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Determination of the effect of biogeographic variability on myrtle ecology in Morocco using a combination of GIS and bioclimatic indices

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Abstract

In order to define the climatic and ecological conditions of natural populations of Myrtle (Myrtus communis L.) in Morocco, with regards to the effect of biogeographical variability, we have adopted an approach based on; prospecting the distribution of the said species in Moroccan forests and determining the climatic conditions where it grows by means of the bioclimatic indexes that are most relevant in the Mediterranean porter. Climatic data and aridity indexes are extracted from two open-access international databases (http://www.worldclim.org and http://www.csi.cgiar.org), using GIS spatial analysis tools. The results obtained show that this species is spontaneously distributed in three biogeographical zones (Central Plateau, Pre-Rif and Western Rif), which climate types according to the different indexes used are: semi-arid, sub-humid and humid, in the Thermo-Mediterranean vegetation stage and the lower part of the Meso-Mediterranean. The natural populations of Myrtle in Morocco have a low to medium drought ratio.

1. Introduction

The identification of borders for biogeographic species borders is essential not only for conservation but for all biological studies [1]. Flawed species frontiers can contribute to the incorrect use of strategies for conservation objectives. The biogeographic distribution of vegetation in the globe is undoubtedly correlated with ecology; in particular climate and its characteristics [2,3]. Hence, biogeographic and ecological variability provides an opportunity to study the adaptation mechanisms developed by plants to different combinations of ecological factors [4].

In the latest decade, several changes have been observed from the degree of physiological adaptation of plants owing to global heating [1,3]. Changes have also been recorded in seasonal events, such as foliage and flowering, which sometimes occur earlier in spring. Changes in precipitation patterns are more difficult to attribute to climate change and more difficult to predict in the future, but they could result in major ecological changes [3]. As a result, stand composition and intraspecific diversity would also have to adapt to climate change [1]. Furthermore, the ecological and genetic factors that determine the adaptation of plants to environmental conditions are of fundamental interest for evolutionary biology, but also for plant selection and conservation as well as for predicting the response to environmental changes. Consequently, knowledge of the ecological conditions of a species serves as a database for dynamic conservation strategies that promote their ability to evolve along with changes in environmental conditions [5,6].

Because of its climate and geology, Morocco can be considered as an important area with remarkable biogeographic and ecological interest [2,7]. It is characterized by a great phytogenetic diversity especially of the aromatic and medicinal plants (MAP) [7]. Among these resources is the Myrtle (*Myrtus communis* L.) [8].

The common myrtle is one of the Mediterranean species that are not only ecologically but also socio-economically important for the local Moroccan population, especially in rural areas [9,10]. The extract of Myrtle leaves is a crucial source of antioxidants because of the high concentration of galloyl-glucosides, flavonol-glucosides and ellagitannins [11]. Evidently, the fruit of this species is astringent and concentrated in antioxidants owing to the presence of tannins, phenolic compounds, anthocyanins and flavonoids [12]. Additionally, the myrtle is very well known for its phytotherapeutic, cosmetic and edible properties [8,9].

Nevertheless, despite these multiple uses and its national and international economic potential, the myrtle has been badly exploited and may become unable to meet consumers' demands [9,13]. In addition to socio-economic pressures, climate change could also increase the degradation of the natural populations of myrtle [9]. Therefore, one must consider a conservation, development and adaptation program in order to ensure a reasonable and sustainable exploitation of the species. This is mainly because it is difficult to assemble the necessary information on the biogeographical distribution of natural populations of the biological model species and to combine it with climatic data and ecological approaches. Yet such results constitute the main database to assess the extent of a species or population's endangerment in the face of climate change, by modelling the ecological conditions for the mentioned species.

On the one hand, the work in question aims to determine the biogeographic area, the climatic conditions and the bioclimatic stage where the populations of the myrtle grow in Morocco. On the other hand, while adopting the point of view of zonation of the bioclimatic stages and the vegetal associations, we will calculate a variety of bioclimatic indices that are of great importance in the Mediterranean area.

2. Methodology

2.1. Biogeographical distribution of the species

Wahid et al [10] surveyed and determined the distribution potential of Myrtus communis L. in different biogeographic regions in Morocco, listing 13 natural populations of Myrtle. To discover more distribution sites of Myrtle in Morocco, we organized a series of field missions during 2018, based on the method described [10]. We based our research on the use of all information obtained from the presence registers which are included in the "Global Biodiversity Information Facility" (http://www.gbif.org) [14] with a resolution of 30 seconds of arc, bibliographic research, and on the communication with the local population and the competent services (services of Water and Forests). As a result, we considered a total of 17 natural populations surveyed and distributed them across three distinct biogeographic zones (Figure 1). The altitude of distribution of these 17 natural populations of Myrtle is measured on site using a GPS (Garmin GPSMAP 62S). Moreover, substrate is an abiotic factor, and as a function of time can be considered stable with respect to the life scale of the trees, therefore, of each population with respect to the chemical composition and physical properties of the soil. Thus, the climate represents a major element given a random character with interannual fluctuations marked high at the scale of Morocco, which can govern the distribution of Myrtle entirely.

