Published with Open Access at Journal BiNET
Vol. 01, Issue 01: 01-09
International Journal of Forestry, Ecology and Environment
Journal Home: https://www.journalbinet.com/ijfee-journal.html

Ecological response to the climate change of the main forest species in the region of Tlemcen-Algeria

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Article received: 06.03.20; Revised: 11.04.20; Published online: 15 April 2020.

ABSTRACT

The Mediterranean forest landscape will undergo the effects of the climatic warming tendency and forest structures of oak groves in the national park of Tlemcen (North-west of Algeria) are exposed to impervious changes. Thus, the favorable dynamics for zen oak and oxycedar juniper compared respectively with cork and holm oaks would be the beginnings of a specific substitution and an ecological and structural modification. Without neglecting the protecting and defending measures, sylviculture based on the species ecology and their dynamism could be a solution if it is led in uneven-aged and mixed stands, the structure that proved real advantages as for the protection of biodiversity and the resilience against fire and pathology risks.

Key Words: *Oaks, Global warming, Mediterranean and Forest management*

Cite Article: Bencherif K. (2020). Ecological response to the climate change of the main forest species in the region of Tlemcen-Algeria. International Journal of Forestry, Ecology and Environment, 01(01), 01-09. **Crossref:** https://doi.org/10.18801/ijfee.010120.01

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I. Introduction

The forest landscape on the south side of the Mediterranean undergoes for a long time, important alterations because of human practices but climate warming have just been added to these causes, imposing new challenges on the scientific research (Décamps and Décamps, 2007). Certainly, the Mediterranean forest demonstrated strong capacities of resilience but should have, in the XXI century, to face temperatures and a pluviometric regime different from the present conditions (Hoff and Serge, 2012). In the case of faster climate change, as it is announced, there will be probably not progressive adaptation of the forest ecosystem (Bonin, 2008). The expected climatic changes in the region are the increase of both intensity and frequencies of the summer droughts (Vaz et al., 2010) and a reduction in water availability during growing season (Vennetier and Ripert, 2010). Specifically, Giannakopoulos et al. (2009) announce for the period 2025-2050, an increase of the number of days with temperatures above 25 °C - 30 °C, with values between 35 and 42 days on the Maghreb. For the period 2050-2100, it is expected warming of the order of 2.5 ° C +/-0.5 ° C and a decrease in rainfall, between 4 and 27 percent. The interactions between species as well as human activity form another vector of change that needs to be taken into account for the development of forest landscape models. Beautiful high forests of holm and cork oaks have disappeared under the combined of both human and fire actions.

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The rural landscape moved closer to the forest landscape, already fragmented and invaded by shrubby species as thorny broom, the laburnum, the cysts and the Asphodel (Bencherif, 2012).

The national park of Tlemcen is a mountain meso-mediterranean ecosystem, where the landscape matrix is predominantly a heterogeneous forest, sprinkled with agricultural and urban stains. The exiting coppices and forest formations (matorrals) are dominated by holm oak (*Quercus rotundifolia*), zen oak (*Quercus faginea*) and cork oak (*Quercus suber*). These opened-fragmented structures, which are also an environment of the important dynamic phenomenon, don't seem enough strong so to hope durable protection against climate change which visible signs are the declining debit of the waterfall of ' Ourit', the scorching summers and the frequency of the forest fires.

Field observations across the Park show a certain dynamism in favor of some species, such as the zen oak and Juniper (*Juniperus oxycedrus* l.) compared to others (Holm oak, Cork oak) (Bencherif, 2012). Given the expected climate changes (increase in temperatures, decrease in precipitations), this dynamism could worsen more, and forest management is brought to keep interested in the causes and the consequences of this trend, providing rules for forest planning (choice of species, silvicultural regime) in line with the current landscape context and especially in the future climate context. The purpose of this note is to bring answers to questions in relation with the evolution of the climate in the region and its possible impact on the oak woods of the national park of Tlemcen on one side, and questions in relation with planning modalities of these stands in a context of climate change and anthropogenic pressure on the other.

