would not bring the desired results (Matić et al., 1997). Firstly it is necessary to enable the process of regeneration of the forest floor, and as already mentioned, due to very good adaptability to adverse conditions in degraded habitats Aleppo pine was chosen for the purpose. Once a Holm oak appears under the stand of Aleppo pine, it is necessary to implement silvicultural methods to cultivate its growth, support the removal of trees that block the sunlight and gradually introduce new seeds of native vegetation (Matić et al., 1997).

Fire plays a vital role in the ecology of Aleppo pine. Aleppo pine belongs to the plant group of pyrophytes, that is plants whose expansion is supported by fires (Trinajstić, 1993). Its mechanism of fire survival lies in the extremely high seed production (Daskalakou and Thanos, 2004). Seeds are located in the cones that crumble or explode during or after the fire because of the intensive heating and cooling thus densely seeding the burnt area (Prpić et al., 2011). Studies in Greece have shown that Aleppo pine can produce an annual amount of 25 to 105,000 seeds per km² (Way, 2006) and within a year and after the first autumn rains, sprouting of new trees begins and the burnt area gets gradually regenerated (Daskalakou and Thanos, 2004). Fire has another major role in the spreading of Aleppo pine trees. This species is the most incendiary species throughout the Mediterranean and it stimulates fires because it destroys competition for new young trees and provides the conditions for successful germination of seeds on areas where it would not be possible without fire due to pre-existing vegetation (Grove and Rackham, 2001). This is the principal mechanism how Aleppo pine spreads on areas that were once densely covered with *macchia*. Large amount of seeds on the trees represents the second step in the control of competing plants, which takes place after the fire. A dense cover of young Aleppo pine trees grows from abundant seeds and their number per hectare ranges from several thousand to over a million (Tolić, 1996). Research in Dalmatia (Dubravac et al., 2006; Dubravac and Baričić, 2012) showed that post-fire number of seedlings per hectare that grew from, for example, 800 burnt trees, ranged from around 40 000 to over 100 000 individuals per hectare.

Thus, a large amount of Aleppo pine seedlings in a small area leads to the depletion of moisture and nutrients from the soil and sheltering of the light which hinders the growth of other species (Miles, 2009). Spreading of the Aleppo pine is therefore often considered as having an invasive character and can be regarded as in contrast with one of the environmental politics of European Union which advocates biodiversity protection of the Mediterranean ecosystems (Chirino et al., 2006; Dubravac et al., 2006). Works of Chaparro and Esteve (1996) have shown the reduction of floral species on the ground layer of Aleppo pine stand by 20% while the research of Trinajstić (1993) has estimated a 50% decrease.

5. Case study: research area and methods

Due to the afforestation efforts in the last century Aleppo pine forests are becoming one of the most important elements of the Mediterranean landscape. Their constant increase in area is often uncontrolled and the official data do not represent the real situation in the field. Thus, the purpose of this research was to investigate the change of landscape structure and dynamics due to the Aleppo pine expansion since the documentation of its first stand in the 19th century on the island of Krapanj onwards. The research has been carried out during June and July in 2013.

The research area refers to Dalmatia, the Mediterranean part of Croatia, precisely its central section, with associated islands. It covers 483.8 km² in total, not including water surface (Fig. 2).