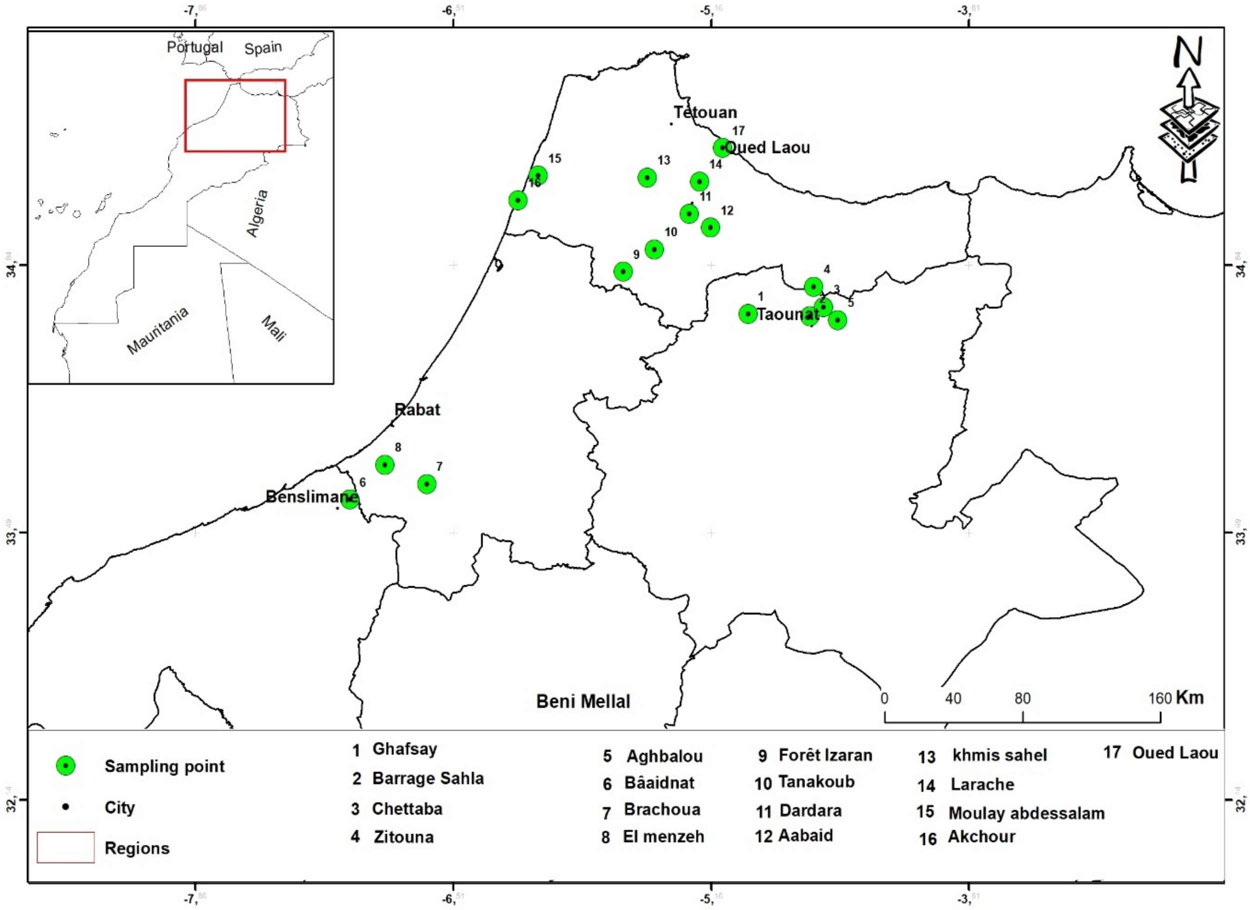

Figure 1. Distribution of sites prospected

2.2. Determination of ecological characteristics

The characterization of climate and bioclimatic stage and vegetation where the populations of myrtle grow in Morocco were extracted from two databases, in the form of different layers for analysis using a geographic information system (GIS). The first database is from Worldclim: it is an open access global climate database (http://www.worldclim.org) [15]. From this source, a set of 19 bioclimatic variables corresponding to the average values from 1970 up to year2000 with a spatial resolution of 30 arc seconds, were downloaded. The second database is from CGIAR-CSI [16], and corresponds to the average values of global climate data in high resolution (30 arc seconds) for the same period of time. It is also related to the processes of potential evapotranspiration (ETP) and the aridity index (IA) (http://www.csi.cgiar.org) [16].

The processing of these data, the creation of the resulting layers, and the combination between them and their interpretation were carried out using the spatial analysis tools in order to explain and deduce the effect of change of some parameters in the distribution of Myrtle in Morocco.

2.3. Calculation of bioclimatic indexes

The evaluation of climate at the scale of the prospected areas took place by calculating some bioclimatic indices of great importance in the Mediterranean area, in the perspective of the zonation of bioclimatic stages and plant associations [17], namely the rainfall quotient of Emberger and the aridity indices of De Martonne and UNEP (United Nations Environment Program) [18, 19, 20].

a. EMBERGER's bioclimatic index

The Emberger rainfall index was developed by the botanist Louis Emberger in 1930. It was modified in 1955 to define the types of Mediterranean climates especially in North Africa [18, 21, 22, 23]. This index takes into consideration the annual precipitation, the average maximum temperature of the warmest month (M with °C) and the average minimum temperature of the coldest month (m with °C) [24]. In fact, it is a ratio between the amount of precipitation and the average of the thermal extremes (warmest and coldest months), all corrected by the extreme thermal amplitude (M - m). Emberger noted that thermal amplitude is an important factor in the distribution of plant species. The combination of the rainfall quotients obtained (Q2) and the minimum temperatures of the coldest month (m) with the observations made on the distribution of Mediterranean vegetation and more particularly in Morocco led Emberger to subdivide the area of the Climagram into characteristic zones by increasing aridity from high to low: these are the "bioclimatic stages of vegetation" [2]. This quotient is calculated by the following formula:

$$Q2 = \frac{2000 * P}{(M + m + 546{,}4) * (M - m)}$$

P: The annual rainfall in mm
M: The maximum temperature of the warmest month in °C (July)
m: The minimum temperature of the coldest month in °C (January)

b. De Martonne aridity index

De Martonne's aridity index is a ratio between the average annual precipitation and the average annual temperature. This index reflects the rainfall deficit over a long period of time of a defined area in relation to high insolation, high daytime temperatures, low humidity and high evaporative power of the atmosphere [19]. It is defined as follows:

$$I = \square\square + 10$$

T: average annual temperature in °C;
P: average annual precipitation in mm.

c. UNEP Aridity Index

The index of aridity UNEP [20] is an index that gives the idea of the degree of aridity of the climate in a given place in relation to the evaporative power of the atmosphere. It is defined as follows:

$$I = \frac{P}{ETP}$$

P: average annual precipitation in mm;
ETP: average annual potential evapotranspiration in mm.

