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Effects of Climate Change on Vegetation in Mediterranean Forests: A review

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Abstract— *A systematic literature review was undertaken to analyze the effects of climate change concerning the forests in the Mediterranean region as it is a climate and a global hot spot of biological diversity and the richest biodiversity region in Europe. Climate change threatens several ecosystems (e.g. forests) with ecological and socioeconomic importance. It is noteworthy that all warming scenarios in the Mediterranean predict an increase of drought and heat events, and a reduction in precipitation within the next hundred years in the Mediterranean basin with important consequences in local vegetation communities. Forests can therefore be used as a tool in developing solutions to the problem of climate change. Nowadays, is considered necessary firstly to continue monitoring and research concerning climate change patterns and impacts on regional scales and secondly to implement management strategies in order to preserve Mediterranean habitats.*

Keywords—Forest, vegetation, management, climate change, adaptation.

I. INTRODUCTION

Mediterranean is considered as global biodiversity hotspot [1,2]. Expanding between temperate-rainy (South Europe) and arid regions (Africa), constitutes essentially, a transitional zone, werevarious types of ecosystems and species co-exist, but in a delicate balance [3].

Climate change effects have already begun to be felt throughout the Mediterranean. Prolonged periods of drought, frequent and severe storms, flooding, increased extreme heat events and more mega-fires are a testimony to this change. The rapid and acute changes in climatic conditions within the next 100 years is expected to produce an important impact on the Mediterranean forests [4].

Mediterranean ecosystems are characterized by contrasting plant functional types competing for water [5]andare sensitive to warming and alsotochanges in water availability [6]. They have undergone numerous climatic changes in the past, responding with various ways (tolerance to environmental changes as a result of phenotypic plasticity of certain species, adaptation by changing physiological procedures, exploitation of genotypes, immigrationetc) [7]. Further temperature increase and water availability reduction is expected to cause Mediterranean biodiversity loss in the future [8] and have notable impacts on natural vegetation.

Hence, the aim of the present activated review is to present comprehensive information about the effects of climate change concerning the forestsin the Mediterranean region, which has been identified as "climate change hot spot"[9,10].

II. METHODOLOGY

In order to review and consolidate existing research on the climate change effects on Mediterranean Forest vegetation, a literature search was conducted using Scopus, Web of Science and Google scholar. A systematic methodology was implemented in order to ensure that a rigorous and repeatable method was applied to each synthetic of the effects of climatic change on vegetation in Mediterranean Forests. The methodology consisted of two stages: (i) the generation of keywords and (ii) a systematic search [11].

III. RESULTS

Environmental conditions play an important role in defining the function and distribution of vegetation, in relation with other factors. Changes in long term environmental conditions that can be collectively coined climate change have significant effects on vegetation community structure, composition and distribution pattern in the future [12].

Mediterranean regions are passing climate regions where it has been presumed that climatic changes may have the greatest impacts. Mediterranean regions are also predicted to have minutely intense feedbacks from the earth to the atmosphere [13].

Climate changes

Climate constitutes a constantly changing system due to both anthropogenic and natural factors. Recent past records indicate a temperature increaseby about 0.85ºC globally and about 1.3ºC in the Mediterranean area compared to the levels of the time period of 1880-1920. Cook et al. (2016) [14] refer in their study that the 1998-2012 period was the driest of the last 500 years.

Future climate patterns foresee a further increase of air temperature.It is noteworthy the fact that the predicted

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future changes in temperature over the next period (2016-2035) are expected to be in the range of 0.3-0.7°C [15] under medium confidence levels.

In the Mediterranean basin, models also predict, increases in temperature and heat stress and reduction in precipitation and water availability [16,17]with increases in extreme heat and precipitation events [18]. Extreme temperature events are provided to become more regularly, intense and longer duration than present [19].Generally, all warming scenarios in the Mediterranean predict worse future conditions compared to the global pattern, with warming to exceed 2°C at the end of the century.Drier conditions are also expected to threat the Mediterranean habitats [9,10,20].

Land use changes

Land use changes in the Mediterranean are significant when studying the effects of climate change. Petit *et al.* (2001) [21] mentions contradicting changes in the basin with deforestation, abandonment and intense use co-existing. Though, the extensive reductions of forests by intense land use [22], wildfires and grazing are the key factors that shaped todaysMediterranean landscape [23].The changes in climate along with those in land uses (conversion of wildlands to agricultural lands and urban areas) are expected affect negatively ecosystems biodiversity [24,2].

Changesinplant growth

Warming, increase of drought and heat events and drastic reduction in precipitation is likely within the next hundred years in the Mediterranean basin with important consequences in photosynthesis, growth and survival of local vegetation [25,26].

