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BIODIVERSITY, AUTECOLOGY AND *STATUS* OF AROMATIC AND MEDICINAL PLANTS IN GEOPARK M'GOUN (MOROCCO)

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Abstract – The M'Goun Geopark vegetation is represented by rich Mediterranean communities composed by *Quercus*, *Juniperus*, *Tetraclinis*, Aleppo pine with high species diversity, particularly medicinal and aromatic ones. Such a richness, depending on region distinct characteristics, generates an ecological diversity as result of climate variation along altitudinal and continental gradients on one hand, and lithological and orographic ones on the other. The main objective of this study is to analyze the specific richness of aromatic and medicinal plants in the Geopark M'Goun (Morocco), their autecology and their *status*. The specific richness of aromatic plants was calculated by 37 linear transects along which species were gathered and counted: 47 species among 396 total species within a 5700 Km^2 area, of which at least six cultivated, are present, confirming a good adaptation of aromatic plants to the ecological conditions of the Geopark. Canonical Correspondence Analysis (CCA) was applied to the *dataset* to verify the relationships between species and environmental factors. Climate, altitude and substrate type resulted the most important factors influencing species richness and distribution. The *status* of species was detected according to IUCN Red List showing that 42 % of these species are not yet evaluated, 3 are close to threat *status*, 2 are vulnerable, and one is endangered. Some of non-evaluated species are under threat, therefore needing of assessment, mentoring, and conservation projects.

Keywords: medicinal plants; aromatic plants; species richness; ecological diversity, biodiversity management.

Introduction

The high plant diversity of the Mediterranean Region has attracted a major attention over last few decades (Cowling et al., 1996); typical features of this Region include an unusual geographical and topographical variability, a pronounced climatic biseasonality, as demonstrated by hot and dry summer and cold and rainy-humid winter, associated with an exceptional plant and animal diversity (Scarascia-Mugnozza et al., 2000): Moreover, due to the increase of the human impact there is an urgent need to identify the greatest endangered biodiversity sectors (Medail & Quezel, 1997). Morocco, as a part of the Mediterranean Region, plays a significant role in keeping plant diversity.

Moroccan vegetation has an outstanding diversity due to several factors; namely the geographical location, which allows a diversity of climates and bioclimatic stages: arid, semi-arid, and sub-humid, favoring the colonization of particular plant assemblages, not to mention the presence of multiple natural environments, as lakes, dayas, estuaries, rivers, coastline, plains, high mountains, deserts etc. In addition, there is a topographic diversity owing to the presence of two mountain ranges: the Rif in the North, the Atlas in the center and the South with plateaus, plains, deserts and 3500 kilometers of coastline; therefore, an extremely diversified lithological and edaphic substrates exist. Thus, becoming the crossroad for these several features, Morocco has its unique diversity.

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Morocco offers a significant potential for the cultivation of medicinal and aromatic plants (MAP) (USAID, 2006); its MAPs flora is remarkable by its richness, diversity and socio-economic values (Fennane & Rejdali, 2016); for example, the exploitation of rosemary (*Rosmarinus officinalis* L.) provides approximately 81,000 JT/year, which corresponds to a value of 4,050,000.00 Moroccan Dirhams (MAD) (approximately 405 000 Euros) (Ministry of Agriculture, 2005). Moroccan wild flora with more than 4200 species is distributed in 41 ecosystems (Rhafouri et al., 2015): 600 species have aromatic or medicinal qualities (Rhafouri et al., 2015; Radi et al., 2022) and 800 have aromatic and/or medicinal interest (Zrira, 2017).

According to the High Commission for Water and Forests, only 2% of the MAPs exploited are cultivated, whereas the majority of MAPs are natural (HCEFLCD, 2018). According to the national agency for aromatic and medicinal plants, Morocco is the twelfth largest exporter of MAP in the world with a rate of 52,000 tons of plants and 5,000 tons of essential oils (ANPAM, 2020). Among 600 aromatic or medicinal species, only 80 are currently exploited (HCEFLCD, 2018). The main spontaneous MAPs encountered in the forest and collective lands are rosemary, white wormwood, thyme, laurel, wild chamomile, carob tree, oregano, lavander, mastic tree, myrtle, irguel, etc (Fennane & Rejdali, 2016). The socio-economic role of MAP is not to be denied; the export revenues generate more than 615 million MAD and offer more than 500,000 working days with a total income of 25 million MAD (ANPAM, 2020).

The main exploited MAPs in Morocco are *Thymus satureioides*, *Rosmarinus* sp., *Ceratonia siliqua*, *Artemisia* sp., *Laurus nobilis* (ELKacimi, 2020); some of the exotic Moroccan medicinal plants is Argan (*Argana spinosa* Skeels), *Artemisia herba-alba* Asso, Atlas Cedar (*Cedrus atlantica* Mannerti), *Laurus nobilis, Laurus azorica*, *Myrtus communis* (Zrira, 2017), at least 15 Moroccan endemic species are exploited as aromatic and/or medicinal plants, such as *Acacia gummifera, Argana spinosa, Cladenthus scariosus, Lavandula maeirii* and *Thymus riatarum* (Fennane & Ibn-Tattou, 1998). However, medicinal plants have received little attention from researchers in the region. Therefore, there aren't many references available (CNEARC et al, 2004). Numerous issues affect the country's aromatic and medicinal plant industry, limiting its growth. Thus, it is up to the experts to combine their efforts to structure and optimize it (ELKacimi, 2020).

In relation to data above mentioned, it is clear that aromatic and medicinal plants can help to improve the lifestyle of the local population and save natural resources. Moreover, it is necessary to rationalize the exploitation of these plants to guarantee sustainable exploitation. M'Goun Geopark is highly selected to emphasize the importance of PAMs in Morocco.

Thus, the aim of the present work is to provide a synoptic view of PAMs found by our field sampling of species, their inventory and classification and finally to take a view on the IUCN *status* of each species. Therefore, this work may help to draw the alarm on the risk that threatens the future of the Morocco region from naturalistic as well as economic point of view.

Materials And Methods

Study area

The Geopark is a part of the Azilal province, located in the center of Morocco, belonging to the Central High Atlas. The area of the Geopark, displayed in figure 1, recognized by UNESCO is 5700 Km^2 containing 15 rural municipalities, home to a 200,000 inhabitants (Association du Géoparc du M'GOUN & UNESCO, 2019). It is located some 100 Km North-East Marrakech. The Geopark has an exceptional geological history dating back to the Triassic period (250 million years ago), however, the main stages took place during the Jurassic (180 million years ago) (UNESCO, 2015) producing an outstanding geological and topographic features and geo-sites: Ouzoud geo-site, Cathedral Mesfrane-geosite, Imi nifri natural bridge, pink terrains, red clay of Azilal, etc.; it has a variety of topographical and climatic characteristics, soils are generally mountainous, and bioclimatic belts are ranged between semi-arid or sub-humid to humid (rainfall between 550 mm and 700 mm in Azilal and up to 1000 mm in the High Atlas) (Taïbi et al., 2015). The character of the climate is Mediterranean, characterized by a cold winter and a hot summer (Ionesco and Mateez, 1964), which leads to significant differences in temperature ranged between negative values in the winter and about 40 °C in the summer. The dominant vegetation is represented by Q*uercus ilex* L. forest spread between 1100 m and 2400 m a.s.l. in high mountains. *Juniperus oxycedrus* L. forms colonies in reduced forests at 1250 m persisting until 2100 m. *Buxus sempervirens* L. and *Buxus balearica* Lam. are the most remarkable species associated with *Quercus ilex* oak groves. The thorny xerophytes represent a Habitat where the most common species are *Cytisus balansae* (Boiss.) Ball., *Alyssum spinosum* L. and *Bupleurum spinosum* Guan., colonizing the extreme elevations (from 1800 to about 3000 m), where temperatures are exceptionally cold during the winter, accompanied by winds and significant snowy rainfall. Pine forests (*Pinus halepensis* Mill.) exist in the regions of Tillouguit near the Cathedral Mesfrane cliffs,

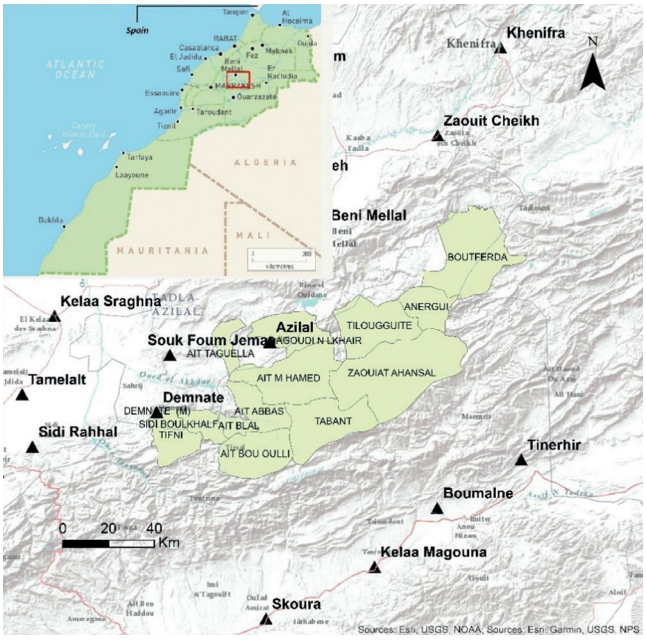

Figure 1. Study area location.

