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By Miss. **RADJAI Aida**

TITLE

Inventory of the southern Cedar forest

of Bordj-Bou-Arreridj province

Floristic biodiversity –Ethnobotany –Conservation

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Dedication

I dedicate this work to my dear parents

my father Radjai Amor

and my lovely sister

To all my family and friends

Aida R.

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Thank Allah, the merciful and the passionate, for providing me the opportunity to undertake this research study and to persevere and complete it satisfactorily. My gratitude goes to my supervisor **Pr. ZEDAM Abdelghani** and my co-supervisor **Dr. SARRI Djamel** for their continuous guidance to accomplish this work and their efforts to improve this dissertation.

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جرد غابة الأرز الجنوبية لولاية برج بوعريريج

التنوع البيولوجي الزهري – علم النبات العرقي – الحفظ

ملخص

لحماية مجتمع النباتات من التدهور والتغيرات البيئية مثل الجفاف والضغوط البشرية في جبل معاضيد، وهو بيئة سهوب متبقية في تشكيل أرز الأطلس (*Cedrus atlantica*) في شمال الجزائر، من الضروري إحصاء وتقييم النباتات البرية الموجودة. سيساعد هذا في تشخيص الحالة البيئية الحالية للمنطقة وإيجاد استراتيجيات الحفظ لهذا التراث الطبيعي. تم أخذ عينات وفق منهاج موضوعي غير احتمالي في 73 مسحًا، وتم تحديد 174 نوعًا عبر 91 جنسًا و39 عائلة نباتية. المنطقة المتوسطية هي المنشأ الكوروجرافي السائد، وأكثر أشكال الحياة شيوعًا هي النباتات الحولية (45%). كشفت التحليلات العددية باستخدام مؤشر التشابه وتحليل المراسلة المنحرفة (DCA) عن مجموعتين من عينات النباتات ذات حالات بيئية متميزة تتعلق بالحرارة والرطوبة والارتفاع وخصائص الموقع. قد تلعب ثراء الأنواع المركزة في مسوحات نباتية محددة دورًا محليًا كبيرًا في الحفظ الموقعي للنباتات والموائل. يجب إعطاء أولوية لهذه المناطق ذات التنوع الأحيائي العالي للحصول على إجراءات حفظ عاجلة. وتدهور للأراضي والجفاف الناجم عن الأنشطة البشرية والتغيرات المناخية هو أزمة صامتة تؤثر على الناس والكوكب. سيكون وقف التدهور وتأهيل الأراضي المتدهورة من خلال الاستعادة مفتاحًا لتعزيز التنوع البيولوجي وإعادة تأهيل خدمات النظام البيئي والتخفيف من آثار تغير المناخ. يمكن للحلول التكنولوجية القائمة على الابتكارات العلمية والمعارف الأصلية، مثل تنويع المحاصيل والنباتات المقاومة للجفاف والحرث المخفف والري المحسن وطرق الحفاظ على الرطوبة، المساعدة في الحد من تدهور التربة وزيادة مرونة الزراعة تجاه تغير المناخ. إن حماية تشكيل أرز الأطلس والمجتمع النباتي المرتبط به في جبل معاضيد أمر بالغ الأهمية لحفظ التنوع البيولوجي وخدمات النظام البيئي وحقوق المجتمعات المحلية التي تعتمد على هذه الأراضي. هناك حاجة إلى نهج قائم على حقوق الإنسان وموارد مخصصة لتنفيذ اتفاقية مكافحة التصحر وتحقيق الأهداف الطموحة لاستعادة الأراضي.

الكلمات الرئيسية: أرز الأطلس، جرد النباتات، التحليل العددي، الحفظ، شمال أفريقيا

Inventory of the southern cedar forest of Bordj-Bou-Arréridj Province. Floristic Biodiversity – Ethnobotany - Conservation

Abstract

To preserve the plant community in the face of degradation and environmental changes like drought and human pressure at Djebel Maadid, a relic steppe environment in the Atlas cedar (*Cedrus atlantica)* formation in northern Algeria, it is crucial to inventory and assess the existing flora. This will help diagnose the current ecological state of the area and inform conservation strategies for this natural heritage. A systematic subjective non-probability sampling was conducted in 73 surveys, identifying 174 species across 91 genera and 39 botanical families. The Mediterranean region is the dominant chorological origin, and the most common life-form is Therophyte (45%). Numerical analyses using Similarity index and Detrended Correspondence Analysis (DCA) revealed two groups of plant samples with distinct environmental states related to temperature, humidity, altitude, and site characteristics. Species richness concentrated in specific vegetation surveys may play a significant local role in the in-situ conservation of plants and habitats. These areas of high species diversity should be prioritized for urgent conservation action. Desertification, land degradation, and drought caused by human activities and climatic variations are a silent crisis affecting people and the planet. Halting degradation and rehabilitating degraded land through restoration will be key to enhancing biodiversity, restoring ecosystem services, and mitigating climate change impacts. Technological solutions based on scientific innovations and indigenous knowledge, such as crop diversification, drought-resilient plants, reduced tillage, improved irrigation, and moisture conservation methods, can help reduce soil degradation and increase agricultural resilience to climate change. Protecting the Atlas cedar formation and the associated plant community at Djebel Maadid is crucial for preserving biodiversity, ecosystem services, and the rights of local communities who depend on these lands. A human rights-based approach and dedicated resources are needed to implement the Convention to combat desertification and achieve the ambitious goals of land restoration.

Key Words: Atlas cedar, Conservation, Flora inventory, Numerical analysis, North Africa

Etat des lieux de la cédraie méridionale de la wilaya de Bordj-Bou-Arréridj
Biodiversité floristique – Ethnobotanique - Conservation

Résumé

Pour préserver la communauté végétale face à la dégradation et aux changements environnementaux tels que la sécheresse et la pression humaine à Djebel Maadid, un environnement de steppe relicte dans la formation de cèdres de l'Atlas (*Cedrus atlantica*) dans le nord de l'Algérie, il est crucial d'inventorier et d'évaluer la flore existante. Cela permettra de diagnostiquer l'état écologique actuel de la région et d'informer les stratégies de conservation de ce patrimoine naturel. Un échantillonnage systématique subjectif non probabiliste a été réalisé lors de 73 enquêtes, identifiant 174 espèces réparties dans 91 genres et 39 familles botaniques. La région méditerranéenne est l'origine chorologique dominante, et la forme de vie la plus courante est le Thérophyte (45%). Les analyses numériques utilisant l'indice de similarité et l'Analyse de Correspondance Détenue (DCA) ont révélé deux groupes d'échantillons de plantes avec des états environnementaux distincts liés à la température, l'humidité, l'altitude et les caractéristiques du site. La richesse spécifique concentrée dans des enquêtes végétales spécifiques peut jouer un rôle local significatif dans la conservation in situ des plantes et des habitats. Ces zones de haute diversité spécifique devraient être priorisées pour une action de conservation urgente. La désertification, la dégradation des terres et la sécheresse causée par les activités humaines et les variations climatiques constituent une crise silencieuse affectant les populations et la planète. Arrêter la dégradation et réhabiliter les terres dégradées par le biais de la restauration sera essentiel pour améliorer la biodiversité, restaurer les services écosystémiques et atténuer les impacts du changement climatique. Des solutions technologiques basées sur des innovations scientifiques et des connaissances autochtones, telles que la diversification des cultures, les plantes résistantes à la sécheresse, la réduction du labour, l'amélioration de l'irrigation et des méthodes de conservation de l'humidité, peuvent aider à réduire la dégradation des sols et à accroître la résilience agricole face au changement climatique. Protéger la formation de cèdres de l'Atlas et la communauté végétale associée à Djebel Maadid est crucial pour préserver la biodiversité, les services écosystémiques et les droits des communautés locales qui dépendent de ces terres. Une approche basée sur les droits de l'homme et des ressources dédiées sont nécessaires pour mettre en œuvre la Convention pour la lutte contre la désertification et atteindre les objectifs ambitieux de restauration des terres.

Mots-clés : Analyse numérique, Afrique du Nord, Cèdre de l'Atlas, Conservation
Inventaire floristique

Introduction

Introduction

According to **Zhang *et al.* (2024)**, the ecological environment is fundamental to human survival and development and serves as the foundation for economic and social progress. In this fact the recognition of the flora and the plant diversity of a specific area are the essential foundation and starting points for any attempt to conservation **(Quézel, 1991)**. It constitutes an indispensable method to achieve the principle of sustainable development. Note that the Atlas cedar exists in a spontaneous state in North Africa where it is found in Algeria and Morocco **(Boudy, 1955)**.

In Algeria, it is found in central and eastern regions in different bioclimatic situations where the surface covered by cedar is very limited and its area is disjoint **(Bentouati, 2008)**. Its sub-humid facet at the limit of the cool and cold winter bioclimatic stage is dominant. It is located in Ouarsenis Mountains, Blidean Atlas, Djurdjura, Babors, Aurès and Hodna Mountains especially in Bou-Taleb and Maadid **(Mediouni and Yahi, 1989)**.

The Algerian surface area of cedar has further decreased **(Quézel, 1998)** and **Rabhi *et al.* (2018)** announce the surface of 33.000,00 hectares. Atlas cedar has always attracted great interest as an important species given its ecological importance and its many forestry qualities such as its low flammability, its production of high quality wood, and its resistance to climatic stress and drought **(Rabhi *et al.*, 2018)**.

Moreover, it contains great floristic richness and generates biocenosis diversity. This main tree has a great ecological value and is subject to degradation.

This degradation of the stands and the gradual thinning of the tree strata causes the cedar forest to evolve towards a preforest and mattoral type vegetation structure **(Quézel, 1998)** and even see a steppization state in the case of a total degradation **(El Bakkali, 2020)**.

The causes of this degradation are linked to climatic disturbances (drought, water stress, saharian influence), to anthropogenic action translated by overgrazing, uncontrolled exploitation, illegal cutting-collecting, and finally to the nature of certain substrates, such as marls, which appear very clearly unfavorable to the recovery of trees whose water retention capacity is relatively low **(Bentouati and Bariteau, 2006)**.

Our study focuses on the floristic diversity and geographic distribution of the cedar's vegetation species of Djebel Maadid cedar forest (Djebel in Arabic means Mountain) in southern of Bordj-Bou-Arreridj province situated in North-eastern Algeria.

The work is carried out following the ecological conditions and strives to preserve this biological community, in a vision of ecological strategy in line with a protection vision for the conservation of plants and the natural environment, by carrying out an inventory and trying to propose a way of protecting the flora and its study places.

This work was carried out according to a methodology consistent with the objectives of the work targeted in this study. It was carried out in two phases:

- A field prospecting with data collection with adequate sampling.

- The second phase concerns the identification of the taxa recorded, the analysis of data and the mapping of locations through the use of multidimensional analysis of data and the exploitation of satellite imagery through the use of the Normalized Difference Vegetation Index (NDVI) to delimit areas to conserve.

The document is structured into four chapters:

- The first concerns information about the atlas cedar species,
- The second treats the study area,
- The third interests materials and methods,
- And the last one is articulated around the results and their discussion.

CHAPTER I

The Atlas Cedar Species

CHAPTER I: THE ATLAS CEDAR SPECIES

1 Atlas cedar presentation

1.1 Atlas cedar presentation and classification

The Atlas cedar (*Cedrus atlantica Manetti*), “Arz Al Atlas” in Arabic and “Idil ; Begnoune” in Amazight, is a coniferous tree that can reach up to 40 meters in height. The medium is around 25 to 30 meters. Following **Aidrous (2007)**, the specie of *C. atlantica* is classified as below (Table 1).

Table 1:*Cedrus atlantica* Menetti classification according to **Aidrous (2007)**

Systematic unit	*Naming*
Branch	Spermaphytes
Under branch	Gymnosperms
Class	Vector
Order	Conifers
Family	Pinaceae
Subfamily	Abieteae
Tribe	Lariceae
Genre	Cedrus
Specie	*Cedrus atlantica Manetti*
English name	Atlas cedar
French name	Cèdre de l’Atlas

1.2 Botanical characteristics

The Atlas cedar is a spontaneous species of North Africa (Algeria and Morocco). It belongs to the endemic flora that grows in altitude habitats. it is a tree of first magnitude (its height well exceeds 20 meters).

The Atlas Cedar, depicted in Figure 1, features a conical crown that broadens as it matures, often reaching heights exceeding 60 meters and boasting a lifespan of up to 750 years or more. Its robust, deep taproot system contributes to its stability, while its bark, characterized by its thickness, rough texture, blackish hue, and deep furrows, aids in channeling rainwater to its roots. With ascending branches, this tree showcases evergreen needles typically arranged in rosettes of 30 to 40 stiff needles measuring 1 to 2 centimeters in length. Notably, it blooms at the conclusion of summer. Remarkably, each tree bears both male and female flowers: male catkins, ovoid in shape and 2 to 3 centimeters long, alongside smooth, resinous female cones that can grow up to 7 to 8 centimetres when mature. Three years post-flowering, these cones disintegrate, releasing winged seeds that disperse over considerable distances, leaving behind the cone axis for an extended period **(Benouaklil , 2018)** (Table 2).

Table 2:Botanical characteristics of the Atlas cedar

Needle size		1 to 2.5 cm
Cones	Length	5 to 8 cm
	Diameter	3 to 5 cm
Seeds	Seed length	0.8 to 1.3 cm
	Wingspan	2.5 to 3.5 cm
Pollination Period		May – September
Maturity period		2 years
Dissemination period		Winter

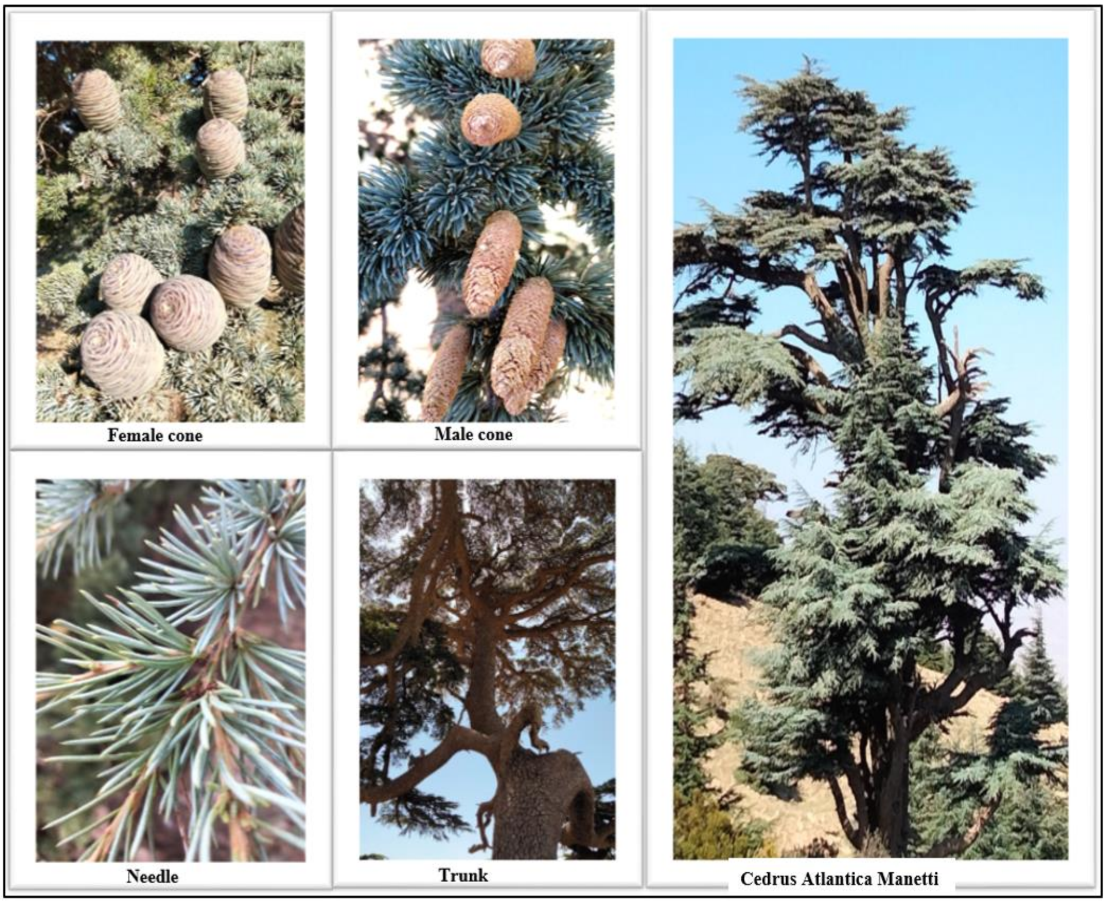


Figure 1: Botanical characteristics of the Atlas cedar tree.