II. The national park of Tlemcen

The national park of Tlemcen is located in the Northern part of the mounts of Tlemcen at an altitude varying between 1084 and 1418 m. Its area of 8225 hectares comprises four forest units: Ain Fezza forest, state forest of Tlemcen (foret de Tlemcen à pin d'Alep), Zariffet forest and Hafir forest (Figure 01). Except for the pure high Aleppo pine forest (*Pinus Halepensis*. Mill) (reforestation (dating from 1890), others are composed mainly of cork oak (*Quercus suber*), holm oak (*Quercus rotundifolia*) and Zen oak (*Quercus faginea ssp tlemcenensis*). These three main species come in the form of pure or most often mixed thickets. The undergrowth consists mainly of: *Erica arborea, Arbutus unedo, Viburnum tinus, Cistus salvifolius, Lavandula stoechas, Ampelodesma mauritanica, Juniperus oxycedrus, Genista tricuspidata, Phillyrea angustifolia, Lonicera implexa, Carexhalleriana, Quercus coccifera, Pistacia lentiscus, Olea europea* and *Ceratonia siliqua*.

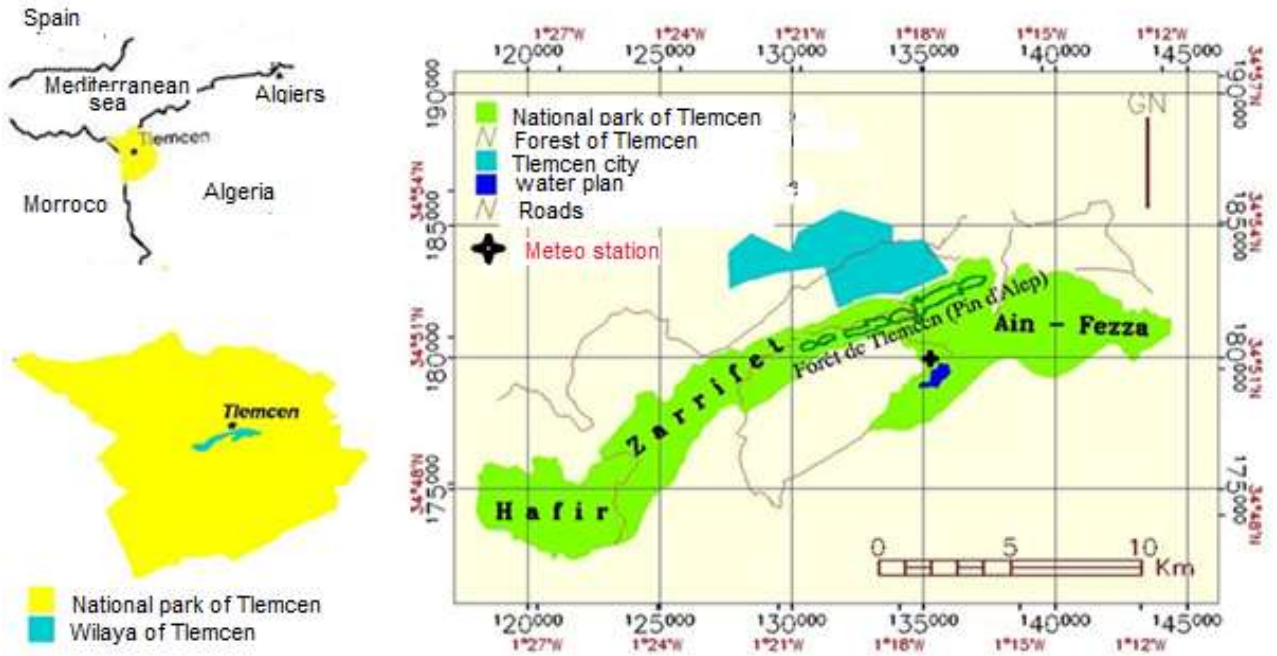

Figure 01. Localization of national park of Tlemcen.