It has been observed that increasing atmospheric CO_2 concentration influence plants photosynthesis, consistently the increases in plant water use efficiency enhancing the photosynthetic capacity and favoring the plant growth [27]. Specifically, rising concentrations of CO_2 in the atmosphere increase photosynthesis rates and vary with plant nitrogen status and species [28]. For example, mature *Fagussylvatica* and *Quercuspetratea* responded more than *Carpinusbetulus, Prunusavium*, and *Tiliaplatyphyllos* in a central European free air experiment enrichment [29]. Tree growth rate might not increase proportionally with increase in photosynthesis because of other limiting factors such as nutrient availability[30,31].

Although experiment enrichment or short – term CO_2 increase can lead to higher net primary productivity [32], tree ring analysis in the Mediterranean shows the opposite [33] probably due to limitations in water and nutrients availability [34,35]. This is in line, with the recorded tree growth reduction [36], increased growth variability [37] and defoliation in Mediterranean forests the last decades.

The higher atmospheric CO_2 concentration (increase from 280ppm in the pre-industrial age to 400 ppm at present, Kennedy 2015 [38]) is not expected to lead to increase in carbon assimilation by natural vegetation in the Mediterranean, mainly because of the impact of drought to metabolic limitation to photosynthesis [39] and limitations in water availability and nutrients [40, 28]. Thus sclerophyllous vegetation, that dominates the Mediterranean, will not be favored by CO_2 changes, while thermophilous species will have to deal with better climatic conditions mainly because of the warmer winters[26].

The Mediterranean species are established to temperature zones where temperature is near its optimum values for photosynthesis [40,41]. An increase in temperature (near or beyond its critical values) combined with low water availability, especially in summer, is expected to lead to photosynthesis decline, reduction in CO_2 assimilation and stomatal conductance, cell dehydration and necrosis [42]. Though, there are species tolerant to high temperatures with specific morphological characteristics (small thick or trichom covered leaves, small leaf angles with the shoot, etc.) and adaptation strategies (such as completion of biological stages before the drought ignition, intraspecific variability, phenotypic plasticity, local adaptation, e.t.c. (seereviews [26,3]) that allow them to grow and survive to warm environments. An interesting review of the adaptation mechanisms of Mediterranean heat tolerant species to drought was presented by Bussotti*et al.* (2014) [26], who also mention extensively reported tree dieback events in southern Europe and in Mediterranean regions and suffering of sclerophyllous Mediterranean vegetation due to severe drought events.

Changes in vegetation patterns

Many studies foresee habitat reduction due to climate change though, with different habitat loss rates [2]. The habitat loss [43] and seed production [44] will be affected by climate change, with direct effects to plant communities. Drought [15] and extreme cold events [46] are also found to affect fauna.

The most sensitive vegetation zones in the Mediterranean are those extended to the southern limits of the Mediterranean basin. Changes in atmospheric CO_2 concentration (reaching 600ppm at the end of the century [25], will have severe impacts on plant populations (Lenoir *et al.* 2008), by affecting plant productivity and water use efficiency [48, 49].

Habitat migration to regions with more favorable climate conditions will also occur as a climate change adaptation strategy of vegetation. Though, many plant species cannot meet the needs of velocity transition requirements in order to establish new plant communities in new areas [50]. Tinner and Lotter (2006) [51] calculated that in order to accomplish a 100 km migration transition, species will need about 250-1000 years, when climate change occurs much faster (according to A1B scenario mean temperature increase velocity will be 42 km per 100 years and in many regions will reach 100-1000 km per 100 years, [52]).

The spatial climate change shifts will occur with different regional velocities, higher at lowlands and lower in mountainous regions [52,53]. Also, different immigration rates are expected among species with respect to their reproductive dynamics and dispersion strategy. For example, Clark *et al.* (2001) [54] found migration rates varying from 300m per year for boreal spruce to 0.1-1 m per year for animal-disperse species, when Higgins *et al.* (2003) [55] estimated much higher rates for specific weeds and shrubs reaching 2186 m per year. In general, Davis *et al.* (2005) [56] estimated local adaptation times from decades to century for herbs and 100-1000 years for trees.

Altitudinal upward shifts of vegetation have also occurred during past along with immigration to southern (cooler) areas. Bussotti*et al.* (2014)[26] states that tree species will follow a migration natural pattern from south to north and from low to high altitudes. Lenoir *et al.* (2008) [47] found upward shift rates in 171 forest plant species in France of about 29m per decade, when warming and elevation lapse rates were much higher (about 75 m per decade).

The evergreen species are generally slower to adaptation in changing environments [57]. Bussotti*et al.* (2014) [26] states that these species in the Mediterranean, are not expected to respond to the fast climate change rates by evolutionary adaptation, but probably will survive by migration and that the evergreen tree species, in the future will extend to xeric regions that nowdays are covered by deciduous oaks and mountains, while mountain conifers and temperate deciduous species will be limited to their southern extension ranges.

Reduce in frost injuries of plants [58] and increase in winter photosynthesis [59] are expected due to warmer winters in the Mediterranean, with regard to plant species [60]. In general the sensitive to cold species will be favored over the existing cold-tolerant and this will increase species-competition and affect forests structure, population dynamics with possible results the conversion of forests to shrublands[60].

