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Mediterranean forests: reasons of deforestation and possibilities of reforestation

Bachelor thesis

Elaborated by: Jan Šmíd

Thesis supervisor: doc. Ing. Bohdan Lojka, Ph.D.

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Declaration

I declare that I have elaborated my thesis independently and quoted only quotations listed in the references.

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Jan Šmíd

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Abstract

Deforestation processes in the Mediterranean have led to emergence of a land which is extremely vulnerable to any type of further human influence. The changes which took place in this region are crucial for its future existence. Soil devaluation has an immense effect on agriculture and forestry, therefore, revitalization of soil structure and fertility should be in the heart of focus. Contemporary ways of forestation do not usually support the land revitalization, and what more, they actually tend to be even more harmful due to inadequate choice of species out of which many are not indigenous and thus have a negative influence on soil processes as well as on biodiversity of indigenous species. Based on my literature review I selected several tree species that could be recommended for reforestation such as *Pinus halepensis*, *Quercus* spp., *Ceratonia siliqua*, *Rhamnus lycioides* and *Pistacia lentiscus*. I also suggested new methods of planting that will enhance the survivability of the plants during the dry season.

Key words: afforestation, biodiversity, climatic change, deforestation, erosion, Holocene, human impact, *Pinus halepensis*, secondary vegetation

Abstrakt

Vykácením lesů ve středomoří vznikla krajina, která se stala vůči jakýmkoliv dalším zásahům velmi zranitelná, a nastaly zde takové změny, jejichž účinek je velmi důležitý pro budoucí život v tomto regionu. Znehodnocení půd má velké následky na zemědělství a lesní hospodářství a obnova půdní struktury a úrodnosti by měla být hlavní prioritou. Současné způsoby zalesňování většinou nepodporují obnovu krajiny, ale naopak ji poškozují a to zejména neadekvátním výběrem druhů, z nichž některé jsou nepůvodní a mají negativní vliv jak na půdní procesy, tak i na biodiverzitu původních druhů. Proto jsem vybral několik druhů rostlin používaných k zalesňování jako je *Pinus halepensis*, *Quercus* spp., *Ceratonia siliqua*, *Rhamnus lycioides* a *Pistacia lentiscus* a navrhnul nové metody jejich výsadby, které zvýší jejich šanci na přežití během období sucha.

Klíčová slova: biodiverzita, eroze, Holocén, lidský dopad, odlesnění, *Pinus halepensis*, sekundární vegetace, zalesnění, změna klimatu

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1. INTRODUCTION

Mediterranean climatic area occupies less than 5% of the world surface, but is home to more than 20% plant species, many of which are endemic and many economical important (Buerki et al., 2012). During more than 4,000 years land use to partial or complete deforestation occurred within the whole territory. People burned forests since the middle Holocene to obtain new fields, pastures or to building new villages. This landscape was completely redesigned and the original deciduous forests were replaced by evergreen shrubs that have become dominate in today's landscape (Jalut et al., 2000; Carrión et al., 2010; Fletcher and Zielhofer, 2011). Deforestation supported by climate changes led to the current problems such as erosion, soil degradation and frequent fires (Dusar et al., 2011).

Erosion is one of the major problems in the region, and leads to the soil degradation. The cause of vulnerability of the soils is the fact that they are located in too steep slopes, soil profile is very shallow or there is a strong deficit of water (Kosmas et al., 1997). These factors lead to desertification which is currently one of the most serious problems in the Mediterranean. The desertification process was started only by human actions and thus is quite different from the classic deserts like the Sahara or Gobi, which arose thanks to ideal climatic conditions for the emergence of the deserts (Jiménez-Moreno et al., 2013; Hooke and Sandercock, 2012).

Another factor influencing the vegetation cover is fire. Great number of studies has been written on this issue, dealing mainly with post-fire vegetation regeneration, the possibilities of risk erosion and species composition on germinating plants. Fires in Mediterranean are very frequent (Naveh, 1975) and arise spontaneously, by intentional establishment of fire or on territories which were selected for afforestation with inappropriate plant species (Agee, 2000).

Fires are closely related to soil erosion. Longer vegetation regeneration after fire, leads to increasing the risk of erosion, so it is important to determine the course of regeneration immediately after the fire (Inbar et al., 1997). Predicting fires despite significant technological progress is still very difficult and we cannot pinpoint the exact site of the future fire. On the dangerous sites is possible to measure the quantity of dry biomass and at least determine the eventual strength and direction of fire spread (De Luise et al., 2004).

Reforestation is probably the only way to prevent soil degradation and thus erosion and desertification and restore biodiversity. The most difficult is to choose, which species is the most suitable for reforestation. Meanwhile the most used tree throughout the

Mediterranean is *Pinus halepensis* and it covers the area of more than 25,000km² (Quézel, 2000). Especially in the western Mediterranean it is the most common tree, and in Spain 43% trees comes from the afforestation (Veléz, 1986). Most studies suggest that these monocultures sooner or later lead to soil degradation, often resulting in fires, but also the number of plant species is smaller than in mixed forests (Maestre and Cortina, 2004; Maestre et al., 2003). Its great disadvantage is shallow root system, which leads to frequent windthrows and also to acceleration of soil drying under pines (Breshears et al., 1997). On the other side it is often used because it is very easy to grow and it is undemanding for the soil conditions (soil moisture, soil depth, fertility) (Barbero et al., 1990). Self-growing trees play an important role in the colonization of inhospitable territory, because of changes within the microclimate, improve soil fertility and attract birds that feed on seeds (Herrera, 1984).

By this study I would like to show the development of vegetation in the Mediterranean from the Holocene to the present and point out the influence of climate and of human. Furthermore, I would like to analyze the individual negative effects which occurred after deforestation and to highlight their importance and the danger which threatens the current fragile ecosystem. And in the end find out what plants are used for reforestation, their pros and cons and solutions that should improve the existing ones.

2. OBJECTIVES AND METHODOLOGY

The objective of this thesis is to summarize historical reasons for the changes in vegetation cover, depending on the impact of climate and human, point out to the current problems arising from changes in vegetation cover. The aim of this review was to find possible solutions to these problems and describe current methods and plants for reforestation. Another point of this work is find out whether current plants are appropriate and successful or they have a negative impact on the ecosystem. I would also recommended new methods that could increase the chance of survival of seedlings and increase biodiversity in forests and prevent erosion or reduce the number of fires. I believe that the currently used plants are not suitable for forest restoration in their original form.

This study is a form of literature review. I collected information from scientific databases, mainly from Science Direct (www.sciencedirect.com) and ISI Web of Knowledge (http://apps.isiknowledge.com) and I collected some practical information in the Mediterranean region. Specialized books and the official website were also used. All sources are listed in the references.

3. LITERATURE REVIEW

3.1 Characteristics of the Mediterranean region

3.1.1 Geographical description

The Mediterranean is located among South Europe, North Africa and Asia to the East. The Mediterranean Sea is situated in the centre, which means it is a semi-enclosed sea. Its area has more than 2.5 million km² and its extent is about 3,700 km in longitude, 1,600 km in latitude. It's surrounded by 21 countries (Lionello et al., 2006). This is an atypical sea for its large number of islands (mainly in Adriatic and Aegean Sea), bays, cliffs and channels. Along almost the entire coast are mountain range, of which the highest are the Alps on the north (Scarascia-Mugnozza et al., 2000). The territory can be accurately determined on the basis of growth specific plant species, characteristic for this area. One of the main indicators is the original spread of evergreen, sclerophyllous forests, which sometimes grew along the coast except the parts of northern Libya (Zelený, 2005).

Depending on the altitude, the area of these forests was very various (Scarascia-Mugnozza et al., 2000). Along the Croatian and Turkish coast grew only in a narrow belt, because of very steep high mountains and along the coast of Libya and Egypt due to the arid conditions which predominated. Conversely in Iberian Peninsula, the south of Italy, on the whole territory of Greece, Lebanon, Israel and all of the Mediterranean islands, grew in the whole territory. On the Balkan Peninsula, Morocco, Algeria and in the southeast part of Israel, there are the islands of vegetation due to natural conditions like are colder air currents from the mainland or arid climate (Zelený, 2005).

One of the possible indicators of the Mediterranean climate is cultivating of olive tree. These species can grow to a height of about 800 meters above sea level and hate long-term decline temperatures below -10°C. This tree and the other species typical for the Mediterranean (*Quercus coccifera, Ceratonia siliqua, Pinus pinea* or *Pinus halepensis*) cannot grow in colder areas, so their cultivation can be indirect indicator of the real Mediterranean (Zelený, 2005).

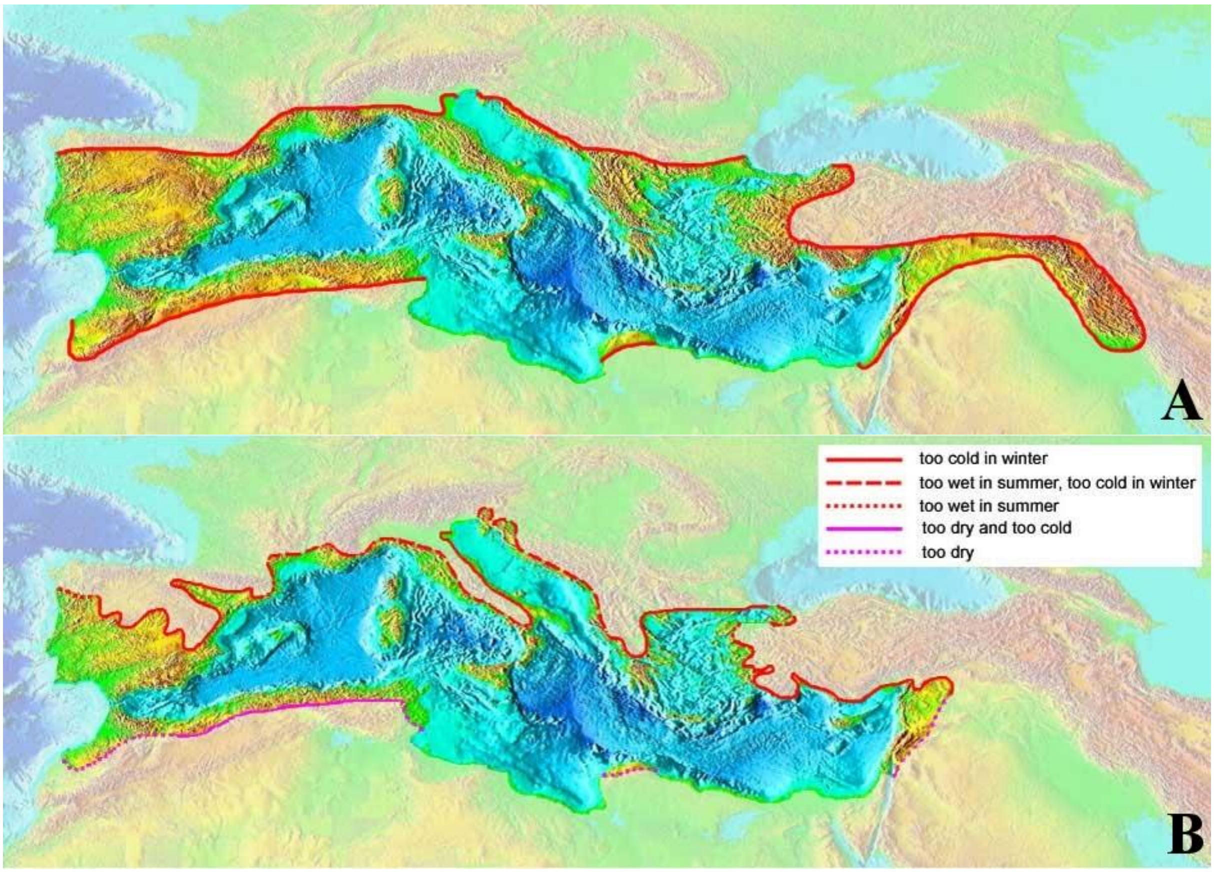


Figure 1. Extending of the Mediterranean climate (A) according to climatic conditions and plant species that are typical for this area and extensions on the basis possibilities growing of olives (B) (Krešimir, 2005).