1.3 The life conditions and the habitat of the Atlas cedar

The cedar groves develop in various climatic conditions, ranging from superior semi-arid to cool humid **(Berka, 1997)**. This species is spontaneous and accommodates on clay and silty soils. It endures drought and cold, extends, in sub-humid and humid bioclimatic atmosphere of the upper Mediterranean cold stage in the Middle Atlas, the Rif and the Aurès to the

Oromediterranean stage, extremely cold in the upper Atlas, but its bioclimatic optimum corresponds to the Mediterranean mountain range between 1600m and 2000m **(M'hirit, 1999)**. **Meddour (1994)**, repports that in Algeria, due to their proximity to the Mediterranean Sea and hence their softening effect, the Atlas Tellian cedars has a wetter and obviously milder climate than that of the southern cedar in Aurès–Belezma and Hodna Mountains. The majority are subjected to cold and very cold bioclimate (Table 3).

Table 3: Ecological characteristics of the North African Atlas cedar **(Meddour, 1994)**.

Types of cedar location	Latitude (N)	Altitudinal limits (m)	Annual Precipitations (mm)	Extremes temperatures (°C)	
				M	m
Western Rif	35°01 - 35°53	1400-2300	1390-1786	28,3 to 24,1	-5,6 to -0,2
Central Rif	34°55 - 35°35	1500-2400	1257-1707	28,8 to 23,7	-5,6 to -0,4
Eastern Rif	33°50 - 35°07	1700-2200	906-1311	26,6 to 24,6	-5 to -1,8
Medium-Tabular Atlas	33°08 - 33°44	1500-2000	871-1066	30,9 to 27,6	-4,7 to -0,5
Middle Eastern Atlas	32°36 - 33°05	1800-2000	615-927	28,7 to 26,5	-6,4 to -3,1
Eastern High Atlas	32°16 - 32°53	1800-2400	499-799	29,6 to 23,2	-8,3 to -3,1
Aurès - Belezma	35°30	1350-2300	499-790	29,6 to 23,2	-8,3 to -3,1
Djurdjura-Babors	36°30	1400-2200	1200-1700	16,8	-8,5

Additionally, the Atlas Cedar (*Cedrus atlantica Manetti*), is an important and essential resource in the economic field. It is a pivotal woody resource in North Africa, due to its distinct qualities like the resistance of the climatic pressure and the high quality woody production **(El Bakkali, 2020).**

1.4 The geographical distribution of cedar

Atlas cedar is a noble essence of the mountains of North Africa. It is endemic to the North African region **(Belloula, 2018)**, in seven blocks, four in the Moroccan mountains and three in the Algerian mountains **(M'hirit, 1999)**, as mentioned in the Figure 2 below.

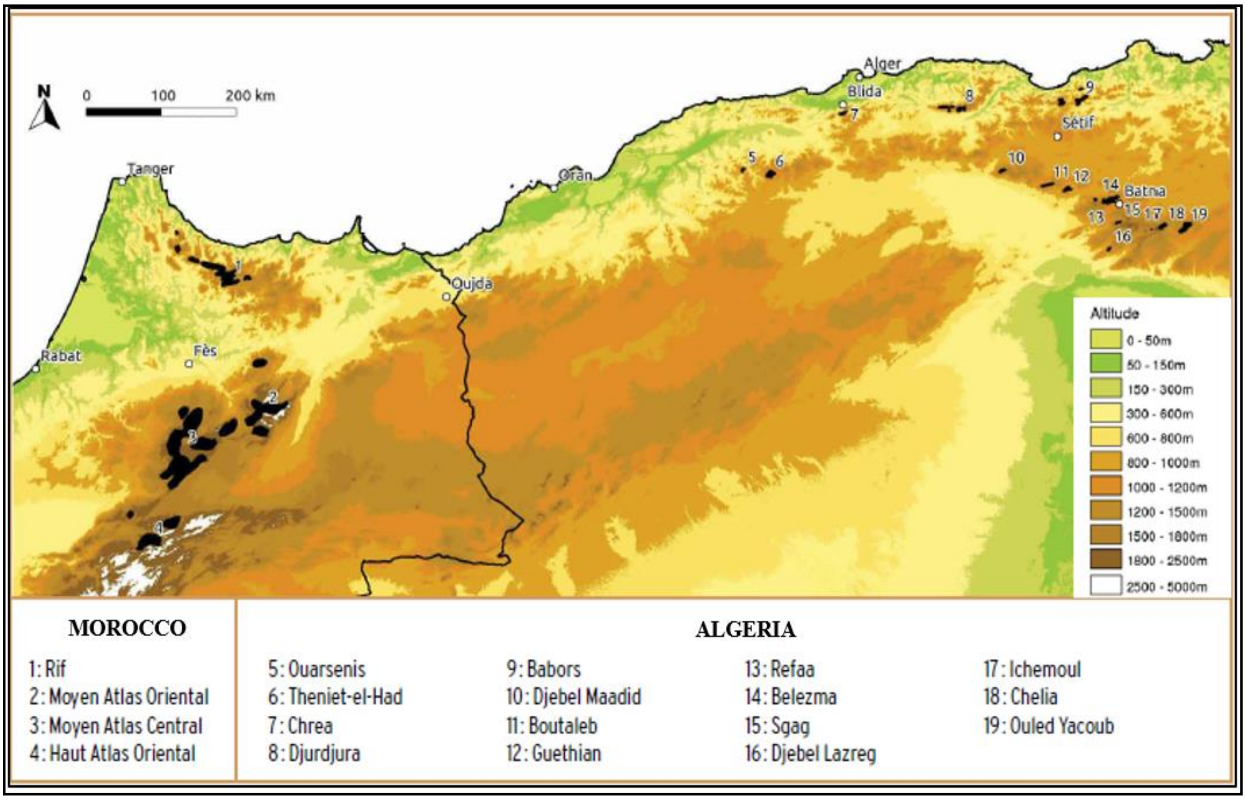


Figure 2: Atlas cedar’s natural areas **(Courbet et al, 2012)**

Boudy (1950) estimated the area occupied by cedar forests to be around 115,000 hectares in Morocco and 30,000 hectares in Algeria, while the potential areas would be 456,000 hectares and 128,000 hectares respectively. Excessive exploitation, centuries-old pastoralism, and undoubtedly anarchic practices have led to the numbers mentioned are unfortunately no longer up to date. An anonymous source (1979) cited by **Derridj (1990)** mentions 23,000 hectares for Algerian cedar forests alone, while Barbéro et al. (1990) in **(Quézel and Médail, 2003)** put forward figures of 90,000 hectares in Morocco and 20,000 hectares in Algeria.

Gaussen (1964) distinguishes in the cedar forests of the Maghreb two different types of ecology:

The meridionalis type, adapted to strong summer drought where young seedlings rarely survive, leading to irregular regeneration. This type is found in the Saharan Atlas and the High Atlas in Morocco.

The tellica type, on the other hand, is sensitive to drought and thrives in significantly wetter environments. It is found in the Tell Atlas in Algeria and in the Rif and Middle Atlas in Morocco.

a - In Morocco

Morocco is the country that holds the largest area occupied by the Atlas cedar **(Toth, 1980)**. It is located on the middle Moroccan Atlas and the northern reverse of the top, Eastern Atlas, on the Rif **(Gast, 1993)**.The area occupied by the cedars in Morocco is about 115.000 ha **(Aidrous, 2007)**, distributed on: The Rif cedars at the north, the Middle Central Atlas cedar forests constitute the entire Atlas, and the eastern middle Atlas cedars which is individualized in small islets in the Bon Iblane and Taffert de Tamtroucht massifs, in addition to the Eastern High Atlas cedars grow on the northern versants of Jbel Layachi and Jbel Masker **(M'hirit, 1999)**.

Destremeau (1974); **Debazac (1977)**; and **Lecompte (1986)** divided the Moroccan, cedar forest into three blocks:

The Rif Mountains above 1400 meters in altitude on the Atlantic slopes and 1600 meters on the Mediterranean slopes, with Abies marocana and Quercus mirbeckii.

The Middle Atlas, including the Tazekka cedar forest which extends over about a hundred hectares on the summit of this massif, is in contact with the Rif.

Finally, there are the populations of the eastern High Atlas, which are less humid, including the Ayachi and Masker massifs **(Aidrous ,2007)**.

b - In Algeria

This species is also an endemic species in the mountains of Algeria. It is encountered in the north and east of the country, they are divided into several islands more or less important **(Demarteau *et al*, 2007)**. The cedar area in Algeria does not exceed 30.000 ha. This same author estimates that this area still decreased to represent at present only 20.000 ha **(Bentouati, 2008)**. It is dispatched in scattered populations on the Ouarsenis, the Blidean Atlas, on the summits of the Djurdjura and the Babors, as well as on the Hodna Mountains (Maadid, Bou Thaleb), and the Aurès **(Gast,1993)**.

According to **Seigue (1985)** and **Aidrous (2007)** the cedar forest area in Algeria is more fragmented and is distributed across:

- The Atlas Tellian region, where there are populations in Ouarsenis, including Teniet El Had, Djebel Meddad with 1500 hectares, featuring *Quercus ilex* and *Quercus canariensis*, and Sraa Si-Abdelkader with 150 hectares, featuring *Q. ilex* and *Pinus* *halepensis* (**Sari ,1977; Derridj ,1990)**. There are also populations in Chréa, in the Blidean Atlas, and those in Djurdjura, covering approximately 2000 hectares. Further east, the Babors and Tababors massifs, well-watered stations, form pure cedar forests (in the southern slope) or mixed with *Q. canariensis* and *Abies numidica*, covering around 1300 hectares **(Seigue, 1985)**.

- The Atlas Saharien region, where there are cedar forests in Hodna, primarily old, non-regenerating stands at Boutaleb, Maadid, and Guethian. Further east, those in the Aurès cover approximately 15000 hectares, divided into several massifs: Bélezma with 8000 hectares, Sgag, Chélia, and Feraoun. Additionally, there is a modest woodland in Djebel Azreg at 1800 meters, just 40 kilometers from Biskra .

1.5 The main natural degradation factors

In general, naturalfactors that predispose forest trees to decline are often abiotic in relation with the climate or biotic with relation with organic organisms like parasites **(Ghaionle *et al*, 2004)**.

The current state of Mediterranean forest ecosystems is the result of a combination of palaeogeographical, climatic and ecological processes **(Barbero *et al*, 2001)**. The decline of the cedar is not recent. Reports by **Boudy (1950)** cited by **Abdessemed (1981)** indicate that exceptional droughts from 1875 to 1888 would have already overwhelmed the cedar appeared around the 1940s and worsened over the past 5 years **(Bentouati *et al*, 2006)**. The causes of this degradation and the stresses suffered by the cedar grove are multiple, they are linked to both climatic hazards : drought, water stress, Saharan influences **(Bentouati, 2008)**, in fact, prolonged droughts combined with the absence of appropriate forestry, which makes it possible to balance the density and structure of forest stands with the water availability of soils and the ecological conditions of habitats **(Abdenbi *et al*, 2014)** and other weakening factors such as defoliating insects (*Thaumetopea bonjeani* Powell, 1922) and fungi such as *Armillaria mellea* (Vahl ex Fr.) P. Kumm. 1871, which is frequently observed on trees whose their vitality decreased or on trees already dead **(Bentouati, 2008)**. For insects in endemic condition, cedar is home to various species of defoliating insects (Thaumetopoidae) or xylophagous and corticolous like: Scolytidae, Curculionidae, Cerambycidae, and Buprestidae **(Ghaionle *et al*, 2004)**.

1.6 Atlas Cedar regeneration

According to **Meddour (1994)**, **M’hirit (1999)** and **Toth (2005)** they mentioned that the duration of the juvenile period of the Atlas cedar is 15 to 30 years. The reproductive cycle takes 3 years to complete. During the first year, flowering and pollination would be crucial steps in determining the potential for qualitative and quantitative seed production. The success of fertilization and growth of the cones in year n+1, as well as the morphological and physiological maturation of the cones in year n+2, would be conditioned by the occurrence of climatic accidents, competition between vegetative and reproductive organs, as well as the action of insects responsible for the losses observed at all stages of development. The disarticulation of the cones, under the effect of "imbibition" followed by tissue freezing and then thawing, allows the release of the seeds towards the end of the third year. After a dormancy period that varies depending on climatic conditions, seed germination starts at temperatures close to +4°C (**Aidrous ,2007)**.

2 Biodiversity

2.1 Definition

Biodiversity is defined as the biological diversity that includes the variability of all species present on earth with all of their origins terrestrial, aquatic and other ecosystems. This includes diversity within species and the ecosystems **(Zedam, 2015**).

Biodiversity integrates biological variability at different ecological scales, from genetics to species and ecosystems to landscapes to the diversity of biodiversity scales, it is almost impossible to fully assess it. The relevant level at which biodiversity should be defined often depends on the issue under consideration, although species richness has historically been the most widely used measure of biodiversity **(Galland, 2020)**.

2.2 Diversity levels

2.2.1 Genetic diversity

Genetic diversity point out to the variety of genes contained in micro-organism, plant and animal species. Each species, ranging from bacteria to higher plants and animals, stores an enormous amount of genetic information **(Belkhous, 2012)**.

Genetic variation in individuals is dates back to two causes: gene and chromosomal mutations and the appearance of sexually reproducing organisms that ensure constant blending genes **(Guechi, 2022)**.

2.2.2 Species diversity

Species diversity refers to the diversity and variety and number of species present in a geographical area and all the various categories that can be measured by "species richness" and "taxonomic diversity" **(Belkhous, 2012)**.

2.2.3 Specific diversity

Specific diversity refers to the number of species present either in a given area or in all the various categories of living beings. The current estimate of known species is around 1,800,000 species. However, this inventory is not exhaustive, as extrapolations based on credible data suggest that there could be between 5 and 10 million species in total **(Dajoz, 2008)**.

2.2.4 Ecosystem and ecologic diversity

It indicates the existence of different types of ecosystems. This concerns the diversity of habitats, biological communities, and ecological processes on the planet. It took millions of years of evolution to assemble and accumulate this rich diversity in nature, but we can lose all of this richness in less than two centuries if this loss ratio of species continues. In recent years' biodiversity and conservation have become of vital environmental issues of international concern as more people throughout the world admit the importance and the role of biodiversity on our planet **(Galland, 2020)**.

Biodiversity and conservation are now environmental issues of international concern, as more and more people around the world begin to recognize the critical importance of biodiversity to our survival and well-being on the planet.

2.3 The importance and threats of the biodiversity

Biodiversity is a global term which indicates all the life-form existing in forested areas and the terrestrial globe besides their environmental roles they play **(FAO, 2020)**. It has a fundamental role in the safeguarding of biological diversity as a genetic complex. Its benefits are often displayed in terms of service ecosystems. These services include providing food, water, timber, etc. in addition to cultural services and their agricultural values **(Souahi, 2022)**.

The concept of biodiversity cannot be dealt with without evoking the crisis in which it lives. It is estimated that about 1.5 billion species have lived on Earth since life. Species appear and other species disappear at a rate of 1 in 1 million species per year **(Ionescu, 2016).**

It shows us the role of diversity at the level of the environment in ecosystem functioning where each species has its place in the ecosystem and plays a role in maintaining it **(Ouici, 2019)**. In addition, the role of organisms in the proper functioning of the ecosystem and in the sustainability of the biosphere is great than in the ecological level. In another part although we do not yet have a precise idea about the socio-economic value of biodiversity, its role is undeniable. Many people benefit from the services currently offer. Preserving it will help to sustain this economy. Finally, for this importance of diversity we talk about danger and the threats that affect it.