Results

3.1. Geographic, orographic and altitudinal characteristics of natural populations of Myrtle in Morocco

The Myrtle grows spontaneously in the garrigues and the matorral of the forest and peri-forest areas, belonging to the plant series mainly holm oak although in some cases, to cork oak, Aleppo pine, and Juniper. It is also found on the borders of Dayas and Wadis. In addition, its appearance in the alliance of *Myrto-Quercetum subersis* [25, 26] of the class *Quercetea ilicis* [27, 28] at the southwestern border of the Mamora subera (Mamora oriental) is very rare [29]. Thus, the myrtle also marks its presence in the alliance of *Querco rotundifoliae-Oleion sylvestris* [25] especially in the climatic systems of pre-Rif and in a sporadic way in the shrubby strata of the grouping *Pistacio lentisci-Quercetum rotundifoliae* [25] in the region of Western Rif. The Myrtle grows spontaneously on all lithological substratum types of sand, with clayey sandstone or clayey sand and calcareous sandstone, schist, granite, and calcareous. In terms of geographical distribution, we could count 17 sites on different ecological conditions (Figure 1, Table 1), which are distributed throughout the country between:

- The Western Rif: Myrtle is among the best characteristic species of this region. It is located between a longitude of 35°01′ and 35°23′ North, and a latitude of 05°09′ and 05°05' West (Table 1). Myrtle is present from the Atlantic coastline in the region of Tangier to the eastern border of the Rif limestone ridge towards the El Hociema road. But it is very abundant in its northern part. Thus, it forms the most extensive and productive stand in the forests of: Ouazzane, Bouhachem, Bab Taza, Al Hamra, Chefchaoune, Larach, and Oued Laou (Table 1). The altitude varies between 350 and 1121 m.
- Pre-Rif: similarly in this region, the Myrtle is more extensive in several sites of Taounate namely: City of Taounate, Ghafsai, and Bouhouda. The orography of these natural Myrtle sites varies between a longitude of 34°33′ and 34°43′ north and a latitude of 04°29′ and 04°37′ west (Table 1). The elevation varies between 380 and 475 m.
- Central Plateau: it is distributed over altitudes ranging from 332 to 220 m (Table 1). As it is found on small and sporadic areas in the cork oak forests namely: Benslimane, Temara, Romani. However, the geographic limits of Myrtle ranging from 33°39′ (versus latitude of 07°02′ west) to 33°49′ north (versus latitude of 06°51′ west).

3.2.Determination of the climatic conditions of the Myrtle sites

3.2.1 Rainfall characteristics

The map in Figure 2 shows the result of the distribution of average annual rainfall. The analysis of the results of this map shows that the Western Rif, where most of the natural populations prospected of Myrtle are located, registers the highest values of annual precipitation which varies between 523 and 1065 mm/year (Figure 2). It is especially the levels of the high peaks of the mountains of the Western Rif that are the most watered; such as the case of rainfall of 1065 mm / year of the population of Myrtle of Jbel Bouhachem (Al Hamra, 1121 m) (Figure 2, Table 2).

Table 1. Geographical characteristics of the Myrtle surveyed areas in Morocco

Code	Administrative region	Provinces	Circles	Caïdats	Municipalities	Ecological zones	Longitude	Latitude	Altitude (m)
1	Fes-Meknes	Taounate	Ghafsai	Ourtzagh	Ghafsai	Pre-rif	34°35′ 39.8″N	04°57′ 59.5″W	441
2			Taounate	Sahla	Barrage sahla		34°35′ 02.1″N	04°38′ 37.7″W	460
3			Bouhouda	Zrizer	Chettaba		34°37′ 46.8″N	04°34′ 17.4″W	380
4			Taounate	Ikawen	Douar zitouna		34°43′ 53.4″N	04°37′ 19.8″W	475
5			Taounate	Béni wlid	Aghbalou		34°33′ 47.6″N	04°29′ 47.1″W	439
6	Casablanca-Settat	Benslimane	Aïn Tizgha	Ziaïda	Bâaidnat	Central plateau	33°39′ 28.4″N	07°02′ 59.7″W	275
7	Rabat-Sale-Zäer	Romani	Had Brachoua	Kourifla	Kourifla		33°49′ 57.7″N	06°51′ 57.2″W	220
8		Temara	Temara	El Menzeh	El Menzeh		33°44′ 10.8″N	06°38′ 52.9″W	332
9	Tanger-Tetouan-Al Hoceima	Ouazzane	Ouazzane	Ouazzane	Forêt Izaran	Western Rif/North	34°48′ 29.0″N	05°37′ 06″W	411
10		Chefchaoune	Bouhachem	Tanakoub	Parc Bouhachem		34°55′25.6″N	05°27′27.9″W	285
11			Bab Taza	Dardara	Centre Ikejioun		35°06′11″N	05°16′23″W	450
12			Bab Taza	Béni Ahmed	Aabaïd		35°01′48″N	05°09′43″W	745
13			Al Hamra	Moulay Abdessalam	Jbel Bouhachem		35°16'58,94"N	05°29'33,93"W	1121
14			Chefchaoune	Talambote	Talambote		35°16'1,12"N	05°13'10,98"W	350
15		Larach	Khmis Sahel	Khmis Sahel	Mezgalef		35°17'50,34"N	06°3'43,36"W	530
16			Larach	Larach	Larach		35°10′02.6″N	06°10′12.9″W	518
17		Tétouan	Oued Laou	Oued Laou	Béni said		35°23'38.50"N	05°05'24,53"W	450

The southwestern slopes of the Western Rif are considered the most rainy sites where the populations Aabaïd (984 mm/year), Bouhachem Park (871 mm/year), Ikejioun Centre (805 mm/year) and Izaran Forest (742 mm/year) are developed (Figure 2, Table 2). In contrast, the stations on the western part of the northern and northwestern slopes, where the Larach and Khmis Sahel populations extend, have annual rainfall between 650 and 800 mm/year. This demonstrates the predominant effect of exposure and altitude.

Approaching the Eastern Rif region, we notice a decrease in the values of the average annual precipitation, in Central Plateau and the Middle and High Atlas (Figure 2). The low values of the average annual precipitation register towards the extreme areas of the south and southeast. Compared to the average annual precipitation in the Pre-Rif, the western sites located in the middle of the mountain are substantially more rainfed (between 653 and 722 mm/year) (Ghafsai populations, Sahla Dam and Douar Zitouna). In contrast, the populations of eastern sites (Chettaba and Aghbalou) have low rainfall values between 595 and 608 mm/year. Moreover, in the central plateau regions, the more removed from the Atlantic exposure, the lower the values of annual rainfall (case of the populations of Kourifla, Bâaidnat and El Menzeh: 469, 470 and 484 mm/year respectively).

