

APPLICATION OF A NEW MODEL BIOCLIMATIC CLASSIFICATION IN TLEMCCEN REGION (NORTHWEST ALGERIA)

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Abstract. The aim of this study is to propose a bioclimatic classification for Tlemcen (NW Algeria) based on the recently developed Global Bioclimatic Classification System (GBCS). The GBCS classification is widely used in vegetation science and landscape ecology. Temperature and precipitation data from 9 weather stations were employed for the bioclimatic classification. The results show that, two macrobioclimates, two thermotypic horizons were identified. The Mediterranean macrobioclimate is the dominant pattern, including a wide range of bioclimates such as the Mediterranean pluviseasonal-continental and Mediterranean xeric continental. Temperate macrobioclimate has only one bioclimate i.e. Temperate Continental. The bioclimatic classification proposed in this study is useful for assessing the relationship between climate and the distribution of species.

Key words: bioclimatic classification; Mediterranean region; Tlemcen; vegetation; Algeria.

INTRODUCTION

Bioclimatology is an ecological science that studies the relationship between the climate and the distribution of living beings and their communities on the earth [1]; in particular, plants and plant communities, considering the main climate variables that are relevant for species distribution [10]. Bioclimatic variables retain the features of climate that are physiologically relevant to plant growth and species distribution. Such classification aims to establish a consistent relationship between worldwide vegetation types and easy-to-calculate bioclimatic indexes [18]. Recently, botanists and biogeographers have been using a bioclimatic classification system established by Rivas-Martinez (1981, 2004) [23, 29], known as Worldwide Bioclimatic Classification System (W.B.C.S.). The system is based on a set of bioclimatic indexes that must be known for any study area in order to achieve its bioclimatic classification. The W.B.C.S is a bioclimatic classification system that is widely used in vegetation sciences, especially in geobotany and landscape ecology [25]. Bioclimatic classification is considered a mandatory environmental layer that has to be taken into account in the analysis [5, 8, 33]. The studies of bioclimatic classification in Tlemcen are many, but those in the conditions of the variability of global climate, get special importance also for the fact of the determination of their impact in bioclimatic indicators, of adaptation chances of cultivated and natural vegetation, for their conservation and use according to the ecological and economical logic. This bioclimatic classification, using a set of climatic parameters and bioclimatic indices according to a hierarchical system, recognizes the following main bioclimatic divisions: macrobioclimate, bioclimate, thermotype and ombrotype (Bioclimatic Belt) [15].

Various authors have studied the climate and bioclimate of Algeria [1, 2, 7, 13, 14]. All of these authors agree to recognize the fact that the Mediterranean climate is mainly restricted to the

northern parts of the country. This climate is a transitional between the temperate and the tropical zones, characterized by a rainy and cold winter, from October to March, and a dry and hot season for almost, six months [7]. Precipitation is very irregular. Highly concentrated during wintertime [15]. Typically, summer is the hottest and least watered season in the Mediterranean.

In Oranie, the Worldwide Bioclimatic Classification System has been used to determine the relationship between climate and diversity of Tamaricaceae [34]. Tlemcen covers one macroclimate (i.e. Mediterranean), four thermotype horizons, and three ombrotypes horizons [34]. The Mediterranean macrobioclimate is characterized by at least two consecutive arid summer months [20].

In this study:

- we apply the recently developed Global Bioclimatic Classification System [26, 27] to the meteorological data of Tlemcen. This system has successfully been applied to different parts of the world and seems to provide good matches between biome and climate boundaries [3, 11, 26-28];

- proposing a bioclimatic zonation for Tlemcen region, this is more useful for ecologists working on the ecology and distribution of plant species in Tlemcen;

- analysis of the vegetation–bioclimate relationships of the region of Tlemcen, if we are not able to detect the relationship between climate and biota, we are not well prepared to understand landscape change [10].

We would like to point out that the study is original and continues the work done by Souddi et Ghezlaoui (2020) [34].