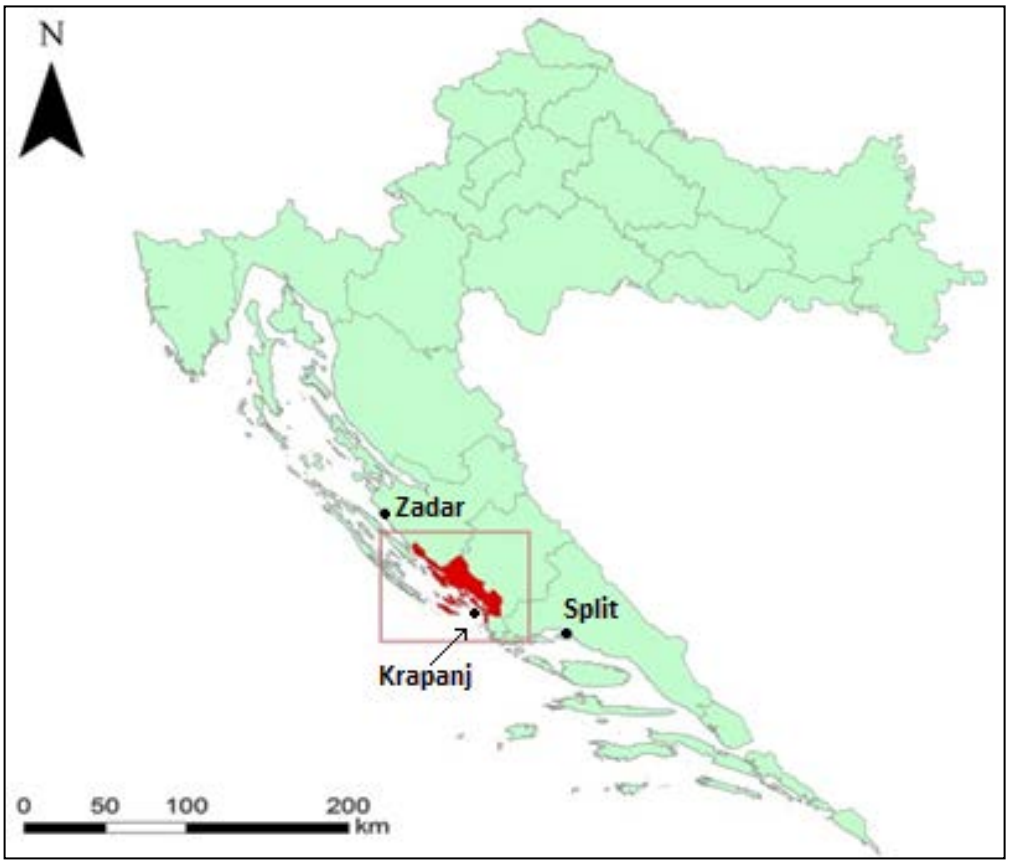

Fig. 2. Research area.
Author: I. Tekić

The research is based primarily on the forestry data of the public enterprise *Hrvatske šume* (*Croatian Forests*), satellite imagery of the *State Geodetic Administration of Republic of Croatia* and *Google Maps Street View* application, as well as on direct field research. All the data is supplemented with

published results from the previous research carried out on the Croatian territory as well as in the broader Mediterranean region. Finally, a map of landscape categories based on Aleppo pine distribution is created in ArcMap 10.0 software (Fig. 3).

6. Results and discussion

The direct consequence of the afforestation carried out in central Dalmatia is the appearance of Aleppo pine stands that did not exist there before. As already noted, Aleppo pine in Croatia is considered native on the coastline south of Split, and on islands south of Krapanj (Kajba et al., 2011; Prpić et al., 2011; Trinajstić, 2011). Therefore, the only wild, natural Aleppo pine forest in the research area can be found on island Krapanj where it was shrunk from 30 ha in 19th century to 3 ha nowadays due to clearing for settlement (Prgin, 1995). This means that all other Aleppo pine forests in research area are of anthropogenic origin, introduced from elsewhere and thus allochthonous. The absence of Aleppo pine in this area (except on island Krapanj) is evident from the work Flora Dalmatica written by De Visiani (1852) where he named the places on Croatian coast where Aleppo pine stands could be found. Nevertheless, Aleppo pine can today be found along the whole coast of the research area, as well as in the interior parts. Its area of growth is constantly expanding due to natural spreading. The first stands of Aleppo pine where planted in 19th century, and by the middle of the 20th century 97% of newly grown forests were Aleppo pine forests (Prgin, 1995).

According to data from *Hrvatske šume d.o.o.* (*Croatian Forests*) and *CORINE Land Cover Database*, Aleppo pine forests cover 5% of research area, but satellite images and field examination have shown that these data include only dense stands of Aleppo pine trees and ignore the appearance of Aleppo pine in combination with other vegetation types. Also, categories in *CORINE Land Cover Database* are not defined precisely which means that categories such as 'transitional forest area' or 'schlerophyllous vegetation' can also include Aleppo pine stands. This is the reason why field research, supplemented with the analysis of satellite images, was conducted.

The results regarding the spatial distribution of Aleppo pine have been grouped in three categories: Aleppo pine dominance, larger clusters of Aleppo pine trees and sporadic appearance of Aleppo pine trees (Fig. 3). Areas where Aleppo pine does not grow have also been grouped in three categories: no Aleppo pine trees, agricultural areas and settlements and other built areas. The differences between these categories could not be quantified, so they were determined on the basis of the visual assessment of landscape and representation of Aleppo pine in contrast to other vegetation types.