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III. The oaks of the national park of Tlemcen

Holm and cork oaks are sempervirent (evergreen) trees localized in the central Mediterranean and the Maghreb for the first one and essentially in the Atlantic seaboard of western Mediterranean for the second one. To the north, holm oak reaches the seaside while it appears only from 400m in coastal Algeria and over 1000m in the upper western atlas. Thermophilic[1], heliophilous[2] and xerophilic[3] species, holm oak prefers warm or even cold variants of subhumid, humid and semiarid climatic stages (Vaz et al., 2010; Quezel, 1979; Quezel, 1976). The cork oak is localized in warm temperate humid and subhumid climatic variants (Vaz et al., 2010; Quezel, 1976). Thermophilic, heliophilous and not tolerant to limestone specie, it requires pluviometric range from 500 to 1200 mm/years. Cork oak is a deciduous tree present in the Maghreb and the Iberian Peninsula up to 1900 m altitude. thermophilic, xerophilous, heliphilous and resistant to cold specie, cork oak meets mainly in humid stages but can occupy in Algeria and Tunisia both thermophilic and mesophile levels (Bonin and Romane, 1996).

The ability of resistance to prolonged water stress depends on morphological and physiological traits (Bonin, 2008). Leaf area index is important in determining the importance of assimilated carbon or the evaporated water (Baldocchi et al., 2010). Holm and cork oaks are hysohydric and control the dehydration through the stomatal closure and to their deep rooting (David et al., 2007). The constraints are various such as illegal cuttings, pasturage and fires. In addition to summer water stress, phyllophags (defoliators) (*Tortrix viridana* and *Lymantria dispar*) and the under-corticolous fungi (*Hypoxylum mediterraneum*) are suspected to be main causes of oaks withering (Dreyer, 1995).

IV. Climate trends at regional and local levels

At planetary scale, there is no divergence on the principle of the existence of observable change in temperatures4 and precipitations. In The Mediterranean area, recognized as a climate change hot spot area, it is expected by 2100, an average increase of temperatures of 3 to 4 ° C, a decline in precipitation and an increase of extreme events (Laignel et al., 2012).

Since the 1970s, the Maghreb undergoes a long period of drought (Meddi and al., 2009) and it is expected (according to the IPCC, A1B scenario) (Grunderbeeck and Tourre, 2008) for the period 2025-2050, an increase in the number of days with temperatures above 25°C and 30°C, with values between 35 and 42 days. For the period 2050-2100, it is expected warming of the order of 2.5 ° C +/-0,5 ° C and a decline in rainfall, between 4 and 27% (Giannakopoulos et al., 2009). According to the latest report of the IPCC in 2013, maybe that warming will exceed 2 ° C according to RCP6.0 and RCP8.5 RCP4.5 scenarios while precipitation will probably decrease.

In Algeria, the rising of temperatures in the twentieth century is located between 1.5° and 2° C, more than the double of the global planetary average increase, which was of the order of 0.74 ° C. As for the decline of precipitations in the twentieth century, it varies between 10 and 20%. This decrease in rainfall caused deficits inflow from 37 to more than 70% from the East to the West of the country (Nekkache et al., 2013). These changes affect both the littoral zone and the Tellian mounts.

On the seaside, warming and cooling phases have marked this territory: the first, from 1970 to 1986, is considered to be normal with the wet trend, the second (1987-2002) and the third (2003-2012), respectively have seen a significant decline and an increase in wet or very humid years (Nouaceur et al., 2013). In the tellian forests, the bioclimatic study of the last 30 years clearly shows such evolution of the vegetation that warmer and drier climate almost everywhere is corresponding to an extension of the shrubs to the North, and a therophytisation to the South, the sign of desertization (Tatar, 2012).