MATERIAL AND METHODS

Tlemcen region is located on the northwestern of Algeria, between 34°25' and 35°25' latitude and between 0°55' and 2°30' longitude covering 9017.69 Km². It is bordered by the Mediterranean Sea in the

North, by the wilaya of Ain Temouchent to the East, by the wilaya of Sidi Bel Abbes in the East-South-East, by Morocco in the West. The geographical position of Tlemcen in northwestern Algeria favor the appearance of different ecosystems (the steppe ecosystem, forest ecosystems, Traras Mountains, Tlemcen Mountains), this ecosystems characterize by the biodiversity of species and plant communities very important. The altitude of Tlemcen Mountains varies from 800 m to 1400 m and the highest mountain is the mountain of Tenouchfi (1840 m) in the Central-eastern region. Due to its geographic position, the climate of Tlemcen is typically Mediterranean. The rains are centered on the cold seasons, and long summer drought, persistent from 2 to 7 or 8 months a year [21].

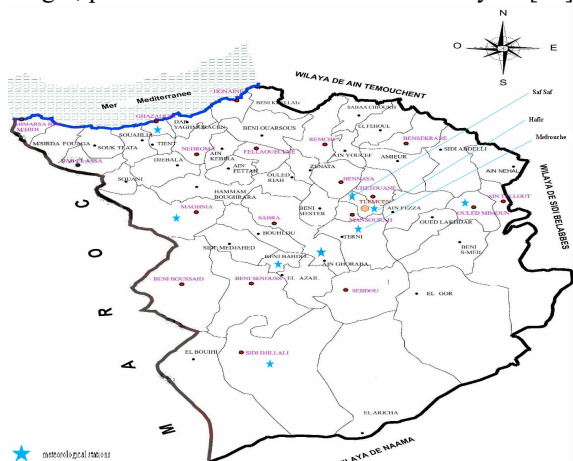


Figure 1. Study area and meteorological stations locations [36]

A network of point meteorological data observations, which are irregular and scarce, covers the study area. To better understand the bioclimatic position of the study area, 9 weather stations were examined. Our bioclimatic study is based on the recent climatic data that are taken from the national office of meteorology [34]. The main previous bioclimatic analyzes on the region of Tlemcen are based on the application of simple bioclimatic indices such as the

De Martonne aridity index [7]. Climatic dates and their parameters and index, as well as floristic and phytosociological data, are very useful tools in the analysis of those links, and allow one to draw the biogeographic boundaries in relatively homogeneous floristic territories [35]. In the present study, we present a bioclimatic classification of the climate of the region of Tlemcen following the approach of Rivas-Martinez (1981; 1993) [23, 25]. It has been used for bioclimatic zonation in North America, Chile [3], Europe [30, 31], and the Iberian Peninsula [11]. The description of the method is available (<http://www.globalbioclimatics.org>) and in [26, 27]. Following this approach, a bioclimatic classification of the region of Tlemcen was derived by calculations of the bioclimatic indices necessary to define the bioclimate of each station. In particular, continentality (I_c) and ombrotype (I_o) indices were obtained as reported in (Rivas-Martinez *et al.*, 2011). The bioclimatic parameters and indices used in this classification are detailed in Table 1, showing the abbreviations used. The characteristics of the weather stations used in this study are presented in Table 2.

RESULTS

The bioclimatic classification of the region of Tlemcen was derived by calculations of the bioclimatic indices necessary to define the bioclimate of each station [34]. In particular, continentality, ombrotype and thermotype were obtained [32].

Climatic data for the different weather stations are presented in table 3. According to the bioclimatic Analysis (GBC), we found two macrobioclimates (Mediterranean and Temperate), four Ombrotype. Two classes of continentality (Weak Subcontinental, Weak Eucontinental), two thermotypic horizons (Thermomediterranean and Mesomediterranean) and four ombrothermic horizons (lower subhumide, lower dry, lower Semiarid and upper Semiarid).