In addition to natural and routine extinction there are five extinct crises, in a very short period of time, eliminating 12 to 75% of families and even 95% of species every year, between 17,000 and 100,000 species of our planet. Some also claim that five all living species can disappear within 30 years as well as the ecological costs. The loss of biodiversity leads to economic costs, a first attempt to measure the cost of inaction was made in an EU-commissioned study in 2008: according to the first findings, in 2050, the damage for the biodiversity would represent at least 7% of global. The leading cause of this situation is the increased and growing world's population **(Ozenda, 2004)**. Among the factors threatening biodiversity there are those include deforestation and fragmentation, wetlands and other forms of housing destruction, industrial and urban development, agricultural expansion, excessive resource consumption, air and water pollution, climate change, desertification and the spread of invasive alien species **(Ionescu,2016).**

2.4 Biodiversity conservation

The conservation and sustainable use of biological biodiversity, as well as the preservation of ecosystem services, are closely tied to ensuring food security, nutrition, and health for the world's population.

The significance of biodiversity and ecosystem services in ensuring food security, nutrition, rural and coastal livelihoods, human well-being, and overall sustainable development has increasingly garnered attention on global platforms. This growing recognition has prompted a shift towards strategies aimed at preserving and conserving biodiversity, giving rise to the field of conservation biology. Within the Convention on Biological Diversity (CBD), five key points have been outlined to address the conservation of biological diversity **(Zedam, 2015)**.

2.4.1 Spaces conservation

The protected area is defined as a clearly defined geographical space, recognized, dedicated and managed through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values by ensured involving local populations in the management of the environment and species.

2.4.1.1 Nature reserve

Protected areas are designated regions aimed at conserving biodiversity, geological, and geomorphological features. They undergo strict monitoring to minimize human impacts and maintain conservation values, serving as crucial benchmarks for scientific research **(Zedam, 2015)**.

2.4.1.2 Wilderness area

These protected areas are generally large intact or slightly modified areas, which have retained their natural character and influence, without permanent or significant human habitation, protected and managed for the purpose of preserving their natural state **(Guechi, 2022)**.

2.4.1.3 National park

These protected areas are large natural or semi-natural natural areas dedicated to protecting large-scale ecological processes, in addition to the features of species and ecosystems in the area, which also provide a basis for visits, science, education and recreation, while respecting communities' environment and culture **(Zedam, 2015)**.

2.4.2 Species conservation

The conservation of the species focuses on two strategies: *in-situ* and *ex-situ*.

2.4.2.1 *In-situ* conservation

It’s the conservation of the species in their environment in some protected areas such as the reserves and national parks, for the preservation of the animal and plant communities to continue their evolution by adapting to changes in the environment and adaptive characteristics of living species implies maintaining them in the environmental conditions proper to their original biotopes **(Zedam, 2015)**.

2.4.2.2 *Ex-situ* conservation

It’s the conservation of species outside their natural environment that are already very disturbed, degraded and even sometimes disappeared **(O'Donnell and Sharrock, 2018)**, overall, botanical and zoological gardens, along with other ex-situ conservation methods, are fundamental in safeguarding endangered species, preserving genetic resources, and supporting reintroduction programs for plants and animals at risk **(Hurka *et al.*, 2004)**

It should be noted that *in-situ* conservation is more effective than *ex-situ* conservation because there is less manipulation and human interaction of biodiversity **(Guechi, 2022)**.

2.5 Endemism

Gimaret-Carpentier (1999) explained the concept of endemism as a relative one, in nature, all plants can be considered endemic, taking into account their distribution area, which can be vast and encompass the entirety of that area. This excludes cosmopolitan taxa that are present on all continents, as well as those that have been manipulated, either voluntarily or involuntarily, by humans.

Endemic taxa whose geographical distribution is limited to a specific region are considered endemic to that region. In other words, endemic taxa are those that are unique to a particular geographic area and are not found naturally elsewhere **(Zedam, 2015)**.

3 Ethnobotany

Generally, the ethnobotany can be defined as the scientific study of relationships between the plants used and human society through the role and the interaction midst them in their environment **(Soejarto *et al.*, 1989)**, by using plants in many aspects of life: utensils, sources of fiber, drugs, poisons, healing remedies ...

It has a remarkable effect for conservation and management strategies and it became more consistently and important for the scientific communities because the ethnobotanical studies make an effective contribution to the modern medicine and therapeutic culture by studying plants in traditional societies and ancient culture in addition those methods are now well promoted by the scientific community around the world **(Paulino *et al.*, 2009)**.

This recent field of studies offers us a deep understanding of relationships between humans and mother nature, it is assumed that we will be familiar with the ethnobotany study for more knowledge about life basis on earth according the interaction flora and fauna our neighboring (**Dinesh, 2010)**. Although ethnobotany was once suffering in the past the absence of educational opportunities, the support of the discoveries and the specialists to achieve the objective of the work started which is to highlight the role of botanical families in ethnobotany **(Bennett, 2005)**, the perception of relationships between the families, and the medical uses in the molecular genetic framework for vascular plants **(Gras *et al*, 2021)**.

3.1 Plant categories

It is generally known that forest resources, the plants which the most notably to meet the social, economic, ecological, and cultural needs in today's and future generations **(Jiofack, 2009)**.

In fact, to deepen information about plants, are used for the properties of essential oil as an active medical ingredient, as a fragrance or as a food flavor, that is also a medical plant if it is used to predict, treat or alleviate different diseases due to its special characteristics **(Aparicio, 2021)**.

3.1.1 Medicinal plant

A medical plant is a plant medicine within the meaning of pharmacies where the plant or part of it has at least medical properties, used in traditional medicine either in dried form or in fresh condition **(Rajaei et al., 2012).** These are all plants that contain one or more substances that can be used for therapeutic purposes or that are precursors in the synthesis of useful drugs **(Benouaklil , 2018).**

3.1.2 Aromatic plant

It is a plant containing odor particles that extract its essential oils from organs in particular flowers, leaves, roots and bark to use as perfume or spice condiment **(Guechi, 2022).**

3.1.3 Food plant

Is a type of edible plant, related to fruit plants in its various parts (roots, lamps, bulbs, tubers), in clouding the vegetation, oil plants, aromatic plants and spices plants.

3.1.4 Industrial plant

It serves as crude material (waterproof cotton, fiber, cell, oil, resins) which relies on in pharmaceutical, cosmetic and food industry from textile fiber factories, dyeing factories, medical stations, oilseeds **(Bennett, 2005)**.

3.1.5 Toxic and poisonous plant

plant type in some or all of its parts contains toxic substances to humans or animals. These toxic substances, in plants, are usually chemical compounds that cause physiological reactions. Toxicity is manifested by swallowing certain organs or by communication or resulting in allergic reactions.

3.2 Harvesting and conservation of plants

The action of medicinal plants depends on the period and the moment of their harvest, their drying as well as their conservation. The time of collection, in nature or in a culture, is determined by the content of the plant in active substances during its vegetative cycle. It is essential that it retains the maximum of its active ingredients.

The picking should preferably be done in dry weather after sunrise and after the disappearance of the dew **(Benouaklil , 2018)**.

The quality and efficacy of medicinal plants depend on several factors, including the timing of harvest, drying methods, and storage conditions **(Mahapatra *et al.*, 2007**). The optimal time to collect plants, whether from the wild or cultivated, is determined by the concentration of active compounds during the plant's growth cycle. It is crucial to harvest at a stage that maximizes the retention of these beneficial substances. Ideally, medicinal plants should be harvested on a dry day, after the morning dew has evaporated and before the intense heat of midday. This timing helps preserve the essential oils and other active ingredients that contribute to the plant's therapeutic properties. After harvesting, the plants must be dried to remove excess moisture and prevent spoilage **(Poós and Varju, 2017)**. Drying can be done using various methods, such as air-drying, dehydrator drying, or microwave drying. The choice of drying method depends on factors like the plant species, desired quality, and available resources. Once dried, the plant material should be carefully inspected for any signs of mold or insect infestation. If the plant is in good condition, it can be packaged in sterilized, airtight containers, such as dark glass jars, to protect it from light, dust, and humidity. Proper labeling, including the plant name, origin, and packaging date, can help track the age and origin of the plant material. By following these guidelines for harvesting, drying, and storage, the potency and therapeutic value of medicinal plants can be maintained for up to a year or more **(Poós and Varju, 2017)**.

For a perfect plant preservation, it is necessary to remove any dead parts. The drying and storage process should take place in a dark, protected, and well-ventilated location. It is crucial to ensure that the temperature does not exceed 37°C.

3.3 Plant preparation remedies

For the first time in 1896, American botanist John William Harshberger coined the word "race plant", although the history of the ethnic plant began well before that. Plant possesses some therapeutic properties of healthy drugs effects on the human body or animal are commonly called "medical plant". People use medicinal plants to treat diseases according to their cultural traditions and the indigenous knowledge **(Hussain, 2020)**.

There are different methods to prepare and use plants according to the quality and purpose of them as follows:

a-Infusion: Prepare boiling water with flowers and leaves fresh or dry in a covered bowl for 10 minutes may be more (**Rajaei, 2012)**.

b-Decoction: This method applies to underground parts of plant (roots) and bark, which barely release their active principles during infusion which consists of extracting plant properties by leave them soaking in hot water, after cooling and liquidating the plant soak.

c-Maceration: it's the same method as decoction with a difference in the plants parts and the nature of solvent solution; here we use a cold water or oil for immersing of the plant for a few hours **(Guechi, 2022)**.

d-Poultice: Prepare the chopped plant coarsely and put it to heat and then squeeze and put it on the skin to calm the muscle pain, recovering nerve pain and fractures.

e-Powder: It is produced after drying and grinding the plant to be prepared later as an herbal drink for internal or surface treatment of the skin.

f-Essential oil: The complex product is extracted from fluid aromatic: The organic substances found in plants. These organic matters are obtained either by introducing steam (and steam entrainment), by watering measurement, and by hydro-distillation (**Khusna, 2023)**.

g-Inhalation: breathing the impact of boiling water vapor mixed with plant leaves or aromatic oil. Dip the plant into boiling water, covering the head and placing it under a towel to keep steam. Inhale after that exhale and deep for a few minutes.

h-Gargling: Prepare the recommended injections or the decoctions of the plant, and cooling that solution and filtered to rinse the mouth with, avoid swallowing it and repeat the process daily.

i- Friction: Use essential oil or cream on the body and apply a massage to activate circulation and heal pain.

3.4 Forms of use of medicinal plants in therapy

Internal use:

- **Herbal tea:** a liquid with therapeutic properties intended to be hot or cold to drunk, obtained by soaking, decoction of (flowers, leaves, stems, roots)
- **Fumigation:** We boil or burn aromatic plants and inhale escalating vapors that are very helpful for treating and hydrating mucous membranes during respiratory diseases **(Xiong, 2020)**.

External use:

- **Compress:** combination of grinding Plant or crushed, heat up and put pressure on the place of pain to treat muscle and inflammation.
- **Lotion:** Plant solution used on the skin for hydration or for cosmetic purposes or to calm irritated, sensitive or inflamed areas using a water-loving cotton pillow.
- **Drops:** It is a preparation for the treatment for some diseases by distilling it into the eyes or ears.
- **Mouthwash**: Solution plant used to suction and wash the mouth to treat the mouth, the throat, and the pharynx.

CHAPTER II

The Study Area

CHAPTER II : THE STUDY AREA

4 Study area presentation

4.1 Geographic situation of the study area

According to **Radjai et al (2023),** the province of Bordj-Bou-Arréridj is a part of the high plains which are bordered to the North and the South by the Tellian Atlas Mountains. Its limits in the North are: Bouira province, Béjaïa province, and Sétif province, in the East the province of Sétif, for the West there is Bouira province and in the South we found the province of M'Sila.

This province is situated 220 km southeast of Algiers and has the following geographical coordinates: 36° 04’ North and 04° 46’ East with an altitude of 900 meters. The study area is a part of the Ouled Khelouf forest which is found in the extreme south of this province. This forest occupies an area of 8.580,47 hectares. It spread over part of the Hodna mountains which are an element of the southernmost Tellian Atlas. The study area of Djebel Maadid, is 40 km south of the province, is situated south of a line directed "west-east" formed by Ghafsitane village in the El Ach locality and southwest of Ouled Aissa village in the Rabta locality (Figure 3).

Our study focuses specifically and precisely on the mountainous northern slope of Djebel Maadid where the Atlas cedar thrives alone or in association with other woody species.

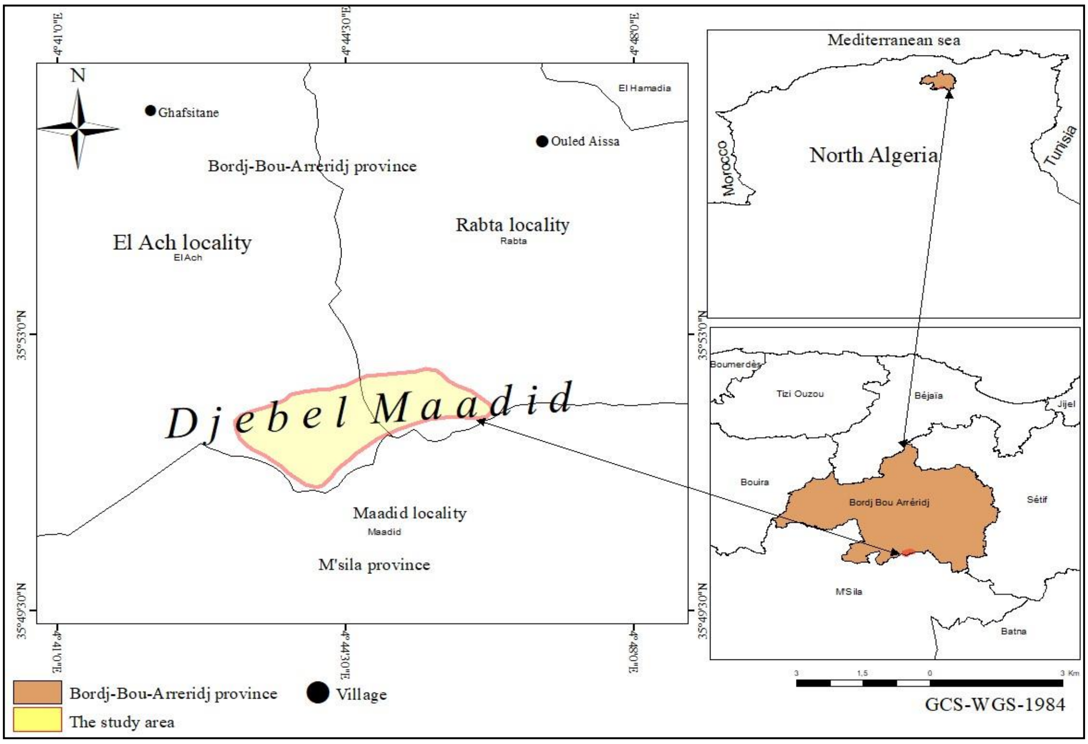


Figure 3: Study area of Djebel Maadid.

4.2 Phytogeography

According to the vegetation division study of **Maire (1926)** and the phytogeographical map to northern Algeria for **Quézel and Santa (1962-1963)**, Algeria's north is divided into 17 sectors and the most important subdivisions. We mention three of them:

- Mediterranean Maghreb,
- Steppe Maghreb,
- High Atlas Mountains.

Our study area is located in the southern Bordj-Bou-Arreridj province as a part of the Atlas Tellien at the Mediterranean Maghreb Domain. It is located in the middle of 3 sectors (Figure 4):

- The north it's bordered by (C1) Constantinean Tell (Tell and Bibans mountains to Bellezma),
- The south by the Constantine High Plains (H2: Constantinean High Plateaus)
- Hodna plain (Hd) in the south.