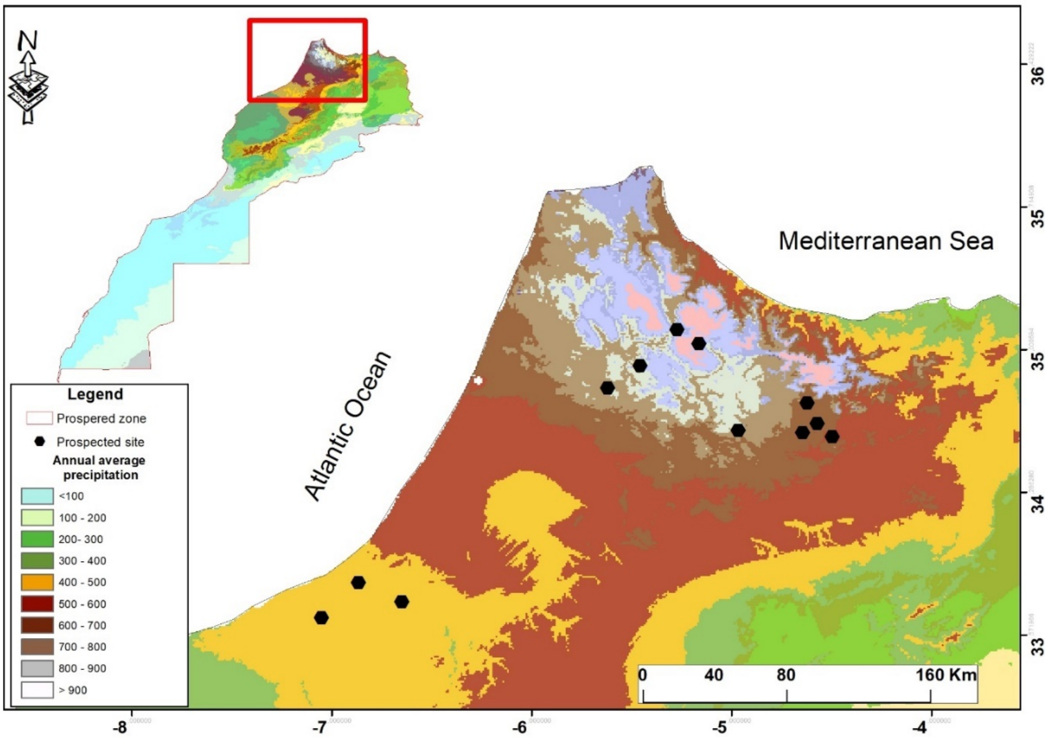

Figure 2. Distribution of average annual precipitation

3.2.2. Characteristics of annual average temperatures

The map in fig 3 shows the result of the distribution of the annual average temperatures. The analysis of these results reveals that the low temperatures which vary between 0 and 8°C are recorded in the summits of the Middle Atlas Mountains where there is no natural population of myrtle (Figure 3). The medium temperatures (between 8 and 18°C) are recorded in the high altitudes of the Western Rif, the Pre-Rif and the Central Plateau where there are natural populations of myrtle. The populations of the Western Rif develop in the summits where the average annual temperatures vary between 13 and 18°C; such is the case for the population of Jbel Bouhachem (13.6°C) (Figure 3, Table 2).

On the one hand, the sites of the populations of the southwestern facade of the Western Rif have temperatures between 15.9 and 18.5 ° C; the case of the populations Aabaïd (15.9 ° C), Ikejioun Centre (16.9 ° C), Talambote (17.1 ° C), Tanakoub, (17.7 ° C), Izaran Forest and Beni Said (18.5 ° C) (Figure 3, Table 2). In this area of the Western Rif, the difference in temperature becomes remarkable - 3°C - as we move from one site to another. On the other hand, the sites of the pre-Rif populations show a modest difference in the average annual temperature, since these values vary from 17.2 to 18.1°C. This is the case of the sites where the populations of Douar Zitouna (17.2 ° C), Aghbalou (17.5 ° C), Sahla Dam (17.7 ° C), Chettaba Forest (18 ° C) and Ghafsai (18.1 ° C) have developed (Figure 3, Table 2).

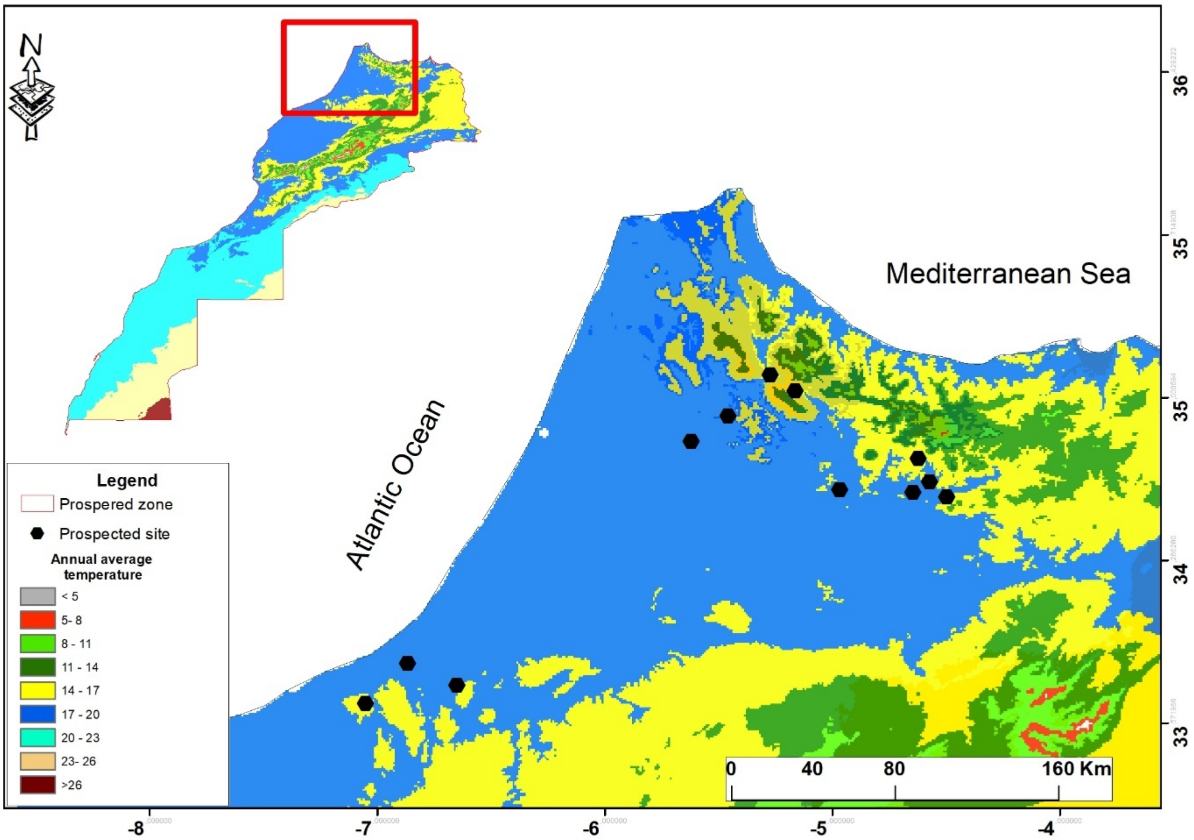

Figure 3. Distribution of average annual temperatures

Closer to the Atlantic Ocean and especially at the western side of the central plateau, where we surveyed three populations at low altitudes (between 220 and 330 m), the average temperature values are low compared to the pre-Rif and western Rif sites (low temperatures at high altitudes). An increase in the average annual temperature towards the south-eastern and southern regions of the country is observed (Figure 3). Its high values are recorded towards the extreme southern and southeastern areas, especially from the Atlantic Ocean to the deserts (South) as well as from the mountains to the southeastern plateaus (Figure 3). These regions are characterized by the absence of the Myrtle populations and their accompanying flora (its floristic cortege).