Table 1. List of bioclimatic indices and definitions

Index	Name and definition	Formula
I_c	Continental Index	$I_c = T_{max} - T_{min}$
I_o	Ombrothermic Index	$I_o = (P_p/T_p) \times 10$
P_p	Positive annual precipitation	/
T_{max}	Average temperature of the warmest month	/
T_{min}	Average temperature of the coldest month	/
T_p	Positive average annual temperature	/

Table 2. Geographic data of weather stations

Meteorological stations	Longitude West	Latitude North	Altitude (m)
Sidi Djilali	1° 27'	34° 27'	1280
Hafir	1° 26'	34° 47'	1270
Mefrouche	1° 16'	34° 51'	1100
Ain Ghoraba	1° 38'	34° 71'	829
Beni Bahdel	1° 36'	34° 45'	700
Ouled Mimoun	1° 03'	34° 09'	650
Saf Saf	1° 17'	34° 57'	592
Maghnia	1° 47'	34° 52'	426
Ghazaouet	1° 52'	35° 06'	4

Table 3. Result of Bioclimatic indices applied to the study area

Meteorological stations	Period	Parameters and indexes				Types of continentality indices (Type / Subtype / Levels)		Isobioclimate	
		T	Pp	Ic	Io	Bioclimate	Ombrotype	Thermostype	
Sidi Djilali	1970-2008	15.53	313.61	34.7	1.68	Continental Eucontinental Weak	Mediterranean xeric continental	Semiarid Upper	Thermomediterranean
Hafir	1990-2010	15.61	483.98	29.15	2.58	Continental Eucontinental Weak	Mediterranean pluviseasonal continental	Dry Lower	Thermomediterranean
Mefrouche	1980-2013	14.38	626.94	28.27	3.63	Continental Eucontinental Weak	Temperate continental	Subhumid Lower	Mesomediterranean
Ain Ghoraba	1975-2008	15.73	517.24	29.47	2.74	Continental Eucontinental Weak	Mediterranean pluviseasonal continental	Dry Lower	Thermomediterranean
Beni Bahdel	1980-2013	17.65	446.76	31.1	2.11	Continental Eucontinental Weak	Mediterranean pluviseasonal continental	Dry Lower	Thermomediterranean
Ouled Mimoun	1980-2010	16.75	332.5	28.7	1.64	Continental Eucontinental Weak	Mediterranean xeric continental	Semiarid Upper	Thermomediterranean
Saf Saf	1980-2010	15.5	345.2	28.3	1.85	Continental Eucontinental Weak	Mediterranean xeric continental	Semiarid Upper	Mesomediterranean
Maghnia	1980-2013	17.98	264.37	31.84	1.22	Continental Eucontinental Weak	Mediterranean xeric continental	Semiarid Lower	Thermomediterranean
Ghazaouet	1980-2013	18.62	338.86	23.38	1.52	Continental Subcontinental Weak	Mediterranean xeric continental	Semiarid Upper	Thermomediterranean

T: average annual temperature in degrees centigrade

DISCUSSION

In the region of Tlemcen, The Mediterranean macrobioclimate is the dominant pattern, with a wide range of bioclimate variation [34]. Several different bioclimates can be distinguished in this macrobioclimate. Mediterranean macrobioclimate of Tlemcen is subdivided into two bioclimates:

Mediterranean xeric-continental (M.x.c): This bioclimate is dominates the large part of Tlemcen (Ghazaouet, Sidi Djilali, Saf Saf, Ouled Mimoun, Maghnia).

Climate diagrams of this bioclimatic zone represent a relatively long summer drought, low amount of annual precipitation but relatively elevated average of winter temperature minima. The progressive evolution of the dry period imposes a strong evapotranspiration on the vegetation, which allows it to develop adaptation systems (reduction of the leaf area, development of thorns) thus modifying the landscape by development of halophilic vegetation (Tamaricaceae) [34]. The Pre-forest formations seem to give way to other xerophilic and asylvatic species [15].

Mediterranean pluviseasonal- continental (M.p.c): This bioclimate is found in the stations of Hafir, Ain Ghoraba and Beni Bahdel. Climate diagrams of three stations show a dry season (4 months) which lasts from June to October with a reduced summer rainfall. Climate diagrams of this bioclimatic zone represent a relatively high precipitation during growing season or months with mean temperature below 0°C.

The Mediterranean macrobioclimate is characterized by at least two consecutive arid summer months, while the temperate macrobioclimate does not have any summer aridity [20].