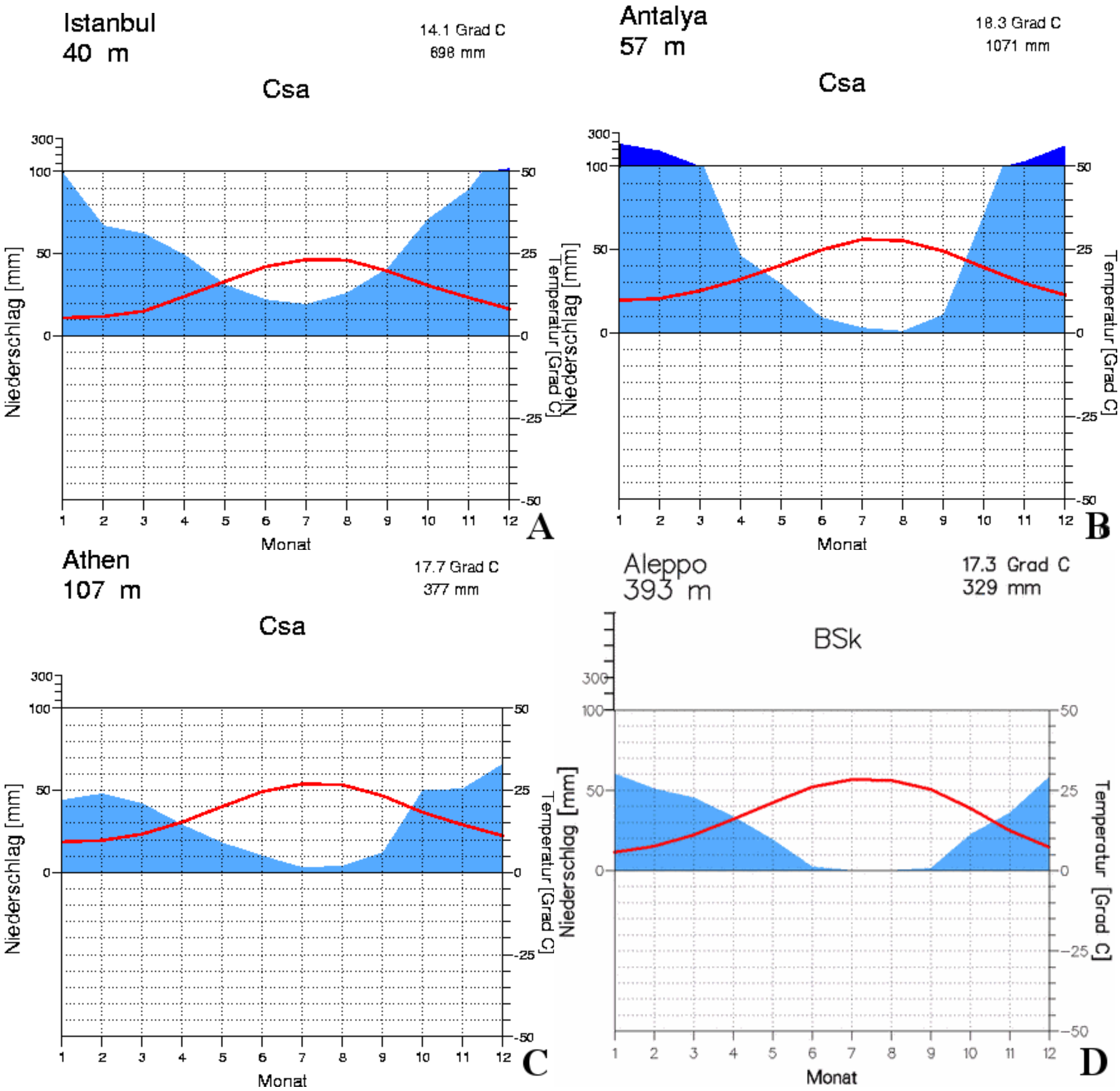
3.1.2 Climatic conditions

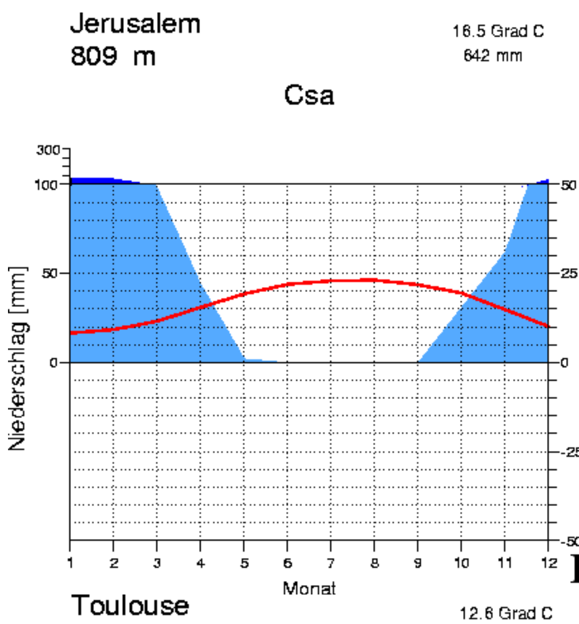
The Mediterranean climate is characteristic for its very hot and dry summers and mild and wet winters (Scarascia-Mugnozza et al., 2000). This situation can be explained by the periodic movement belt of subtropical anticyclones. In the summer predominates anticyclones and their formation is in the Azores islands and their moving occurs to displacement cyclones to the North and Middle Europe. In winter, the anticyclones are in the South of Africa and the cyclones from North Europe bring rain to Mediterranean. In addition to alternation of these two air masses, occurs for influencing climate by South Asian Monsoons in the summer, especially in the eastern Mediterranean, and by Siberian high-pressure in winter. The western part is under the influence of East Atlantic Ocean and North Arctic Ocean in winter. The North Arctic Ocean has an important role in influencing the temperature and cloud cover especially in summer, but in winter influence of the Atlantic

Ocean prevails (Lionello et al., 2006). The East part of Mediterranean is mainly under the influence of north-easterly and north-westerly air circulation (Krichak and Alpert, 2005a). The Mediterranean Sea Surface Temperature has a significant influence on the course of temperatures and there is a correlation between high temperatures in the summer in the Mediterranean and monsoons in West Africa. High temperature causes evaporation of sea water, which instead to fall in the Mediterranean, falls in the Sahel region, and this has a significant effect on the moisture conditions in this dry region so it is obvious that the Mediterranean Sea can affect even very remote areas (Lionello et al., 2006).

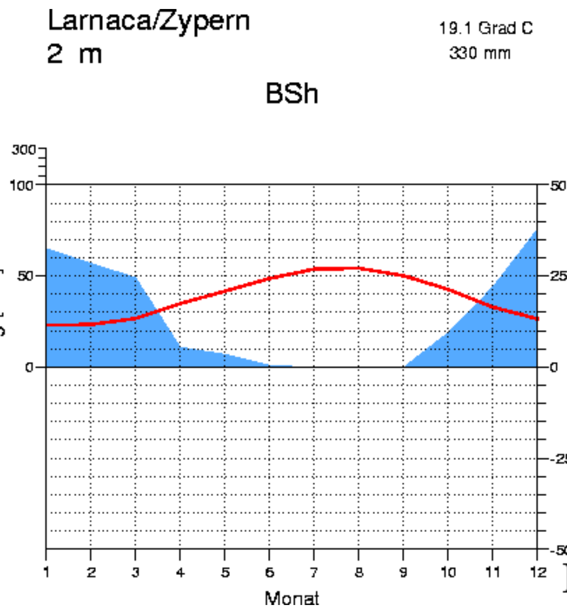
The Mediterranean is such a large area that the temperatures vary almost every kilometer. This is mainly due to the relief of the landscape, distance from the sea and other water resources, representation of vegetation and the altitude. For example, on the coast of Croatia there is considerably higher temperature in winter and summer than a few kilometers further to inland, where there are high mountains Dinara and Biokovo, and in winter can fall down two meters of snow and the temperature can drop to -20 °C. In Spain there is a very well noticeable difference between the temperatures and precipitations on the coast and inland, where the climate is more continental and temperature fluctuations are higher. On the coast of Croatia, Montenegro and Albania the average annual temperatures range between 14 and 16 °C, where the precipitation activity is relatively high, ranging from 780 mm in Hvar to 1,595 mm in Rijeka. On the southern and eastern coast of Spain the average January temperature is between 10 and 12 °C, in July between 25 and 28 °C and the average precipitation in Gibraltar is 845 mm and in Valencia only 406 mm. This difference in precipitation is mainly given by the distance from the Atlantic Ocean. In the interior of Spain the average annual temperature in Ciudad Real is 13.8 °C and the precipitation is 370 mm per year. However, in these areas temperatures above 40 °C are very frequent and vice versa in the winter is no exception light frost and snow. On the coast of Tunisia, Algeria and Morocco the influence of Sahara is noticeable. Temperatures and precipitation are quite identical to those in the western Mediterranean, but there are larger temperature fluctuations between day and night. In Greece there are also differences between inland and coastal areas. In the inland the average temperatures range between 12 and 14 °C and precipitation between 700 and 1,500 mm, but due to complicated terrain, there are significant differences, and almost every valley has its own microclimate. On the islands and the coast, the average temperatures range from 16 to 19 °C and precipitation from 300 to 600 mm. Turkey, which also belongs to this region, due to its large size and mountainous terrain with very big differences in temperature and precipitation, and the central and eastern parts, does not belong to the Mediterranean climate due to the absence of Mediterranean vegetation (Zelený, 2005; Lionello et al., 2006).

Climate has a major role in the expansion of Mediterranean vegetation, and even small changes can have major consequences. Due to the changing climate, global warming, lower precipitation and rising sea levels, the plants must constantly adapt in order to survive (Zelený, 2005).




Jerusalem
809 m
16.5 Grad C
642 mm
Csa
Niederschlag [mm]
Temperatur [Grad C]
Monat

E


Larnaca/Zypern
2 m
19.1 Grad C
330 mm
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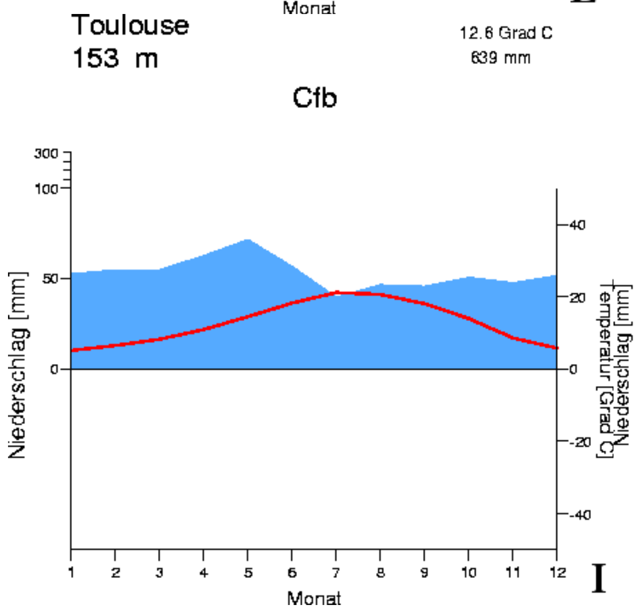
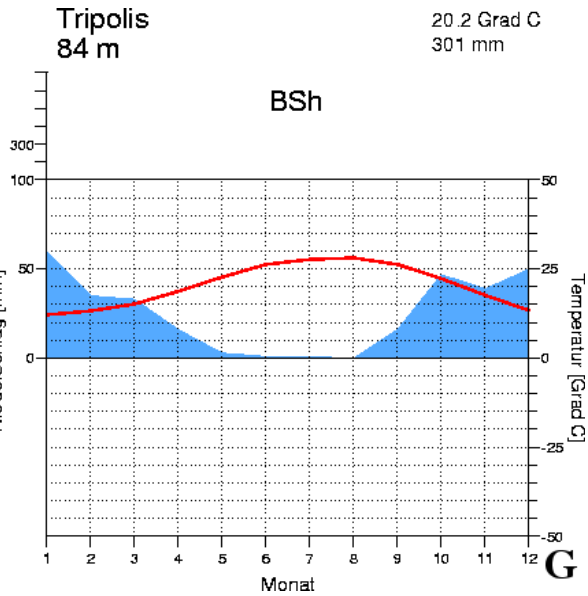
F


Toulouse
153 m
12.6 Grad C
639 mm
Cfb
Niederschlag [mm]
Temperatur [Grad C]
Monat

I


Tripolis
84 m
20.2 Grad C
301 mm
BSh
Temperatur [Grad C]
Monat

G

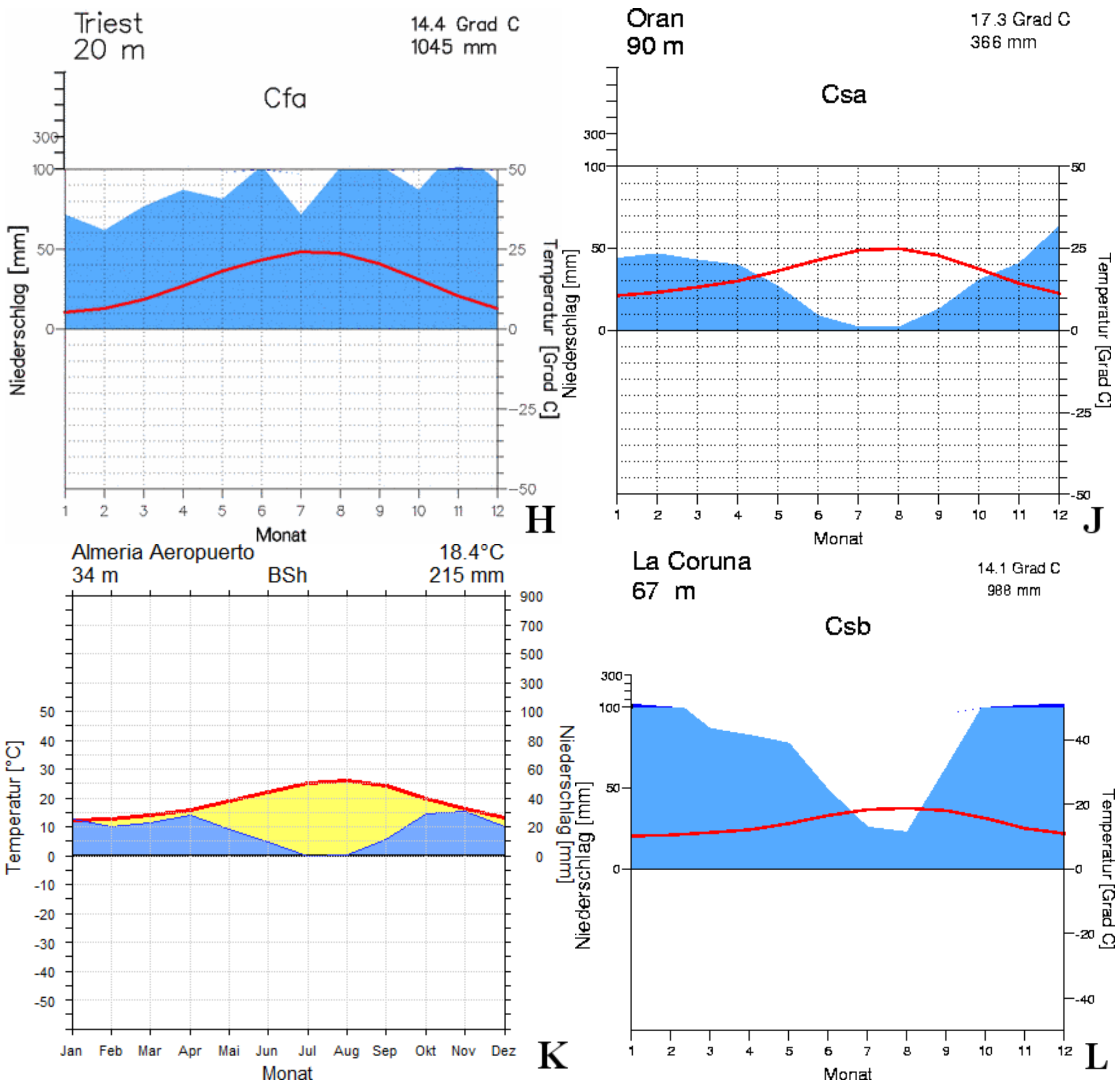


Figure 2. Here are represented climate diagrams from different areas in the region, in which are shown the average annual temperatures and precipitation in individual months. Climate diagram A is from Istanbul, B is from the southern coast of Turkey, C is from the Greece, D is from Syria from inland, E from the central Israel, F from the southern Cyprus on the coast, G from the western Libya on the coast, H is in northeastern Italy at the Adriatic sea, I is in the south of France in the inland of province Languedoc, J from the western Algerian coast, K from the southern Spain on the coast and L is from the west coast of Spain along the Atlantic Ocean (Mühr, 2011).