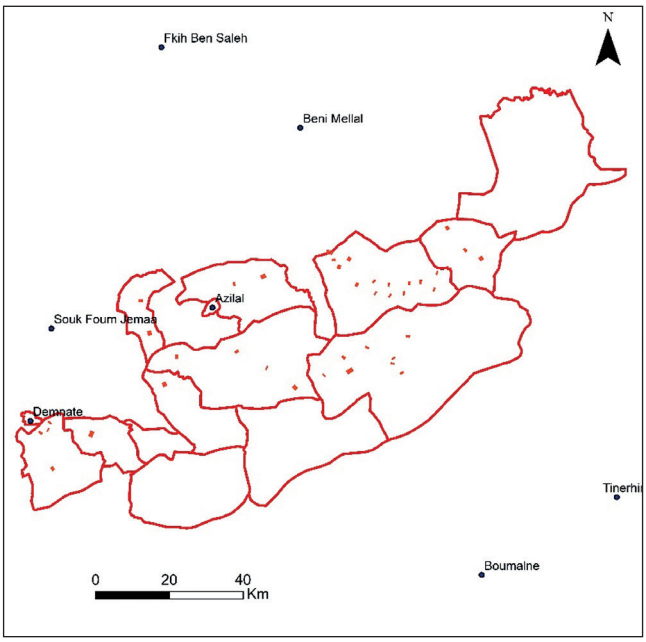

Figure 2. The transects map.

Ait Abbas, ZauitAhensal and Demnat where altitudes vary between 1200 and 1700-1800 m. a.s.l.

This area was chosen because it's a protected area, containing the most important Moroccan habitats, forming a home for an outstanding biodiversity, especially in the Atlas Central, a crossroad of the most important Moroccan ecosystems and environments, Middle Atlas in the West, High Atlas in the East, Tadla plain in the North and the desertic arid domain in the South.

Sampling Methods

The methods of sampling were developed to permit accurate estimations based on the goals pursued, like the extent of the vegetation, its characteristics, and the resources available (Glèlè, 2016). Among the numerous sampling techniques the sampling method adopted in this study is the random sampling, and stratified sampling; it means that instead of sample all the Geopark habitats sampling process will occur once in each habitat, which requires a forest cover relatively homogeneous (Bouxin, 2011); its use is justified by the redundancy of the same plant communities all over the area at large scale. In the ground the different size of transects were managed to sample the species and track their presence, abundance and the soil type.

Method of transects, more suitable with the study area feature, especially in this mountainous topography, was used. In total we realized 37 transects with different size comprised between 200 m and 500 m. Transects were linear, along which species were gathered and numbered. Inside each transect we created 5 plots, each of about 100 m^2 depending on the environmental characteristics (slope, river presence, rockiness etc.) (Figure 2). In each plot data were collected: coordinates, species presence-absence, soil type, etc. Sampling was carried out within the different Geopark's habitats, especially Aleppo pine (*Pinus halepensis* L.) forests, Holm oak (*Quercus ilex* L.), cushions of xerophytes, red juniper (*Juniperus phoenicea* L.) associated with *Tetraclinis*. In the field work, the species were recognized, sampled and classified. This phase is the most crucial being the basis of the investigation, with the identification and localization of the species, using the practical flora of Morocco (Fennane & Ibn-Tattou, 1998, 1999), the Synonymic Index of the flora of North Africa (Dobignard & Chatellain, 2010, 2011a, 2011b, 2013). Classification adopted was the APG III and APG IV(The angiosperm phylogeny group, 2009, 2016).

Climate

The climate parameters (precipitation, mean, minimum and maximum temperatures) and GIS (Geographical Information System) data were gathered. After, maps of topography, precipitation, temperatures, climate and bioclimate, geology and soils were realized. The results were then combined by projecting plants coordinates plots on these maps. Determining the different locations of each species and its extent allow the determination of its autecology by restoring the climate features (Precipitations, Tmin and Tmax), bioclimate, lithological, and topography using the superposition of layers under ArcMap software, and the distribution of species.

Statistical Analysis

The DEM (Digital Elevation Model) of the study area is used to determine the altitudes and elevations from USGS site (Usgs, 2022), the geological map is used to summarize the main substrates (Commission de Topographie marocain, 1971), and the site Worldclim serves as the climate data source (Fick & Hijmans, 2017).

The bioclimatic map is built using the Pluviometric Quotient (Q2) of Emberger (1930) for the Mediterranean climate zone: Q2= (P*2000)/(T-t) (T+t)

Where P represents the total annual precipitation, T is mean maximum temperatures for the warmest month and t is mean minimum temperatures for the coldest month (Marres, 1930). The Q2 permits the characterization of the different bioclimatic zones, and t the minimal temperature of the coldest month allows the definition of the climatic variants (Daget, 1977; Quézel & Barbero, 1982). The Mediterranean vegetation strata (see Figure 11: thermo-Mediterranean, meso-Mediterranean, supra-Mediterranean, etc.) are related to the vertical plant distribution, build basing on the correspondence created by Emberger, Quezel and Berbero (Achhal et al., 1979).

In order to track the vegetation status through the region, we will use the IUCN Red List Criteria (International Union for the Conservation of Nature), the package Red List "taxize" in R allows to determine the species categories (Chamberlain et al., 2022). The IUCN categories and criteria classify species into nine groups: Extents (EX), Extent in the wild (EW), Critically endangered(ED), Endangered (EN), Vulnerable (VU), Near Threatened (NT), Least Concern (LC), Data Deficient (DD), and Not evaluated (NT) (IUCN, 2022).

CCA (Canonical Correspondence Analysis) is used to study statistically the dependency of the medicinal and aromatic

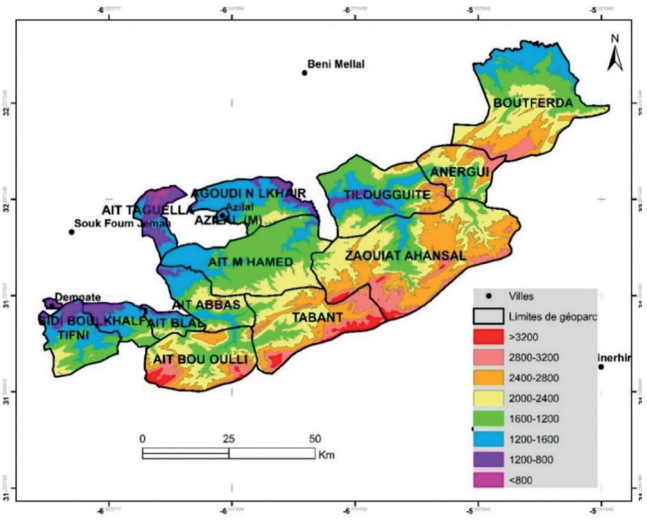

Figure 3. Geopark M'Goun altitudes map.

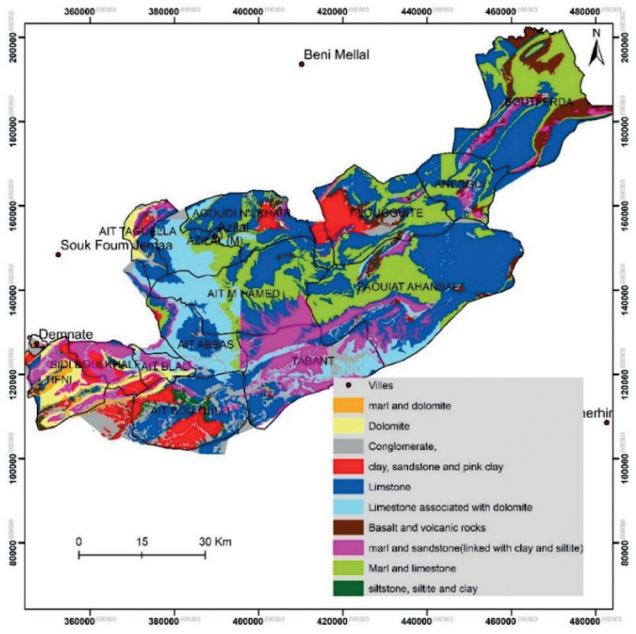

Figure 4. Different substrate types of the Geopark M'Goun.