Temperate macrobioclimate covers the majority of the European continent with the exception of circum-Mediterranean region, inlands of the Iberian Peninsula and much of the Scandinavia [30]. Several different bioclimates can be distinguished in this macrobioclimate in Europe [12].

The difference is in the values of continentality index (Ic):

- Temperate hyperoceanic (Tho): $Ic \leq 11$;
- Temperate oceanic (Toc): $11 > Ic < 21$;
- Temperate continental (Tco): $Ic > 21$;
- Temperate xeric ≥ 7 [26, 27].

In Tlemcen, Temperate macrobioclimate in the locality Mefrouche (Commune Terny Beni Hdiel) is represented by **temperate continental bioclimate**. Such small party of temperate macrobioclimate because of the particular microclimatic and precipitation distribution patterns. Temperate macrobioclimate has an important amount of annual precipitation occurring during winter months. Climate diagram corresponding to this bioclimate show clearly the absence or the very short duration of the dry season.

This station is an exception by exposing the thermo-tropical because of the very high humidity percentage due to the presence of the lake where the Dam of El Mefrouche which was built in the watershed of Oued el mefrouche at the level of 1952 with a

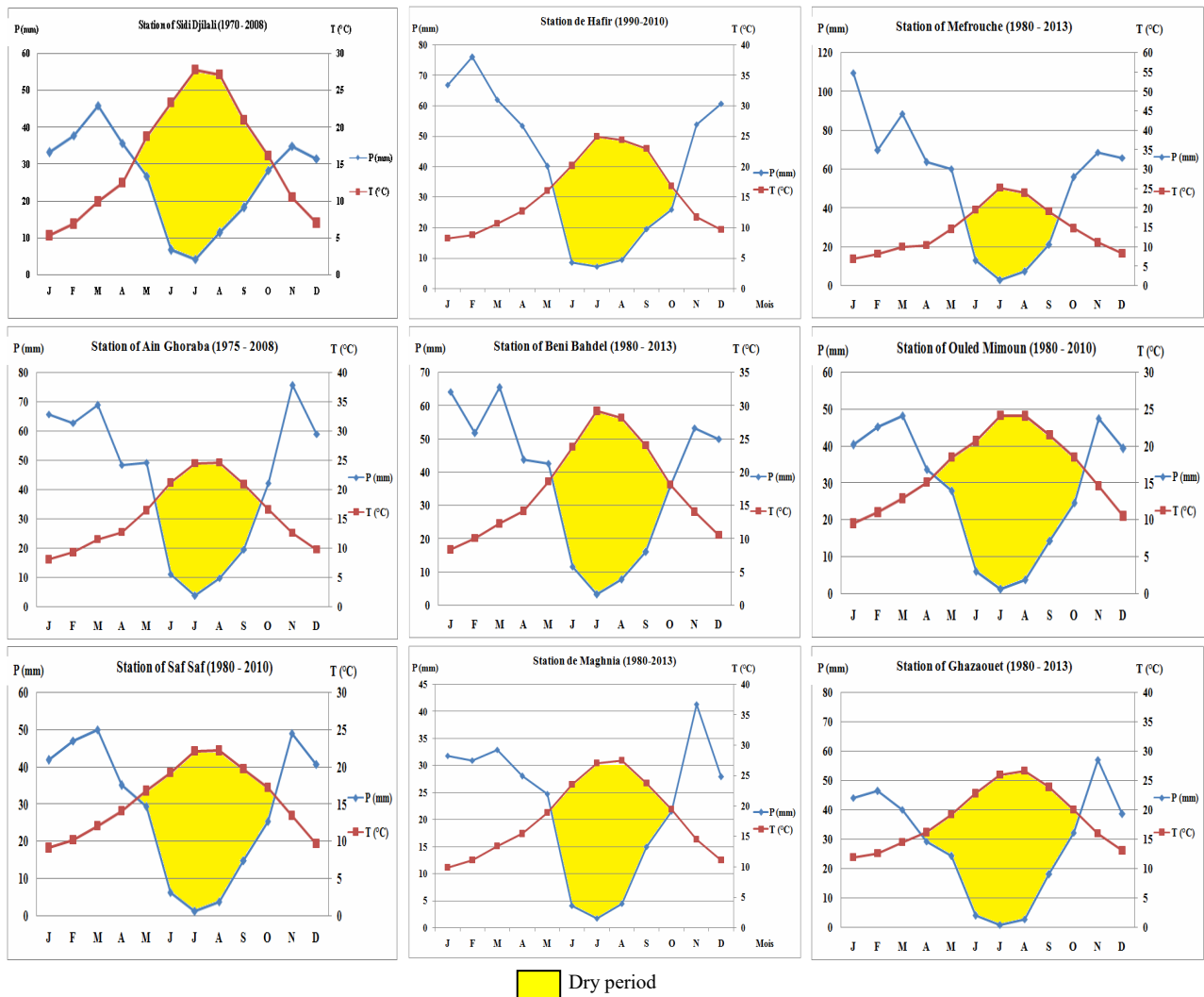


Figure 2. Emberger climagram for each station

capacity of 15 million cubic meters and an area of 200 hectares. This artificial lake has created a rather exceptional microclimate in the region.

The region of Tlemcen is characterized by high climatic variability and great diversity, due to its geographical position and orographic heterogeneity. On the one hand, this region has a varied relief, going from the north to the south and on the other hand, it is bordered by the Mediterranean Sea.