Table 2. Bioclimatic and biogeographical conditions of the prospected sites

Code	Site	Longitude	Latitude	Altitude	Average annual precipitation	Average annual temperature	Bioclimatic stage	Vegetation stage	Type of climate according to De Martonne	Type of climat according to UNEP
1	Ghafsai	34°35′ 39.8″N	04°57′ 59.5″W	441	772	18,1	Sub-humide	Thermo-Mediterranean	Sub-humide to humid	Semi-arid
2	Barrage sahla	34°35′ 02.1″N	04°38′ 37.7″W	460	653	17,7	Sub-humide	Thermo-Mediterranean	Sub-humide to humid	Semi-arid
3	Chettaba	34°37′ 46.8″N	04°34′ 17.4″W	380	608	18	Sub-humide	Thermo-Mediterranean	Sub-humide to humid	Semi-arid
4	Douar zitouna	34°43′ 53.4″N	04°37′ 19.8″W	475	654	17,2	Sub-humide	Thermo-Mediterranean	Sub-humide to humid	Semi-arid
5	Aghbalou	34°33′ 47.6″N	04°29′ 47.1″W	439	595	17,5	Sub-humide	Thermo-Mediterranean	Sub-humide to humid	Semi-arid
6	Bâaidnat	33°39′ 28.4″N	07°02′ 59.7″W	275	470	16,7	Sub-humide	Thermo-Mediterranean	Semi-arid	Semi-arid
7	Kourifla	33°49′ 57.7″N	06°51′ 57.2″W	220	469	17	Sub-humide	Thermo-Mediterranean	Semi-arid	Semi-arid
8	El Menzeh	33°44′ 10.8″N	06°38′ 52.9″W	332	484	17,2	Sub-humide	Thermo-Mediterranean	Semi-arid	Semi-arid
9	Forêt Izaran	34°48′ 29.0″N	05°37′ 06″W	411	742	18,5	Humid	Thermo-Mediterranean	Sub-humide to humid	Semi-arid
10	Parc Bouhachem	34°55′25.6″N	05°27′27.9″W	285	871	17,7	Humid	Thermo-Mediterranean	Sub-humide to humid	Sub-humide to humid
11	Centre Ikejioun	35°06′11″N	05°16′23″W	450	805	16,9	Humid	Thermo-Mediterranean	Sub-humide to humid	Sub-humide to humid
12	Aabaïd	35°01′48″N	05°09′43″W	745	984	15,9	Humid	Thermo-Mediterranean	Sub-humide to humid	Sub-humide to humid
13	Jbel Bouhachem	35°16'58,94"N	05°29'33,93"W	1121	1065	13,6	hyper-humid	lower part of the Meso-Mediterranean	Sub-humide to humid	Sub-humide to humid
14	Talambote	35°16'1,12"N	05°13'10,98"W	350	685	17,1	Humid	Thermo-Mediterranean	Sub-humide to humid	Sub-humide to humid
15	Mezgalef	35°17'50,34"N	06°3'43,36"W	530	800	17,4	Humid	Thermo-Mediterranean	Sub-humide to humid	Semi-arid
16	Larach	35°10′02.6″N	06°10′12.9″W	518	654	17,7	Humid	Thermo-Mediterranean	Sub-humide to humid	Semi-arid
17	Béni said	35°23'38.50"N	05°05'24,53"W	450	523	18,5	Humid	Thermo-Mediterranean	Sub-humide to humid	Semi-arid

3.2.3. *Emberger rainfall quotient (Q2)*

The result of the calculated Emberger rainfall quotient (Q2) is laid out on the map in Figure 4. Its values show a significant variation in the Moroccan territory, which has resulted in a distinction between bioclimatic stages determined by the value of Q2 and the umbrothermal diagram of Emberger [22]. The lowest values of Q2 are recorded in the southern region and part of the southeastern side of the country, since they do not exceed 12, which qualifies the climate of these areas as Saharan (Q2<12) (Figure 4). Towards the Anti-Atlas and the southern slopes of the High Atlas, up to the high plateaus of Melouia, we recorded a slight increase in the Emberger quotient. This varies between 12 and 30 with a precipitation rate that does not exceed 300 mm/year that characterizes the arid climate in that specific region (12<Q2<30; 100<P<300 mm/year).