At the level of the Tlemcen National Park, and more precisely to the “Meffrouche” meteorological station, during 68 years of observations (1943-2011), annual precipitations varied from 281 mm (1965-66) to 1062 mm (1973-74). Before 1973-1974, the period is referred to be wet, the one after as dry. The deficit in the second period compared to the first, is estimated at 30% for precipitations and

[1]That needs higher temperatures to live
[2]That only grows optimally in full light
[3]Living in very poor environments in water
[4]Global warming is not a continuous and linear phenomenon from year to year: even if temperatures rise less quickly than expected, they are still rising (IPCC, 2013).

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more than 60% for flows (Nekkache et al., 2013). The same observations were made on the evolution of rainfall during the years 1961-1980 and 1981-2003 where two periods are distinguished (Figure 02): the first where rainfall is average or above average and the second where they are below the average (Bellifa et al., 2014).

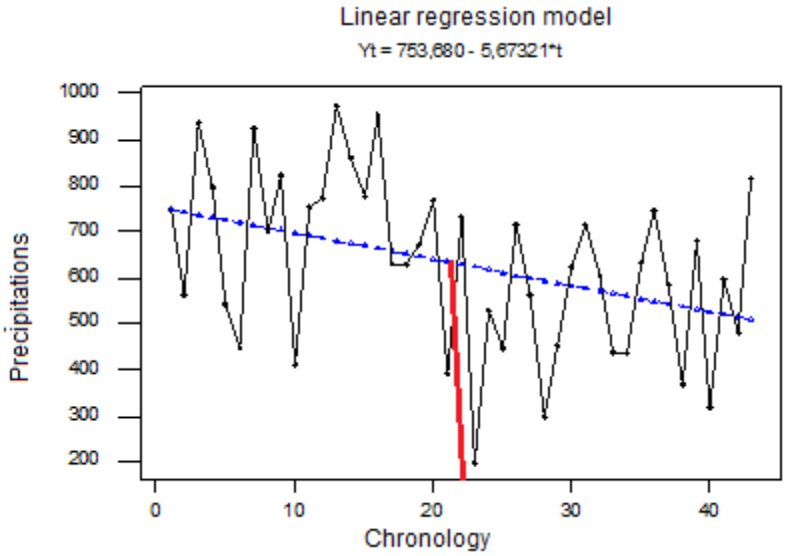

Figure 02. Evolution of the precipitations during the period (1983-2010) in the National park of Tlemcen (Bellifa and al., 2014).

To the East and the South of Tlemcen, the same observations are made. Thus in the 'basin of the "Mactaa", annual rainfall has fallen off about 40% on average over the period 1930-2002 while in "Sidi Bel Abbès" precipitations declined by 28 to 36% on average over the period 1976-2002, compared to the period 1949-76 (Meddi et al., 2009). To the South, the bioclimatic analysis shows a variation between the ancient period (1913-1938) and the recent (1970-1992) period) with a net vertical regression, on the Emberger climate diagram, in the area of the steppe to the South of Sebdou (Benabadji and Bouazza, 2000).

The combined effect of climate change and the human activity impact would cause a water shortage for the population (Laignel et al., 2012). Given that climate always acts in synergy with human activity, it has been developed the vulnerability index of climate change (climate change vulnerability Index (CCVI)[5] allowing to identify regions with risk by considering 42 socio-economic and environmental factors and to assess vulnerabilities in different countries of the world. In 2012, sylvatic northern Algeria is ranked at high risk while the asylvatic southern Algeria is ranked at very low risk

V. Climatic analysis

The meteorological station of El-Meffrouhe is retained to characterize the current climate. Its average altitude is 1100 m and its geographical coordinates are latitude (34 ° 51' N) and longitude (01 ° 16' W). Climate data on temperatures (T) and precipitations (P) related to the period 1989-2009 and come from the ONM (National Office of meteorology). Besides, results of a dendrochronological analysis of an Aleppo pine stem from the forest of Tlemcen (a sample of 117 years tree) are used to follow the evolution of the precipitations at the local level over the period 2010-2050, taking as a reference the period 1961-2003. The processing of raw climate data (1989-2009) provided the values of M (30.5°C) and m (2.3°C) as well as the value of the annual average rainfall (550 mm) and the number of days with temperatures above 25°C (N = 30).