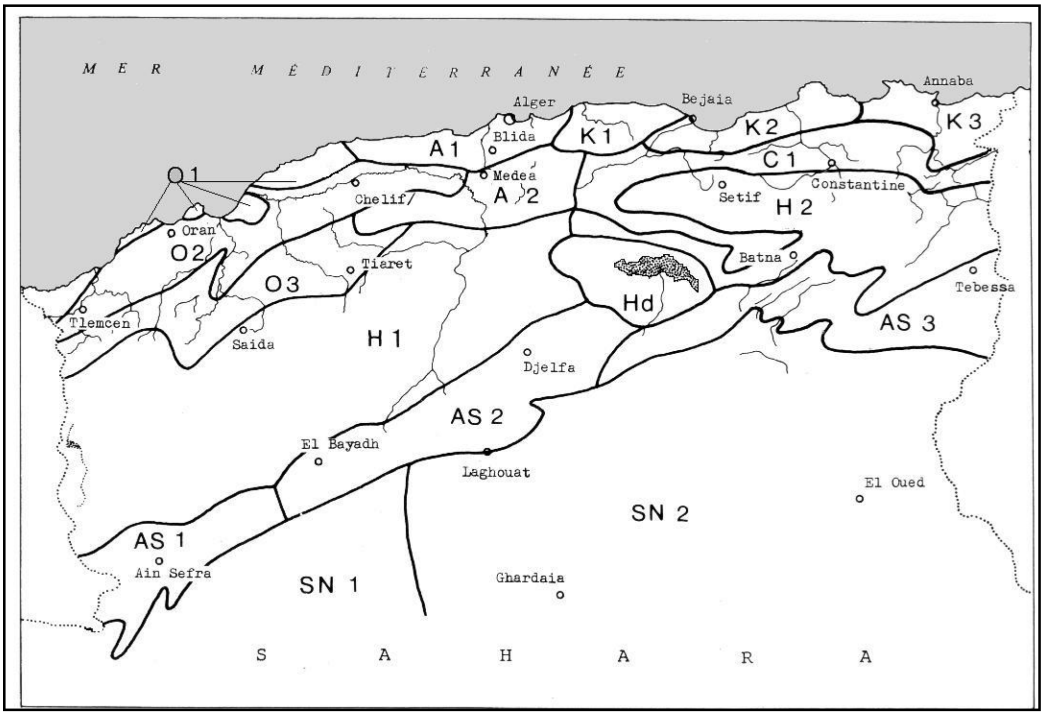


Figure 4: The phytogeographic subdivisions of Algeria **(Quézel and Santa ,1963)**

According to **Meddour (2010)**, the study region of Maadid belongs to the Mediterranean region. The North slope and the high Southern slope of the Maadid region belongs to the Maghreb-Tellian Domain, and to the Tello-Constantinean Sector and to the Belezmo-Hodnean District (C2). The lower Southern slope belongs to the Maghreb-Steppe Domain, Sector of the High Steppe Plains and to the and Oriental-Steppe district (H2).

According to **Quézel & Santa (1962-1963), Meddour (2010) and Guechi (2023)** the Belezmo-Hodnean district, where our study area is located, includes the transverse chain that serves as the link between the Tellian Atlas and the Saharan Atlas. This chain connects the Bibans chain in the Aurès massif.

The Hodna mountain range stretches from the northwest to the southeast, encompassing various mountains such as Ouennougha (Djebel Choukchot 1832 m), Dréat (Djebel Mansourah 1863 m), Maadid mountains (Highest point at 1865 m), jebel Bou Taleb (Afghan jebel 1890 m), Ouled Sellem mountains (djebel Guetiane 1840 m), and the Belezma mountains (Djebel Tougour and Djebel Refaa), as described in the figure 5 below.

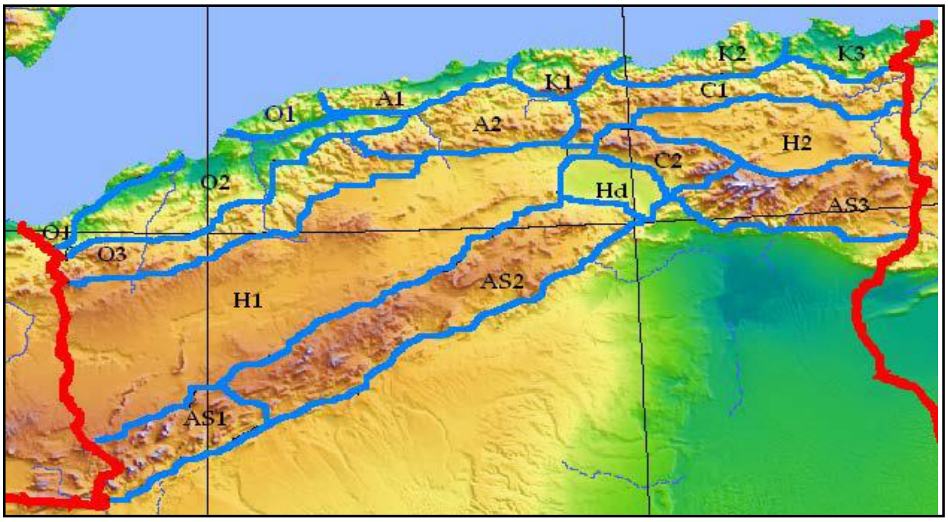


Figure 5: The phytochorological districts of Northern Algeria **(Meddour, 2010)**

4.3 Hydrography

The state's hydrographic system has two directions for splitting flowing water. These natural boundaries are compatible with the large watersheds of Soummam and Chott El Hodna **(Benlaharche, 2019).** Near the water store of Chott el-Hodna. Two large networks converge towards this depression: to the north, the wadi Ksob drains the waters of the slopes of the Hodna Mountains, to the south the wadi Bou Saada, the wadi Chai"r and the wadi Melh drain those of the Atlas Sahara mountains. **(Kaabeche, 1995),** which make the Bordj- Bou -Arreridj region, in particular the southern half, contains many natural reservoirs and water sources as the dam Ain Zada, placed on the Bosellam Valley allows the supply of cities such as Bordj- Bou -Arreridj, Setif, El Eulma, Ain Taghrout, Sidi Mebarek, Medjana and Hasnaoua, for drinking and industrial water. In this state there are six mountain reservoirs found around a Bordj –Bou-Arreridj Waud Tixter has higher capacity compared to other valleys with 2 million m^3. The other five valleys: Lachbour, Hamadia, Boukaba have almost same capacity, 0.4 Mm^3 each (**Boulaouad, 2018).**

4.4 Geology and relief

The Bordj Bou Arreridj province contain of three geographical areas as first the high plains which occupies the largest proportion of the state's area, and mountainous in the north part, and on the South-West side is a steppe area. The altitude of the province varies between 302 m and 1885 m **(ANDI ,2013** cited by **Benlaharche ,2019)**. The highest point in the commune of Taglait at 1885m on Djebel Ech Chlendj of the Maâdid range and the lowest point on the Oued Bousselam in the East is 302m. Schematically, the relief of the province can be broken down into three large areas:

-The area of the high plains: This area characterized by a undulating relief whose high parts see outcropping the marl substrate and the lower parts are drowned by alluvial and colluvium. The high plains occupy the most important areas, with a fairly decent rainfall of between 400 and 600mm, except during drought.

-The mountainous area: The northern mountains are thick shale clays interspersed by limestone and sandstone. The whole is very sensitive to mechanical erosion.

-The steppic zone: The South-West zone consists of light soils with agro-pastoral vocation.

with a variety of Relief and forests:

In Ouled Khelouf forest the Most of them are consisting of silt, gravel, sand and reddish mud.

4.5 Pedology

In the Bordj Bou Arreridj province there are different types of soil it is divided into regions:

-The mountainous zone: This area is so rich in shallow mud soil and medium and high mountain soil positioned on the mother rock of limestone and sandstone origin.

-High plains zone: Mostly brown classical soil with or without inks on glass, virtuous soil, stone soil and regosol.

- The Southern zone: For Southern Region, soil cover is a Marl Stone.The region's soil was classified into two major categories, the minimally soil category and the calcimagnesite soil .

In addition to mineral soils of erosion and Soil with low erosion evolution, soils with little evolution of inputs, vertisols and calcimagnesite soils **(Mohammadi, 2013).**

4.6 Vegetation

Among a large percentage of the environmental aspects in the ecosystem the vegetation is the most important one and the most influential biological element in the environment for the purpose of preventing desertification, mitigating runoff and conserving soil and water in arid ecosystems, especially We can consider forests as nature reserves for endangered species in the global to conserve the biodiversity in addition to safeguarding the endemic species in spite of the fact that existence of harmful humaneffect (**Naceur Youcefi *et al.*, 2019).**

At the present time in our study area we have more than one vegetal formation along with the atlas cedar:

-The pure Cedar

The greater part at south of Bordj Bou Arréridj state specifically Maadid massif is clearly covered by the Atlas Cedar as a dominant species, with a remarkable new regeneration in recent years and a considerable density and a huge number individual of *Cedrus Atlantica* Manetti when the altitude exceeds 1700 m (Figure 6 and 7). This species that can withstand severe winter cold damage, but at the same time all other environmental physiological properties analyzed show that its environment is compatible with moderate climates **(Toth, 1980).**

Figure 6: The Atlas Cedar of Djebel Maadid “a” (photos Radjai, 26/05/2022).

Figure 7: The Atlas Cedar of Djebel Maadid “b” (photos Radjai, 26/05/2022).

-The Cedar grove with parched Lawns

In Djebel Maadid when the altitude exceeds 1800 meters appears to us the lawns rich in resistant plants and the adaptation species to the cold season (Figure 8) like: *Bupleurum spinosum* Gouan, *Berberis vulgaris subsp.* australis (Boiss.) Heywood.

Figure 8: The Lawns of Djebel Maadid (*Bupleurum spinosum* station)

(photos Radjai,22/05/2022).

- Green Oak Matorral

This plant formation stationed under 1600 m of altitude and represented by the *Quercus ilex* (Figure 8). With a great vegetarian diversity: *Juniperus oxycedrus*, *Bellis sylvestris* Cyrillo, *Astragalus hamosus* L, *Poa bulbosa* L. (Figure 9)

Figure 9: The green oak grove matorral of Maadid (photos Radjai ,26/05/2022).

4.7 Climate

We can define climate as an interaction and overlap of a combination ecologic factors such as temperature, precipitation, humidity…, and it plays a very fundamental and crucial role in the natural environment, overlapping by modifying the ecological characteristics and characteristics of different ecosystems **(Benlaharche, 2019)**. In case of the diversity of north African's climatic and ecological conditions and its attitude towards meeting European plants, deserts and pastoralists make it a genuine crossroads of undeniable diversity and complexity **(Laaribya *et al.*, 2020)**, particularly in Northern Algeria, the steppes have a Mediterranean climate with a summer season of about 6 months, dry and hot, the winter semester (Oct. - April) being rather rainy and cold. For the steppes, however, this is a particular form of this climate characterized essentially by: Low precipitation with high inter-monthly and inter-annual variability and relatively homogeneous but highly contrasted continental thermal regimes **(LE Houerou, 1989).** In general, the climate of Bordj-Bou-Arreridj is continental semi-arid to cool winters and dry - hot summers.

The climate data used cover a period of 37 years from the site NASA Website

4.7.1 The Temperatures

The temperature is a key factor in the environment because of its influence on plant species. We can classify it as a limiting factor for the plant behavior's so that the plant species are more sensitive to maximum, extremes, and minimum temperatures, each species has an optimal temperature interval where they can live. **(Belloula, 2020),** that interval will be limited by maximum and minimum temperatures **(Boulaouad, 2018).** Where the Algerian interior areas know a contrasting continental thermal regime, the thermal amplitude annual is everywhere more than 20°C **(Le Houerou *et al.*, 1977)**. The thermal regime of our region is also severely influenced by altitude; which is a factor to distinguish between extreme points. The maximum average temperatures, minimum average temperatures, and the average temperatures from 1985 to 2022 are distributed per month in the table 4 below.

The annual average temperature is 16,39°C and where the coldest month is January with 6,14 °C and the hottest month is August 25,02°C. (Figure 10).

Table 4: The temperatures (°C) from 1985 to 2022.

Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
M (°C)	16,13	18,23	22,23	25,80	30,87	35,22	37,35	37,17	33,07	27,79	21,32	16,85	37,85
m (°C)	-3,85	-3,72	-2,62	-0,33	3,17	8,10	11,82	12,86	9,39	4,74	-0,39	-2,76	-5,06
(M+m)/2 (°C)	6,27	7,26	9,81	12,73	17,02	21,66	24,58	25,02	21,23	16,26	10,47	7,05	16,39

With:

- M (°C): maximum average temperatures in Celsius degrees.
- m (°C): minimum average temperatures in Celsius degrees.
- (M+m)/2 (°C): average temperatures in Celsius degrees.

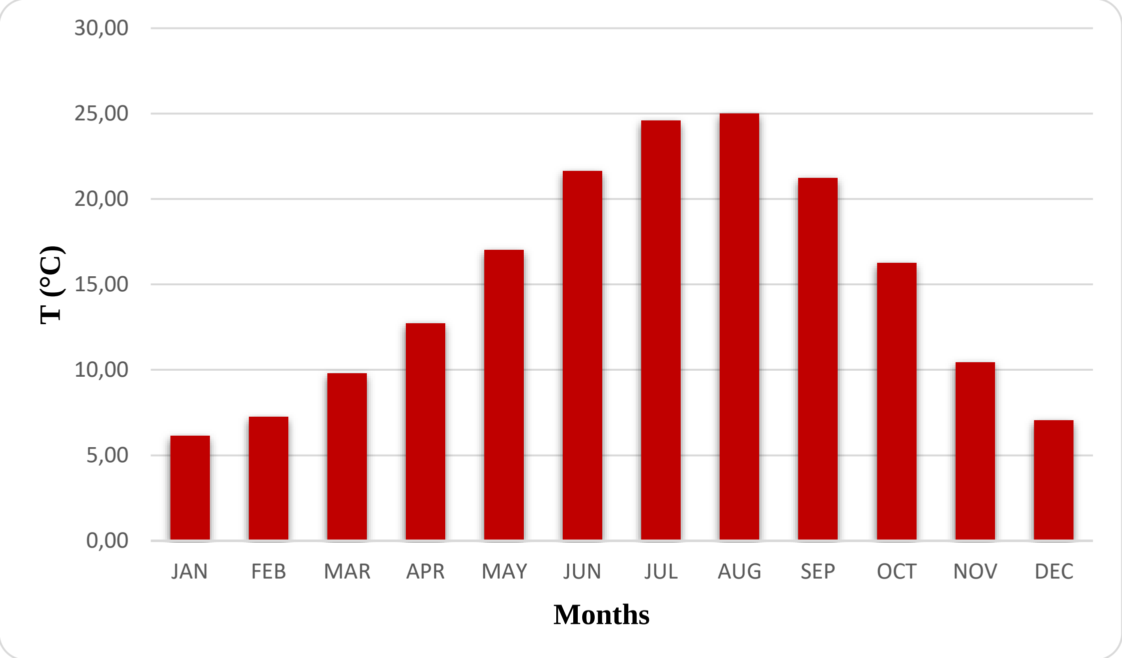


Figure 10: The variation of the monthly average temperature (°C) from 1985 to 2022.

4.7.2 Precipitations

The water is an essential element for any living organism in the environment. The presence of precipitations (rain and snow sometimes) is marked by a seasonal distribution with two maxima in year which are autumn and spring. **(Boulaouad, 2018)**. The rainfall averages sometimesdo not show the characteristics of the rains, nor! This is due to the high intensity of rainfall, which causes runoff and accentuates the lack of balance in the water balance **(Kaabeche, 1996)**. The monthly average precipitations from 1985 to 2022 are distributed per month in the table 5 below. The annual precipitation attains 520 mm (Table 5).

The rainiest month in the resort of Maadid is January with 59.86 mm. The least rainy month is July with 6.84 mm and it should be noted that it is drier with August 14.71 mm. But it happens that autumn thunderstorms begin from the first days of August, rainfall rates will rise again in September (Table 5) and (Figure 11).

Table 5: The monthly average precipitations (mm) from 1985 to 2022.