The category „Aleppo pine dominance“ represents areas where Aleppo pine trees completely cover the landscape without other types of vegetation being visible, even though it is present on the surface layer (Fig. 4). This type of landscape prevails mainly in the vicinity of settlements for those areas are

among the first ones that have been afforested due to development of tourist activities, and on islands where agricultural activity has almost completely diminished, leaving the abandoned farmlands open for Aleppo pine expansion. The actual coverage partly coincides with the data gathered from *Hrvatske šume d.o.o.* (*Croatian Forests*) and *CORINE Land Cover Database*, however, it shows three times greater extent, i.e. 13% of research area.

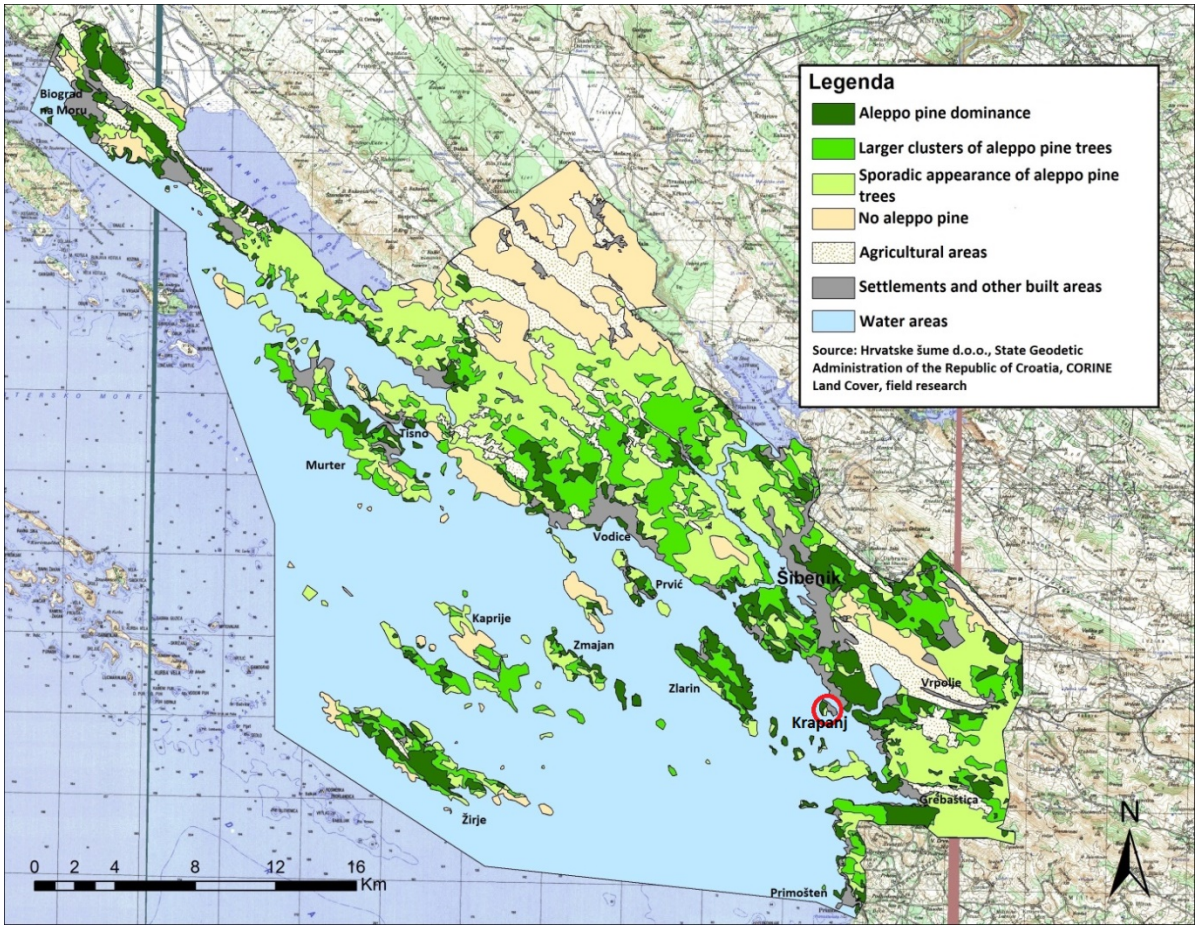

Fig. 3. Landscape categories in research area based on Aleppo pine distribution (The initial area of Aleppo pine stands on island Krapanj; circled).
Author: I. Tekić

The type of landscape where the Aleppo pine trees are still the most prominent visual element, although trees do not grow so tight and other vegetation elements such as high *macchia* are visible, have been classified in the category „larger clusters of Aleppo pine trees“ (Fig. 5). These areas cover 19% of the research area. Still, in these areas official data do not register the existence of Aleppo pine trees.