3.2 Characteristic of the Mediterranean vegetation

Present extension and composition of vegetation is the result of adaptation to new conditions and in fact all the vegetation in the Mediterranean can be perceived as secondary (Zelený, 2005). Current forests largely consisted of broad-leaf, evergreen and sclerophyllous trees such as *Quercus ilex, Q. suber, Q. coccifera, Q. pubescens, Q. Cerris, Pinus halepensis, P.nigra*, *P. brutia*, *Castanea sativa*, *Fagus sylvatica*, *Cedrus* sp. and *Juniperus phoenicea* and along watercourses growing *Alnus* sp., *Fraxinus* sp. and *Populus alba* (Scarascia-Mugnozza et al., 2000). The Mediterranean region is characterized compared to central and northern Europe a high proportion of broadleaf species (≈ 60%) whose representation is different in individual regions (from 76% in Italy to 49% in Portugal) (Dafis, 1997). Today 20-30% of the areas in the northern Mediterranean is forested, 1-8% in the southern part and 5-10% in the eastern part (Scarascia-Mugnozza et al., 2000). For example, Crete has now forest coverage of only about 2% and Spain 10%. At many places along the coast, the so-called halophytic vegetation occurs that grows at natural salt marshes or on the rocks near the shore or in places where salinisation caused by human activities occurred. There are two dominant types of natural vegetation distinguished: macchia and garrigue (Zelený, 2005).

3.2.1 Macchia type

In places where natural reforestation took place, higher shrubby growths called macchia emerged. Macchia is now the most widespread type of vegetation throughout the

Mediterranean. These growths of bushes are from one to five meters high, which are very difficult to be passed through because of the high density of vegetation and some spination species (Zelený, 2005). The leading types of macchia are: *Quercus illex*, *Quercus pubescens, Arbutus unedo, Arbutus andrachne*, *Phillyrea angustifolia*, *Juniperus oxycedrus, Pistacia lentiscus, Pistacia terebinthus, Olea europaea ssp. Oleaster, Paliurus spina-christi*, *Callicotome villosa*, *Ruscus acculeatus*, *Spartium junceum*, *Myrtus communis*, *Erica arborea, Ulex europaeus* and all kinds of *Cistus* sp. and many other species of lower and higher shrubs and trees (Semis and Celik, 2005; Scarascia-Mugnozza et al., 2000). Especially the species of the *Fabaceae* and *Cistaceae* families are fascinating in flower dominating the landscape. Macchia is not the only recent plant community, but had existed even before the arrival of human in very dry places, with little soil or on steep slopes. These primary macchia cannot be distinguished from the present ones (Zelený, 2005).

3.2.2 Garrigue type

Low shrubs, shrublet and herbs dominate in areas where overgrazing by herbivores or degradation macchia occurred. This type of vegetation is called garrigue, but according to the prevailing plants are distinguishes in many countries on other plant formations like *tomillar*, *esplegar*, *jaral*, *brezal* or *retamar* in Spain, *frygana* in Italy, Greece and Cyprus and *batha* in Palestine. In general in all these formations the following plants grows: *Thymus vulgaris*, *Salvia officinalis*, *Rosmarinus officinalis*, *Sarcopoterium spinosum*, *Helianthemum* sp., *Fumana* sp., *Origanum* sp., *Phlomis* sp., *Euphorbia acanthothamnos*, *Lavandula angustifolia* and some species of *Genista*, *Ulex* or *Stachys*, the bulbs and tuberous plants like *Tulipa*, *Crocus*, *Fritillaria*, *Asphodelus*, *Gladiolus* and some species from family *Orchideacea.* The maximum height of the stand is 0.5 meters and the vegetation cover is usually sparse, which is the main distinguishing character from Macchia (Zelený, 2005).

3.2.3 Cultivated crops and trees

From the Mediterranean area a large number of crops originate. They are economically highly important and are a staple food for hundreds of millions of people around the world. From cereals it is Mediterranean *Triticum dicoccoides*, *Hordeum distichon*, *Avena byzantina* or *Secale cereale*, from which varieties of contemporary cultural varieties were improved. Important is also the family *Fabaceae*, from which edible plants or forage for cattle like *Lens esculenta*, *Pisum sativum*, *Cicer arientium*, *Medicago sativa*, *Medicago arborea*, *Faba vulgaris* or *Lupinus luteus* originate. From the other families are economically important these herbs: *Linum usitatissimum*, *Crocus* sp., *Daucus carota*, *Apium graveolens*, *Leucosinapis alba*, *Brassica napus* subsp. *napus*. And of course, also one of the most economically important plants in the world, *Vitis vinifera* comes from this region which is closely related to *Quercus suber*, and *Olea europaea* subsp. *sativa*. Without these two commodities, life would be unimaginable in the region. From other plants that have been used in the food industry, in the technical industry, in dyeing or in the woodwork industry, we should mention *Spartium junceum*, *Rubia tinctorum*, *Laurus nobilis*, *Majorana hortensis*, *Lavandula angustifolia*, *Rosmarinus officinalis*, *Ziziphus jujuba*, *Arbutus unedo*, *Ceratonia siliqua*, *Capparis spinosa*, *Quercus ilex*, *Ficus carica*, *Pinus halepensis* and many more (Zelený, 2005).

Large number of plants has also ornamental use. It testifies to the fact that the Mediterranean, despite the damage caused by human over millennia, is incredibly rich and diversity of plants in such a small area. The number of species in Mediterranean is aprox. 25,

000. For comparison, the number of species in central and northern Europe is only 6, 000 (Scarascia-Mugnozza et al., 2000). In the Mediterranean a considerable amount of endemic species can be found. Especially in the mountains and on the islands 10 to 20% of all plants are endemic (Médail and Quézel, 1997). For example, in Greece 323 endemic plants were detected; in Pyrenees the number is about 180. It is due to the fact that the climate is relatively stable for several thousand years and the changes are not as pronounced, as the ice age in the northern and central Europe or extension Sahara in Africa so plants become accustomed to constant weather in their habitats, but due to adverse weather conditions and natural obstacles they were unable to expand elsewhere (Zelený, 2005).

3.3 Development of the vegetation from the Holocene to the present

3.3.1 Development of the vegetation and climate in western Mediterranean

In the period before 8,000 years BC in the region dominated by steppe communities and trees grew scattered. Near the coast grew birch (*Betula* sp.) and inland and in mountains predominated pine (*Pinus* sp.). At this time are not yet documented evidence of human impact on the landscape (Kaal et al., 2010). In the south-eastern Spain, studies show that there began expand first sclerophyllous plants and summer drought probably lasted longer than three months (Jalut et al., 2000).

In the period between 8,000 and 6,000 years BC began the expansion of oaks, especially in this region by species *Quercus robur*. Along the coast and in the lowlands grew birch, and the other species as species from the families *Ericaceae* and *Fabaceae* there were very underrepresented. Fires still arise spontaneously, and the first people who at that time settled in this area, probably had no share of the inception (Kaal et al., 2010). Forests were still created by deciduous tree species, because at that time oceanic climate prevailed and summers were colder, wetter and colder winters. In the part of middle Spain before 7,500 to 7,000 years BC on the contrary was the arid period, so here there was a rapid development xerophytic communities than in northern Spain and southern France (Jalut et al., 2000).

In the period between 6,000 and 4,000 years BC was a period of maximum expansion of *Quercus* forests in south France and north-western Spain (Kaal et al., 2010). In this period were very favorable conditions for its growth, it was warm and humid, which was caused by a Holocene temperature maximum (Gómez-Orellana et al., 1998). There was also recorded a higher number of fires. There are no records of changes that could explain this event and it is not clear whether human activity is responsible for fires (Carcaillet et al., 2002). In the southeast Spain and in the Balearic Islands, Mediterranean climate began to predominate around year 5,000-4,900 BC, mainly in coastal areas. Inland of this region extended Mediterranean climate between years 4,300 and 4,000 BC (Jalut et al., 2000).

In the period between 4,000 and 2,000 years BC charcoal analysis show that in north-western Spain around 3,500 BC there was a sharp decline of oak forests and significant soil erosion. From the pollen analysis it is obvious that herbs and shrubs began to predominate. Further analysis of the samples shows that people began to burn forests and converted it to pasture for cattle and fields. These conditions were ideal for the expansion of *Erica arborea*, which can quickly take advantage of post-fire situation and overgrow damaged areas. Also in some places shrubs of the family *Fabaceae* extended. In this period, people have changed the landscape for their fields and pastures throughout the area and also in northern Europe (Kaal et al., 2010). Compared to the maximum temperature in the Holocene cooling about four to five degrees Celsius due to the short-term cooling period took place, which occurred in northern and central Europe. This cool period lasted until approximately 1,500 BC and was characterized not only by lower temperatures, but also large fluctuations in the moisture (Martínez-Cortizas and Pérez Alberti, 1999). This cooling can also explain the rapid deforestation and soil erosion and the overall fragility of the landscape and the intensification of human activities are one of the strongest pre-industrial interference in the environment (Martínez-Cortizas et al., 2009). In the southern France, in the Provence and in the Languedoc still dominated temperate climate and forests were made up of deciduous oak forests. Breakthrough area between temperate and Mediterranean climate on the east coast of Spain was roughly south of Barcelona. In the southern France has been a change towards a Mediterranean climate around year 2,500-2,000 BC, when the oak forests began to recede and were replaced by thermophilic and xerophyte vegetation (Carcaillet et al., 2002). This change was not caused by human activity, but global warming. It has resulted in seasonal migration of pastoralists to the mountains above 2,000 meters above sea level, due to low rainfall in summer and higher temperatures (Esteban Amat, 1995).

During the Bronze and Iron age (2,000-0 BC) intensity of fires again increased and it led to increase number of *E. arborea* and decline of oak forests in north-west Spain. Presence of a large number of fragments of *Urtica* and *Plantago* in charcoal means intensive livestock breeding and land use. There was also a significant reduction in the number of *Arbutus unedo*, which was caused by climate change. These changes were probably caused by grazing and increased intensity of fires and the gradual replacement by *A.unedo E.arborea*, which is more adaptable (Kaal et al., 2010). Between years 1,500-1,000 BC occurred to a short-term renewal of oak forests because in northern and north-western Spain there was a short humid period (Fábregas Valcarce et al., 2003). After this period, again declined the number of oaks in the samples and increased the proportion of shrubs of the family *Fabaceae*, *Erica arborea* and also significantly increased the number of *A.unedo*. In the charcoal in these shrubs and peat samples were found large quantities of lead and heavy metals, which means that was the transition between the Bronze age and the Iron age. This process is characterized by great technological and economic changes in the agrarian production system (Kaal et al., 2010). In some areas of Campo Lameiro, it has been shown that there was cultivated wheat and millet already around the year 700 BC (Aira Rodríguez et al., 1990), but in this area growing cereals was not the main reason for burning forest, the main reason was to create pastures for cattle. Earlier this period was in NW Spain colder climate, but gradually the temperatures began to increase and reached its maximum in the Roman Warm Period (200 BC-300 AD) (Holzhauser et al., 2005). In the Balearic Islands and in the south-eastern coast of Spain, between years 1,700-1,300 BC, the number of plants from the family *Chenopodiacea* has increased due to decreased precipitation and aridification. In the Gulf of Lion (41°30 and 44°N), the Mediterranean climate was relatively weakened and was unstable between the years 3,000-2,000 BC. It can be proved very late planting olive tree, up from year 300 AD. After the year 0 in the Gulf of Lion, the climate was similar to present climate, so we can talk about the modern Mediterranean climate (Jalut et al., 2000).

Since the beginning of our era to present, proportion of oaks in the charcoal samples decreased by more than 80%, and was replaced by *Erica* sp. The marked change in the composition means that the fires were more intense (Kaal et al., 2010). Also significantly was reduced the number of samples containing *A.unedo*, *Alnus* sp. and family *Fabaceae*, which were replaced again *E.arborea* (Carrión et al., 2010). The change was caused by the end of the Roman Warm Period (Ballesteros Arías, 2003). But *Erica arborea*, which was dominating the new landscape, was exposed to great pressure (fires, grazing), as evidenced by a curved growth rings. In the last few centuries, the share of *Quercus* sp. increased slightly at the expense *E.arborea* in the north-west Spain (Carrión et al., 2010). Whereas forest's boundary was reduced due to climate change and burning the forest by human, so currently there are located in the hills just growths of shrubs and grasses, hills are mostly destroyed by erosion and forest residues are only found in the valleys. Plants of the family *Fabaceae* did not disappear due to climate change, but because they need enough light and dense growths *E.arborea* these conditions did not allow them, like light oak forests. From this, it follows that the indicator of environmental degradation is *Erica* sp., which can grow in the damaged areas, because it lives in symbiosis with fungi that enable it to grow on very poor, destroyed by erosion, soils (Kaal et al., 2010). Around year 700-1,000 AD along the coast of the Gulf of Lions warming occurred, and this period is called the medieval climate optimum. About this evidenced by the extensive cultivation of olive trees (Jalut et al., 2000).