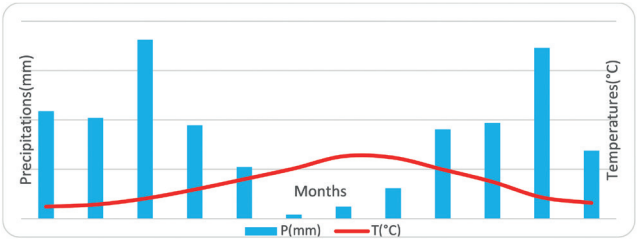

Figure 5. Climogram of Demnat, 900m.

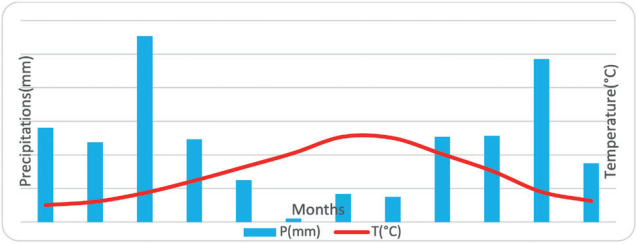

Figure 6. Climogram of ZaouitAhensal, 2000m.

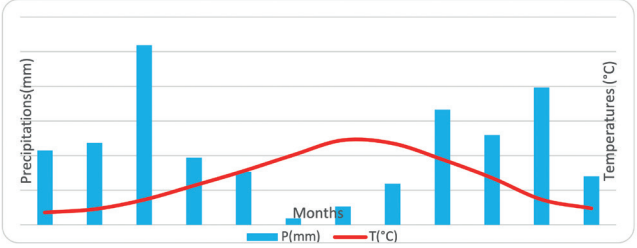

Figure 7. Climogram of AitBougmmaz (Tabant, 1866 m).

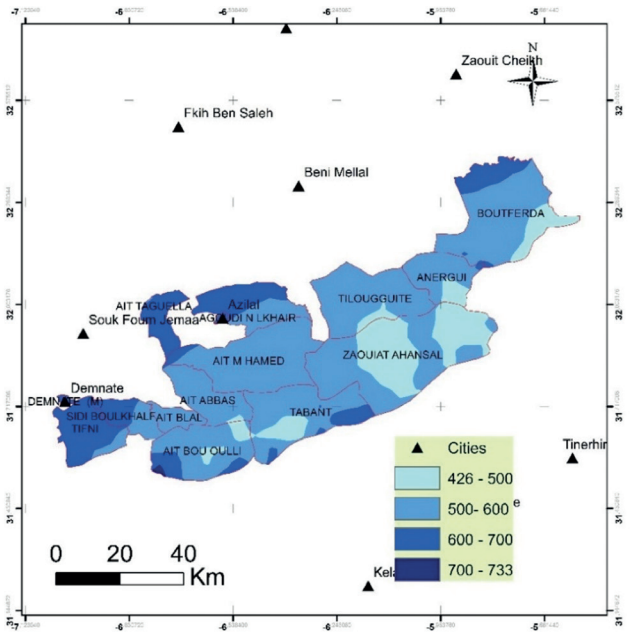

Figure 8. Precipitation map of the study area. Precipitation varies widely throughout the study area, ranging from 400 mm to 730 mm.

plants richness on the environmental factors. Since its debut in 1986 (Pillsbury & Miller, 2008), CCA has become one of the most popular multivariate methods in community ecology (Xia, 2020). This technic represents a multivariate procedure to elucidate the relationship between species and their environment (Ter Braak and Verdonschot, 1995), assuming a reasonable unimodal response curve of *taxa* to environmental variables (Xia, 2020). CCA is used when species are directly related to measured environmental factors and to explain the species distribution in the context of environmental data (Cao et al., 2011). The Past software is used for running CCA.

Results

Topography and substrates

The altitudes oscillate between 539 m and 3695 m a.s.l.. The average altitude is 1588 m. Moving southward, the topography becomes more pronounced (Figure 3).

The Azilal region's territory is a complicated area with significant substrate complexity, exposing a variety of magmatic rocks, red siltites, evaporites, and basalts underlined by limestone formations, marl, and clayey-sandstone. In general, the regions of Demnate, Azilal, and AitBoulli are characterized by detrital formations and associated with red clays and sandstones as substratum. In addition, the majority of the Geopark area is formed by carbonate formations: limestone, dolomite, or both combined (Figure 4).

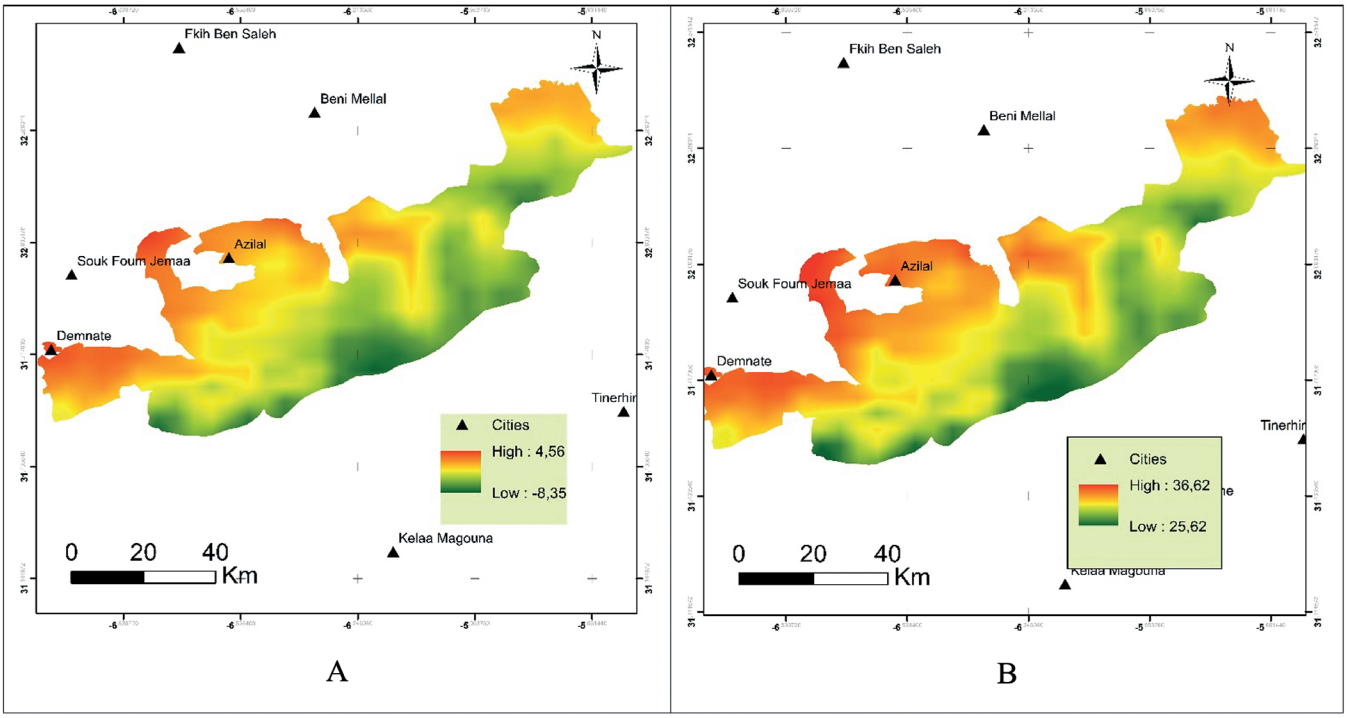

Figure 9. Temperature fluctuation in the study area. A: minimum temperature variation and B: maximum temperature variation.

Climate data

The climate of the study area is characterized by a hot and dry summer and a wet and cold winter, which demonstrates its Mediterranean character (Figures 5, 6, 7).
The temperatures vary considerably inside the geoparc M'Goun; the minimum temperatures oscillate between -8.35 and 4.56 °C, concerning the maximum temperatures, the enregistered values vary from 25.62 to 36.62 °C (Figure 9 A, B).