Fig. 4. Landscape type in the category „Aleppo pine dominance “
Source: I. Tekić, 6 July 2013

Fig. 5. Landscape type in the category „ larger clusters of Aleppo pine trees “
Source: I. Tekić, 6 July 2013

The category „sporadic appearance of Aleppo pine trees“ shows areas where Aleppo pine grows in smaller groups of trees or individually with several tens of meters of distance between them. The landscape of this category mostly consists of dense *macchia* or *garrigue* and represents areas where Aleppo pine trees vanished due to frequent fires, or areas where Aleppo pine has just begun its expansion and is still fighting for survival with other vegetation of *macchia*. It also includes abandoned agricultural areas such as pastures, olive groves and vineyards that are under the process of secondary succession where Aleppo pine's invasive features are most visible (Fig. 6). Covering 33% of research area this category of landscape represents the zone of potential rapid expansion of Aleppo pine trees in the future.

Fig. 6. Aleppo pine invading pastures, example of landscape in the category „sporadic appearance of Aleppo pine trees“
Source: I. Tekić, 8 July 2013

Areas where Aleppo pine trees where not detected in radius of several hundred meters are classified in „no Aleppo pine“ category. Those are mainly inner continental parts of research area where Mediterranean climate is turning into sub-Mediterranean, Holm oak as the dominant element of vegetation cover is being replaced by Downy oak (*Quercus pubescens*) and evergreen vegetation makes a gradual transition into deciduous. Here, the climate conditions do not favor the growth of Aleppo pine and the most prominent pine species is Black pine (*Pinus nigra*). In the Mediterranean part of research area this category of Aleppo pine distribution is present in areas that have been exposed to frequent fires, parts of islands that are facing the open sea and surfaces overgrown with thick *macchia* where Aleppo pine was unable to penetrate. Altogether, landscapes with no Aleppo pine cover 15% of research area, most of it being in the sub-Mediterranean section.

Categories „agricultural areas“ and „settlements and other built areas“, being under constant and direct human impact, do not provide conditions for Aleppo pine to grow, therefore they are excluded from the total research area (Tab. 1).

Table 1 - Share of landscape categories according to Aleppo pine appearance in the total research area

Category	*Area in hectares*	*Share in total area (%)*	*Share in research area without agricultural and built areas (%)*
Aleppo pine dominance	6 400	13.2	16.4
Larger clusters of Aleppo pine trees	9 280	19.2	23.7
Sporadic appearance of Aleppo pine trees	16 100	33.3	41.1
No Aleppo pine trees	7 350	15.2	18.8
Agricultural area	5 380	11.1	*not included*
Settlements and other built areas	3 870	8	*not included*
Total	48 380	100	100

Source: Hrvatske šume d.o.o., CORINE Land Cover database, State Geodetic Administration of the Republic of Croatia, field research.

The results show that Aleppo pine covers 81% of the research area, while 40% of area with thick cover of stands (categories „Aleppo pine dominance“ and „larger clusters of Aleppo pine trees“). Comparing the recent cover with the one before the afforestation activities, when the only Aleppo pine forest of merely 30 ha was located on island Krapanj, the spreading of dense stands over the 51 000% larger area in 160 years can be calculated. Taking into account the area of sporadic distribution, the expanding rate goes to 105 000% or 600% per year. That makes Aleppo pine the species with the highest rate of spreading in the Croatian littoral and the main modifier of this region’s landscape.

7. Conclusion

Despite the extent of afforestation with Aleppo pine and the time that has passed since its beginning, a critical review and analysis of the environmental impact of these plantations in semi-arid areas of the Mediterranean basin has not yet been made (Maestre and Cortina, 2004). Understanding the environmental and social consequences is important in order to assess past and future forest policies and devise alternative strategies for vegetation recovering. The importance of this issue goes beyond the

borders of the Mediterranean since afforestation with Aleppo pine forests started in other areas of the world with Mediterranean climate such as Australia and California.