Around the year 1,300 AD there was a decrease of temperatures due to the Little Ice Age (LIA), which lasted until the mid 19th century. In the Iberian peninsula glacier fields expanded in the Pyrenees and in the Picos de Europa and the Sierra Nevada range (González Trueba et al., 2008) and the temperature was on average 0.9 ° C lower than today (Fletcher and Zielhofer, 2011). In contrast to the warm and dry weather early Middle Ages period, increased rainfall activity and from ecclesiastical documentary records shows that rainfall were very intense and there were heavy floods (Barriendos, 1997). Climate at the time of LIA was extremely variable and unstable and there were frequent extreme climatic events. The peak of LIA was between the years 1,675-1,715 AD and was characterized by very low temperatures and frequent alternation of strong floods (Benito et al., 1996) and drought (Alvarez Vázquez, 1986) and this period is also called the Maunder Minimum (Kington, 1994).

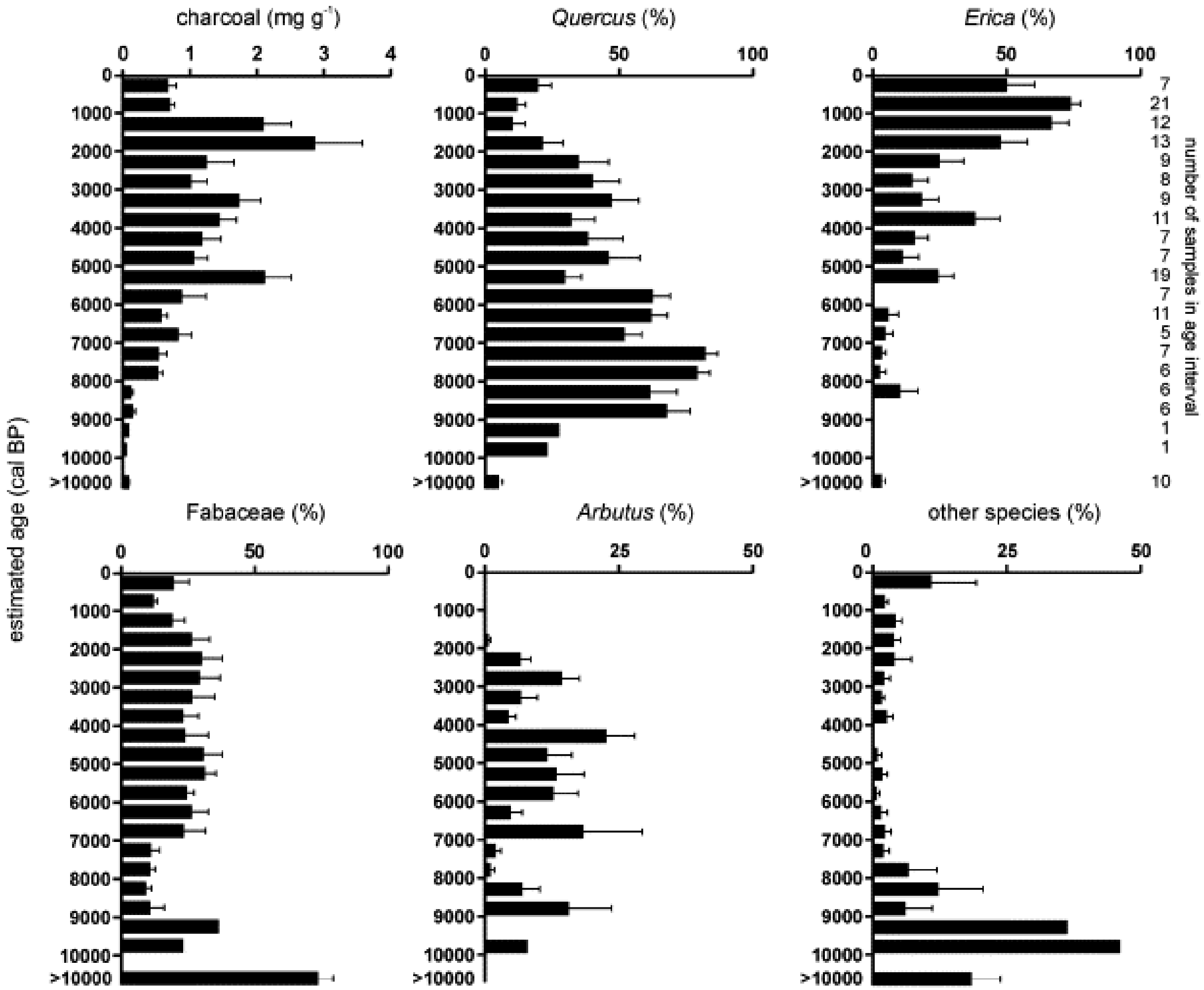


Figure 3. Macroscopic (>2 mm) charcoal content of the main species in NW Spain, which are listed in the percentage representation. Age is shown in BP (Before Present), there are error bars in each interval and the number of samples in these intervals is indicated to the right. In other species, before years 7,500 BP, are most represented *Betula* and *Alnus* (Kaal et al., 2010).

3.3.2 Development of the vegetation and climate in central Mediterranean

The results from Lago dell Access shows that in the period between 8,600-6,500 BC was in the area from the south of river Po to central Italy extended forest, which was consisting mainly of *Quercus pubescens*, *Corylus avellana* and *Fraxinus excelsior*. This forest replaced grassland areas and pine forests that have been previously here. Due to the fact that previously there were growing pine trees (*Pinus* sp.) and the climate was drier, there were frequent fires, but after the expansion of oak forests, the number of fires has reduced. This type of vegetation had been dominant until 6,500 BC, when was replaced by *Quercus ilex*, because the climate was drier again (Colombaroli et al., 2007), with the exception of a wet period between years 6,200-4,000 BC, known as Holocene temperature maximum (Gomez-Orellana et al., 1998). Around 6,600 BC, there were major changes caused by human, which led to the retreat of forests and the partial replacement *Q.ilex* by deciduous oak forest. Evidence of these changes is the expansion of weeds that grow in nutrient-rich habitats, such as *Plantago lanceolata*, *Rumex acetosella*, *Cichorioideae*, *Chenopodiaceae*, *Apium*, *Artemisia* and *Pteridium*. Some of the plants could be used in agricultural production. The destruction of the original vegetation was again mainly a human. Forests were also replaced in many places by macchia and despite frequent fires, it is surprising, that in contrast to the expectations was *Q. ilex* more widespread (Colombaroli et al., 2007).

Same situation was around year 8,500 BC in Sicily, where according to pollen analysis in Nebrodi Mountains open ecosystems have been replaced by deciduous and evergreen oaks. Maximum extension of oak forests was around year 7,700 BC, and by the higher amount of pollen from *Ilex aquifolium* and *Hedera helix*, which are shade-tolerant, it is clear that the density of these forests was high (Bisculm et al., 2012). In southern Sicily in Gorgo Basso at that time were very dry conditions and forest composition were different from the forests in the inland (Bertolani Marchetti et al., 1984). The dominant species in this site was *Pistacia* sp. Due to the dry conditions that were in Sicily, were extended deciduous forests only in the inland and at higher altitudes (Bisculm et al., 2012).

Malta had been inhabited since around year 6,000 BC and settlers arrived here from Sicily. First evidence of the transformation of the landscape are from year 5,300 BC, when human started to change the landscape, especially by burning of forests and by overgrazing. Secondary vegetation was created mainly by *Pistacia* sp., on the cultivated fields were weeds as *Plantago lanceolata*, *Rumex* sp. and on disturbed habitats grew *Asphodelus* or *Theligonum* (Carroll et al., 2012).

The significant changes occurred between the years 5,000-3,000 BC, when the expansion of deciduous forests was at the expense of evergreen (Bisculm et al., 2012) and this change was accompanied by a diversity reduction (Odgaard, 2006). Sudden change in the composition of forests could be caused by shortening the period of summer drought and increased humidity or increased human activity and thus increasing fires. Probably a major influence had human activity, due to increased amounts of pollen of the family *Poaceae*, which grows mainly in open areas and disturbed sites. The human destroyed forests mainly in the central regions, whereas along the coast of Sicily, the forests were not disturbed (Bisculm et al., 2012). In the central regions were found evidence of growing cereals and figs, and the first farmers from the coastal areas were moved around the year 5,000 BC to inland (Noti et al., 2009). Agricultural activities and grazing facilitated expansion of other plants such as *Asteraceae*, *Mentha* sp., *Ranunculus* sp. and ferns (Bisculm et al., 2012).

At the Maltese islands around the year 4,800 BC a large amount of pollen from *Urtica* sp., *Plantago* sp., *Asphodelus* sp. and pollen from *Poaceae* had been found in sediments, suggesting that grazing was an important part of the agricultural economy. Around the year 3, 800 the proportion of *Poaceae* pollen increased at the expense of *Plantago* sp. and *Urtica* sp., which means that it is a transition between mixed farming and greater use of arable land. The years 4,800-2,300 BC marked the beginning of the so-called social progress, when the intensification of agricultural production occurred, especially cereals, but at the end of this period, there was almost complete end of cultivation cereals due to regional landscape aridity (Carroll et al., 2012).

To a further significant increase of *Poaceae* in the samples occurred in the period between 3,000-1,900 BC and 900-500 BC, and between the years 3,000-2,500 BC, were increased some weeds as cereals, *Cichorioideae*, *Plantago*, *Rumex* and *Asteroideae*. Increased number of these plants indicates that there had been disruption of forests by human activities, especially fires. The final destruction of *Q*. *ilex* forests in Italy is dated around 3,000 BC (Colombaroli et al., 2009) and were caused by intense human activity and by cooling over the last 5,000 years (Carroll et al., 2012).

Maltese Islands were one of the first places settled in the central and western Mediterranean, and therefore there was a disturbance of the landscape much sooner. Between years 900-500 BC open grassland areas began to re-expand as it was before 10,000 BC. Greeks settled in Sicily around 700 BC and they stayed only along the coast, while inland was still inhabited by indigenous people (Carroll et al., 2012). Significantly increased the number of inhabitants and cattle, which led to more intensive agriculture and burning the rest of the forest (Noti et al., 2009). Still to increased human activity occurred during the Roman domination in this whole area. Today, forests are limited to minor islands of *Quercus* sp. and the region is dominated by pastures and fields (Carroll et al., 2012).

Around the year 2,300 BC and between 500-0 BC were in the area of Lake Shkodra on the border Albania and Montenegro recorded two wet seasons. These events have been documented also in Italy and Spain, so these wet seasons influenced vegetation across the western and central Mediterranean. Despite the fact that they were substantiated four more humid period between years 150-450 AD, 600-700 AD, 850-1,150 AD and about year 1,850 AD, there was a significant decrease in the percentage in arboreal pollen and pollen concentrations due to deforestation caused by human, mainly from 11 century. On the contrary, the very dry conditions were in the central and western Mediterranean between the years 1,250-1,800 AD, when in Europe was the Little Ice Age. It follows that due to intensive human activity and drier conditions, the original deciduous oak forest could not recover and there were dominated and dominate xerophyte vegetation (Zanchetta et al., 2012).

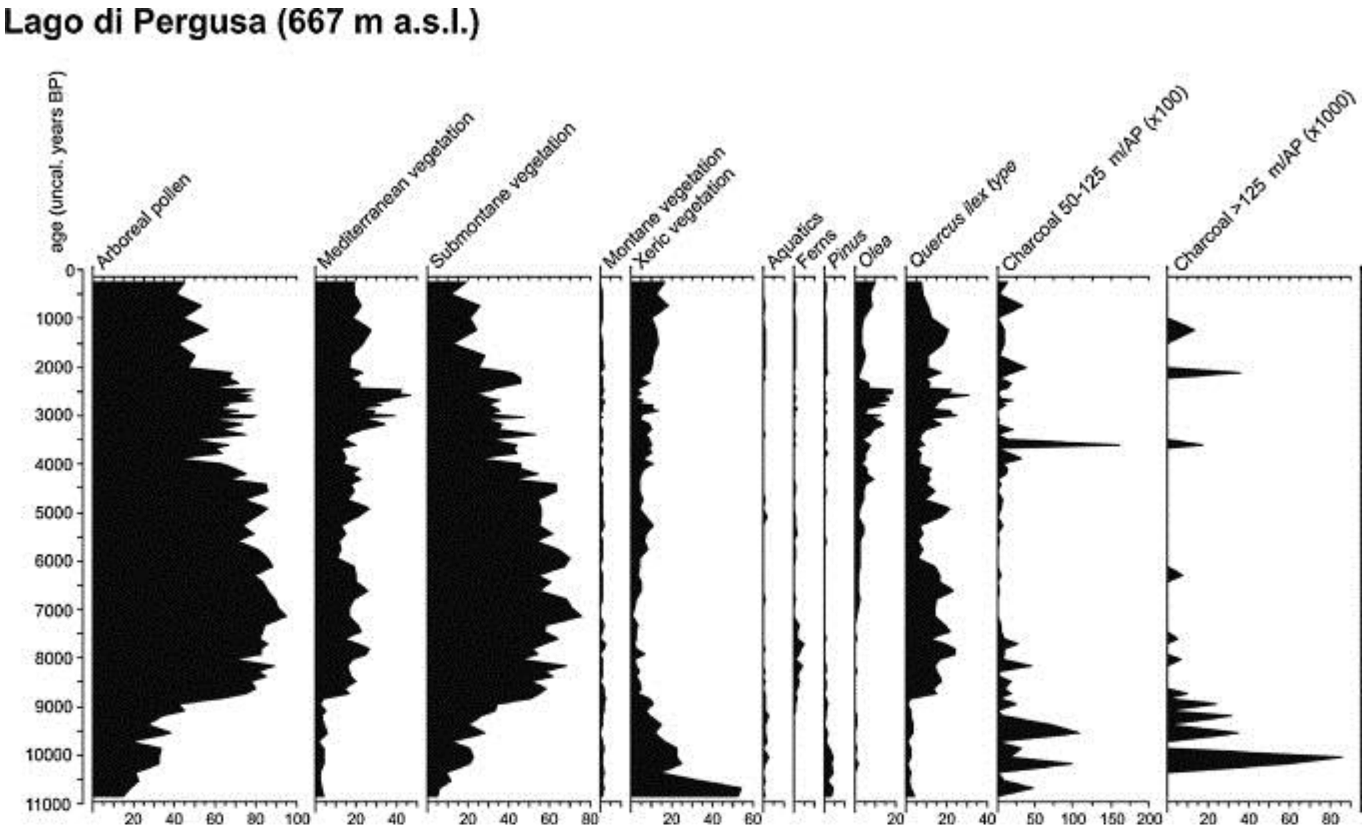


Figure 4. Pollen percentages of various groups of plants from Lago di Pergusa in Tuscany. Age on the right side of the diagram is given in BP. Mediterranean vegetation includes *Cistus*, *Phillyrea*, *Quercus ilex*, *Rhamnus*, *Olea*, *Pistacia*, *Fraxinus ornus*, *Carpinus orientalis.* Submontane vegetation includes *Acer*, *Carpinus betulus*, *Corylus*, *Fraxinus oxycarpa*, *Quercus* deciduous group, *Q. cerris/suber*, *Tilia*, *Ulmus*. Montane vegetation includes *Abies*, *Picea*, *Betula*, *Fagus*. Xeric vegetation: *Artemisia*, Chenopodiaceae, *Ephedra* and *Helianthemum* (Sadori and Giardini, 2007).