Bioclimate Variables

The region exposes two bioclimate types: semi-arid and subhumid; the semi-arid has a cold, fresh, and temperate winter in the low elevations and a very cold winter at the top of the mountains; however, the sub-humid in the rest of the Geopark has three winter varieties: cold, very cold, and fresh (Figures 9, 10). The region contains five bioclimatic zones: Oro-Mediterranean, mountain Mediterranean, supra-Mediterranean, meso-Mediterranean and thermo-Mediterranean (Figure 11).

Medicinal and aromatic plants

A wide variety of habitats was found in the M'Goun Geopark region, including oak groves, *Juniperus* woodlands, *Tetraclinis* matorral, pine forests, lawns, and thorny xerophytes formations. These habitats are extremely abundant in fragrant and therapeutic species: on a total of 396 species, 47 were classified as aromatic and medicinal plants, representing almost 12%.

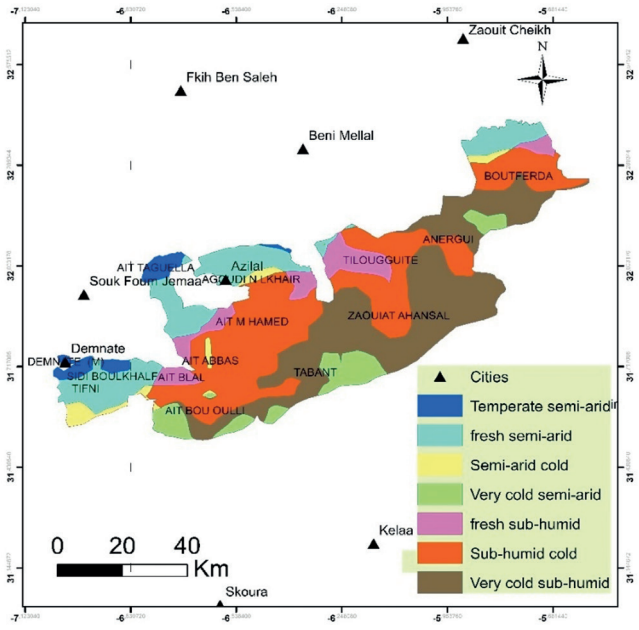

Figure 10. Bioclimatic map derived by Pluviometric quotient of Emberger.

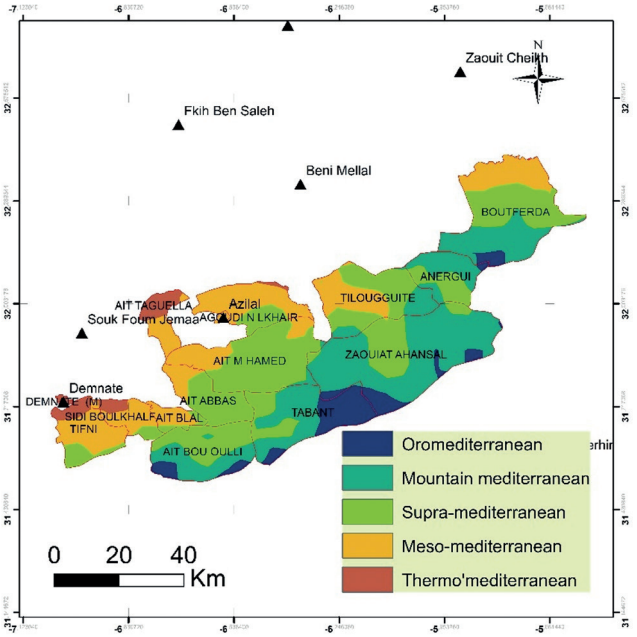

Figure 11. Map of vegetation bioclimatic zones.

Species are reported below in Table 1:

Families	Species
Lamiaceae	*Thymus satureioides* L. *Rosmarinus officinalis* L.* *Mentha pulegium* L. *Mentha spicata* L.* *Marrubium vulgare* L. *Thymus algeriensis* Boiss. &Reut *Thymus zygis* L. Mentha rotundifolia L. Salvia verbenaca L. *Verbena officinalis* L. Salvia officinalis L.* Ballota hirsula L. Thymus pallidus Coss. *Ziziphora hispanica* L. *Micromeria hochreutineri* Briq. *Ajuga iva* L.
Lauraceae	*Laurus azorica* L.
Aceraceae	*Chamaerops humilis* L.
Erecacea	*Arbutus unedo* L
Compositae	*Lavandula multifida* L. *Globularia alypum* L. Artemisia *herba-alba* L. *Pseudognaphalium luteoalbum L.* Ormenis scariosa *Ball.* *Anacyclus pyrethrum* L. *Cladanthus arabicus* (L.) Coss Globularia arabica L.
Myrtaceae	*Myrtus communis* L.*

Cupressaceae	*Juniperus oxycedrus* L. *Juniperus phoenicea* L. *Juniperus thurifera* L Tetraclinis articulata (Vahl) Mast.
Anacardiaceae	*Pistacia lentiscus* L.
Rosaceae	*Crataegus azarolus* L. *Rosa canina* L.
Fabaceae	*Ceratonia siliqua* L.
Iridaceae	*Crocus sativus* L.*
Euphorbiaceae	*Euphorbia resinifera* L.
Caryophyllaceae	*Silene vulgaris* Gracke
Oleaceae	*Olea europaea* var. *europaea sylvestris* L.
Rhamnaceae	*Ziziphus lotus* L.
Amaranthaceae	*Dysphania ambrosioides* L*.
Géraniaceae	*Pelargonium graveolens* L*.
Cistaceae	*Cistus albidus* L. *Cistus creticus* L. *Cistus lauriflorus* L.
Capparaceae	*Capparis spinosa* L.

*Cultivated species.

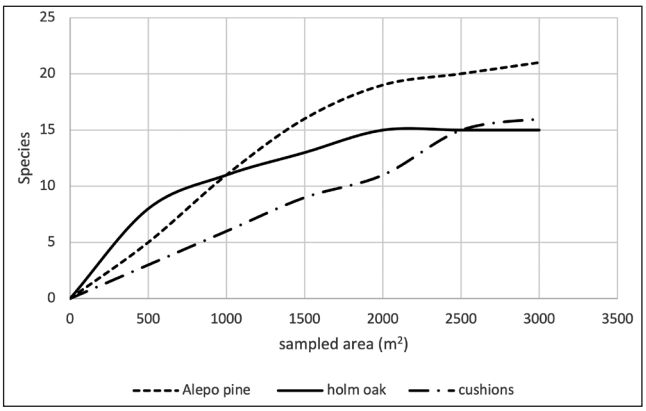

Figure 12. Species-area plot.

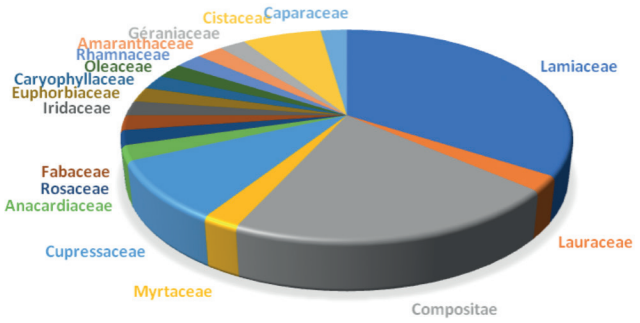

Figure 13. Medicinal and aromatic plants distributed by family**.**

Three distinct habitats are used to build the area-species relationship; Aleppo pine, Holm oak and xerophyte cushion. The curves show a variability of the species richness in each habitat type: Aleppo pine forests (*Pinus halepensis* L.) present the highest species richness, followed by cushions vegetation and finally holm oak forests (*Quercus ilex* L.) (Figure 12).

Within the M'Goun UNESCO Geopark, there are roughly **47** species of aromatic and medicinal plants, at least 6 of which are cultivated, namely *Rosmarinus officinalis* L., *Verbena officinalis* L., *Myrtus communis* L., *Pelargonium graveolens* L., *Salvia officinalis* L. and *Mentha spicata* L. *Lamiaceae* family shows the highest species number (16), followed by *Asteraceae* (9), *Cupressaceae* (4), *Cistaceae* (3), *Rosaceae* (2) and other families have one species each (Figure 13).

Canonical Correspondence Analysis (CCA)

In the CCA diagram the environmental variables are represented by arrows, species by spots: variability of the species distribution in the study area is also showed (Figure 14).