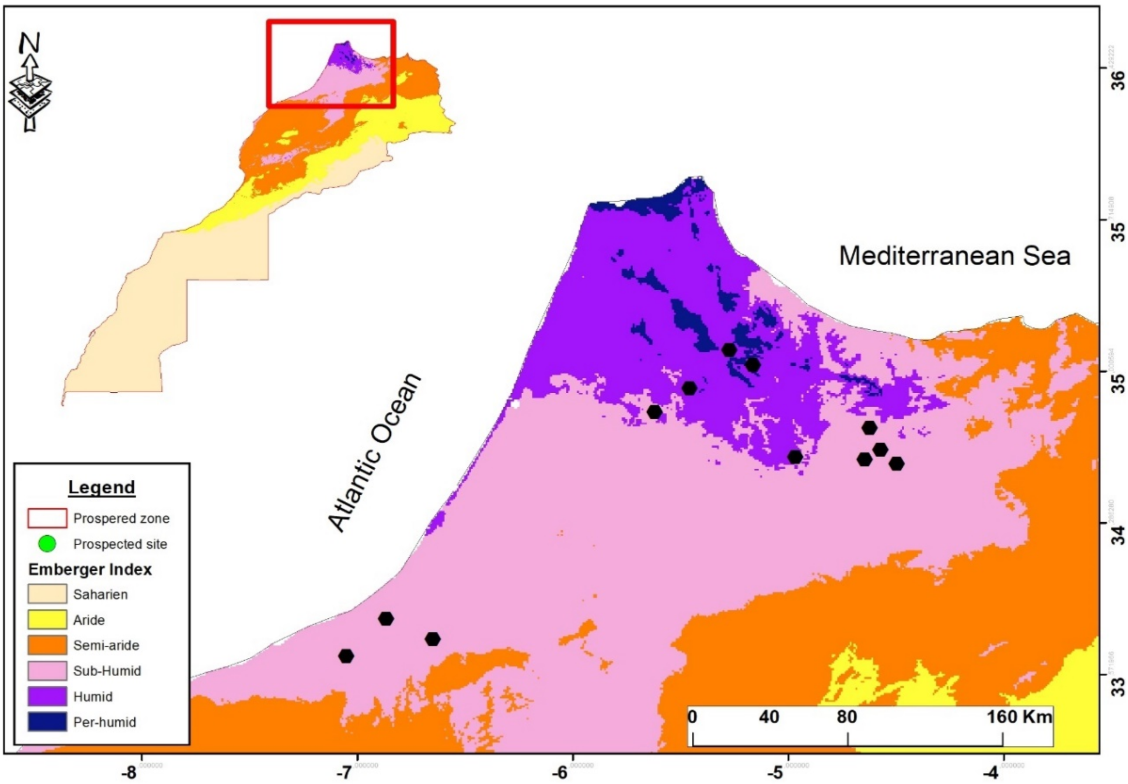

Figure 4. Distribution of natural myrtle populations according to bioclimatic stages

Towards the centre at the western side of the High Atlas and the Middle Atlas, to the Atlantic borders and towards the northern facade of the high plateau of Melouia, we recorded values of Q2 that varies between 30 and 60, with precipitation between 300 and 600 mm / year: a semi-arid climate. In these areas, with hyper-arid bioclimate (Saharan), arid and semi-arid, natural populations of Myrtle were completely absent. At the central plateau where we have prospected three natural populations of Myrtle (Bâaidnat, Kourifla and El Menzeh) and in the pre-Rif where there are five populations (Ghafsai, Sahla Barrage, Chettaba, Douar Zitouna and Aghbalou) and also in the plateaus of Saïss, the Emberger quotient record values vary between 60 and 100 with a precipitation rate of 600 and 700 mm / year: a sub-humid bioclimate.

The highest values in Emberger quotient are recorded in the region of the Western Rif where we prospected most of the natural populations of Myrtle: varying between 100 and 140 with a rainfall between 700 and 900 mm / year. The Emberger quotient sometimes exceeds 150 at the level of the crests of the mountains of Rif and registers the presence of a population of Myrtle, e.g., the population of Jbel Bouhachem. We therefore transition from a bioclimate that is humid (100<Q2<140; 700<P<900 mm/year) to another one that is hyper-humid (Q2>140; P>900 mm/year).

3.2.4. De Martonne aridity index (Im)

The map in figure 5 shows the distribution of the studied natural populations of Myrtle according to the aridity rate obtained in the calculated index of De Martonne (I_m). The values of I_m show a variation in the rate of aridity in the Moroccan territory, causing the appearance of different classes of climate according to De Martonne.

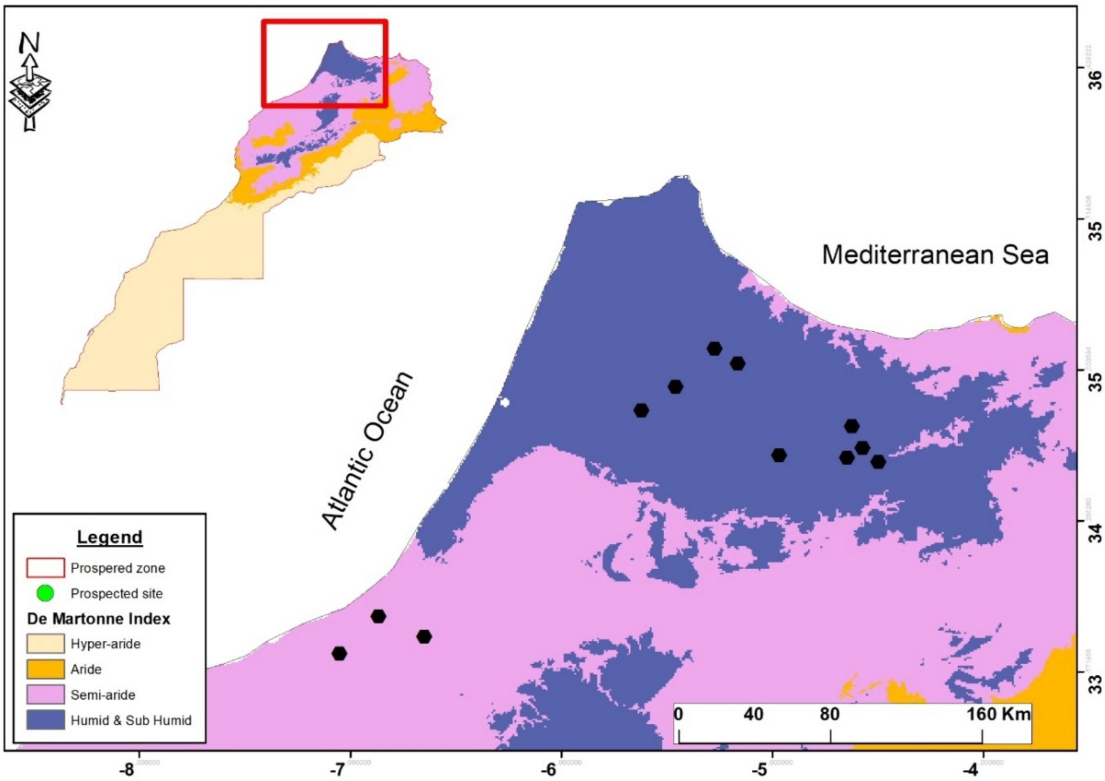

Figure 5. Distribution of natural myrtle populations according to De Martonne's aridity index

In the northern part of the country, pre-Rif and western Rif, where the majority of the natural populations of Myrtle prospected (14 populations) are found (Figure 5), the values of I_m are higher than 20 regardless of the relief, exposure and altitude of the sites. This is also the case in the Middle Atlas Mountains, which explains the high rate of precipitation perceived in these areas, as well as the low average annual temperatures. It is a sub-humid to humid climate according to the classification adopted by De Martonne. In the central plateau, where there are three natural populations of Myrtle (Bâaidnat, Kourifla and El Menzeh) and towards the plateaus of Saïss and the high plateau of Melouia and the region of Haouz (Figure 5), the index of De Martonne begins to decrease and registers values between 10 and 20. This means that the climate of these areas is semi-arid according to De Martonne (25% of the total area of Morocco) (Table 3). Towards the Anti-Atlas, the eastern side of the High Atlas and the southern part of the high plateau of Melouia, the climate is arid because of the values of I_m that do not exceed 10. The advancement towards the southern regions is characterized by a low index of De Martonne which does not exceed 5. We switch therefore from an arid climate ($5< I_m <10$) to a hyper-arid climate ($I_m <5$) (Figure 5). There are no remnants of natural populations of Myrtle in these two climate classes.