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
P(mm)	59,86	45,37	57,90	59,07	53,24	18,55	6,84	14,71	47,86	43,01	53,91	59,16	**519,48**

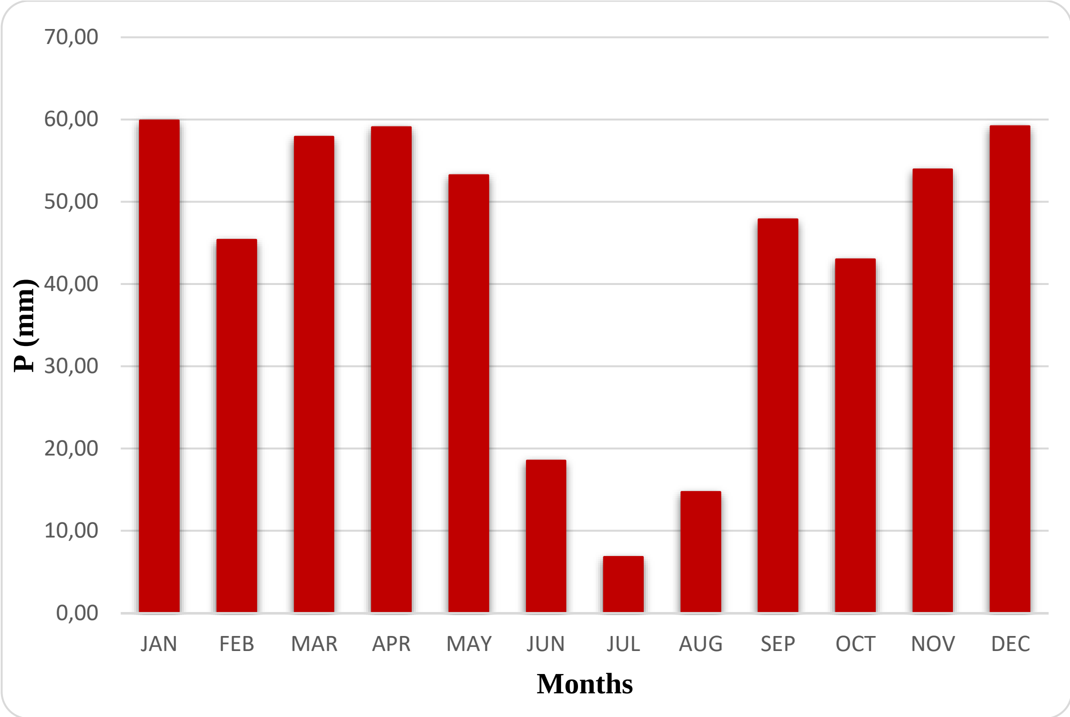


Figure 11: The variation of the monthly average precipitations (mm) from 1985 to 2022.

4.7.3 The Wind

Wind is a major factor in the dispersion and transport of seeds and the spread of plant species by assisting in the process of natural pollination; besides influencing on the plant's situation, such as" Sirroco" wind: dry and hot, which have a significant impact on the vitality of heat-sensitive plant species (**Ben Fadel *et al.*, 2018)**. The average monthly wind speeds from 1985 to 2022 are distributed per month. The average annual speed is 6,94 M/s. Up to 7,10 M/s in months April and 7,42 M/s in February, on the other hand, is weak in August with 5,72m /s in (Table 6) and (Figure 12) below

Table 6: The average monthly wind speeds (m\s) from 1985 to 2022.

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
max	14,28	14,46	14,36	13,88	12,80	12,40	11,67	11,18	12,28	12,48	14,29	13,58
min	0,36	0,37	0,36	0,32	0,34	0,28	0,35	0,27	0,26	0,28	0,30	0,30
The average monthly wind speeds (m\s)	7,32	7,42	7,36	7,10	6,57	6,34	6,01	5,72	6,27	6,38	7,29	6,94

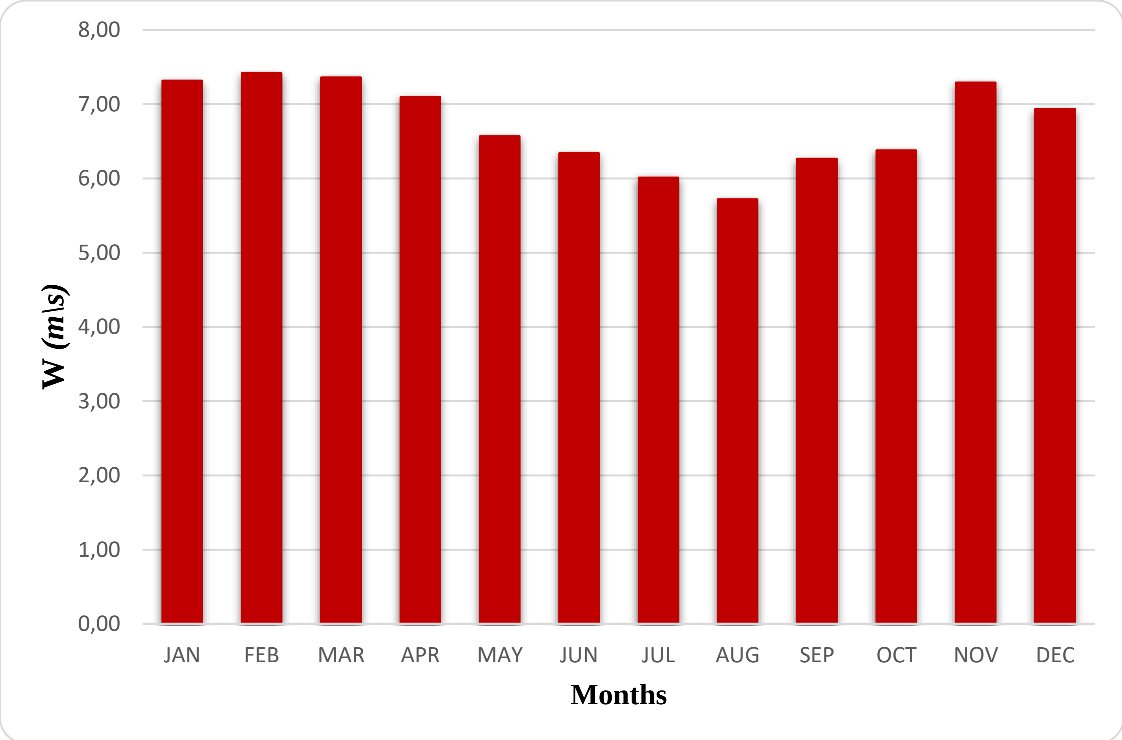


Figure 12: The variation of the average monthly wind speeds (m\s) from 1985 to 2022.

4.7.4 Relative humidity

It increases during the night by compensating for the loss of water during the day. This relative humidity has been recorded in the protected area from December to May which is gradually decreasing **(Garba *et al.*, 2012)**. The average relative humidity from 1985 to 2022 are distributed per month,

The highest average relative humidity is recorded in the months of December and January (HR>80%). The value is less than HR = 50% during the months of July and August, this is the rate the weakest of the year (Table 7) and (Figure 13)

Table 7: The average relative humidity (%) from 1985 to 2022.

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
The average relative humidity (%)	81,25	76,03	70,99	66,04	61,22	54,46	47,72	48,36	61,24	67,80	77,02	82,25

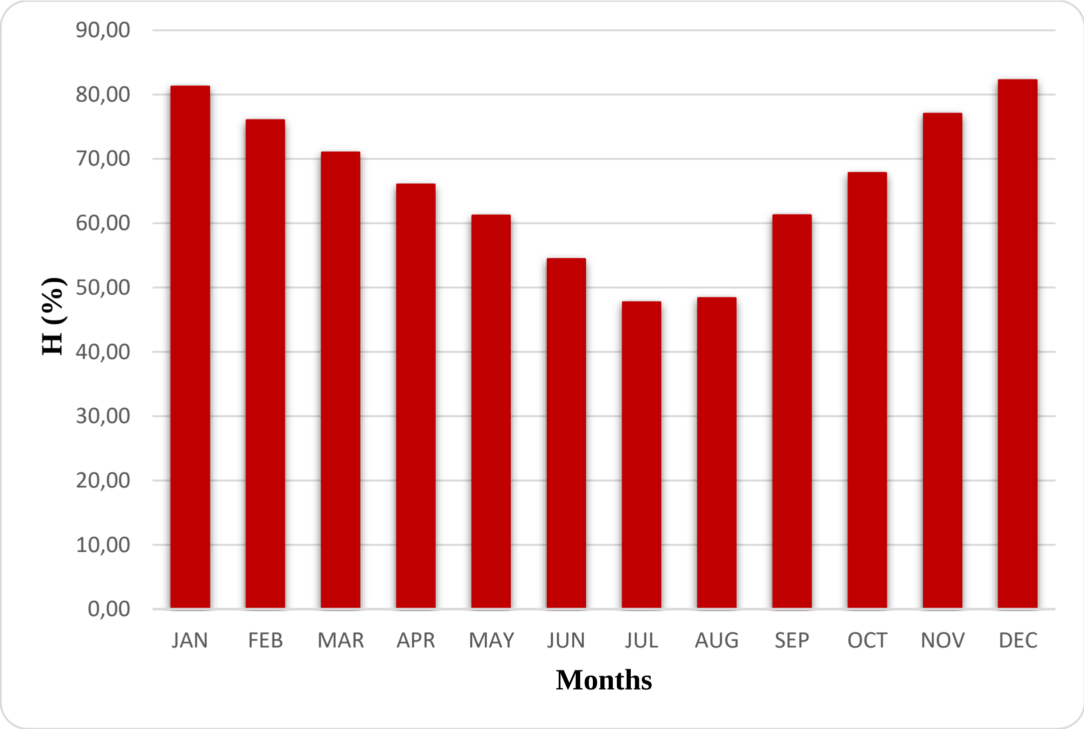


Figure 13: The average relative humidity (%) from 1985 to 2022.

4.7.5 Ombrothermal diagram

The Ombrothermal diagram of **Bagnouls and Gaussen (1957)** and the Climagram associated with the rainfall quotient of **Emberger (1966)**, are the two most used indices in the Mediterranean region for bioclimatic synthesis **(Gharzouli, 2007)**.

The dry season is the intersection between the curve of precipitation and that of temperatures averages by doubling the scale **(Guechi, 2022)** in (Table 8) and the dry period extends from the beginning of June until September ,where it reaches a highest degrees of temperature and the lowest level of precipitation in the months of July and August ,the rest of the year is a wet period (Figure 14).

Table 8: The temperatures averages and precipitation for the ombrothermal diagram of (1985 – 2022).

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
T(°C)	6,14	7,26	9,81	12,73	17,02	21,66	24,58	25,02	21,23	16,26	10,47	7,05
P(mm)	59,86	45,37	57,90	59,07	53,24	18,55	6,84	14,71	47,86	43,01	53,91	59,16

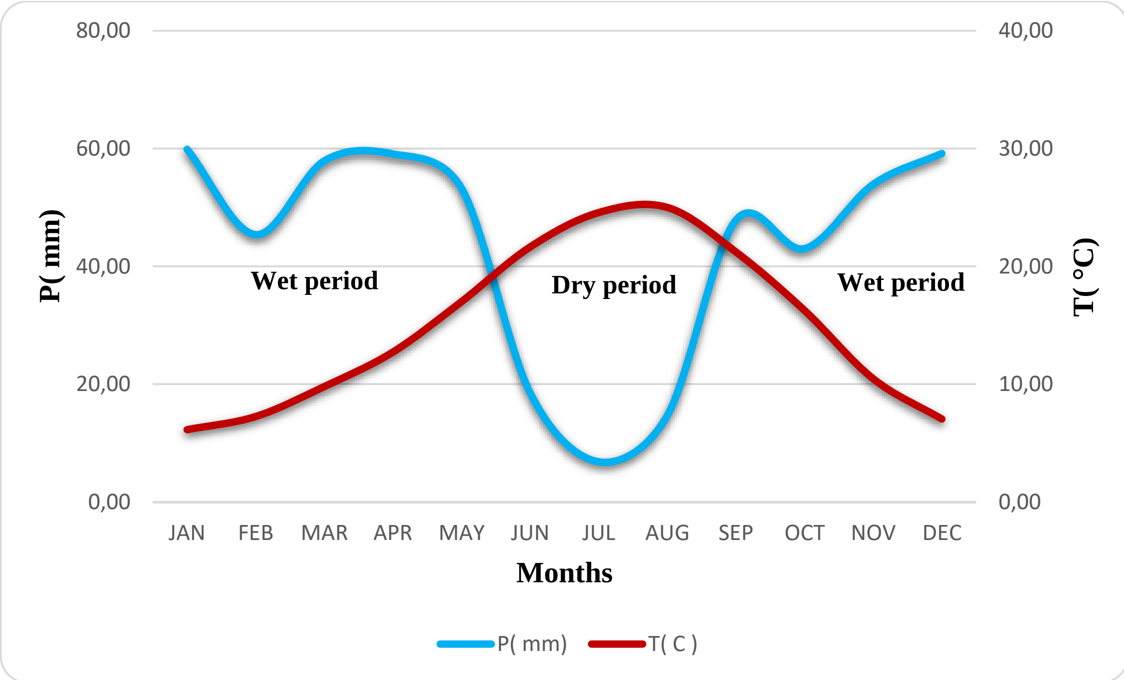


Figure 15: Ombrothermal diagram for the study area from 1985 to 2022.

4.7.6 Emberger's climagram

According to **Zedam (2015)** the EMBERGER pluviothermic quotient (Q_2), is a climatic index that translates the severity from North to South of the Mediterranean climate. take into account two climatic parameters namely: precipitation and temperatures (Table 4 and Table 5) and (Figure 15) as following (1):

$$Q_2 = \frac{1000\ P}{\frac{(M+m)}{2}(M-m)} \quad (1)$$

P : Annual precipitation in mm

(M-m) : Extreme thermal amplitude

Where : M : Average of the maxima of the most hot month in K

m: Average of the minima of the most cold month in K

NB: T (K) = T(°C) + 273,15 **(De Parceveaux et Huber, 2007) .**

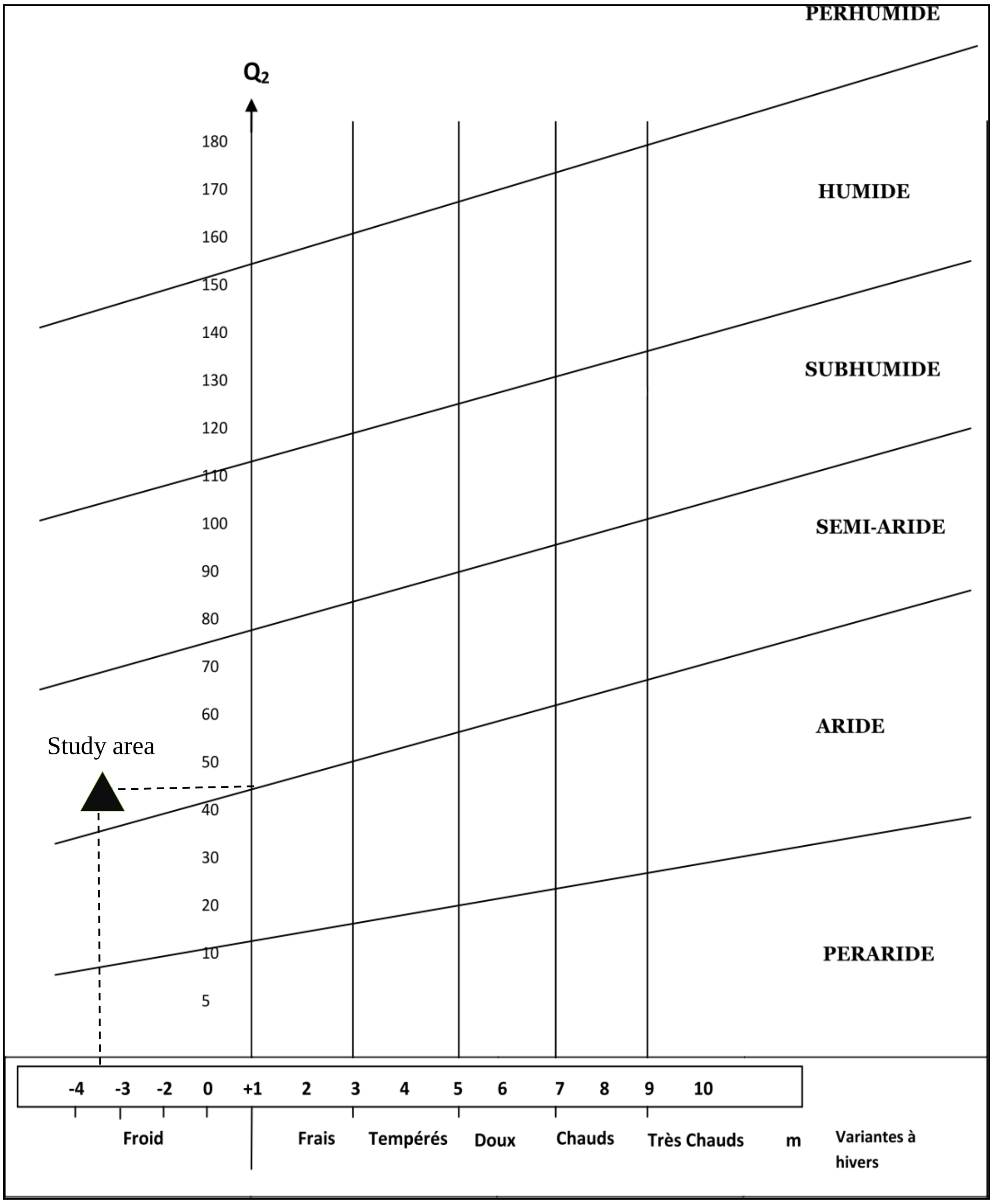


Figure 16: The studied area Emberger climagram's from 1985 to 2022.