Nowadays, the purpose of Aleppo pine afforestation is being questioned by numerous authors (Španjol et al., 2006, 2009; Tolić, 1996; Maestre and Cortina, 2004; Ruiz-Dowry and Gonzalez-Rebollar, 2013). It is generally considered that Aleppo pine afforestation enables the succession of autochthonous Holm oak in the ground layer. However, the replacement of Aleppo pine forest with Holm oak forest requires intensive silvicultural procedures. Once the ecological conditions for quality growth of Holm oak have been provided, natural regeneration of Aleppo pine will cease. Eventually Aleppo pine trees that live up to 150 years will begin to disappear. Their place will be taken by Holm oak trees that have vitality, longevity and resistance to fire unmatched by no other alien species in this region (Prgin, 1995). However, throughout the Mediterranean there is no example of Aleppo pine forest that survived without fire for so long to be replaced by other species such as the Holm oak (Grove and Rackham, 2001).

Acknowledgment*: The authors would like to express their gratitude to Ms. Solange Barišić and Ms. Maja Čatlak for their assistance in the translation of the text.*

8. Bibliography

BEUG, H. (1967). On the forest history of the Dalmatian coast. *Review of Palaeobotany and Palynology, 2*, 271-279.

CHAPARRO, J., ESTEVE, M. A. (1996). Criterios para restaurar la vegetación en ambientes mediterraneos semiaridos. *Quercus, 121*, 14-17.

CHIRINO, E., BONET, A., BELLOT, J., SÁNCHEZ, J. (2006). Effects of 30-year-old Aleppo pine plantations on runoff, soil erosion, and plant diversity in a semi-arid landscape in south eastern Spain. *Catena, 65*, 19-29.

DASKALAKOU, E. N, THANOS, C. A. (2004). Postfire regeneration of Aleppo pine – the temporal pattern of seedling recruitment*. Plant Ecology, 171*(1-2), 81-89.

DE VISIANI, R. (1852). Flora Dalmatica: sive enumeratio stirpium vascularium quas hactenus in Dalmatia lectas et sibi digessit. Lipsiae: Hopfmeister.

DUBRAVAC, T., VRBEK, B., LALIĆ, Z. (2006). Prirodna obnova u sastojinama alepskog bora (Pinus Halepensis Mill.) nakon požara. *Radovi-Šumraski institut Jastrebarsko, Izvanredno izdanje 9*, 37-51.

DUBRAVAC, T., BARČIĆ, D. (2012) Prilog poznavanju prirodne obnove nakon požara i problematika njege opožarenih površina u sastojinama alepskoga bora. *Vatrogastvo i upravljanje požarima, 1*(3). 38-50.

EUFORGEN, 2009: Distribution map of Aleppo pine (*Pinus halepensis*), http://www.euforgen.org/distribution_maps.html [Accessed 28th July 2013]

GROVE, A., RACKHAM, O. (2001). *The Nature of Mediterranean Europe, An Ecological History*. London: Yale University Press.

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

HUGHES, D. (2005). *The Mediterranean: An Environmental History*. Santa Barbara: ABC-CLIO, Inc.

KAJBA, D., GRAČAN, J., BOGDAN, S., IVANKOVIĆ, M. (2011). Dostignuća na oplemenjivanju vrsta drveća sredozemnih šuma. In S. Matić (Ed.), *Šume hrvatskoga Sredozemlja* (pp. 329-351). Zagreb: Akademija šumarskih znanosti.

LIPHSCHITZ, N., BIGER, G. (2001). Past distribution of Aleppo pine (Pinus halepensis) in the mountains of Israel (Palestine). *The Holocene, 11*(4), 427-436.

MAESTRE, F., CORTINA, J. (2004). Are Pinus halepensis plantations useful as restoration tool in semiarid Mediterranean areas?. *Forest Ecology and Management, 198* (1-3), 303-317.

MATIĆ, S., ANIĆ, I., ORŠANIĆ, M. (1997). Podizanje, njega i obnova šuma kao temeljni preduvjeti ekološkog, društvenog i gospodarskog napretka Mediterana. *Šumarski list, 121*(9-10), 463-472.

MATIĆ, S., ANIĆ, I., ORŠANIĆ, M., MIKAC, S. (2011). Njega i obnova šuma hrvatskoga Sredozemlja. In S. Matić (Ed.), *Šume hrvatskoga Sredozemlja* (pp. 375-387). Zagreb: Akademija šumarskih znanosti.