3.2.5. UNEP aridity index (Iu)

The map in Figure 6 shows the distribution of natural populations of Myrtle in relation to aridity rates according to the calculated UNEP index. The values of I_u show important fluctuations in the Moroccan territory, and consequently the appearance of five climatic zones according to the UNEP classification. In fact, in the mountains of the North and Western Rif, the values of I_u are between 0.51 and 0.65 (dry sub--humid climate) (Figure 6), but they exceed 0.65 in the relatively high altitudes where we prospected five natural populations of Myrtle: populations (Tanakoub, Ikejioun Centre, Aabaïd, Jbel Bouhachem and Talambote) where the climate is of a sub-humid to humid type (I_u >0.65). In the low altitudes of the north (Mezgalef and Larach) and the southern part of the Western Rif (Izaran Forest) and also in the pre-Rif, the central plateau (Bâaidnat, Kourifla and El Menzeh) and the Middle Atlas, the rate of aridity (I_u) is values between 0.20 and 0.50: the climate of these areas is semi-arid. Towards the southeast of the country and towards the region of Haouz and at the level of High Atlas and Anti-Atlas, the climate is of arid type (0.05< I_u <0.20). Towards the southern regions of Morocco, the values of I_u decrease, and they register less than 0.05: we approach the hyper-arid climate (I_u <0.05) (Figure 6). In these regions there is no natural population of Myrtle.

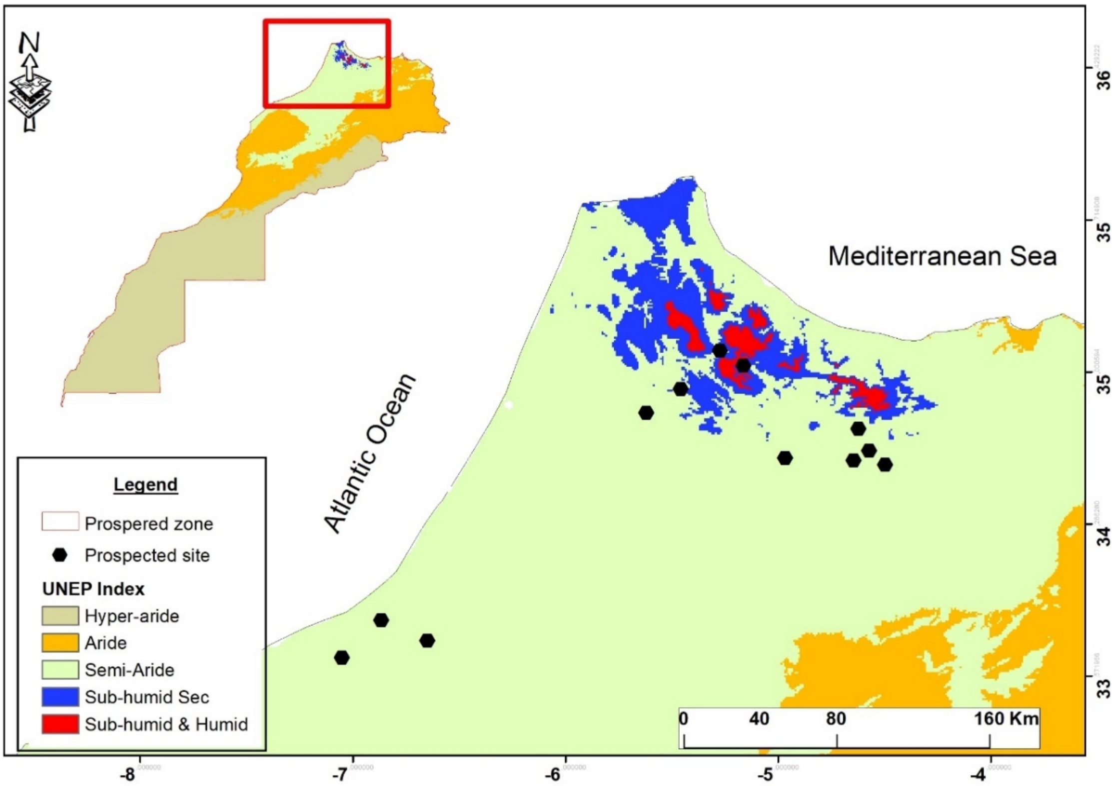

Figure 6. Distribution of natural populations of myrtle according to UNEP's aridity index

4. Discussion

The questions on the biogeographical variability and on the ecology of the Myrtle in Morocco have been answered in the present work (Table 2). Thus, it develops on a multi-layered, longitudinal, latitudinal and altitudinal range,Western Rif (Case of : Izaran Forest, Bouhachem Park, Ikejioun center, Aabaïd, Jbel Bouhachem, Talambote, Mezgalef, Larach, Béni Said) of which we noticed the presence of a characteristic phytocenosis of the alliance *Pistacio lentisci-Quercetum rotundifoliae* [24], the species are entitled: *Pistacia lentiscus* L., *Pinus halepensis*, *Quercus rotundifolia* Lamk, *Tetraclinis* *articulata*, *Arbutus unedo*, *Asparagus acutifolius* L. In the region of Pre-Rif (Ghafsai, Barrage Sahla, Chettaba, Douar Zitouna, Aghbalou) where these develop species that are characteristic to the association *Querco rotundifoliae-Oleion sylvestris* [24] (*Olea europea* L.subsp. *europaea* var. *sylvestris*, *Ceratonia siliqua* L., *Pinus halepensis*, *Tetraclinis articulata*, *Pistacia lentiscus*, *Quercus rotundifolia*, *Arbutus unedo*, *Cytisus villosus* Pourr) and the Central Plateau (Bâaidnat, Kourifla, El Menzeh) which records the presence of species characteristic of the alliance *Myrto-Quercetum subersis* [24,25], it is *Quercus suber* L., *Arbutus unedo*, *Phillyrea angustifolia* L., *Cistus salviifolius* L., *Chamaerops humilis L.*, *Pinus halepensis*. This explains the remarkable resistance of this species to the different ecological conditions, characteristic of each of the biogeographic regions of Morocco (Western Rif, Pre-Rif, Central Plateau). Previous studies have revealed the biogeographic plasticity of myrtle in Morocco [10, 30, 31, 32, 33]. It is subject to great orographic, edaphic and bioclimatic variability, as reported at the Mediterranean scale from the Azores to Iran [34, 35].