CHAPTER III

Matrials and Methods

CHAPTER III: MATRIALS AND METHODS

5 Study objective

Our study focuses on a biodiversity assessment and spatial distribution of the cedar flora in the Djebel Maadid forest in the southern Bordj-Bou-Arreridj province (Northeastern Algeria). This aims to evaluate the ecological conditions for plant protection and conservation by conducting and establish an inventory and proposing a method to protect the existing flora. This study will allow us to update our knowledge of the flora in this Atlas cedar forest which remains completely unknown ecologically and botanically in order to establish preservation techniques for its endangered flora across numerous aspects against degradation linked to climatic disturbances (drought, water stress, Saharan influence …), the nature of certain substrates with low water retention capacity **(Bentouati and Bariteau, 2006)**, and finally anthropogenic actions manifested through overgrazing, uncontrolled exploitation, and illegal cutting and collecting.

6 Study material used

To carry out a specific inventory on plants and plant biodiversity associated with Atlas cedar in our study area we used the following material:

-A camera: For taking photos for the species encountered in the field.

-A knife to take some plant parts.

- Plastic bags for taking plant samples.

- An illustrative guide.

- A data sheet.

-GPS and compass.

- Notebook and a pencil.

- Programs (Arc map, Google Earth, Past)

- Cardboard and newspaper paper for drying plants (samples).

7 Floristic assessment

7.1 Sampling

To establish the floristic assessment of the Atlas cedar flora in the Djebel Maadid forest, we used a non-probability mixed sampling approach, incorporating both subjective and systematic sampling methods **(Zedam, 2015**; **Zedam and Fenni, 2021**; **Merabti *et al.*, 2022)**. In our case, we based our approach on the characteristics of the vegetation facets in the cedar forest (physiognomy). The surveys or samples were conducted during the spring-summer seasons in May-July for the years 2021 and 2022. We employed the minimum area method **(Guinochet, 1973)**, which determines the area required for a floristic sample **(Lacoste, Salanon, 2005)**. This methodology has been applied by various authors, such as **Hammada (2007)** in the study of Morocco's wetlands vegetation; **Hamel *et al.* (2013)** regarding the rare and endemic vascular flora of the Edough peninsula (Northeastern Algeria); **Zedam (2015)** focusing on endemic flora in the Chott El Hodna wetland (North Algeria); **Larbi *et al.* (2021)** concerning the floristic and phytogeographical diversity of a cedar forest in Djurdjura (North Algeria); **Zedam and Fenni (2021)** in an advanced research on vascular flora in the highlands of Algeria; and **Souahi *et al.* (2022)** exploring the variation in plant diversity along a watershed in a semi-arid region (Northeastern Algeria).

It is important to note that on the one hand for the collection of the different plants encountered and on the other the identification of the species accompanying the cedars, the presence of the latter was obligatory **(Larbi *et al.*, 2021)**.

According to **Gounot (1969)**, the sample areas varied from 200 to 400 m^2. This range of areas is suggested for forests studies in accordance with **Guinochet (1973)**, **Géhu and Rivas-Martinez (1981)**, **Ozenda (1982)**, and **Meddour (2011)**.

The surveys were carried out considering topographical elements and the methods of determination, which encompassed altitude, latitude, and longitude determined through GPS, as well as exposure, determined using a compass.

7.2 Number of floristic surveys

Floristic surveys were collected in many stations of the study area of Djebel Maadid south of Bordj-Bou-Arreridj province. These stations are located globally on the northern slope of the study area. We realized a total number of 73 floristic surveys carried out for inventorying and diagnosing the plant biodiversity of the Atlas cedar forest. This total was obtained firstly during the year of 2021 where we get 30 floristic surveys and secondly we get 43 floristic surveys in the year of 2022, in addition to the floristic surveys conducted by Zedam in 1991, which identified a total of 63 species, serve as a foundational dataset for diagnosing changes in vegetation dynamics, these surveys, carried out between May and July of 1991, provide essential reference data for understanding how the vegetation has evolved over time.

7.3 Identification and determination of species

For the species determination, we have used the following works:

-New flora of Algeria and southerly desert regions by **Quézel and Santa (1962-1963)**; updated by Flora Corsica of **Jeanmonod and Gamisans (2007)**.

- Sahara Flora by **Ozenda (2004)**.

All the plant species and their geographic distribution areas in addition to the biological types for these plants are defined by **Raunkiaer (1934)** and determined by in situ observation **(Emberger, 1966)** , for the taxon nomenclature used refers to the International Plant Names Index **(IPNI, 2024)** available at: **http://www.ipni.org** and the website: **www.tela botanica.org.**

7.4 Floristic Analysis

After outlining the survey characteristics, our data analysis initially focused on conducting a comprehensive floristic analysis where we utilized Microsoft Office “Excel” for Windows 2013 software. The floristic analysis encompassed: taxonomic richness, life forms, chorology, endemism and rarity, and the perturbation index (PI).

7.4.1 Taxonomic richness

After identifying the taxa encountered in our surveys, it is clear to determine the total number of species or species richness, genera, and botanical families. Species richness refers to the total number of recorded species, as defined by **Grall and Coïc (2006)**, and **Marcon (2024)**.

7.4.2 Life forms

Regarding the biological types or life forms used in our study, we employed those of **Raunkiaer (1934)** and the indications of **Emberger (1966)**, which advocate for the use of actual biological types observed in the field during the plant collection but where the biological type was not readily identifiable, additional information was obtained through the examination of other flora and references, such as **Dobignard and Chatelain (2010 - 2013)**.

The **Raunkiaer** system is based on the protection of buds during critical periods for vegetation, whether in winter or summer depending on the climate types. He distinguishes 5 main biological types as follows:

- Therophytes, which overwinter as seeds (these are annual plants).
- Chamaephytes, whose buds are above the ground but at a height of less than 25 cm (these are woody and perennial plants).
- Hemicryptophytes, whose renewal buds are at ground level (these are non-woody and perennial plants).
- Geophytes, whose buds are in the soil: rhizome geophytes, bulb geophytes, etc. (these are non-woody and perennial plants).
- Phanerophytes, whose buds are more than 25 cm above the soil surface (these are woody and perennial plants).

From the result of the biological types found, the biological spectrum will be derived; where **Lahondère (1997)** states that it is the percentage expression of each biological type based on the number of species. It is classified in descending order of importance as stipulated by many authors such as: **Yahi *et al.* (2008)**; **Ghezlaoui *et al.* (2011)**; **Beghami et al. (2013)**; **Hamel et al. (2013)**; **Negadi et al. (2014)**; **Zedam (2015)**; **Bounab (2020)**; **Habib et al (2020)**; **Sakhraoui et al. (2020)**; **Bouchibane et al. (2021)**; **Larbi et al. (2021)**; **Zedam and Fenni (2021)**; **Guechi (2022)**; **Souahi et al. (2022)**; and **Radjai et al. (2023)**.

7.4.3 Chorology

The chorology or biogeography of the recorded plants refers to their original geographical distribution. To determine this, we consulted the floras: Newflora of Algeria and southerly desert regions by **Quézel and Santa (1962, 1963)**, Sahara Flora by **Ozenda (2004)**, and occasionally the Synonymic Index of the Flora of North Africa by **Dobignard and Chatelain (2010 - 2013)**.

7.4.4 Endemism and rarity

Among all the determined species qualified as endemic according to the floras: Newflora of Algeria and southerly desert regions: **Quézel and Santa (1962, 1963)** and Sahara Flora: **Ozenda (2004)**, some are mentioned as "endemic"; noted as "End", they are considered "Algerian endemic" according to **Véla and Benhouhou (2007)**. However, the rarity annotation in the flora of **Quézel and Santa (1962, 1963)** for our taxa is indicated by a single index that presents four levels of rarity: extremely rare (RRR), very rare (RR), rare (R), and quite rare (AR).

7.4.5 The perturbation index (PI)

We proceeded to assess the perturbation index of the encountered taxa where we used Microsoft **Excel for Windows 2013 software**. The degree of disturbance for a vegetal community is gauged by the perturbation index (PI), a metric defined by **Loisel and Gomila (1993)** and widely adopted by numerous researchers to comprehend and quantify the impact of anthropogenic activities on floristic diversity. This index takes into account the value presence of two life-form species: therophytes and chamaephytes as following (2):

$$\mathrm{PI} = \frac{[(\text{Number of chamaephytes} + \text{Number of therophytes})\ \mathrm{X}\ 100]}{\text{Total number of species}} \quad (2)$$

7.4.6 Data collection for mapping

This study analysis of changes in vegetation cover over a 13 years period from 2009 to 2022 using Landsat satellite images. Two medium-resolution (30 m) Landsat images were obtained from the US Geological Survey (USGS) National Center: for 2009, 2017 and 2022. All images were acquired during the dry season when vegetation differences are most pronounced compared to other land use elements. The images were pre-processed and processed using ArcGIS (Version 10.8, 2019). The Normalized Difference Vegetation Index (NDVI) was calculated, which varies from -1 to +1. Low NDVI values correspond to bare soil, snow, and clouds, while moderate values represent shrubs, moderate vegetation, and grazing areas. High NDVI values indicate dense vegetation cover. Bare soil has NDVI values closest to 0, while water bodies have negative NDVI values. NDVI is a vegetation index used to estimate the quantity, quality, and development of vegetation based on the intensity of reflected or emitted radiation in specific electromagnetic spectrum bands1 by analysing changes in NDVI over time, this study provides insights into the dynamics of vegetation cover in the study area between 2009 and 2022 **(Khallef and Zennir, 2023)**: figure 16.

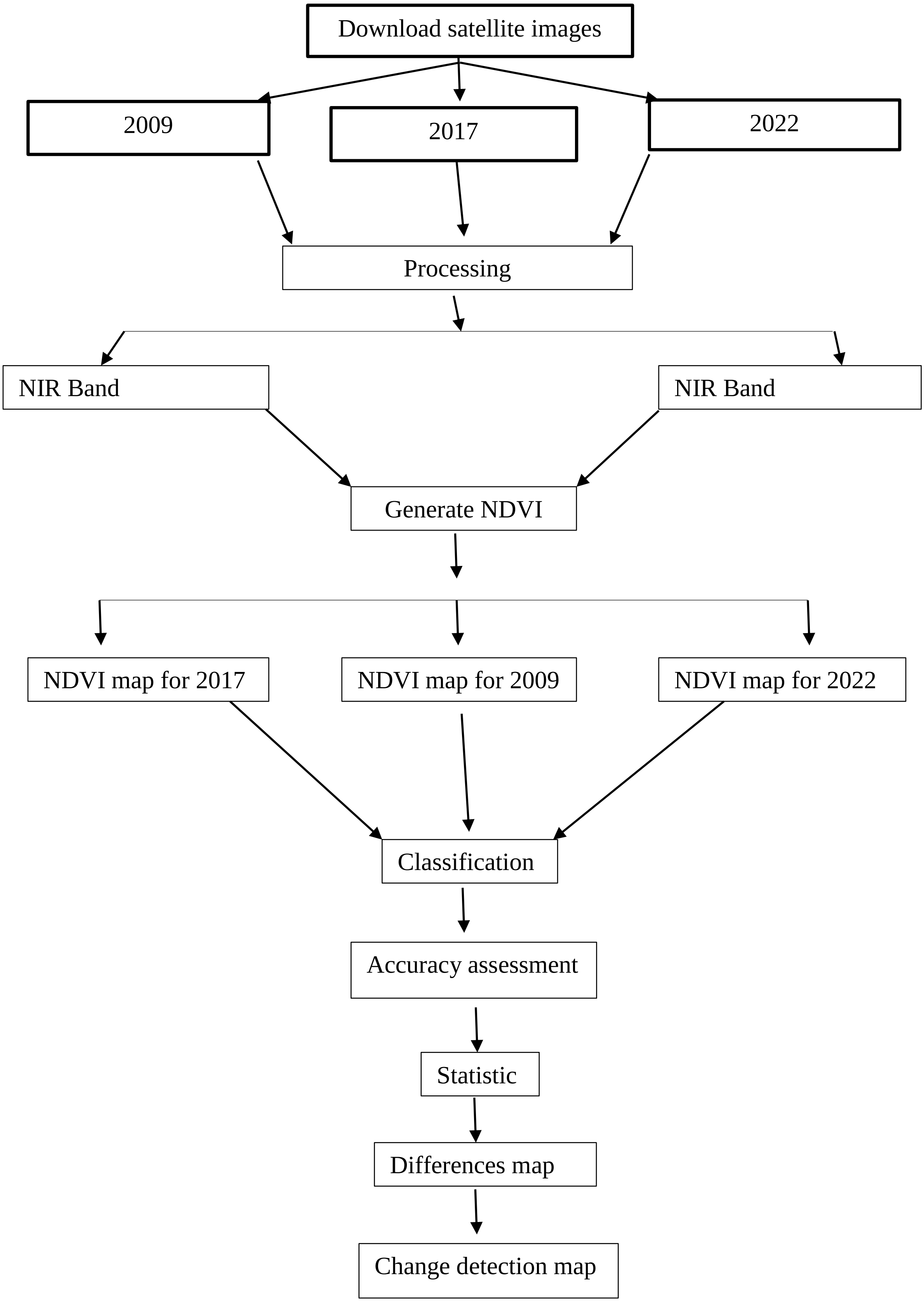


Figure 17: NDVI maps generation

7.5 Ethnobotany

7.5.1 Ethnobotanical surveys

Initially, our ethnobotanical study focused on the plant products offered by the cedar forest. However, the population's interest shifted towards medicinal plants due to the absence of artisanal activities that require forest products such as woodturning, crafting kitchen utensils and tools, and ancestral constructions... For these reasons, our research shifted towards phytotherapy.

For the ethnobotanical study of medicinal plants, conducted for academic rather than commercial purposes **(Asigbaase *et al.*, 2024)**, we engaged with the local population residing in the immediate vicinity of our study area, which pertains to the cedar forest, specifically in the village of Ghafsitane. To accomplish this, we employed a survey represented by questionnaire forms **(Bouayyadi *et al.*, 2015)**, with each form containing 20 questions. This survey was conducted from May 2021 until September 2022.

We engaged in open discussions and interviews with the individuals surveyed regarding medicinal plants and associated treatment methods **(Heinrich *et al.*, 1998)**. The questions posed and outlined in the questionnaire form focused on two aspects: first, the profile of the informant (age, gender, residence, education level, occupation, knowledge of medicinal plants, and use of phytotherapy or lack thereof); and second, information about therapeutic plants in the study area (name, usage, part used, harvest period, harvesting-drying-storage method, target ailment, method of use, and duration of treatment).

It should be noted that our questionnaires were completed with the prior agreement and consent of the individuals surveyed **(Larit *et al.*, 2022)**, while adhering to the ethical code set forth by the International Society of Ethnobiology (http://www.ethnobiology.net, accessed on 31 May 2021) was strictly followed.