CCA1-horizontal axis represents 40.25 % of variance (p=0.006), CCA2-vertical axis 29.83% (p=0.001), CCA1 and CCA2 represent an accumulation variance of 70.08%.

CCA planes show the environmental factors correlated to species pattern. The most of species are distributed along the axis 1 which in fact explains the higher variance value. CCA1 is positively correlated with climatic variables (Tmin, Tmax, Precipitation) and with silicate substrate type; species distributed in this upper right sector of the diagram are *Cladanthus arabicus, Pistacia lentiscus, Cistus albidus, Ceratonia siliqua, Olea oleaster* etc. (see Figure 14); axis1 is negatively correlated with altitude and carbonate substrate type; species distributed in this upper left sector are *Ormenis scariosa, Juniperus thrurifera, Crategus azarolus* etc.(see Figure 14). CCA2 doesn't show significant correlations between environmental factors and species pattern.

The most of species present in the Geopark area are herbaceous aromatic and medicinal plants (Table 2). The lawns, in particular, host herbaceous species, among which different species of *Thymus* (*Thymus pallidus* Coss., *Thymus algeriensis* Boiss. & Reut., *Thymus zygis* L.), developing every year during the spring and summer, then disintegrating at the end of the year to survive during the cold season as roots. Also *Scorsonera* sp. and many *Poaceae* species colonize this habitat.

Red juniper (*Juniperus phoenicea* L.) occurred under the holm oak distribution area and may reach 1820 m a.s.l.. The

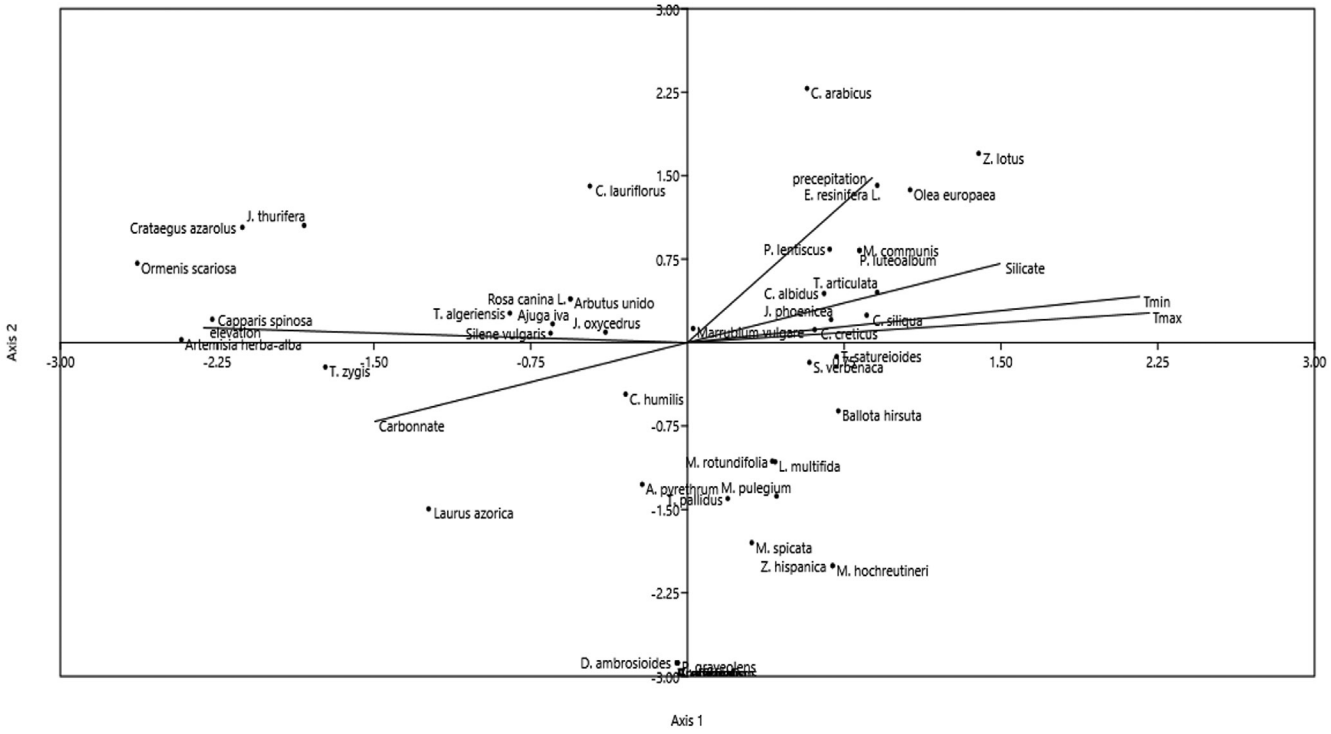

Figure 14. Relationship between species and environmental variables in the CCA plane.

Table 2. Aromatic and medicinal plants Autecology.

Species	Associated vegetation	Altitudes	Type of substrate	Climatic variants	Bioclimatic zone	Precepitaton (mm)
***Juniperus phoenicea* L.** Berber name: Kizou Arabic name: Araar	Forests and matorrals where it is the most remarkable species	reaches 1800 m	All types, essentially calcareous soils	Temperate Fresh	*Semi-arid*	500-700
Tetraclinis articulata L Berber name: Aarar Arabic name: Laaràra	Forests and matorrals; co-existes with J. *phoenicea*	Reaches 1500 m	Clay and limestone soils	Temperate Fresh	*Semi-arid*	400-600
***Juniperus thurifera* L** Berber name: Tawalt Arabic name: Laarar lfawwah	Deteriorated woodlands among the cushion of thorny xerophytes	From 1800 m	Limestone	Cold Very cold	Sub-humid	400-500
***Ceratonia siliqua* L** Berber name: Tikit, Tichit Nom Arabe: Lkherroub	Associated with juniper, oak, and thuja trees	Reaches 700m	Clays and limestones	Temperate Fresh	Semi-arid	500-700
***Olea europaea* var. *europaea sylvestris* L** Berber name: Azemmour Arabic name: Zittounberri	Associated with carob tree, thuja, juniper, mastic tree…	Presents at 1200 m	clays l, rocky cliffs and soils with calcareous mother rock.	Temperate Fresh	Semi-arid	400-700
***Juniperus oxycedrus* L.** Berber name: Tikki	It appears on degraded oak groves	From 1080m, abundant at 1250m and persists to 2100m	Limestone and clay	Cold Fresh	Sub-humid	500-600
***Laurus azorica* L.** Berber name: Taslt Arabic name: Asat Sidna Moussa	Rocky cliffs where access is extremely difficult	From 1650 m	Limestone and dolomite	Cold	Sub-humid	500-600

***Arbutus unedo* L.** Berber name: asasnou Arabic name: sasnou	Coexists with holm oak in the fresh zones	1570 m	Limestone	Fresh	Semi-arid	About 600
***Pistacia lentiscus* L.** Berber name:Tidit Nom Arabe : Drou	red juniper, thuja formations and the presence of holm oak	reaches 1600 m	Limestone and clay	Fresh	Sub-humid	400-600
***Crataegus azarolus* L.** Berber name: Admam Arabic name: Zaarour	holm oak forests and clearings	From 1700m	Limestone	Cold Fresh	Semi-arid	500-600
***Ziziphus lotus* L.** Berber name: Azeggour Arabic name: Sedra	In the hottest and most arid regions of the Geopark	Sampled up to 1300 m	Clay	Temperate Fresh	Semi-arid	600-700
***Rosa canina* L.** Berber name: Taghfert	Moist and well-drained habitat	Reaches 1600 m	Clays, dolomite and calcareous	Fresh	Sub-humid	700
***Capparis spinosa* L** Arabaic and berber name: Lkbbar	Cliffs and rocky area	1400 m to 2000m	Carbonates	cold	subhumid	400-600
***Euphorbia resinifera* L** Berber name: Tikiwt, Tichiwt Arabic name: Zeggoum	Colonizes the sunny slopes and cliffs, where co-exisst with carob trees and thuja, holm oak etc.	From 700 m to 1950 m in sheltered zone and warm areas	Limestone	Temperate Fresh Cold	Semi-arid	500-600
***Chamaerops humils* L.** *Berber name:Tgzdemt* *Arabic name:Doum*	Exposed slopes, degraded forests, and cliffs	From 1200 to 2050 m	Limestone and clays	Fresh Cold Temperate	Semi-arid Sub-humid	400-700
***Globularia alypum* L.**	Formations of thuja and red juniper	1800 meters in the Zaouit Ahensal region	Clay soils	Cold	subhumid	400-600
***Globularia arabica* L.**	Rocky and cliffy areas with less vegetation.	From 1100 m	Calcicole	Fresh	Semi-arid	400-600
***Cistus albidus* L.** Berber name: Irguel	Mostly inhabits holm oak forests	reach 1400 m.	calcareous, less prevalent on silicate soils	Fresh	Sub-humid	400-500
***Cistus creticus* L.** Berber name: Irguel	associated with *Cistus albidus* sharing similar habits	sampled until a height of 1600 meters.	Limestone	Fresh	Sub-humid	400-500
***Cistus lauriflorus* L.** Nom berbère : Irguel	Mountains and sunny slopes	Reaches 1500m	All types of soil	Fresh Cold	Sub-humid	500-600
***Thymus satureioides* L** Berber name: Azouknni Arabic name: Zaitra	Aleppo pine, holm oak, red juniper, on open areas, or in matorrals	Up to 2100 meters in ZaouitAhensal. And 1500m in Demnat	Limestone, clay and rocky soils	Fresh	Sub-humid and semi-arid	500-700
***Thymus algeriensis* L** Berber name: Tazouknit Arabic name: Zaitra	either in open regions or places with less extensive oak cover	1800 m, discovered at Tillouguit	Limestone	Fresh Cold	Sub-humid and semi_ aride	500-600
***Thymus zygis* L** Berber name: Tazouknit Arabic name: Zaitra	either in open regions or places with less heavy oak cover	sampled at Tillouguit at an elevation of 1700 m	Limestone	Cold	Sub-humid	400-600
***Thymus pallidus* Coss.** Berber name: Azouknni Arabic name: Zaitra	Clearings, rocky regions, and uncultivated fields	From about 1600 m to 2500 m	Limestone	Cold	Sub-humid	500-600