Statistical treatment

Statistical treatment is a tool that can help us determine the relationship that may exist between the stations study. Many software programs exist which allow these analyzes to be easily carried out, but the delicate part remains the interpretation which should always remain nuanced. These digital treatments were carried out using the "Minitab 16" software. Climate variables (Io, Ic, T, Pp) were analyzed to correlate the parameters between them, to better understand the relationship between bioclimate and vegetation. This analysis allows the stations to be positioned between them (Fig. 4). Two similar points will therefore have similar characters. The similarity between the stations illustrated by a dendrogram (Fig. 3) shows the

existence of association between stations according to the results of the ombrothermic index for the new period treated in this study:

The first group composed by a single station (Mefrouche), with a rate of 69.47%. This station has a bioclimate Temperate Continental.

The second group represents the Mediterranean bioclimate, this group divided into two subgroups:

- Sub-group 1: composed by three stations with a rate of 71.98%. The stations of Beni Bahdel, Ain Ghoraba and Hafir have a bioclimate Mediterranean pluviseasonal- continental.

- Sub-group 2: composed by 5 stations with a rate of 86.38%.

- 1- The station of Maghnia has a bioclimate Mediterranean Xeric continental and ombrotype (Semiarid Lower).

- 2- The stations of Sidi Djilali, Saf Saf, Ouled Mimoun and Ghazaouet present a bioclimate Mediterranean Xeric continental and ombrotype (Semiarid Upper).

This classification confirms the results of bioclimatic zonation. Climatic zonation involves the

identification of zones and regions with similar climate.