Our objective, through this study on the use of medicinal species in traditional pharmacopoeia by the local population, in line with the works of several authors such as **Miara *et al.* (2018)**, **Al-Fatimi (2019)**,**Ouarghidi and Abbad (2019)**, **Palabaş Uzun and Koca (2020)**, **Lin *et al.* (2021)**,and **Shaheen *et al.* (2023)**, is to identify and gather information regarding treatment methods, various therapeutic uses, and determine the most commonly used medicinal plants. This would allow us to assess the potential overexploitation and uprooting of specific taxa related to the phytogenetic heritage of the cedar forest. Indeed, our work aims at preserving this heritage.

After botanical confirmation, of the taxa subject to this survey such as those of the cedar flora encountered, the information collected was processed **(Bouayyadi *et al.*, 2015)**. For our case we used Microsoft Office “Excel” software for Windows 2013.

7.5.2 Herbarium production for ethnobotany

To prepare our herbarium we start as a first step by drying the sample and plant species; putting our samples in the newspapers for a sufficient period of time to dry and then as a second step, stick them with non-acid Canson paper. For each herbal plate we mark the collector's name, harvest date, and GPS points of the station where we collected the plant species, scientific name and family name of the species.

7.6 Numerical analysis

The numerical analysis focused on three steps: Sørensen-Dice's similarity index, detrended correspondence analysis (DCA), and the maps establishment.

- Sørensen-Dice's similarity index is used to demonstrate potential links or connections between species groups **(Marcon, 2024)** or to compare associations **(Hammer *et al.*, 2001)**.
- DCA does not exhibit the arch effect and does not compress the data like correspondence analysis (CA) does **(Bakker, 2024)**. According to **Cano *et al.* (2019)**, the detection of "Species-Samples" group affinity is sought. This state is attributed to the characteristic species associated with each group **(Fennane, 1988)**.
- The maps establishment using arc GIS program - Version 10.2 (ESRI):
    - The distribution of the cedar’s samples,
    - The vegetation evolution state using the normalized difference vegetation index (NDVI) which quantifies vegetation by measuring the difference between near-infrared and red light of the satellite images for the years 2009, 2017, and 2022,
    - The flora zones conservation.

It is important to reminder that the first two analysis, performed by the free program: PAleontological Statistics (PAST), version 4.13 where we operated by using a binary data of the encountered species as cited by **Wolda (1981)**; **Dalirsefat *et al.* (2009)**; **Faye (2010)**; **Ghezlaoui *et al.*,(2011)**; **Kallio *et al.* (2011)**; **Rupprecht *et al.* (2011)**; **Zedam (2015)**; **Zedam *et al.*, (2016)**; **Zedam *et al.*, (2017)**; **Zedam and Fenni (2021)**; **Zedam *et al.* (2022)**; **Hammer (2023)**; **Radjai *et al.* (2023)**; and **Marcon (2024)**. In the same way for a comparison between groups, opposing evaluation, and intelligent automation and soft computing, the similarity analysis was used and operated by **Nyo *et al.* (2022)**; **Shah *et al.* (2023)**; and **Gnanakumari and Vijayalakshmi (2023)**.

Note that the species binary data are obtained by converting the abundance-dominance which is a semi-quantitative coefficient attributed to the species encountered in the samples into a qualitative coefficient of presence-absence **(Gillet, 2000)**.

CHAPTER IV

Results and Discussion

CHAPTER IV: Results and discussion

8 Surveys characteristics

Following our exploration of the region, we completed 73 sampling sessions spanning altitudes from **1510** m to **1850** m. Subsequently, we conducted a comprehensive inventory of the entire vascular flora found within each sample (Table 9).

Table 9: Surveys characteristics of Djebel Maadid cedar forest

N° of the sample	Altitude (m)	Exposure	N° of the sample	Altitude (m)	Exposure
1	1580	North	38	1570	North –East
2	1600	North	39	1650	West
3	1780	West	40	1816	West
4	1630	West	41	1805	West
5	1630	East	42	1820	West
6	1540	East	43	1748	West
7	1760	East	44	1750	West
8	1830	East	45	1750	West
9	1650	East	46	1761	West
10	1600	East	47	1800	West
11	1630	East	48	1824	West
12	1630	East	49	1826	West
13	1690	East	50	1850	West
14	1510	East	51	1810	West
15	1670	East	52	1619	West
16	1630	North	53	1750	West
17	1670	North	54	1720	West
18	1690	North	55	1735	West
19	1590	North	56	1635	West
20	1650	North	57	1700	West
21	1630	North	58	1680	West
22	1690	North	59	1670	West
23	1690	North	60	1645	West
24	1690	West	61	1625	West
25	1750	West	62	1690	West
26	1800	West	63	1670	West
27	1800	West	64	1630	West
28	1740	West	65	1600	West
29	1720	West	66	1584	North-West
30	1670	West	67	1570	North

31	1600	West	68	1600	North-East
32	1590	West	69	1540	North –East
33	1585	West	70	1670	North
34	1580	West	71	1580	North
35	1550	West	72	1540	North
36	1535	East	73	1530	North
37	1543	East	/	/	/

Our surveys are depicted in the studied area map (Figure 17), where the exploration covered homogeneous forest areas. In these areas, samples were collected and the existing flora was collected.

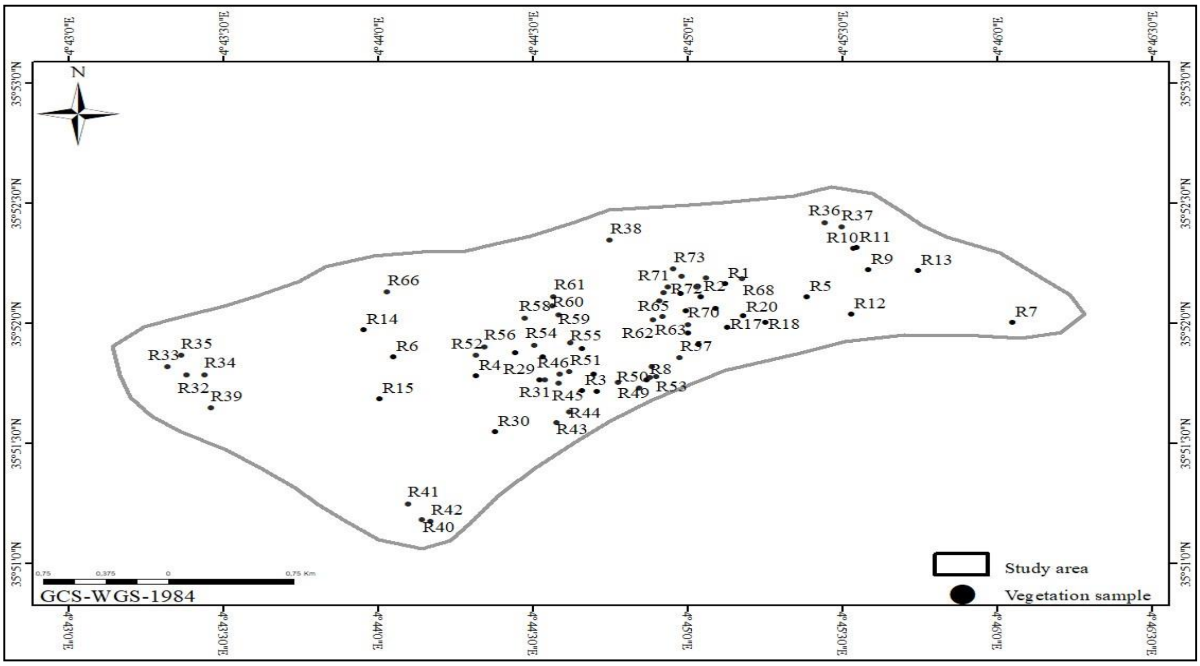


Figure 18: Cedar’s samples of Djebel Maadid

The density of the cedar is more pronounced in the center of the massif and as a result the number of our studied surveys is more concentrated in the central zone than in the sides (Figure 15).

9 Floristic analysis

9.1 Taxonomic richness

The analysis of the **73** floristic surveys unveiled that the samples yielded and carried out in the cedar forest; over an altitude ranging from 1510m to 1850 m; got as results **174** species, spanning over 91 genera and **39** botanical families. The bulk of families, totaling eight (08), encompass more than 68% (118 species) of the entire encountered flora: Asteraceae (35 species), Poaceae (15 species), Fabaceae (15 species), Brassicaceae (15 species), Lamiaceae (12 species), Apiaceae (10 species), Caryophyllaceae (09 species), Plantaginaceae (7 species), Rosaceae (5 species), Papaveraceae and Rubiaceae (4 species for each). The remaining families contain each between 1 to 3 species. Furthermore, it is noteworthy that twenty families consist of singletons, as outlined by **Magurran (2005)**, with each family represented by a single species (Figure 18).

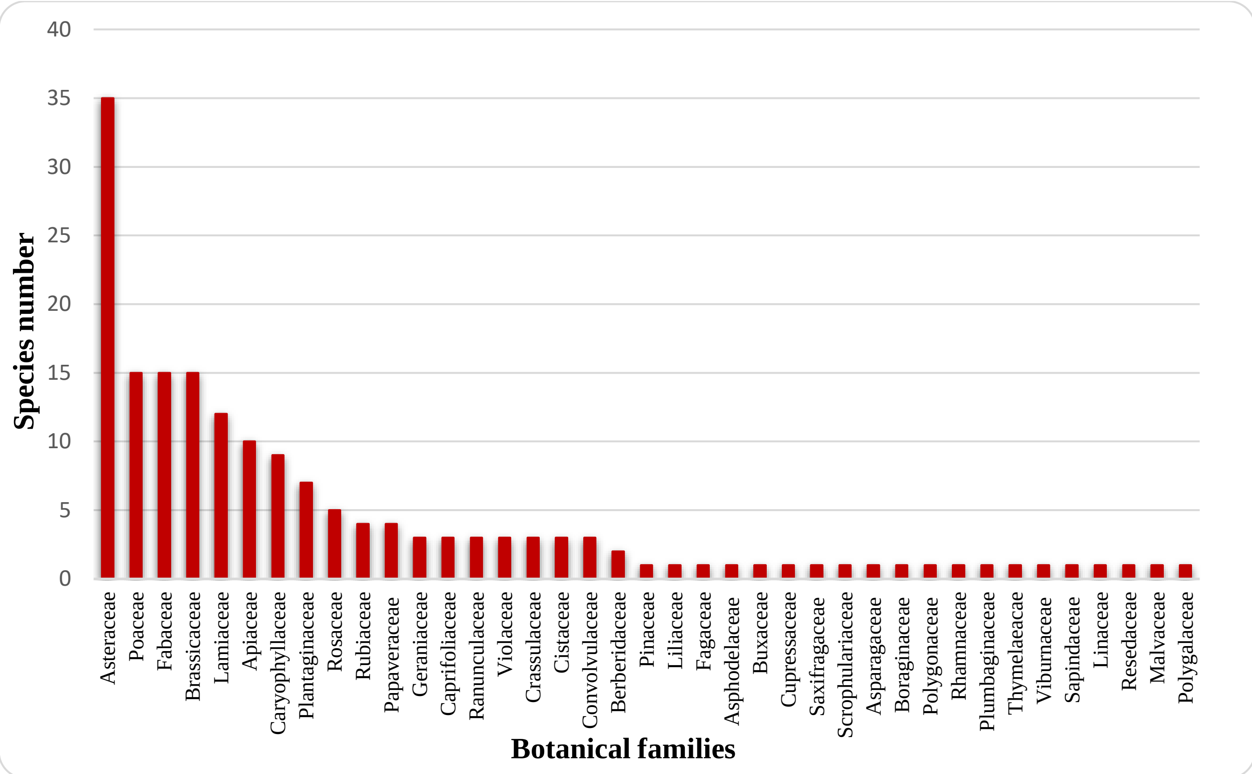


Figure 19: Botanical families distribution of Djebel Maadid cedar forest

In this context, **Quézel (1964)** observed that the most significant family in the Algerian flora is Asteraceae, a finding corroborated by our results.

9.2 Life -form

Our species' life forms as following results: Therophyte (Th) with 78 species, Hemicryptophyte (He) with 49 species, Chamaephyte (Ch) with 22 species, Phanerophyte (Ph) with 13 species, and Geophyte (Ge) with 12 species. The most dominant life form is the therophyte, accounting for over 44% of all species (Figure 20).

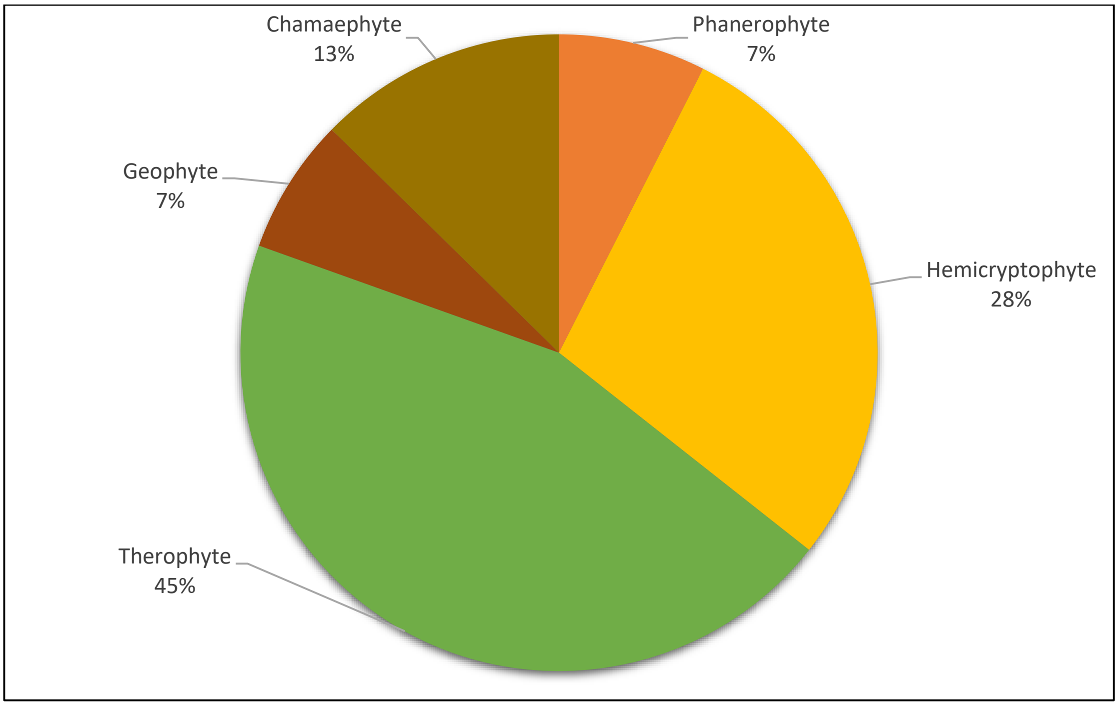


Figure 19: Species life-form distribution of Djebel Maadid cedar forest

According to figure 19, in the Djebel Maadid area, the distribution of life forms follows the sequence or biological spectrum:

Th > He > Ch > Ph > Ge

However, in the primary forest areas of the studied cedar stations (Tellian and Saharan Atlas), as documented by **Yahi *et al.* (2008)**, the order shifts to: He > Th > Ch > Ph > Ge. If we include nanophanerophytes (small phanerophytes) with phanerophytes life-form found by **Larbi *et al.* (2021)** at Ait Ouabane cedar forest (Djurdjura Mountains), its biological spectrum would be:

He > Ph > Th > Ch > Ge

This situation indeed suggests a less pronounced degradation and disturbance of the area. **Dahmani – Megrerouche (1996)** indicates that in forest and pre-forest environments rich in hemicryptophytes, the number of therophytes is relatively lower. Additionally, the shading induced by the canopy of phanerophytes, along with the lack of light, may negatively impact therophyte presence and colonization. Therophytes reveal their characteristic as heliophilic species **(Tchibozo Djikpo *et al.*, 2022)**, as noted by **Deconchat and Balent (2001)** and **Rebbas *et al.* (2011)** regarding the decrease in floral richness.

On their part, **Bouchibane *et al.* (2021)** in the Mountains of the Kabylia of Babors (Northeastern Algeria) propose the biological spectrum: He > Th > Ge > Ph > Ch, and state that the significance of therophytes is reflected in overgrazing and repeated vegetation cover fires.