***Marrubium vulgare* L.** Berber name: Merrouyn Arabic name:Merroyt	Oak woodlands and their clearings	Sampled between 1100m and 1900m	Limestone	Cold Fresh	Sub-humideznd semi arid	500-600
Lavandula multifida L. Berber name: lkhzama Arabic name: Lkhzama	Open area and wadis	About 1800	Siliceousclay	Fresh	Subhumid	500-600
Artemisia *herba-alba* L Berber name: Tafsit, chiba. Arabic name: Chih	Juniper matorrals and clearings	Abundant at altitudes of 1800-1900 m	Limestone and dolomite	Cold Very cold	Sub-humid	500-600
Ormenis scariosa Ball. Location Berber name: Idzghi	Thorny xerophyte habitats	emerges at 1900 m common at 2500 m.	Limestone	Cold Very cold	Sub-humid	500-600
***Mentha pulegium* L.** Berber name: flio Arabic name:Flio	Wetlands (riverbanks and springs)	between 1200 and 1700 m	All soil types	Fresh	Sub-humid and semi-arid	hydrophile
***Micromeria hochreutineri* Briq.**	Degraded holm oak forests and open zones	1800 m	Limestone	Cold	Sub-humid	400-600
***Cladanthus arabicus* L.**	Shape of seasonal pastures during spring	Low altitudes in the region of Demnate	Clay soils	Temperate	Semi-arid	500-600
Mentha rotundifolia L Berber name: Timijja Arabic name: Mrsita	Wetlands (rivers and springs)	abundant at 1600 meters and can reach 2000 meters	All soil types, abundant in carbonates.	Cold Fresh	subhumid	hygrophyte
***Anacyclus pyrethrum* L.** Berber name: Aguendis Arabic name: Oud al attas	Grows naturally on clearings or uncultivated parts of fields	From 1000 to 2500 m	Limestone	Cold Fresh	Sub-humid	500-600
Silene vulgaris Berber name: Taghighacht Arabic name: Taghcht	Holm oak in clearing and fields	Wellabundant at 1800 m	Limestone	Cold	Sub-humid	500-600
***Ziziphora hispanica*L.** Berber name:Taflayout	Open areas, degraded matorrals or forests	1500 to 1700m	Limestone	Cold	Sub-humid	500-600
Ajuga iva L. Berber name:Touftlba	Rocks and rocky soil	Appears from 1800 m	Limestone	Fresh Cold	Sub-humid	500-600
Ballota hirsula L.	Inhabit the red clay and rocky soils	Reaches 1600m	clay	Fresh	Semi-arid	500-600
Salvia verbenaca L	Widespread, especially colonizes open areas	From 1200m to about 2000 m	Various soil types	Fresh and cold	Semi-arid and sub-humid	400-700
Pseudognaphalium luteoalbum* *L	Rocky and sandy soils	Sampled in 1600m	Limestone	Cold	Sub-humid	500-600
***Mentha spicata* L** Berber name : Naȧnaȧ Arabic name Naȧnaȧ	Cultivated	All elevations	All soil types	fresh and cold	Semi-arid and sub-humid	Irrigated
***Verbena officinalis* L**	Cultivated	Thrives in low elevations about 1200m	All soils types	Fresh	Semi-humid	Irrigated
Salvia officinalis L Arabic and berber name:Lwiza	Cultivated	1500 m	Various soil types	Fresh	Semi-humid and semi-arid	Irrigated

***Crocus sativus* L** Arabic and berber name: Zaàfran	Cultivated	Low altitudes	Sandy and loamy soils	Fresh	Semi-arid	Irrigated
***Dysphania ambrosioides* L** Arabic and berber name: Mkhinza	Cultivated and thrives next polluted steams	About 1300 and 1500	Organically rich soils	Cold and fresh	Semi-humid	Irrigated and humid areas
***Pelargonium graveolens* L** Arabic name *: àtarcha*	Cultivated	About 1400	Sandy and loamy soils	Fresh	Semi-humid	Irrigated
***Rosmarinus* officinalis L** Beber name: Azir Arabic name: Iklil ljabal	Cultivated and natural in the poor rocky open areas	All altitudes lowlands and uplands	Sand and clay soils	Fresh and cold	Semi-arid and humid	400- 500
***Myrtus communis* L** Arabic name: Rihan	Cultivated	Low altitudes	Various soil types	Fresh	Semi-arid	Irrigated

Berberian thuja (*Tetraclinis articulata* (Vahl) Mast.) appears at low elevations and reaches 1500 m a.s.l.; it forms forests and matorrals where it is remarkable the presence of species at low altitudes; then *Cistus* spp. leave the area gradually to the red juniper. *Globularia* and *Lavandula* species are widely distributed in these woodlands (mainly *Glubularia alypum* L. and *Lavandula multifida* L.).
Alyssum, Genista, Cytisus, and *Astragalus* are a few of the numerous *genera* of thorny xerophytes that can be found at high altitudes above 1800 m. *Ormenis* and *Thymus* are the relevant aromatic plants at this level, *Ormenis scariosa* emerges at 1900 m in the Zaouit Ahensal region, where reaches the highest abundance values at 2500 m, forming the cushion plants habitat occurring in particular places, presenting optimal environment condition such the soil deepness, protection from the wind, with a greatest abundance. Additionally, there are few isolated *Juniperus thurifera* trees spread across these cushions, which create altered woodlands in the Tillouguit, Zaouit, Ahensal, and Anergui regions.

Discussion

Species richness

Results demonstrated that species richness detected in the study area is generally high. Three habitats were selected to test the trends of the relation species/area (MacArthur & Wilson, 1967): *Pinus halepensis* forests and cushion xerophytes formations showed coherent patterns, while in *Quercus ilex* forests, when area size exceeds 2000 mq, species number no longer increases. Evidently, in a forest keeping homeostatic capacity in balance with climate and soil, species number has a threshold in correspondence of a certain area extension. On the contrary, in more open vegetation like *Pinus halepensis* forest and cushion xerophytes formations, species access is more influenced by the area size.

Aromatic/Medicinal plants

As regards aromatic and medicinal species, it is remarkable that the highest species richness was found in the *Lamiaceae* family (Figure 13), supporting a study carried out in Greece (Cheminal et al., 2020) where authors proved that this *taxon* is of great importance for its chemical composition and properties. So, also in Morocco *Lamiaceae* species can improve ecosystem services increasing the cultivation, *f.i*., of *Rosmarinus officinalis, Salvia officinalis. Mentha spicata*.