Taking into account forecasts for the period 2025-2100 (A1B scenario of IPCC), the number of hot days (T>25° C) would increase from 30 to 70. According to the scenario A1B and scenarios[6] RCP6.0, RCP8.5 and RCP4.5 (IPCC, 2013), monthly average temperatures of the maxima (M) and minima (m) would move up respectively from 30.5° C to 33° C and 2.3° C to 4.8° C. With an average decline of 25%, the precipitations will be reduced to 400 mm. In this same way, the linear regression model, resulting

[5]http://maplecroft.com/about/news/ccvi.htm
[6]Scientists have identified representative profiles of change in concentration of gas of greenhouse and ozone precursors of aerosols representative of an increase in the energy balance: the RCP (Representative concentration pathways).

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from the study of radial growth according to precipitations and the temperatures of the period 1961-2003 provides a regressive trend of precipitations for the period 2010-2050 (Bellifa et al., 2014). Figure 03 shows respectively the actual and the expected precipitations and their future trend.

These new data highlight water stress to which vegetation should eventually face and the importance of the risk fire that would accentuate the phenomena of steppisation and desertization. Although the Mediterranean flora has independent dynamics from climate change (Vennetier and Ripert, 2010) and was already well adapted to extreme droughts, it is not certain that the oak woods of the Park would have the same behavior. Indeed, climate evolutions in the region were spread over several hundred years so that the current situation and the one expected in the next few years is characterized by the speed of change (Grunderbeeck and Tourre, 2008) that do not allow gradual acclimatization of forest ecosystems (Bonin, 2008).

VI. Interspecific competition

Yet some scenarios of global warming over 100 years, argue that hardwoods are advantaged compared to coniferous and that among of deciduous trees, the trend would be favorable to the Oaks (Lexer et al., 2006). Although, these scenarios concern Medio-temperate forests, we cannot dismiss the possibility that they recur in Mediterranean forests. The three deciduous species have different ecological behaviors and the Cork oak seems the most disadvantaged especially regarding precipitation (400 mm) which will be below its minimum requirements (500 mm). However, the morphology of the Park (mountain relief) could offer to this species, shelter areas (such as fresh valleys) so to remain (Plate 01). The zen oak invades the oak cork groves especially in the burned areas and this process could become more noticeable when monthly average temperatures of the maximas increase of 3° C. On the southern slopes (driest), this rise in temperatures seems to be also favorable to Juniper that already overruns stands of holm Oak on rocky ground. Probably, the result will be a climb up of the holm oak in altitude but also a dynamic towards vulnerable to fires and plant health risks mono-specific structures.

Plate 01. Shrubland extension after Burnt cork oak stand (In yellow *Calycotome spinosa)* (Source: Bencherif, 2017).

Overall, climate change should not affect the same way throughout the Mediterranean basin (Hoerling et al., 2012) just as it should not be the only one responsible for the recession of some Mediterranean species given the importance of human impacts. However, specific cases can be considered such as the hardwood stands in the Park of Tlemcen. Certainly, the distinction between the human and climate impact is not always easy to establish but may be considered from landscaped forest structures and their degradation stages because at this level, these processes can be analyzed more effectively (Quezel , 2000).

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VII. Forest planning under changing climate

The debate should not be resumed to the presence or absence of forests and must take into account their ability to ensure their functions (Brang et al., 2008). Forest planning must share out the risks (hydric stress, fire, Wasting away) while leading present structures towards stronger and multi-specific ones capable to reduce the climate change impact. That's why planning modalities, others than the ones used actually or eventually than the ones practiced in the past, could be projected. On the structural plan, it's recognized that open low stands (coniferous or hardwood) and low and dense (coniferous) are the most vulnerable to fires compared to low and closed stands (deciduous oaks) or high and opened ones (Fernandes, 2009). Actually, at the level of the park, fires affected already all types of covers (high forest, coppice, shrub-lands) creating low structures with various density degrees. Another constraint linked to the aging of stamps compromises also the coppices' future.