MEŠTROVIĆ, Š., MATIĆ, S., TOPIĆ, V. (2011). Zakoni, propisi, uredbe i karte u povijesti šuma hrvatskoga Sredozemlja. In S. Matić (Ed.), *Šume hrvatskoga Sredozemlja* (pp. 25-40). Zagreb: Akademija šumarskih znansti.

MILES, C. (2009). Best practice guidelines for the removal of Aleppo Pines, Coorong District Council, *South Australian Murray-Darling Basin Natural Resource Management Board*, 1-18. Available at: http://www.gwlap.org.au. [Accessed 13th August 2013]

PAUSAS, J. G., BLADÉ, C., VALDECANTOS, A., SEVA, J. P., FUENTES, D., ALLOZA, J. A., VILAGROSA, A., BAUTISTA, S., CORTINA, J., VALLEJO, R. (2004). Pines and oaks in the restoration of Mediterranean landscapes of Spain: New perspectives for an old practice – a review. *Plant ecology, 171*(1-2), 209-220.

PRGIN, D. (1995). Uspijevanje alepskog bora (Pinus halepensis Mill.) na području šibenskog primorja. Doctoral Dissertation. Zagreb:Šumarski fakultet Sveučilišta u Zagrebu.

PRPIĆ, B., TIKVIĆ, I., IDŽOJTIĆ, M., SELETKOVIĆ, Z. (2011). Ekološka konstitucija značajnijih vrsta drveća i grmlja. In S. Matić (Ed.), *Šume hrvatskoga Sredozemlja* (pp. 245-270). Zagreb: Akademija šumarskih znanosti.

RUIZ-MIRAZO, J., GONZALEZ-REBOLLAR, G. L. (2013). Growth and structure of a young Aleppo pine planted forest after thinning for diversification and wildfire prevention. *Forest systems, 22*(1), 47-57.

QUÉZEL, P. (2005). Large-scale Post-glacial Distribution of Vegetation Structures in the Mediterranean Region. In S. Mazzoneli, di Pasquale, G., Mulligan, M., di Martino, P., Rego, F. (Ed.), *Recent Dynamics of the Mediterranean Vegetation and Landscape* (pp. 3-13). Chichester:John Wiley & Sons.

ŠOŠTARIĆ, R. (2005). The development of postglacial vegetation in coastal Croatia. *Acta Botanica Croatica, 64*(2), 383-390.

ŠPANJOL, Ž., BARČIĆ, D., ROSAVEC, R., UGARKOVIĆ, D. (2006). Ameliorative role of Aleppo pine (Pinus halepensis Mill.) in the regeneration of climatozonal vegetation. *Periodicum biologorum, 108*(6), 655-662.

ŠPANJOL, Ž., HRŠAK, V., BARČIĆ, D., ANČIĆ, M., DUBRAVAC, T., ROSAVEC, R., ORŠANIĆ, M. (2009). Pine reforestation of degraded sites on the island of Rab, Croatia. *Plant biosystems, 143*(3), 482-495.

TOLIĆ, I., (1996). Njegom do kvalitetne stabilne sastojine i drvne mase. *Šumarski list, 120*(7-8), 339-346.

TRINAJSTIĆ, I. (1993). Problem sukcesije vegetacije na požarištima alepskoga bora (Pinus halepensis Mill.) u Hrvatskom primorju. *Šumarski list, 117*(3), 131-136.

TRINAJSTIĆ, I. (2011). Fitogeografska raščlanjenost biljnoga pokrova. In S. Matić (Ed.), *Šume hrvatskoga Sredozemlja* (pp. 182-192). Zagreb: Akademija šumarskih znanosti.

TRINAJSTIĆ, I., FRANJIĆ, J., IDŽOJTIĆ, M., ŠKOVRC, Ž. (2011). Taksonomska problematika i rasprostranjenost glavnih vrsta drveća. In S. Matić (Ed.), *Šume hrvatskoga Sredozemlja* (pp. 162-172). Zagreb: Akademija šumarskih znanosti

VIDAKOVIĆ, M. (1972). Novi pogledi na pošumljavanje degradiranog krša. *Šumarski list, 96*(11-12), 426-431.

WAY, S. (2006). Strategic managment of Aleppo Pines on Lower Eyre Peninsula to maximise biodiversity conservation outcomes, *Department for Environment and Heritage* 1-54. Available at: http://www.environment.sa.gov.au. [Accessed 17th August 2013]