Relationship between species and environmental factors

In order to evaluate which environmental factors more influence richness and distribution of aromatic/medicinal species, CCA results demonstrated that Temperature, Precipitation, Altitude and substrate type were the most significant. Axes 1 and 2, representing a high value of accumulation variance (70.08%), explain the species distribution in the CCA diagram (Figure 14). Axis 1 was positively correlated with climatic variables (Tmin, Tmax, Precipitation) and with silicate substrate type; negatively with carbonate soil types (limestone, dolomite) and altitude. Species like *Cladanthus arabicus, Pistacia lentiscus, Cistus albidus, Ceratonia siliqua, Olea oleaster* are dominant on silicate soils, sunny slopes, forest clearings, hot shrublands and matorral.
The species group distributed on the left CCA sector is well adapted to carbonate soils and important elevations: *Ormenis scariosa*, *Artemisia herba-alba*, *Crataegus azarolus*, *Juniperus thurifera*, *Capparis spinosa* and *Thymus zygis,* belonging to xerophytes habitat. A second group is

Table 3. IUCN species categories.

Species	IUCN Categories
Rosmarinus officinalis *Mentha pulegium* *Mentha spicata* *Thymus zygis* *Verbena officinalis* Salvia officinalis *Laurus azorica* *Globularia alypum* *Pseudognaphalium luteoalbum* *Myrtus communis* *Juniperus oxycedrus* *Juniperus thurifera* *Pistacia lentiscus* *Crataegus azarolus* *Rosa canina* *Chamaerops humilis* *Ceratonia siliqua* *Silene vulgaris* *Cladanthus arabicus* *Arbutus unedo*	LC
Marrubium vulgare *Juniperus phoenicea* *Olea europaea*	NT
Mentha rotundifolia *Anacyclus pyrethrum*	VU
Tetraclinis articulata	EN
Thymus satureioides *Thymus algeriensis* Thymus pallidus Artemisia *herba-alba* Ormenis scariosa *Crocus sativus* *Euphorbia resinifera* *Ziziphus lotus* *Dysphania ambrosioides* Ballota hirsula *Pelargonium graveolens* *Cistus albidus* *Cistus creticus* *Cistus lauriflorus* *Capparis spinosa* Globularia arabica Salvia verbenaca *Lavandula multifida* *Ziziphora hispanica* *Micromeria hochreutineri* *Ajuga iva*	NE

represented by species moderately influenced by altitude: *Laurus azorica*, *Silene vulgaris*, *Thymus algeriensis*, *Rosa canina, Arbutus unedo*, *Ajuga iva*, *Cistus laurifolius*, *Juniperus oxycedrus*, *Anactylis perethrum*, *Chamaerops humilis*; the most of these species are spread in holm oak habitat. In high altitudes *Laurus azorica* is reduced in solitary individuals, suffering its extensive exploitation that has confined its range to rocky cliff.

Species sensible to elevation like *Ceratonia siliqua*, *Tetraclinis articulata*, *Pistacia lentiscus*, *Phoenicea articulata, Thymus satureioides*, *Cistus albidus*, *Cistus creticus* inhabit especially the Aleppo pine, red juniper or *Tetraclinis* habitats. Other species don't tolerate high altitudes like *Euphorbia resinifera*, *Olea europaea* var. *europaea sylvestris* and *Ziziphus lotus,* colonizing the most arid and drought habitats in the Region.

The temperature plays an antagonist effect on species compared to elevation, since the temperature obviously decreases with altitude: these two climatic variables, displayed in fact on the opposite side of CCA1 (Figure 14), more influence the PAMs in the study area.

Mentha species were distributed on right side of CCA (Figure 14), correlated with silicate soils; generally, in fact, they were found on soils rich in silicates (clays) rather than carbonates.

In synthesis, according to bioclimatic stages (Figure 10), CCA results (Figure 14) and species autoecology (Table 2), we can summarize as follows:

vegetation referred to oro-Mediterranean stage is mainly characterized by xerophytes. The mountain Mediterranean level is inhabited by *Juniperus thurifera* and xerophytes, among which the most dominant PAM is *Ormenis scariosa*; it emerges at 1900 m. in the Zaouit Ahensal region, where reaches the highest abundance values at 2500 m, forming the cushion plants habitat occurring in particular places that are protected from severe climatic condition, with a greatest abundance. *Alyssum, Genista, Cytisus* and *Astragalus* are a few of the numerous *genera* of thorny xerophytes that can be found at high altitudes above 1800 m. Additionally, there are few isolated *Juniperus thurifera* trees spread across these cushions, which create altered woodlands in the Tillouguit, Zaouit, Ahensal and Anergui regions.

The supra-Mediterranean stage is mainly colonized by the sclerophyll forest of oak groves associated essentially with *Buxus*. The meso-Mediterranean stage is dominated by oak groves accompanied by *Juniperus oxycedrus*, Aleppo pine forests, and the top level of *Juniperus phoenicea*; this zone is highly rich in *Thymus* species and other PAMs (Table 2).

Finally, the thermo-Mediterranean stage is characterized by a large species diversity represented by *Juniperus phoenicea, Tetraclinis articulata*, *Ceratonia siliqua*, *Olea oleaster*, *Pistacia lentiscus, Ziziphus lotus* etc. (see again Table 2).

The distinctive MAP of the Ait Bougmaz region is Artemisia (*Artemisia herba-alba* L.); it grows primarily on limestone substrates on the borders of wadis and mountain slopes, as well in uncultivated areas with less grazing. The pyrethrum (*Anacyclus pyrethrum* (L.) Link), which is practically extinct, is found on limestone grounds above 1800 meters. However, trials of its cultivation on these grounds were successful. The *Capparis spinosa* L. species also inhabits the cool cliff areas.

In the Tillouguit region and in the center of the Geopark, the dwarf palm (*Chamaerops humilis* L.) colonizes the sunny slopes in the form of circular colonies linked to holm oak degraded areas. In the region of Ouzoud, Demnate and Azilal, *Euphorbia resinifera* L. thrives on calcareous exposed slopes and cliffs, reaching 1900 m in the warm and protected zones. *Zyziphus lotus* is also confined to the hottest and most arid sites. Moving southward, in the Anergui and ZaouitAhensal regions, the slopes are characterized by cushions of *Genista* species.

JUCN Evaluation

The study showed that most of the species (44%) are not evaluated in the IUCN Red List (Table 3); this may affect negatively the conservation plans, however, the 42% of species are not affected by the exploitation or is slightly exploited. In addition, three aromatic and medicinal species in the region are near threatened (*Marrubium vulgare, Juniperus phoenicea, and Olea europaea)*, 2 are vulnerable (*Mentha rotundifolia*, *Anacyclus pyrethrum)* and one is endangered (*Tetraclinis articulata)*.

The overexploited species in the region are *Thymus satureioides* L, *Juniperus oxycedrus* L, *Artemisia herba-alba* L, *Marrubium vulgare* L, *Anacyclus pyrethrum* L.; therefore, the control of their harvest is required. Some of these species are not indexed in IUCN Red List, like *Thymus satureioides,* a threatened species (Rankou et al., 2020). Other plants, particularly the trees with poor renewal rates, as thurifer juniper, suffer of intensive deterioration for therapeutic purposes and tar manufacturing; they are threatened in relation to overexploitation.

The spontaneous growth of several natural species demonstrates their optimal adaptation to the Geopark's ecological conditions. Initiatives for the production and marketing of one of the most valuable fragrant plants have recently been established in the Geopark and the Azilal region. Saffron (*Crocus sativus* L.) has been dubbed the "Red Gold" and trials of its introduction have yielded positive results.

Conclusions

The region is home to a large specific richness in general, and aromatic and medicinal species particularly as a result of a set of environment variables and ecological diversity. The M'Goun Geopark region, Azilal in general, and other locations with comparable characteristics (the Atlas) present potentialities and chances for investment in several agricultural fields, particularly the still-young and promising field of aromatic and medicinal plants. Aside from that, individuals are adapting their lifestyles to include the use of bio products, healthy practices, and environment protection. Since the activity of the population directly depends on the forest, there are numerous threats to the natural resources in this area. Therefore, by supporting initiatives to cultivate aromatic plants, new revenue streams can be generated, easing the constant strain on natural resources, these plants should be managed rationally, support and monitoring programs should be developed.

References

Achhal A., Akabli A., Barbero M., Benabid A., M'Hirit O., Peyre C., Quézel P., Rivas-Martinez S., 1979. À propos de la valeur bioclimatique et dynamique de quelques essences forestières au Maroc. Ecologia Mediterranea 5(1), 211-249.

Agence Marocaines des plantes aromatiques et midécinales, 2020. Rapport sur les plantes aromatiques et midécinale, in Rapport sur les plantes aromatiques et midécinale.