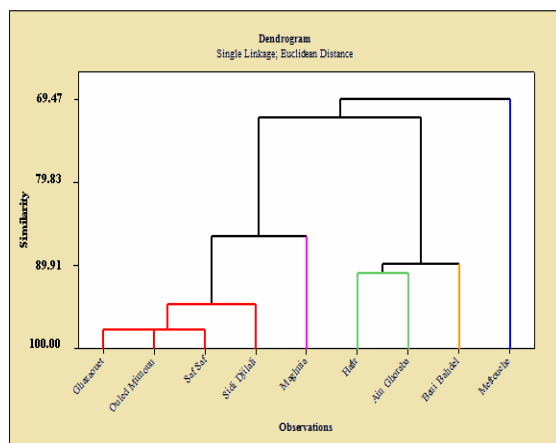


Figure 3. Dendrogram of station groups

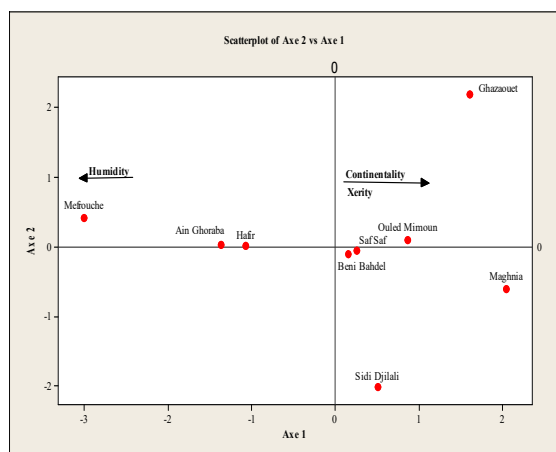


Figure 4. Plan Axe 1-Axe 2

The vegetation of Tlemcen region

Tlemcen is one of the regions most diversified in plant biodiversity, in N.W Algeria. The analysis of biodiversity at these sites, through 04 stations (Rachgoun, Hammam Boughrara, Remchi and El-Aouedj), contains 195 species [34], and contains more than 300 species [4]. This high phytodiversity rate is the result of an interaction between climate variability and landscape diversity. The present vegetation of Tlemcen region established after an interaction between local climate changes and anthropogenic activities. To better understand the distribution between vegetation of the Tlemcen region and these climate and anthropogenic changes, it is necessary to obtain a good understanding of the modern relationships of climate vegetation. Although the flora and vegetation of Tlemcen have been extensively investigated for a long time [4, 7, 9, 15].

Mefrouche station: It's a matorral where the *Chamaerops humilis* is associated with the species that are faithful to it: *Ampelodesma mauritanicum*, *Urginea maritima*, *Asphodelus microcarpus*. *Chamaerops humilis* is a Chamaephytic species that shows the stage of degradation of a forest [16].

The Hafir forest massif located in the south-west of Tlemcen is dominated by Mediterranean pluviseasonal-continental. The analysis of the floristic diversity of forest massif "Hafir-Zariffet" in the Tlemcen National Park has revealed the existence of 211 taxa which belong to 65 families and 164 genera [17]. There are mainly two bioclimatic floors: sub-humid and semi-arid, which gives it a geographical and special orographic position forming large areas of vegetation successively extending from the leafy forest to the south-west, passing through the mixed oak grove to the north then to the artificial coniferous forests and to the natural *Quercus ilex* matorrals to the northeast [17]. This region is characterized by a mixed forest of *Quercus ilex*, *Quercus suber*, *Quercus coccifera* and *Quercus faginea* subsp. *tlemcenensis* [4].

The zeen oak (*Quercus faginea*) is a deciduous oak of meso and supra-Mediterranean types [19, 22] endemic to the western Mediterranean. It would be represented in the Mounts of Tlemcen by a subspecies: *Quercus faginea* subsp. *tlemcenensis*. Among the accompanying taxa are: *Cytisus arboreus* subsp. *Baeticus*, *Cytisus villosus*, *Hedera algeriensis*, *Ruscus aculeatus*, *Smilax aspera*, *Viburnum tinus*, *Lonicera implexa*, *Asplenium ceterach*, *Umbilicus rupestris*, *Phillyrea latifolia*, *Ampelodesmos mauritanicus* [4].

Most parts of Tlemcen correspond with Mediterranean Xeric-continental bioclimate. This vast area offer a very diverse landscape, related to climate, soil and topography. Comparison of biological spectra in the Tlemcen region shows the importance of therophytes [6]. The variations in the floristic composition of the flora in Tlemcen region can, to be explained by this bioclimatic subdivision.

Tlemcen is one wilaya of Algeria; were are important climatic differences, which are the result of the geographical position and orographic heterogeneity. The typical Mediterranean climate characterizes this region. The bioclimatic study of the region of Tlemcen by the application of a new Global Bioclimatic Classification reveals two macrobioclimates (Mediterranean and Temperate), four ombrothermic horizons (from lower dry to lower sub-humid). The dominant bioclimate of Tlemcen is the Mediterranean Xeric continental bioclimates, which are represented in the Mediterranean Basin. The composition of the biological spectrum shows a predominance of therophytes on other life forms [34]. This situation is similar to that of Mediterranean ecosystems [4, 14,15]. Therophytes, which represent the current expression of plants adaptation in arid conditions, appear to be clearly the majority compared to other biological types.

Conflict of interest. There is no actual or potential conflict of interest in relation to this article.

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