3.3.3 Development of the vegetation and climate in eastern Mediterranean

At the end of the last ice age, the whole area was covered by *Artemisia–Chenopod* open steppe vegetation as in the other parts in Mediterranean (Roberts et al., 2001a). The early Holocene climate was more humid than the Mid Holocene and the steppe vegetation has been replaced gradually by deciduous oak forests. In Turkey in Anatolia were the dominant species pine trees, deciduous oaks, *Cedrus* sp. and *Juniperus* sp. (Roberts and Wright, 1993), in southern Turkey were open deciduous oak forests, *Corylus* sp., *Juniperus* sp. and *Pistacia* sp. (Roberts et al., 2001b), in the north-western and south-western Turkey was the same as the composition of the vegetation like in the southern Turkey (Eastwood et al., 1999a). By the transition to the Mid-Holocene, trees were partially replaced by shrubs and herbs due to fluctuations in humidity, but in some places the forest remained like in the western Iran and in north-western Greece (Van Zeist and Bottema, 1977). People began to cultivate first crops already around the year 9,000 and 8,000 BC (Yasuda et al., 2000). At this time, the impact of human on the landscape was still minimal and the vegetation cover was still high (Dusar et al., 2011).

Around the year 4,500 BC was reduced precipitation and climate tended towards to more arid conditions. This trend was recorded in the whole area. Except decreased precipitation, temperatures also decreased, which was recorded not only in the eastern Mediterranean, but also in the central and western parts of the Mediterranean. An exception was the southeast region of the Aegean Sea, where temperatures remained relatively stable. Climate change was of course reflected in the vegetation, where occurred a decrease of pollen of trees in the region and began to dominate the steppe vegetation and sclerophyllous vegetation (Finné et al., 2011).

At the beginning of the Bronze Age, temperatures and precipitation increased in some areas (Finné et al., 2011). More humid climate records are documented from the area around the Levantine Sea around year 3,000 BC (Robinson et al., 2006), also in areas of Israel between years 3,400 and 1,500 BC (Migowski et al., 2006), in Lebanon between years 2,000 and 1,000 BC (Kaniewski et al., 2008b) and in Turkey until to year 2,000 BC (Wick et al., 2003). In the southeast area of the Aegean Sea was warm and humid period between years 3,400-2,300 BC and humid climate was also in the northern part around the year 2,500 BC (Triantaphyllou et al., 2009). Just in the Bronze Age great changes in the development of vegetation in the whole region occurred. On the Peloponnese occurred to a strong deforestation and the forests were replaced by large plantations of olives (Jahns, 1993). Also in Turkey around 1,350 BC were forests systematically destroyed as evidenced by the large amount of pollen from cultivated field plants (Eastwood et al., 1998). Systematically deforested landscape became sensitive to erosion and also thanks to the extreme precipitation events and by a gradual transition to the arid conditions that occurred throughout the eastern Mediterranean (Dusar et al., 2011).

Significant climatic event in the eastern Mediterranean occurred around the year 2,200 BC (Mayewski et al., 2004). Scientists suggested that there was a volcanic eruption and severe drought that hit the region for a period of 300 years (Finné et al., 2011). However, the Avellino eruption of the volcano in Italy that occurred around year 2,300 and 1,800 BC (Zanchetta et al., 2011) and the volcano eruption in Iceland in 2,260 BC (Hall et al., 1994), had not a major impact on climate change. Records from the year 2,200 BC show in the whole region from Italy to Oman significant drought period. In Italy was documented a significant decrease in vegetation cover and dry area has been shifted to the north of 43 ° N (Finné et al., 2011). Di Rita and Magri (2009) explain this event by moving African anticyclone to the north. Records from lakes in Turkey, from the Dead Sea and the Aegean sea confirm this event, but still cannot explain how and what the increased of aridity was exactly caused (Finné et al., 2011). Human impact on the landscape at that time was already considerable and the landscape was due to deforestation, agricultural activities and other activities very sensitive, especially in combination with a dry climate that dominated at that time. In many places there was an irreversible erosion and occurred to soil washing away into rivers and seas (Dusar et al., 2011).

In the late Holocene, after more than 4,000 years of the dry season, a change of climate occurs and begins to resemble that of the present climate. This period is called Roman warm period. About the end of the dry period evidenced cultivation of large quantities of crops (Finné et al., 2011). Onset of the wet season is from the records of lakes in Turkey dated around year 100-0 BC (Roberts et al., 2001a) and in western Anatolia between years 0-500 AD (Lamy et al., 2006). In the Middle East began to wet period around year 0 and lasted until the year 700 AD (Schilman et al., 2002). In addition to increasing rainfall increase of temperatures occurred, such as in Italy around the year 350 BC (Frisia et al., 2005) and along the Adriatic Sea around the year 100 BC (Piva et al., 2008).

During the Late Holocene occurred to environmental changes that probably were not associated with climate (Kaniewski et al., 2007a). Anthropogenic changes in the landscape were caused by the so-called Beyşehir Occupation Phase (BOP) (Dusar et al., 2011). The BOP was first define by Van Zeist et al. (1975) from pollen cores around Lake Beyşehir in Turkey and it means that vegetation change is caused by other factors than by climate changes. This change is dated around 1,400 BC (Van Zeist et al., 1975), at the Bronze Age, but some authors claim that it did not have a solid beginning or end (Kaniewski et al., 2007a). The main change in vegetation during the BOP, the forest clearance along with the occurrence of secondary anthropogenic indicators such as cereals, fruit (*Vitis*, *Olea*, *Juglans*) and anthropogenic disturbance indicators such as weeds *Rumex*, *Artemisia* and *Plantago* (Kaniewski et al., 2007b). During BOP people had a very significant influence on the development of vegetation and climate in the eastern Mediterranean. Climate change in the third century BC known as the Roman warm period and the disappearance of forests, caused by human, functioned as a trigger for larger cultivating crops and fruit trees (Kaniewski et al., 2008a). Growing fruit trees in southwestern Turkey is documented around the year 300 BC (Vermoere et al., 2000) and eastern Turkey around year 100 BC (Wick et al., 2003). Around the Levantine Sea is significant agricultural activity documented around the year 250 BC in Jordan around the year 0 (Schwab et al., 2004). Thanks to the warm and wet period, was for example widespread growing of olives even in high altitudes (1,400 m a.s.l.), where today it is not possible (Kaniewski et al., 2007a). BOP began in the Bronze Age and continued in the Hellenistic period, throughout the whole Roman period and ended between years 400 and 670 AD. After the end of BOP, a sharp decline in agricultural activities followed and the creation of secondary forests, which coincide with those of today in their composition (Kaniewski et al., 2007b), and which are created mainly by *Pinus*, *Juniperus*, evergreen and deciduous *Quercus* and *Cedrus* (Eastwood et al., 1998). Kaplan et al. (2009) suggested that around the year 300 BC were agriculturally suitable areas in Algeria, Tunisia and in Greece deforested from more than 90%, while agriculturally suitable areas in central and western Europe from 10% and 60%.

After the BOP period followed a period of drought and low temperatures, which lasted from the 7-8 century AD until mid-eleventh century (Dusar et al., 2011). From the records of Trieste, cold conditions occurred about the year 500 AD and lasted until the year 750 AD. In the Adriatic Sea there were the same conditions from the year 300 to the year 500 AD, after which followed a brief warm and dry period around the year 600 AD (Piva et al., 2008). After a brief period of drought and heat that here lasted about 150 years, followed by a cold period to the mid-11th century. Due to the adverse conditions that occurred after the Roman warm period, there was a decline in agricultural production in the region. After the collapse of the Roman Empire population decreased and the density of forest was increased (Kaplan et al., 2009). From the pollen records is recorded a decrease of agricultural production in Greece around the year 650 to 850 AD and in Turkey around the year 720 AD, not only due to unfavorable conditions, but also due to the raids of the Arabs (England et al., 2008). This event marked the decline of crop production in Turkey, but on the other hand, increase the number of native tree species (Eastwood et al., 1998). In the Middle East is a decline in agricultural production dated from year 650 and 750 AD due to low rainfall, which lasted until 1,150 AD (Schwab et al., 2004).

In the second half of the eleventh century there was an increase in temperature and precipitation, which is called the Medieval Climate Anomaly (MCA), which is characterized by warmer temperatures and lasted until about the fourteenth century (Hughes and Diaz, 1994). This wet period was followed by a period of increased aridity, which is associated with a Little Ice Age (LIA) and by extension glacier fields around the world (O'Brien et al., 1995). From the marine sediments of the Dead Sea follows that dry conditions lasted from about year 1,400 to year 1,700 AD (Schilman et al., 2002). At approximately the same time, the influence of MCA and LIA is also recorded in Turkey from the sediments of Lake Nar Gölü (Jones et al., 2006), in Iran from the lakes Mirabad and Zeribar (Stevens et al., 2006), from southwestern Tunisia (Marquer et al., 2008) and from Adriatic area (Piva et al., 2008). The coldest conditions in the area of Trieste are from the period between year 1,500 and 1,850 AD (Frisia et al., 2005). Around the year 1,400 AD as a result of the plague in Europe, significantly decreased the number of population and thereby in most places deforestation was halted and in some places was even a slight increase in forest cover. The population to its original state before the plague returned relatively quickly, and since 1,500 AD there was a very intense deforestation (Fig. 5) (Kaplan et al., 2009).

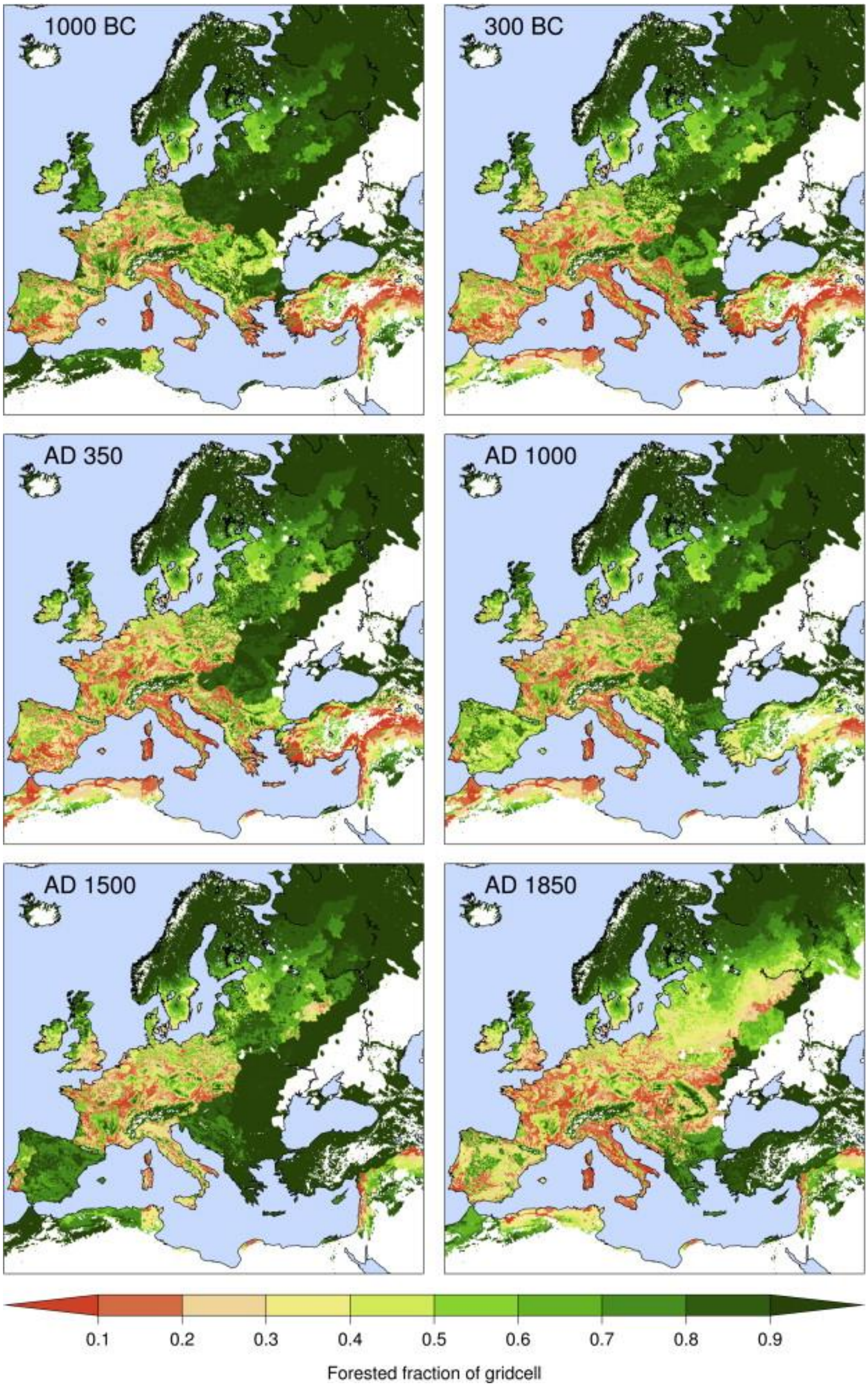


Figure 5. Demonstration of progressive deforestation between years 1,000 and 300 BC, 350, 1,000, 1,500 and 1,850 AD. Places covered with ice, deserts, savannah, steppes and rocks are shown in white (Kaplan et al., 2009).