ANPAM, 2020. Etude sur le secteur des Plantes Aromatiques et Médicinales dans la Réserve de Biosphère Intercontinentale de la Méditerranée. Edited by Bureau d'Etudes TTOBA. Agence pour la Promotion et le Développement Economique et Social des Provinces du Nord.

Association du Géoparc du M'GOUN, UNESCO, 2019. Rapport d'activités du Géoparc UNESCO M'Goun.

Bouxin G., 2011. Analyse statistique des données de végétation. Revue des Sciences de l'Eau.

Cao H., Li M., Dang H., Gu J.D., 2011. Responses of aerobic and anaerobic ammonia/ammonium-oxidizing microorganisms to anthropogenic pollution in coastal marine environments. Methods in Enzymology 496, 35-62.

Chamberlain S., Szoecs E., Foster Z., Arendsee Z., 2022. Package 'taxize'. Taxonomic Information from Around the Web.

Cheminal A., Kokkoris I.P., Strid A., Dimopoulos P., 2020. Medicinal and Aromatic Lamiaceae Plants in Greece: Linking Diversity and Distribution Patterns with Ecosystem Services. Forests 11(6), 661.

CNEARC, DPA, ALCESDAM, 2004. Les plantes aromatiques, médicinales et tinctoriales. *Un atout pour le développement rural de la région de Tata?*. Centre National d'Etudes Agronomiques des Régions Chaudes. Etude n° 5.

Commission de Topographie marocain, 1971. Moroccan Geological Map.

Cowling R.M., Rundel P.W., Lamont B.B., Arroyo M.K., Arianoutsou M., 1996. Plant diversity in mediterranean-climate regions. Trends in Ecology & Evolution 11(9), 362-366.

Daget P., 1977. Le bioclimat méditerranéen: analyse des formes climatiques par le système d'Emberger. Vegetatio 34, 87-103.

Dobignard A., Chatelain C., 2010. Index synonymique de la flore d'Afrique du Nord Volume 1: Pteridophyta, Gymnospermae, Monocotyledonae. Ville de Genève, Éditions Des Conservatoire Et Jardin Botaniques, Genève, Switzerland.

Dobignard A., Chatelain C., 2011a. Index synonymique de la flore d'Afrique du Nord. Volume 2: Dicotyledoneae: Acanthaceae – Asteraceae. Ville de Genève, Éditions Des Conservatoire Et Jardin Botaniques, Genève, Switzerland.

Dobignard A., Chatelain C., 2011b. Synonymic index to the flora of North Africa. Volume 3: Dicotyledoneae: Balsaminaceae-Euphorbiaceae. Ville de Genève, Éditions Des Conservatoire Et Jardin Botaniques, Genève, Switzerland.

Dobignard A., Chatelain C., 2013. Index Synonymique de la Flore d'Afrique du Nord, Volume 5: Dicotyledonae, Oleaceae à Zygophyllaceae. Ville de Genève, Éditions Des Conservatoire Et Jardin Botaniques, Genève, Switzerland.

ELKacimi I.E., 2020. Plantes Aromatiques et Médicinales et Dérivés: Etat des lieux et Stratégie d'amélioration Cas expérimental: Stabilité de l'Huile Essentielle deThymus satureioides. Doctoral dissertation, Université Mohammed V de Rabat.

Fennane M., Ibn-Tattou M.,1998. Catalogue des plantes vasculaires rares, menacées ou endémiques du Maroc. Published under the auspices of OPTIMA by Herbarium Mediterraneum Panormitanum.

Fennane M., Ibn-Tattou M., 1999. Flore Pratique du Maroc. Vol 1. Institut Scientifique du Rabat.

Fennane M., Rejdali M., 2016. Aromatic and medicinal plants of Morocco: richness , diversity and threats. Bulletin de l'Institut Scientifique, Rabat: Section Sciences de la Vie 38, 27-42.

Fick S.E., Hijmans R.J., 2017. WorldClim 2: new 1-km spatial resolution climate surfaces for global land areas. International Journal of Climatology 37(12), 4302-4315.

Glèlè Kakaï R., Salako V.K., Lykke A.M., 2016. Techniques d'échantillonnage en étude de végétation. Annales des Sciences Agronomiques 20(1659-5009), 1-13.

HCEFLCD, 2018. Strategie nationale de developpement des plantes aromatiques et medicinales spontannees. Direction de développement forestier 1-31.

Hengeveld R., MacArthur R.H., Wilson E.O., 2002. (1967, reprinted 2001). The theory of Island biogeography. Acta Biotheoretica 50, 133-136.

Ionesco, J., Mateez, T., 1964. Climatologie, Bioclimatologie et Phytogeographie du Maroc. 1st edn. Rabat: Centre National de Documentation.

IUCN Standards and Petitions Committee, 2022. Guidelines for Using the IUCN Red List Categories and Criteria. Version 15.1.

MacArthur, R.H. Wilson E.O. 1967 (reprinted 2001). The Theory of Island Biogeography. Acta Biotheor 50, 133–136 (2002).

Marres P., 1972. Louis Emberger 1897-1969. In: Méditerranée, deuxième série, tome 9, 1-1972. pp. 1-4.

Medail F., Quezel P., 1997. Hot-Spots Analysis for Conservation of Plant Biodiversity in the Mediterranean Basin. Annals of the Missouri Botanical Garden 84(1), 112-127.

Ministry of Agriculture, 2005. Plantes Aromatiques ET medicinales : 'Note de Synthèse', Ministère de l'Agriculture du Développement Rural et des Pêches Maritimes (608), 1-9.

Pillsbury F.C., Miller J.R., 2008. Habitat and landscape characteristics underlying anuran community structure along an urban – rural gradient. Ecological Applications 18(5), 1107-1118.

Quézel P., Barbero M., 1982. Definition and characterization of Mediterranean-type ecosystems. Ecologia mediterranea 8(1),15-29.

Radi F. Z., Khamar H., Remok F., Amine S., Drioiche A., Aoudry S., Zekri N., Bouzoubaa A., Zair, T., 2022. Aromatic and medicinal plants in the Ifrane region (Morocco): Floristic diversity, with special emphasis on ethnobotanical and socioeconomic studies of six spontaneous plants. Journal of Pharmacy & Pharmacognosy Research 10(3), 517–550.

Rankou H., M'Sou, S., Ait Babahmad, R.A., Diarra A., 2020. Thymus saturejoides. The IUCN Red List of Threatened Species™.

Rhafouri R., Aafi A., Zair T., Strani B., El Omari M., Ghanmi M., Bentayeb A. 2015. Ethnobotanical study of medicinal plants in Ifran's National Park (Morocco). Journal

of Materials and Environmental Science 6(3), 619-630.

Scarascia-Mugnozza G., Oswald H., Piussi P., Radoglou K., 2000. Forests of the Mediterranean region : gaps in knowledge and research needs. Forest Ecology and Management 132(1), 97-109.

Taïbi A.N., El Khalki Y., El Hannani M., 2015. Atlas régional de la région du Tadla-Azilal. Angers: Université d'Angers.

Ter Braak C.J.F., Verdonschot P.F.M., 1995. Canonical correspondence analysis and related multivariate methods in aquatic ecology Canonical correspondence analysis and related multivariate methods in aquatic ecology. Aquatic Sciences 57(3), 255-289.

The Angiosperm Phylogeny Group, 2009. An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants: APG III. Botanical Journal of the Linnean Society 161(2), 105-121,

The Angiosperm Phylogeny Group, Chase M.W., Christenhusz M. J., Fay M.F., Byng J.W., Judd W. S., Soltis D.E., Mabberley D.J., Sennikov A.N., Stevens P.F., 2016. An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants: APG IV. Botanical Journal of the Linnean Society 181(1), 1-20.

UNESCO, 2015. Géoparc Unesco du M'Goun – Maroc. Qu'est ce qu'un Géoparc ?

USAID, 2006. Projet Partenariats Agricoles pour la Productivité et la Prospérité (AP3). Institut Agronomique et Vétérinaire Hassan II 1-6.

Usgs, 2022. Earthdata | Earthdata. Available at: https://www.earthdata.nasa.gov/ (Accessed: 25 January 2023).

Xia Y., 2020. Correlation and association analyses in microbiome study integrating multiomics in health and disease. Progress in Molecular Biology and Translational Science 171, 309-491.

Zrira, S. (2017). Some Important Aromatic and Medicinal Plants of Morocco. In: Neffati M., Najjaa H., Máthé Á. (eds), Medicinal and Aromatic Plants of the World – Africa Volume 3. Medicinal and Aromatic Plants of the World, vol 3. Springer, Dordrecht.