Silvicultural regimes of conversion into mixed uneven-aged or selection high-forest (or regime of Coppice with standard) seems to be promising management actions. Indeed, the result is structured less exposed to risks linked to climate change (Brang et al., 2008; Jactel and Brockerhoff, 2007; Pautasso et al., 2012). As for the regeneration, the cover density proves decisive since the shade reduces water stress of oaks seeds and procure under drought conditions, high stomatal conductance, high photosynthetic rate and high rate of azote concentration (Marañón et al., 2009).

On the silvicultural plan, the invasion of zen oak form in some places pure stands (Plate 02) and as for the holm and pubescent oaks in the north Mediterranean, where it's possible the replacement one another (Bonin and Romane, 1996), this invasion must be considered as a natural tendency where zen oak becomes the structuring specie. It's also the case of juniper that overruns holm oak stands. For the planners, it corresponds to the rule of the main specie into a stand, the frame on which will be grafted the ecosystem biodiversity (Chauvin, 2001).

Plate 02. Pure zen oak grove inside burnt cork oak forest (Forest of Hafir). (Source: Bencherif, 2017)

The selection method (or uneven aged method) seems interesting for the biodiversity because of the trees dimensions heterogeneity (Fuhr et al., 2010), of their long lasting regeneration (Bachofen, 2009] and as well as for the development of many heliophilous species (Mozziconacci and Vanstaevel, 2003). A selected mixed grove is less flammable than a pure one (Fernandes, 2009) and the oaks will find favorable light conditions in mixture with Aleppo or stone pines (less compact canopy). These mixed stands have real advantages about productivity, resilience and biodiversity.

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Silvicultural practices have also their part of the responsibility. The observed withering in cork oak stands could be due to classical exploitation constraints such as bark stripping, pasturage and ploughing (Montgolfier, 2008), to the dryer and warmer climate or ageing. This last constraint seems to be the most plausible as the regeneration was quite often neglected in aid of bark harvesting. Possibly, for future plantations, forest planning should integrate silviculture and bark harvesting and plan the introduction of ecotypes coming from semiarid zones.

VIII. Conclusion

Climate-related adjustments don't have anything to do with the actual effect that South-Mediterranean forests are undergoing due to the human constraints they support. Nevertheless, a hardwood stand of oak in the countrywide park of Tlemcen will face up to unexpected climate changes such as changing rainfall regime related to a lengthening of the duration of water stress, to heavy rainfall and/or to the sudden bloodless spell. Faced with those new conditions, management based on mixed uneven-aged excessive forest method promoting the greater dynamic specie should be the best measure. For goal decision-making, shrubs and herbaceous must be studied, and the socioeconomic evolution known within the short and long term. At last and not at least, as anthropogenic pressures and climate change are acting synergistically, it's necessary to reduce human pressures to remain in possible resilience conditions.

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HOW TO CITE THIS ARTICLE?

MLA
Bencherif, K. "Ecological response to the climate change of the main forest species in the region of Tlemcen-Algeria." International Journal of Forestry, Ecology and Environment 01(01) (2020): 01-09.

APA
Bencherif, K (2020). Ecological response to the climate change of the main forest species in the region of Tlemcen-Algeria. International Journal of Forestry, Ecology and Environment, 01(01), 01-09.

Chicago
Bencherif, K. "Ecological response to the climate change of the main forest species in the region of Tlemcen-Algeria." International Journal of Forestry, Ecology and Environment 01(01) (2020):01-09.

Harvard
Bencherif, K. 2020. Ecological response to the climate change of the main forest species in the region of Tlemcen-Algeria. International Journal of Forestry, Ecology and Environment, 01(01), pp. 01-09.

Vancouver
Bencherif, K. Ecological response to the climate change of the main forest species in the region of Tlemcen-Algeria. International Journal of Forestry, Ecology and Environment. 2020 April 01(01):01-09.

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