A climatic variability has been revealed in Morocco through the classification of climate types by means of different calculated climatic indices. This climatic diversity is related to the orographic richness of Morocco based on the maps extracted for its territory. This result has been proven by some previous studies [2,6]; temperature and precipitation are two of the many climatic factors controlling the distribution and development of plant species [36]. They represent limiting factors. In order to reveal their combined impact on the distribution of natural populations of myrtle in Morocco, we calculated bioclimatic indices based on these two factors, to determine bioclimatic stages (Emberger's umbrothermal quotient) and aridity (De Martonne and UNEP indices). Indeed, these indices are commonly used to determine the distribution of vegetation in Morocco [36].

The present study demonstrates the effect of climatic conditions on the distribution of Myrtle populations in Morocco. There is homogeneity of the climate classes and the different indices used where the Myrtle develops. This confirms the role of climate in the distribution of vegetation [1, 37, 38]. According to the classification of bioclimates by the Emberger quotient, the common Myrtle develops in three types of bioclimates: (i) the sub-humid one whose Q value varies between about 60 and 100 with an annual precipitation rate between 300 and 700 mm and an annual average temperature range from 10°C to 20°C; (ii) the humid one which is characterized by Q values between 100 and 140, where the precipitation varies from 700 to 900 mm/year and the temperature between 8°C and 14°C; and (iii) the hyper humid climate (Q>140), which has a precipitation rate higher than 900 mm/year and an annual average temperature varying between 5°C and 8°C.

This means that Myrtle supports a relatively wide range in terms of precipitation and temperature, from warm and temperate to cold and humid in altitudes between 220 m and 1150 m, which corresponds to the characteristics of the thermo-Mediterranean vegetation stage and the lower part of Meso-Mediterranean. These results were also confirmed by the floristic procession accompanying the Myrtle in its natural habitat. Among the flora are: holm oak (*Quercus rotundifolia*), cork oak (*Quercus suber*), cedar (*Tetraclinis articulata),* Aleppo pine (*Pinus halepensis*), arbutus (*Arbutus unedo*), oleaster (*Olea europea* L. subsp. *europaea* var. *sylvestris*), lentisk (*Pistacia lentiscus*), *Cistus salviifolius*, *Phillyrea angustifolia*, *Asparagus acutifolius* [2, 7, 25, 26, 28, 29, 38].

According to the classification of De Martonne (P/T+10) and UNEP (P/ETP), the Myrtle grows spontaneously in a homogeneous climate. Last but not least, for the spatialization of natural populations of Myrtle according to aridity, we recorded a great homogeneity regarding the climates where it develops spontaneously according to the classification of De Martonne (P/T+10) and UNEP (P/ETP). Moreover, it is distributed in semi-arid (Central Plateau), sub-humid and humid (Pre-Rif and Western Rif) climates for both indices. In fact, for the index of UNEP the sites located in the Central Plateau are characterized by a relatively high aridity rate, between 0.2 and 0.5, which means that the evaporative power of this area is more important than the rate of precipitation.

On the other hand, the sites located in the Pre-Rif and the Western Rif are characterized by a low aridity rate (I between 0.5 and 0.78), which reflects a high annual rainfall compared to atmospheric evapotranspiration. For the De Martonne index, the Central Plateau area where the myrtle is located is characterized by an aridity rate between 10 and 20, which means that the average annual temperature is greater than the rate of precipitation. Evidently, the sites of the Pre-Rif and the Western Rif have an aridity rate between 20 and 66 as a consequence of the high rainfall in these areas compared to the average annual temperature. Taking into account the aforementioned results, we find that this species supports a medium to low aridity rate which is related to a low rate of drought and a relatively high demand in terms of rainfall. Thus, we notice that the rate of continentality is important for the distribution of Myrtle in Morocco since most of the populations are concentrated in the centre of the northern part of the country.

In addition to the effect of the variation of the climatic conditions on the geographical distribution of the natural populations of myrtle in Morocco and its evaluation as a very rare species [29], the climatic changes can affect the existence and the continuity of its populations because of the succession of the years of drought and the increase of the number of days of the dry period. Nevertheless, some populations of myrtle are under pressure of overexploitation through cooperatives that invested in the production of their essential oils, with a great concentration in the pre-Rif region. Other areas are highly polluted by the siting of unregulated rubbish dumps in the periphery of forests. These have adverse effects on ecosystems as well as the Myrtle; e.g., the area of Dardara. All these effects can cause or contribute to the disappearance of some populations of myrtle. We must ring the alarm, raise awareness and adopt a preventive program to deal with this situation.

Conclusion

The approach adopted to determine the effect of geographical distribution on the ecology of Myrtle in Morocco is based on the use of climatic data and bioclimatic indices, most adopted in the Mediterranean region. It has been shown that the distribution of the Myrtle in Morocco on a large biogeographical area is limited to three biogeographic zones: the Central Plateau, Pre-Rif and the Western Rif. But the natural populations of Myrtle in the Moroccan territory require a well determined climatic spectrum (Range). According to the Emberger index, the common Myrtle is distributed in three types of climates (sub-humid, humid and hyper humid, in altitudes between 220 and 1150m and annual temperatures that vary from 5 ° C to 20 ° C, with the annual rainfall being between 300 mm and 1000 mm. This corresponds to the thermo-Mediterranean vegetation stage and the lower part of meso-Mediterranean. When it comes to the aridity indices, the Myrtle is distributed in semi-arid, sub-humid and humid climates which have an aridity ratio that varies from medium to low. This species does not tolerate dry conditions.

Faced with global heating and socio-economic activity, the common myrtle is considered among the species threatened by the erosion of biological and genetic diversity, which requires the creation of an integrated program of protection of its resources in addition to its development in a sustainable way.

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