3.3.4 Development of the vegetation and climate in North Africa

According to the pedological records from Tadrart Acacus massif in Libya, the climate across North Africa before the year 9,000-7,200 BC was rich in rainfall due to monsoon rains from the Gulf of Guinea and from the Southeast Asia. The landscape consisted of a patchwork of savannah and wooden grassland with high biodiversity. Even the types of plants grew there that required permanent freshwater sources such as *Typha*, *Potamogeton*, *Lemna* or *Scirpus* (Cremaschi and Zerboni, 2009). As the evidence of wetter conditions in the area Djara in central Egypt can serve *Anastatica hierochuntica* (*Cruciferae*), *Capparis decidua* and *Maerua crassifolia* that grow in areas where there are summer and winter rainfall. *Anastatica hierochuntica* due to low rainfall withdrew to the north and now grows only in the Negev desert and in Egypt on the plateau of Gilf Kebir. According to the archaeological evidence, the maximum human settlement in the Egyptian Limestone Plateau was reached between years 6,400-5,300 BC. Around the year 5,300 BC the population began to decline as a result of changing climate and lengthening drought and people left this area to move to the Nile Valley. Today the Djarja area belongs to the subtropical desert climate zone, and its climate is hyper-arid, and annual precipitation is in average five mm, compared to humid period before 10,000 years ago (Kindermann et al., 2006). In Gebel Umm Hammad, there were two dry events between the years 6,120-5,790 and 4,770-4,630 BC, which can be confirmed by the occurrence of plants that grow in arid regions such as *Capparis decidua*, *Acacia nilotica*, *Acacia tortilis*, *Boscia salicifolia* or *Balanites aegyptiaca* (Moeyersons et al., 1999). Lakes in erg Uan Kasa in Libya had reached its highest water level in the sixth millennium BC and around the year 6,200 BC its level dropped, which coincides with the dry season across North Africa (Cremaschi and Zerboni, 2009).

In the period between the years 4,000-3,000 BC in the western Mediterranean a change in flow of the sea occurred. Water temperature on the surface was reduced and also low-latitude atmospheric circulation changes including the abrupt retreat of monsoon extension over the tropical part of western Africa occurred (DeMenocal et al., 2000). The shift towards arid conditions is documented from analyzes of pollen in Algeria (Ritchie, 1984) and in Tunisia (Ben Tiba and Reille, 1982), where there was a reduction of forest cover and expansion of xerophilous communities. The decline in water level was recorded in Sidi Ali and Tigalmamine in the Middle Atlas region of Morocco (Barker et al., 1994) and in lakes in the northern edge of the Sahara in Algeria (Gasse, 2002). Around the year 3,400 BC in the river basin in Morocco was reduced potassium content, and that means that there was a decrease in the level of the river during the onset of the dry season (Holz et al., 2007). In the erg Uan Kasa, around the year 5,000-4,000 BC, there was a large number of fragments of ceramics, animal bones and remains of buildings on the former banks of the lakes and it follows that at this time there were many shepherds and farmers. Around the year 3,500-3,200 BC in the erg Uan Kasa lakes dried up due to interruption of monsoon precipitation from the western tropical Africa. The lakes were covered with crust of gypsum, due to the prevalence of evapotranspiration over precipitation and increased salt concentrations. Also, due to the reduction of vegetation cover, the area was affected by wind erosion, which removed most of the stored soil from Holocene wet phase (Cremaschi and Zerboni, 2009).

Moeyersons et al. (1999) states that, shortly after the year 3,000 BC was achieved in most places in North Africa, current climate conditions and Mediterranean vegetation was compressed to the coast. Around the year 2,700 BC were described the first clay dunes formed at the beginning of the dry season in the Saharan region in North Africa. Due to the deteriorating weather conditions, the people began to migrate from the inner part of the Sahara, so that from year 2,700 BC human impact on the vegetation occurred and therefore it is difficult to estimate the effects of climatic influences and human events caused in north-western Africa (Faust et al., 2004). During the period 1,500-500 years BC in Morocco and Algeria in the Atlas Mountains pollen records from the Alboran Sea and lakes shows colder periods, which caused the replacement of forests by bushes and grass communities. Also, reduction in fire intensity due to the lack of plant fuel occurred, which is an indicator of declining forests thanks to climatic conditions. The highest degree of aridity in the area from Morocco to Tunisia peaked between 1,200 and 700 BC (Fletcher and Zielhofer, 2011). These dry conditions could be caused by depression temperatures in the North Atlantic (Bond et al., 2005). Around 500 BC, the north-western Africa was firstly intensively used by Puns and then the Romans (Stevenson et al., 1993). Among the most populated areas in Tunisia were the fertile plains of Medjerda river and its surroundings (Gabriel, 1984). In the basin of the river Medjerda there was already in Punic times intensive cultivation of wheat and during the Roman period there was a significant expansion of olive cultivation (Faust et al., 2004). With considerate farming during the Roman period no disturbance of the landscape occurred, because the Romans built irrigation canals, terraced fields and plantations of trees, which were adapted to natural conditions in the area (White, 1970).

From the year 250 to the year 430 AD are reported in Tunisia stable climatic conditions due to the Roman warm periods, which are characterized in most places North Africa by drought (Marquer et al., 2008). Low levels of precipitation are recorded in Italy between years 200 BC and 174 AD (Reale and Dirmeyer, 2000), in Gölhisar Lake (Turkey) between years 0 and 500 AD (Eastwood et al., 2007) and in Lake Tigalmammine (Morocco), which suggesting drought throughout the Mediterranean (Cheddadi et al., 1998).

Climate throughout the year 550 AD was very unstable and alternated between dry and wet phases accompanied by heavy floods (Marquer et al., 2008). These climate changes have led to a reduction in temperature and solar radiation and the development of humid conditions (Jones et al., 2006), as evidenced by significant rainfall in the eastern Mediterranean around year 700 AD (Schilman et al., 2001). This wet period did not last long and after a year 750 AD, the climate began to stabilize, it was warmer and drier. After the collapse of the Roman Empire, the area was negatively affected by climate and also by human. *Quercus ilex* as bioclimatic indicator dry conditions proves the dry season around the year 600 AD. Adverse weather conditions were reported throughout the northern hemisphere and are consistent with social decline in the African Mediterranean area and with the Great Migration of Nations (Faust et al., 2004). Due to frequent wars in the region there was a decline in agriculture by the influence of unstable weather conditions and there were heavy floods (Faust and Zielhofer, 2002). In the period around the year 650 AD there was an increase in grazing, especially goat farming, and deforestation, which can explain the decline in deciduous oak pollen (McGregor et al., 2009). In addition, in Morocco *Argania spinosa* spread, which is known for the high oil content in the fruit and is also sought-after goats that eat the fruit, but leave the core. Cores collected the farmers and made oil from them, and therefore this tree was expanded in Morocco (Charrouf and Guillaume, 1999). Large amounts of pollen from *Asteraceae* plants (including *Artemisia*, *Cichorioideae*, *Asteroideae*), grasses, and *Plantago*, point to the degradation of the landscape, because they are typical plants of open areas and disturbed sites (Barbero et al., 1990). Shrub *Launaea arborescens* (*Cichorioideae*) is typical for degraded areas and grows in the Atlas Mountains. Its high incidence was probably caused by disturbance of soil or land use changes. Family *Asteraceae* indicates a structural change in the composition of vegetation and reduction of vegetation cover. Reduction in the vegetation cover may have resulted in erosion (McGregor et al., 2009). In the years 1,280-1,340 AD in Sebkha Mabeul the climate was stable and as a result high solar radiation, hydrological anomalies and of high levels of explosive volcanism, the climate became drier (Bradley et al., 2003). In NW Africa in the period between 1,100 and 1,300 AD there was heavy deforestation and increases in agricultural activities, but the population was not too high (Faust et al., 2004). During this centuries were recorded strong fire events in the years 400-430, 530, 745, 850 and 1,070 AD that indicate unstable socio-economic period that it started the conquest of Carthage by Vandals in 439 AD, in the year 533 was re-conquested by Byzantines and in the year 647 AD was again conquered by Arabs. In these periods, there were changes in population, new nations came and thus changes in agricultural processes were frequent, mainly was frequently used slash-and-burn system, by which people created most often new fields. After the year 1,100 AD, the situation was very stable due to the long domination of the Arabs and later the Turks in this area (Marquer et al., 2008). Was abandoned practice slash-and-burn system and intensive production of cereals and olives was concentrated on the area along the Mediterranean Sea, while the steppe areas in the inland and the mountains were used as grazing for goats (Brun, 1983).

After 1,300 AD significant change in climatic conditions occurred, which is called the Little Ice Age (O'Brien et al., 1995). From the dendrochronological data from *Cedrus atlantica* in Morocco it is obvious that the increased precipitation during the LIA in north-western Africa led to wet conditions in contrast to the drought in the early Middle Ages (Esper et al., 2007). The Afourgagh lake in the Atlas Mountains showed highest water levels for the past 1, 800 years (Detriche et al., 2008). After 1,645 AD had a climate trend moved towards more regular hydrological conditions without pronounced inundation events. Ritchie (1984) determines the onset of present-day degradation conditions after year 1,600 AD. After the occupation of the colonial powers, farmers had moved from the fertile lowlands to the mountains, where their actions led to extensive soil erosion (Faust, 1993). Around the year 1,870 AD, a reversal trend was initiated (Marquer et al., 2008). At the end of the LIA around year 1,850 AD gradually again an increase in temperature and aridity occurred, owing to increased solar radiation and the optimal ocean flows. As for the vegetation, degradation of stands continued, which was in accordance with the land use in the Middle Ages and modern times. The agricultural activities indicate the pollen amount of *Cichorioideae*, *Launaea*, *Plantago* and *Artemisia* as well as degradation of pistachios growths due to grazing by goats. Increased aridification or desertification confirms higher quantity of *Calligonum* and *Plumbaginaceae* pollen. Also is still large extension of the argan tree in Morocco, suggesting its economic utilization and protection against over-grazing by goats. After year 1,800 AD intensive farming methods were being introduced and further soil degradation occurred (McGregor et al., 2009). In the Atlas Mountains there are records quadruple values of pollen from *Olea europaea* and its cultivation took place mainly in mountain valleys below 1,200 m, where there is still sufficient moisture for commercial use (Parish and Funnell, 1999).

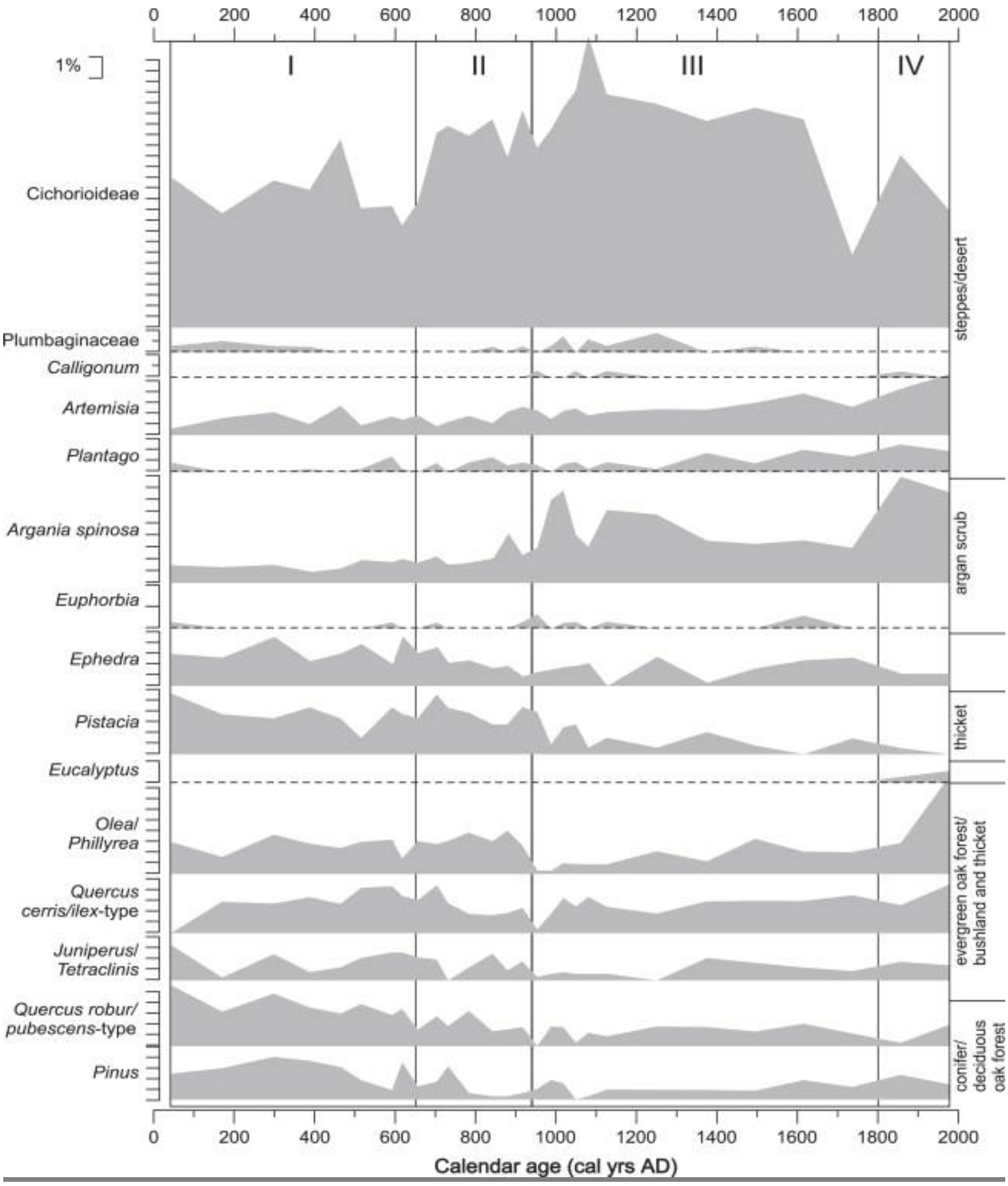


Figure 6. Percentage of selected species and their occurrence from year 50 to 1,950 AD in western Morocco. Roman numerals (I-IV) indicate major changes in the content of pollen. Each interval on the right represents 1% of the content and left scale shows location plants in different vegetation zones (McGregor et al., 2009).