The Mediterranean mountains are considered as extremely vulnerable to climate change [9,10]. It is predicted that will undergo warming, precipitation decrease and interannual variability more intense than other mountains [20] with higher species losses [61]. Ruiz-Labourdette*et al.* (2013)[62] forecast for the Mediterranean mountains' vegetation that xerphylous vegetation will considerably increase and dominate low mountain areas and perennial sclerophyllous species will also increase, while moderate-tolerant to water availability vegetation will notably decrease. At higher altitudes vegetation will up-shifted, the semiarid forests will expand, the broadleaf forest will reduce and cold gymposperm forest will radically reduce their expansion ranges.

Changes in phenology

Beyond its impact on vegetation composition and species ranges, climate change affects also species phenology and reproductive process. Phenology is affected both by precipitation and temperature [63,64] and can be considered as a reliable index to track climate change impacts to the species ecology [65].

Changes in phenophases have already being tracked the last few decades [66] with advancement of flowering date and increase in the length of the growing season. Parry et al. (2007) [67] found a rate of spring onset advance by 2.3-5.2 day per decade, since 1970s. Gordo and Sanz (2010) [68] conducted an extensive research in Spain (29 species from 1500 sites) and found advancement rates of 4.8, 5.9 and 3.2 days per decade in leaf-out, flowering and fruiting, respectively and a rate of 1.2 days per decade delay in leaf abscission since 1970s. Morin *et al*. (2010) [63] conducted experimental warming and found advancing leaf-out of 8-13 days both for evergreen and deciduous oaks, while Cleland *et al.* (2006) [69] found advanced flowering by 2-5 days for annual species though with phenological responses variations among groups to elevated CO_2 and N manipulations.Richardson *et al.* (2013)[70] consider that climate change will result to further advancement of vegetation's growing period in winter-spring and also earlier onset and longer summer drought period.

Drought also affects phenology especially to species sensitive to water availability such as shrubs [71] or grasses. Peñuelas et al. (2003)[72] addresses rainfall and water availability changes, as important factors leading to significant phenological changes in Mediterranean species of bushes such as *Erica multiflora*and*Globulariaalypum* in Catalonia with subsequent changes in the structure, composition and operation of their communities. Though trees are more tolerant because of the structure of their rooting system that allows to exploit soil water from deeper [73].

Changesin wildfires

Fires are a key factor in the Mediterranean, with their numbers to have increased the last decades [74] and further increase is expected due to climate warming [75]. Additionally, under future climate change patterns, wildfires are expected to be more aggressive and not easily to manage with current fire-suppressing strategies [76].

The forest fires have significant effect on vegetation dynamics in the Mediterranean which is mainly dominated by non-resilient, to fire, species with low regeneration ability [77]. Increases in fires frequency and/or intensity will impose the succession by oaks, shrublands and grasslands [78], with high risk for other native species not to succeed seeders regeneration [79] and the risk to increase the invasion of non-native species [3]. In all cases the wildfires frequency and specifically the length of the period between fire events is crucial. According to Valdecantos (2008) [80] if the period between two consecutive fire incidents is too small, is rather unlikely to achieveproper seed-regeneration, with consequences to future post-fire succession and rehabilitation of the ecosystem, especially for exclusively seed-regenerated species such as *Pinus sp., Ulexparviflorus, Cistus sp.* etc.

Changes in soils

Soil processes are affected by precipitation [81]. Climate change impacts on vegetation is expected also to affect soils due to both climate change [82] and vegetation changes [83]. These soil changes will again adversely affect vegetation dynamics as already occurred during the Holocene [84]. Johnstone and Chapin (2003) [85] mention that the local expansion of pines against spruce, increased fire incidents and reduced soil carbon.Both changes in soils and vegetation regimes will have impacts in local hydrology and water chemistry e.g. lakes [86]. Important is the effect of soil depth on climate change impacts, mainly because it affects evapotranspiration and runoff dynamics [5].

IV. CONCLUDED REMARKS

Climate change scenarios predict massive impacts on Mediterranean forests. Though, changes in climate have also occurred in the past and plants managed to adapt to the new established environments through morphological, anatomical, physiological and molecular mechanisms and processes [57]. In the Mediterranean plants adopted survival mechanisms in order to avoid the winter frost or summer drought. Webb (1986) [87] estimates that vegetation adaptation will occur fast enough, so to accomplish equilibrium with climate.

Doblas-Miranda (2016) [3] mentions that different climate change factors, when combined, can alter the effect of others, changing the impacts of global change, especially in the Mediterranean, where many contradicting factors co-exist. They also state that "although global change is unavoidable in many cases, change does not necessarily mean catastrophe, but adaptation" and consider as a challenge the conservation of Mediterranean ecosystems.

Under this point of view and in order to meet climate change challenge, it is considered necessary a) to continue monitoring and research concerning climate change patterns and impacts on regional scales and b) to implement management strategies in order to preserve Mediterranean habitats and improve vegetation's adaptation to the new established environments.

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