4. RESULTS AND DISCUSSION

4.1 Historical changes in vegetation cover

The period of Holocene was climatically very unstable and changes, caused by climate or human, led to a changing landscape to its present form. In the period between years 10,000 – 5,000 BC deciduous broadleaf trees dominated in a landscape and climate was relatively humid with a short dry season (Jalut et al., 2009). Mediterranean climate was found only in the southern part of the region, while in the north of the region in southern France, northern Italy, in the northern part of the Adriatic Sea and northern Turkey supra-Mediterranean climate and oceanic climate occurred (Ozenda, 1994). The period from 5,000 to 3,500 BC was characterized by low levels of solar radiation in the northern hemisphere (Mayewski et al., 2004), which meant frequent climatic changes that ended the wet period in northern Africa (Haynes et al., 1989). In the period from 3,500 BC began to dominate arid climate and this period lasts to today. Because of the aridification vegetation cover decreased and sclerophyllous, evergreen trees and shrubs, typical of the type of present vegetation has expanded (Jalut et al., 2009). Around the year 2,000 BC-500 AD a Mediterranean climate was extended almost to its present form (Mayewski et al., 2004; Jalut et al., 2009).

Burning of forests, land use, population growth and social problems increased the impact of climate changes on the landscape (Jalut et al., 2009). Also the human was responsible for the development of sclerophyllous vegetation by the fact that burned the original oak forests and thus supported aridification and climate changes (Sadori and Giardini, 2007). Burning of forests by man or lightning strikes bald spots appeared, which were overgrown with pioneer plants as *Caryophyllaceae*, *Asteraceae*, *Ericaceae*, *Artemisia* and *Plantago*. Opening the landscape created pastures, on the slopes there was erosion and thereby the original vegetation was replaced by xerophilous broad-leaf shrubs and trees. In Turkey, during the Beyşehir Occupation Phase (Dusar et al., 2011), there was created landscape in which are represented cultural plants as *Juglans regia*, *Vitis vinifera* and cereals. According to a study from the eastern Mediterranean around the start of the first century AD there was the final transformation of native forests to macchia vegetation type and the deciduous oak forests replaced *Quercus coccifera*. Other xerophilous plants like *Cistus* spp., *Rhamnus* spp., *Pistacia atlantica*, *Ephedra* spp. were extended and expansion of agricultural land were also extended weeds like *Artemisia herba-alba*, *A. campestris*, *Helianthemum*, *Chenopodiaceae* and *Plantago* (Kaniewski et al., 2008).

From this review is evident that human influence in shaping the landscape and climate in the late Holocene was essential and in most places, due to forest burning, grazing and erosion, originated xerophyte shrubby communities that before 8,000 years ago grew only on steep slopes and naturally deforested areas prevailed in the whole region (Jalut et al., 2009; Kaniewski et al., 2008). An environment that is the result of human activity and climate is very fragile and sensitive to any further negative interference. These changes have led to the current problems such as soil degradation, overgrazing, water and wind erosion, frequent fires and spread of exotic species used for reforestation that have become invasive. The current situation is not only caused by historical processes, but is still deepening by inadequate changes in this fragile ecosystem.

4.2 Land degradation and erosion

Probably the most serious problem, which arised by deforestation, is currently land degradation. Soil degradation, which leads to desertification, is particularly problematic in high-stress zones (arid and semi-arid areas) (López-Bermúdez et al., 1998). Lal (1994) defined the land degradation as a loss of the potential utility or production capacity of the soil, because during heavy rains water washed away the soil and its nutrients. Land degradation is usually caused by erosion, human pressure, overgrazing or mechanization and represents the main process of soil degradation in the region (Chikhaoui et al., 2005). For example, in the Rif Mountains in Morocco there was washed away from 2,000 to 6,000 t km^{-2} $year^{-1}$ the soil (MAMVA, 1993). López-Bermúdez et al. (1998) reported that in Spain there were more than 22 million hectares of land, 43.8% of the land, affected by erosion, at which loses more than 12 t ha^{-1} $year^{-1}$ of land and 9 million hectares land in this area, 18.1% of the land on which there were losses 50 t ha^{-1} $year^{-1}$ of soil. The effect of erosion on agriculture is enormous. To the highest losses of agricultural land occurs in the vineyards, olive groves and almond orchards, while the lowest losses are in abandoned olive grove and in abandoned fields as indicated in Table 1 (Koulouri and Giourga, 2007). In the last few decades in the region have seen the abandonment of agricultural land as a result of social and economic changes. One option how to protect agricultural land is build stone terraces that reduce the risk of erosion (Koulouri and Giourga, 2007). Another way to prevent the erosion is the use of cover crops in orchards or other permanent growths. Cover crops are mainly used in olive and almond orchards, but there may be competition for water between the main crop and the cover crop, so it is necessary to use as a cover crop plants, which have a period of vegetation growth at other times than the main crop. Cover crops can very effectively prevent erosion, promote the formation of humus and also prevents water runoff. As a suitable plant to the undergrowth trees in orchards is *Lygeum spartum* (Hooke and Sandercock, 2012). The other suitable plants are presented in Table 2. Thornes (1990) suggested that the minimum value of the vegetation cover to prevent erosion must be greater than 30%.

Table 1: Amount of soil washed away by erosion in kg ha^{-1} year^{-1} at selected ecosystems.

Land use	**Mean soil erosion (kg ha^{-1} year^{-1})**
Abandoned olive grove (5 years)	30
Cultivated olive grove	65
Grazed olive grove	55
Abandoned cultivation—1 year	24
Abandoned cultivation—2 years	32
Abandoned cultivation—5 years	41
Abandoned cultivation—20 years	19
Cereals	176
Vines	1428
Eucalyptus plantation	238
Shrubland (maquis)	67
Abandoned olive grove (short-time)	8

Source: Arhonditsis et al., 2000; Francis, 1990; Kosmas et al., 1997.

Table 2: Recommended plants used against erosion in orchards, reforested areas, abandoned lands and in places prone to erosion.

Land-unit	Type of plants
Reforested land	Grasses (*Stipa tenacissima* and *Brachypodium retusum*, *Helictotrichon filifolium*) and shrubs (side bank: *Salsola genistoides*, other hotspots: *Rosmarinus officinalis*, *Anthyllis cytisoides*, *Rhamnus lycioides*, *Pistacia lentiscus*)
Croplands	Weeds, legumes and grass species
Abandoned lands	Grasses (*Lygeum spartum*, *Brachypodium retusum* and *S. tenacissima*) in combination with more deeper rooted shrubs (*Anthyllis cytisoides*, *A. halimus* or *Salsola genistoides*) on terrace wall. On fields *Rosmarinus officinalis* and *Dorycnium pentaphyllum*
Hillslopes and gullies	Grasses (*S. tenacissima*, *Lygeum spartum*, *Helictotrichon filifolium*) and shrubs (*Salsola genistoides*) on steep slopes. Grass species (*Brachypodium retusum*) and reed species (*Juncus acutus*) to vegetate drainage lines. For stabilizing gully floors a combination of grasses (*Lygeum spartum*, *S. tenacissima*, *Brachypodium retusum)*, deep rooted shrubs (*Salsola genistoides*, *Anthyllis cytisoides*, *A. halimus*) or trees (*Tamarix canariensis*) should be considered
Channels	Grasses (*Lygeum spartum*) on fans. Grasses (*S. tenacissima*, *Lygeum spartum*) and trees (*Tamarix canariensis*) to stabilise valley walls. Larger tributaries/channels, consider either trees/shrubs (fine substrate – *Tamarix canariensis*, coarse substrates–*Nerium oleander*) and grasses (*Lygeum spartum*). Where water accumulates plant *Juncus* sp. and *Phragmites australis*

Source: Hooke and Sandercock (2012)

Land degradation and desertification is not only due to deforestation and land abandonment, but also by overgrazing. Overgrazing is one of the major causes of desertification in the Mediterranean. Permanent pastures occupy 15% of the Mediterranean region (1.25 million km^2) and in the area there was more than 147 million sheep and other animals such as cattle, horses and goats. In North Africa, Asia Minor and in the Middle East cattle breeding is a traditional industry, but this is also still a relevant economic activity in the European part of Mediterranean. Grazing affecting soil properties, hydrology and mainly the vegetation cover (Koulouri and Giourga, 2007). By grazing biodiversity is reduced as a result of prioritizing various plants by different species of animals (Heady and Child, 1994). Animals also causing poaching of soil and vegetation and by overgrazing grasses and shrubs is reducing the amount of organic matter supplied to the soil, arises physical degradation of soil and by repeated grazing is reducing of water infiltration capacity and increases surface runoff water during heavy rains (Gamougoun et al., 1984).

4.3 Fire occurrence

Since the time when man began to deal with agriculture, used the simplest way of obtaining new fields and this method is burning the forest or also slash-and-burn system. This method was widely used almost throughout the Holocene, except for the period of Roman rule, when there were chosen gentler methods of agriculture, and then throughout the Middle Ages. Forests were also fired in response to the unstable socio-economic conditions, such as wars, rebellions or economic crisis. By the fallowing the original vegetation, which was not able to recover after a fire or was not competitive with other resilient species, was replaced (Marquer et al., 2008). After the replacement the original deciduous forests by xerophytic sclerophyllous shrubs and trees, the number of fires in the region increased. Type of vegetation that currently prevails in the Mediterranean, is one of the largest fire-prone biomes in the world (Bond et al., 2005) and from the time when these plants began to spread, fire is the main process in controlling vegetation dynamics and structure (Naveh, 1995; Retana et al., 2002).

Plants of these communities have a high regenerative capacity and after the fires very quickly regenerates, either from seeds, sprouting from roots or from the burned remnants of strains. These plants in burned areas grow up again, because they are more capable in competition than the deciduous species, and the risk of fires increases again (Capitanio and Carcaillet, 2008). Thanks to such frequent fires grow here only those species that are fully adapted to this environment and other species are strongly reduced in growth and spread (Gill and Groves, 1981). It follows that by frequent fires some species are preferred such as *Erica arborea*, *Pinus halepensis* or *Ulex europaeus* and thus reduces the biodiversity of vegetation and increases the risk of fire (Baeza et al., 2006; Keeley et al., 2005). Structure of vegetation depending on the frequency of fire is shown in Figure 7.

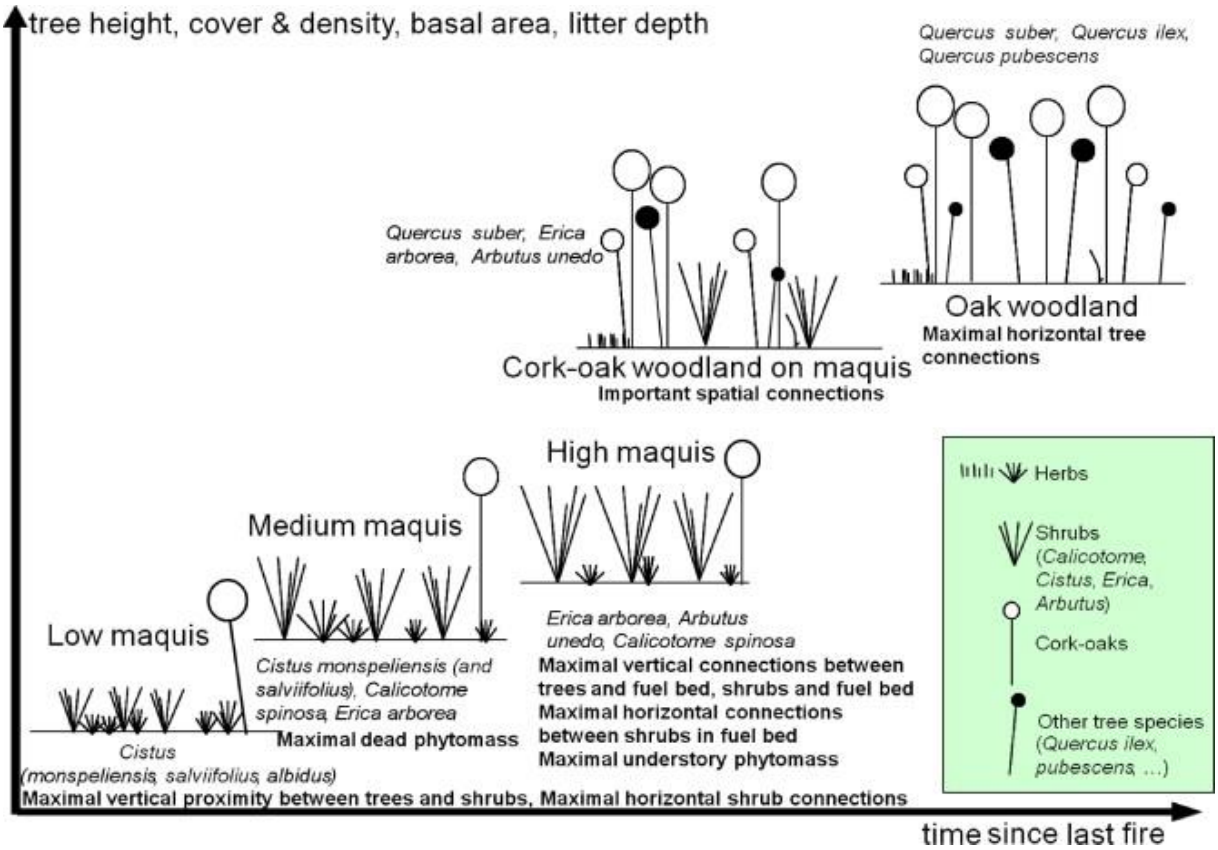


Figure 7. Vegetation structure and its composition, depending on the time since the last fire and factors inducing changes in fire risk (Schaffhauser et al., 2011).

It has been proven that fires very significantly affect the composition of the vegetation and its density (Barbero et al., 1987; Tavsanoglu and Gürkan, 2005). The fire behavior depends strongly on the type and density of vegetation (De Luis et al., 2004). For example, the fire is spread rapidly in shrubs communities, while in oak forests is its speed low. Therefore, it is important to know the composition of the vegetation and the amount of dead biomass and thus prevent rapid fire spreading (Fernandes and Rigolot, 2007). Repeated fires at intervals of 15-20 years, leads to development of medium-high macchia where the dominant species are *Erica* sp. and *Cistus* sp. which is in dry period highly flammable. If the interval between fires is extended, high macchia is created and there is accumulation of large quantities of flammable biomass and if there is a fire, it has devastating effects. If the fire wasn't appeared to 50 years, natural oak forests will incur (*Quercus suber*, *Q. ilex* and *Q. pubescens*). In these forests, it also leads to the accumulation of flammable biomass, but the fire spread only at the ground and therefore these forests are damaged by fire fewer than artificially planted highly flammable pine forests (Schaffhauser et al., 2011). Carcaillet and Capitanio (2008) supposed that in the place dominated today by pine forests the fire will not occurred during 110 to 120 years, these forests will be replaced by mixed evergreen and deciduous oak forests.

The worst impact of fires in Spain was in year 1,994, when more than 140,000 ha of forests was burned, which is 12% of the area of forests in Spain. Another devastating fires were recorded in the years 1,978 to 1,979 when 154,000 ha was burned within two years. These changes in increase of fires can be explained by increasing average temperatures, but also the depopulation of villages and moving people to the cities. When people leave their villages, this will reduce to agricultural activities, field start to overgrow and begin to accumulate biomass, also vegetation will not be destroyed by grazing and the amount of accumulated biomass will increase the risk of fire. This is an actual problem, which will increase likely in the future and this is why to be addressed it (Pausas 2004).

4.4 Suitable methods and plants for reforestation

One of the options how to prevent soil degradation, soil erosion and partially to forest fires is restoration the forest. The trees modifies microclimate conditions under their canopies and around them, creating a shadow, increase soil fertility and also keep the soil together with their roots (Breshears et al., 1998). Trees have a significant effect on the undergrowth under their canopy, either positive or negative. The negative influence is the competition for water with other plants, and either roots, so capturing water by their canopies (Barnes and Archer, 1999). Positive influences is fortunately more than negative, especially creating shade and undergrowth protection against direct sunlight and also reducing water losses by transpiration and improvement of soil fertility by accumulating of dead biomass (Breshears et al., 1997; Callaway, 1995). Therefore, trees have a positive impact on future undergrowth of shrubs and improve poor conditions for growth (Montero and Alcanda, 1993).

Without question the most frequently used tree species for afforestation throughout the Mediterranean is *Pinus halepensis* (Querejeta et al., 2008). This species covers an area greater than 25,000 km² and is the dominant tree in the arid and semi-arid areas in this region (Quézel, 2000). Bautista (1999) stated that in the province of Alicante (SE Spain) 2600 of the 3000 ha consists of just this species and similar situation is also in Algeria, Turkey and Morocco. However, views on the negative impact to other plants, and also the possibility of an increased risk of erosion, fires and soil degradation in monoculture plantations are still controversial (Maestre and Cortina, 2004).

Bellot et al. (2004) reported that *Pinus halepensis* has a clearly negative influence on soil moisture in the area below the canopy. This can be explained by the fact that in dense vegetation of trees that have broad canopies, increase water retention in the trees canopies occur and thus it may be captured up to 35% water (Chirino et al., 2001). As regards the soil moisture below the soil surface, it was found that *P. halepensis* has the most roots at a depth 10-20 cm where it is also the driest soil, mainly thanks to high density of fine roots, which are mainly responsible for water consumption from the soil (Bellot et al., 2004). The lowest density of the roots is just below the soil surface at a depth of 0-10 cm, so that there was not recorded a negative effect on soil moisture (Koechlin et al., 1986). Higher consumption of water is also related to further negative influence on the shrubs growing in the undergrowth. One of the few plants that is capable of competition with *P. halepensis* is *Quercus coccifera*. *Q. coccifera* has massive roots in a depth, where the roots *P. halepensis* has not. Maestre et al. (2003) argues that by improving microclimatic conditions under the canopies cannot compensate for the reduced availability of water and reduction in the growth of other plants. This negative effect can have serious consequences on the dynamics of vegetation in semi-arid and arid regions where it *P. halepensis* is grown (Maestre and Cortina, 2004).

Another problem, which is often discussed, is the influence of pine on the frequency and intensity of fires. In large plantations a large amount of highly flammable biomass such as needles, resin or cones accumulates (Maestre and Cortina, 2004). For example, in Spain in the years 1,969-1,983 it was found that on 10-20% burnt area grew just this pine (Vélez, 1986). Similar results were also found by Herranz (2000), which found that *P. halepensis* represented up to 47% of the total burned area and also Moreno (1999) that in Spain between years 1,974 and 1,999 26% of burnt areas were plantations with *Pinus halepensis*. Fires in these stands strongly inhibit the regeneration of the other vegetation and on the burned places again grows up the pine because the mature trees produce large quantities of seeds and initial growth is relatively fast (Maestre and Cortina, 2004).

Figure 8. View of terraced plantation of *Pinus halepensis*, on which is apparent low density of trees, and are also seen erosive processes (Maestre and Cortina, 2004).

From these arguments, it is clear that monoculture plantations of *P. halepensis* are not the best solution for the already damaged landscape of the Mediterranean. Bellot et al. (2004) came to the conclusion that a more appropriate solution would be to use existing vegetation and to this vegetation shrubs or trees planting that are adapted to local climatic conditions. It is also possible to use as cover the above described species of grasses, e.g. *Stipa tenacissima, Brachypodium retusum* or *Helictotrichon filifolium*. These species of grasses do not compete with woody species for water because the trees pumping water from greater depths while grasses from the upper soil layer. They also improve soil fertility because their clumps the soil and humus captures during the rain. These grasses also operate like living mulch and reduce water evaporation from the soil. Planting grasses should be the first stage of reclamation of degraded sites, and after the grasses cover the soil, planting trees or shrubs is recommended. Meanwhile the grasses create suitable conditions for planting trees and their roots holds the soil and prevent the erosion. (Hooke and Sandercock, 2012). Vallejo et al. (1999) proposes to increase of biodiversity in existing plantations by the introduction of an indigenous species like *Pistacia lentiscus, Pistacia terebinthus, Ceratonia siliqua, Olea europaea, Rhamnus lycioides* or *Quercus* spp. These species are widespread and they are suitable alternative instead planting the conifers. It should increase the soil fertility by nutrient accumulation, prevent erosive processes and also creating an appropriate ecosystem for wildlife. This solution seems to be good, but there is low ability of young plants to survive due to severe weather conditions (Bellot et al., 2004). Hidalgo et al. (2008) examined the use of cork oak (*Quercus suber*) to afforestation in Spain, where the species is original. The disadvantage of this oak, that it prefers areas with sufficient precipitation and high soil quality, because in the long drought has small increments and grows poorly, so it can be used for afforestation at higher altitudes or in areas around the Atlantic Ocean. A clear advantage is that its bark can be used for obtaining cork and therefore forests formed by these oaks have a dual use like antierosion cover and industrial use. This species of tree is very suitable for reforestation in the Iberian Peninsula and in southern France. Other suitable oaks for reforestation are *Quercus ilex* (Holm oak) and *Quercus pubescens* (Pubescent oak). These species are not highly demanding on soil conditions but cannot grow in very dry areas mortality of young plants could be high (Sánchez-Andrés et al., 2006). It is recommended to use Quercus ilex in areas with higher rainfall because there grow better but is also suitable for reforestation in arid areas because it is very adaptable to site conditions (Valdecantosa et al., 2011; Colombaroli et al., 2007). *Quercus pubescens* was the most common oak before changing the structure of the forests, but due to the current aridity it mainly grows in the mountains and on soils with plenty of ground water (Colombaroli et al., 2007). For optimum growth, it is important eliminate weeds that compete seedlings for water (Sánchez-Andrés et al., 2006).

It seems that *Pinus halepensis* and other types of Mediterranean pines are probably most resistant trees used for reforestation. The use of evergreen oaks and native evergreen trees is still limited, mainly by high mortality of young plants due to extreme weather conditions in the summer such as mainly lack of water and lack of nutrients for growth. For example, survivals of seedling of native trees in SE Spain were reported very low: *Q. ilex* is 2.7-8.3%, *Olea europaea* 50% and *Pistacia lentiscus* 62.5-75%. The amount of rainfall during the experiment was only 384 mm (Navarro-Cerrillo et al., 2009). It is obvious that *P. lentiscus* and *Olea europaea* are very resistant to drought and suitable for planting in arid and semiarid areas. Another attempt was reported from south-western Portugal where due to higher rainfall (833 mm) the survival rate was: *Olea europaea* 94% and *Pistacia lentiscus* 95% (Oliveira et al., 2011). Larchevêque et al. (2006) suggested that for the reduction of seedlings mortality compost should be added during the planting and thanks to compost not only the nutrition of young plants was improved, but also the ability of the soil retain the water. Increasing the nutrition of young seedlings also increased the ability to competition with *Pinus halepensis*, mainly in the summer because potassium improved water management and thereby seedlings can survive summer drought. Oliveira et al. (2011) reported that compost has a short-term positive effect for plant development but in the first year after planting an increased amount of nutrients is important for the survival of the summer drought. Larchevêque et al. (2006) also points to the content of hazardous elements, such as Cu, Zn in the compost, which might adversely affect the pH at doses above 40 kg m^{-2}. Well-developed root system is one of the prerequisites for successful growth and therefore Chirino et al. (2008) studied the effect size of the container used for growing seedlings in forest nurseries. He found that existing containers with a depth of 18 cm were not suitable to generate a sufficiently large root system and the result of his research is, that the ideal depth of the container is 30 cm. Thanks to more massive root system roots reached faster to zones, where the humidity is stable and have a greater chance of survive (Chirino et al., 2008; Bellot et al., 2004). Plants in a deep container also created more aboveground biomass and this increased their competitiveness with other species during summer drought (Chirino et al., 2008).

In my opinion, the combination of high-quality compost used in planting, plants with a deep and quality root system and planting the trees under the pine canopies, can substantially increase the chances of survival of young seedlings and accelerate their initial growth. By accelerating growth of seedlings, they can grow to larger sizes before the dry season will start and thus their chances of survival increasing and loss of planting material will be lower. I also think that is better to use indigenous species for reforestation than non-native species like *Eucalyptus* spp., *Acacia* spp. or *Ailanthus altissima*, which in addition do not improve the condition of vegetation and soil, and are only a short term solution. The species listed in Table 3 are most commonly used for reforestation instead of *Pinus halepensis*, because they show faster growth and easier cultivation than other shrubs and trees species, which are common in the region. As cover plants can be used the above mentioned types of grasses. Information that *Pinus halepensis* is not a suitable solution I can confirm from my observations, when I saw that to fires occurred mainly in these forests, while mixed oak forests, fires were less frequent and were not as extensive.

Table 3: Recommended plant species suitable for reforestation and to preventing the erosion. On each plant is also suitable growing area owing to their demands on the climate and terrain.

Latino name	English name	Family	Suitable area for growth
Quercus suber	Cork oak	*Fagaceae*	Humid areas/Arid areas, coastal areas
Quercus ilex	Holm oak	*Fagaceae*	Arid areas, steep slopes
Quercus pubescens	Pubescent oak	*Fagaceae*	Humid areas, steep slopes
Pistacia lentiscus	Mastic tree	*Anacardiaceae*	Arid and semiarid areas, steep slopes
P. terebinthus	Terebinth tree	*Anacardiaceae*	Arid areas, steep slopes
Olea europaea	Olive tree	*Oleaceae*	Arid areas, steep slopes
Phyllirea latifolia	Filirea	*Oleaceae*	Arid areas, steep slopes
P. angustigolia	Filirea	*Oleaceae*	Arid areas, steep slopes
Rhamnus lycioides	Black hawthorn	*Rhamnaceae*	Arid areas, steep slopes
Ceratonia siliqua	Carob tree	*Fabaceae*	Arid areas, steep slopes, coastal areas

Source: Hooke and Sandercock, 2012; Vallejo et al., 1999, Larchevêque et al., 2006, Maestre et al., 2003

5. CONCLUSION

In this study, I described in detail the course of vegetation development in the entire region from a historical perspective, including the consequences resulting from deforestation. It is quite obvious that the only way to prevent negative impacts of deforestation is reforestation. From species used for reforestation, I focused mainly on *Pinus halepensis* because is currently the most used, but also this species is often criticized due to the above described problems with its impact on the environment and other plants. That's why I suggested to use for reforestation evergreen or deciduous tree species, which has shown positive effect on the environment and also are native in this region. The most important of them are oaks (*Quercus suber*, Q. *pubescens*, Q. *ilex*), *Ceratonia siliqua*, *Pistacia lentiscus*, *Pistacia terebinthus*, *Phyllirea* spp. and *Rhamnus lycioides*. Since the chances of survival of young seedlings during summer drought is very low, I suggest that a combination of three well-proven methods: (i) like planting into the undergrowth of adult pine trees, (ii) the seedlings should be planted in deep containers and (iii) during planting compost should be added. This can increase their chance for survive and accelerate initial growth by faster reaching soil moisture in a depth and by nutrient content of the compost. Canopies of adult pines will protect them from direct sunlight and thereby evapotranspiration will be reduced.

This method seems to be relatively expensive, but since it can substantially increase their survival in the first years, final cost would be lower as it can save large amount of seedling material. This technique also increases biodiversity in forests, diminishes the risk of fire and erosion, and in addition, these trees can recreate the in indigenous forests that had existed in the area before the start of deforestation.

I think that fully restore the forests in their original form, given the current climatic conditions is almost impossible, but it is possible at least to prevent further degradation trough reforestation using suitable native tree species.

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