The prevalence of Therophyte and Hemicryptophyte life forms in our study mirrors the observations made by **Beghami *et al.* (2013)** in their research on thuriferous Juniper (*Juniperus thurifera* L.) in the Aurès Mountains of Algeria. This alignment is particularly evident in the forestry community of Cedar-Thuriferous Juniper found at high altitudes.

This observation underscores the distinct characteristics of the species and the prevailing ecological conditions within our study area:

- Species requirements and plant growth: These include temperature preferences, moisture availability, altitude, and soil depth, all of which influence the distribution and abundance of different life forms.
- Anthropogenic activities: Various human interventions such as trampling, overgrazing, harvesting of valuable plants, habitat loss and conversion, land degradation, fragmentation, wildfires, wild camping, and illegal logging, all exert significant pressures on the ecosystem.
- The condition of the community, described as possessing sylvatic physiognomy **(Beghami *et al.*, 2013)**, appearing semi-open, or displaying signs of degradation, provides valuable insights into the overall health and resilience of the ecosystem.

Degradation observed within the community may serve as an indicator of the impact of human activities or environmental stressors on the ecosystem's stability.

The observations documented by **Yahi *et al.* (2008)** regarding the prevalence of therophytes in Algerian cedar forests, indicative of disturbances such as clearing and grazing, are noteworthy. This dominance of the therophyte life-form is often interpreted as an adaptive response to arid conditions, as highlighted by **Negre (1966)**, there by reflecting the aridity of the environment, as emphasized by **Negadi *et al.* (2014)**. Moreover, **Madon and Médail (1997)** noted that the Mediterranean therophytes are primarily stress-tolerant species.

For his part, **Zedam (2015)** further elucidates that the abundance of therophytes signifies a pioneer stage linked to the prevailing climate. The prevalence of therophytes thus serves as a valuable ecological indicator of both human activities and local climatic conditions. Understanding these dynamics is imperative for devising effective conservation and management strategies tailored to these unique ecosystems.

In the Hodna Mountains and surrounding areas, the dominance of therophytes is conspicuous, a state reported by numerous authors including **Kaabeche (1990)**, **Sedjar (2012)**, **Zedam (2015)**, **Bounab (2020)**, **Yaici (2020)**, **Zedam and Fenni (2021)**. Even **Guechi (2022)** highlights a fairly significant proportion of therophytes in her research, where their presence indicates the degradation and the disturbance of the area related to drought on one hand and anthropogenic pressure such as overgrazing and fires on the other. Finally, **Meddour (2010)** asserts, in the study of plant communities in the Djurdjura region, that the prevalence of therophytes in these groups indicates a trivialization of the original flora and extensive grazing.

In summary this abundance of therophytes in the study area proved that environmental disruption due to human activities, particularly grazing, underscoring the influence of human activities on plant diversity and the impact of anthropogenic factors on ecosystem health (El **Bouhissi *et al.*, 2021)**.

Regarding hemicryptophytes, their presence is linked to high-altitude Mediterranean forest environments **(Dahmani - Megrerouche, 1996)**, soil richness in organic matter **(Barbero *et al.*, 1989**; **Gharzouli, 2007)**, and the moisture of their high-altitude habitats **(Barbero *et al.*, 1990)**.

The infrequent presence of Chamaephytes is indicated by the appearance of low-growing woody plants, possibly due to significant human activity **(Dahmani - Megrerouche, 2002)** where they have allowed another type of vegetation instead of forest formation, known as "matorral," to become established **Meddour (2010)** and even better, their proportions increase as soon as there is degradation of plant formations **(Bouazza *et al.*, 2001)**. Furthermore, this kind of plants is typically considered well-adapted to cooler temperatures and dry conditions, as noted by **Raunkiaer (1934)** and **Orshan *et al.* (1984)**.

The Phanerophytes and the Geophytes are the least represented life forms in our study area. The first ones are the dominant physiognomic biological type, but in terms of numbers, they are outnumbered by the preceding ones. Their species form the forest ecosystem rich in sylvatic flora **(Meddour, 2010)** and the impoverishment of the vegetation in a location results in the progressive disappearance of phanerophytes and the expansion of chamaephytes **(Bensenane *et al.*, 2015; Benabadji, 2023)**.

In fact, geophytes are the least represented in most of the formations studied, although their rate is relatively higher in forest environments than in grasslands and steppe areas where they can disappear completely **(Dahmani - Megrerouche, 1996)**.

Bensenane *et al.* (2015) and **Benabadji (2023)**, on the other hand, note that phanerophytes and geophytes are often overshadowed by therophytes and chamaephytes in certain case studies affected by exaggerated anthropogenic actions and a relatively dry climate.

9.3 Chorology

According to **Quézel and Santa (1962, 1963)** and **Ozenda (2004)**, the spectral analysis of the chorological types (figure 20) indicates the prevalence of four types in the studied cedar formation. The examination of the main chorological types encountered reveals the strong presence of the Mediterranean taxa with 54 species (31,03 %) in the second rank after the most dominant origin which is the wide distribution with 68 species (39,08 %). This situation was highlighted by **Yahi *et al.* (2008)**, where the Mediterranean element dominates in the cedar forests of the Tell Atlas with nearly 47% of their flora.

These elements are followed by Nordic taxa with 34 species (19,54 %), and the endemic species with 14 species (8,04 %). Finally, the cosmopolitan group presents only 4 species (2,29 %).

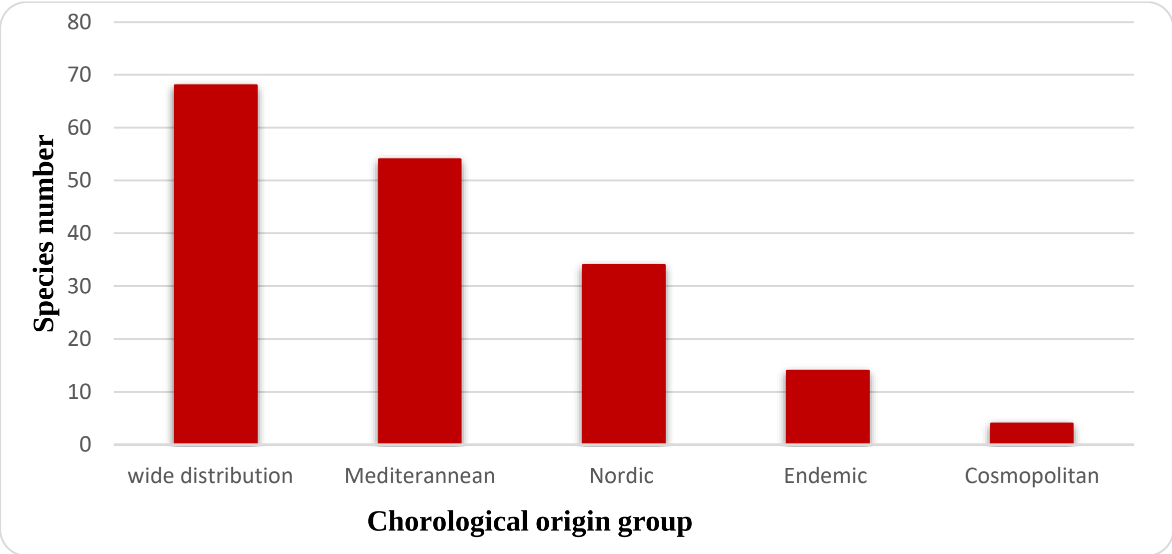


Figure 21: Species chorology of Djebel Maadid cedar forest.

As mentioned by **Dahmani – Megrerouche (2002)**, the overview of pluri-regional elements or wide distribution in a floristic assemblage indicates the alteration of the studied phytogenetic heritage, which corresponds perfectly to our case study.

This analysis has revealed a gap in the current list of species receiving protection at the national level, prompting a recommendation to enhance the list by including species meeting criteria such as rarity, endemism, and ecological significance. In terms of phytogeography, the flora of the cedar grove in the Maadid massif displays a diverse composition, with a notable prevalence of Mediterranean plant species **(Belkhous, 2012)**.

According to **Maire (1926)** who pointed out that the presence of the northern elements (European, Eurasian, temperate paleo…) could be explained by the particularly humid character of these groups attributes the introduction of the northern complex in North Africa, to the humid periods older than the Quaternary through two migration routes: one Iberian and the other Italian.

The marked presence of the endemic element at the level of certain groups seems to be linked to altitude and microclimatic conditions **(Quézel, 1957)**. This phytogeographic type is abundant among hemicryptophytes and would indicate a moderation of anthropogenic action **(Belkhous, 2012).**

Dahmani -Megrerouche (1997) confirm that the presence of the Mediterranean-Iranian-Touranian and Mediterranean-Saharan-Sindian elements within the Maadid massif appears to be associated with local climatic conditions. The specific microclimatic conditions in the Maadid massif likely favor the growth and survival of these plant species, allowing them to thrive in this particular area despite being more commonly found in other regions

9.4 Endemism and species rarety

Quézel and Santa (1962-1963), **Véla and Benhouhou (2007)** and **Guechi (2022)** indicate that the number of endemic or subendemic taxa in Algeria is 464, which includes 387 species, 53 subspecies, and 24 varieties across the entire national territory. For northern Algeria, the number of endemic taxa is 407, comprising 338 species, 48 subspecies, and 21 varieties. This distribution highlights the diversity of endemic species in Algeria, with different regions exhibiting distinct patterns of endemism. Specifically, the country is characterized by:

-Strict Algerian Endemism: This category includes 224 taxa that are unique to Algeria and are not found in any other region.

-Algerian-Moroccan Endemism: This group consists of 124 taxa that are endemic to both Algeria and Morocco.

-Algerian-Tunisian Endemism: This category includes 158 taxa that are endemic to both Algeria and Tunisia.

-Algerian-Sicilian Endemism: This category includes only one taxon that is endemic to both Algeria and Sicily.

-These patterns of endemism are significant for understanding the biodiversity and conservation of Algeria's flora, particularly in the context of the country's Mediterranean region and its unique ecological niches.

For the study area we have inventoried 14 endemic taxa of which 5 species are north African endemic, 4 Algerian -Moroccan endemic, 4 Algerian endemic and 1 Algerian - Tunisian endemic species (Table 10)

Table 10 :The endemic species in the studied area

Endemism status	Species
North African	*Viola munbyana Boiss. et Reut.,* *Thymus algeriensis Boiss. & Reut.,* *Alyssum scutigerum Durieu,* *Bupleurum montanum Coss. & Durieu,* *Thymus ciliatus ssp Bios.Reut*
Algerian -Tunisian	*Linaria raflexa.L.Desf,*
Algerian -Moroccan	*Cedrus atlantica (Endl.) Manetti ex Carrière.,* *Festuca atlantica Duv. Jouve,* *Carthamus rhaponticoides (Pomel) Greuter,* *Catananche caespitosa Desf,*
Algerian	*Centaurea acaulis L ssp. balansae (B. et R.) M.,* *Ammoides atlantica (Coss. et Dur.) Wolff.,* *Draba hispanica Boiss.,* *Erysimum bocconei (All) Pers.*

According to **Quézel and Santa (1962-1963)**; **Véla and Benhouhou (2007)**, and **Guechi (2022)** the information provided in the search results, for northern Algeria, a total of 1630 rare taxa have been recorded, including 1034 species, 431 subspecies and 170 varieties.

Throughout the national territory, there are 1818 rare taxa, including 1185 species, 455 subspecies and 178 varieties. In our study the majority of the species listed in this inventory are 50 common to Tell with species, 30 very common, 10 quite common, and 4 extremely common. (Figure 21 *"a"*)

By virtue of Executive decree n° 12-03 of January 4, 2012, fixing the list of uncultivated plant species protected in Algeria, 14 taxa identified in the Maadid massif are included in this protection list. We cite the following species: *Buxus sempervirens* L., *Cedrus atlantica* Manetti, *Juniperus* oxycedrus L., *Daphne laureola* L, *Bupleurum montanum* Coss. & Durieu, *Phlomis bovei* de Noé, *Poa nemoralis* L. *Teucrium polium* L.

In our study area and according to the flora distribution the rare flora has 80 species, of which 36 are rare, 24 are quite rare and 20 are very rare (Figure 21 *"b"*).

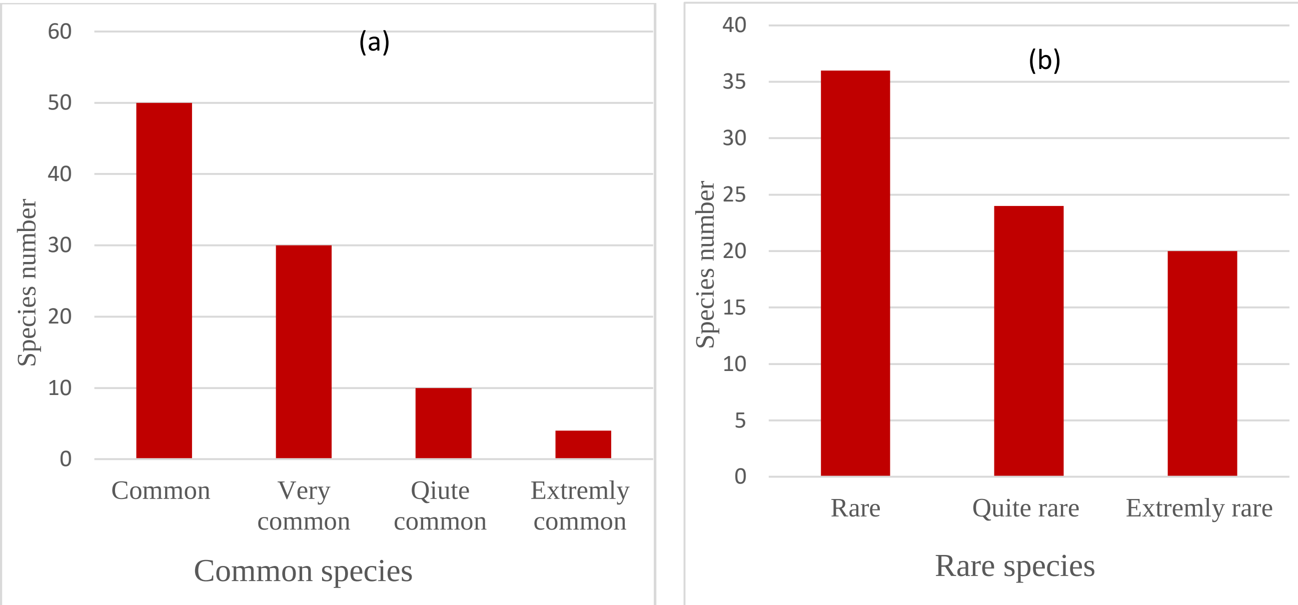


Figure 22:Species rarity and common of Djebel Maadid cedar forest.

9.5 Perturbation index

The Perturbation Index (PI) serves as a measure reliant on the abundance of therophytes and chamaephytes, offering a quantification of therophytization within an environment **(Loisel and Gomila, 1993)**. In our case study, featuring 78 therophytes and 22 chamaephytes, the calculated PI stands at 57.47%. This value is higher to those reported by **Beghami *et al.* (2013)**, ranging from 55.26% to 61.86% for degraded formations and from 28.13% to 45.50% for less degraded ones, for **Bounab (2020)** where she reports a (PI) of 57.75% ± 1.48%, and **Radjai *et al.* (2023)** with 55.56% in the central part of the cedar forest of Djebel Maadid. Our (PI) exceeds also the results of **Yaici (2020)** and **Guechi (2022)** where each indicated a (PI) of 40%; and lastly**, Larbi *et al.* (2021)** documented a perturbation index (PI) of 27%, which represents the lowest value observed in a mountainous forest setting. These disparities may be attributed to local conditions, management practices, and ecological contexts.

A higher perturbation index "PI" signifies greater degradation within the plant community, characterized by a significant presence of identified therophytic and chamaephytic species. This condition reflects the opening up of plant formations **(Hebrard *et al.*, 1995**;

Belhacini *et al.*, 2016), consequently resulting in a reduced representation of substantial perennial species, particularly phanerophytes (sylvatic formation). Such observations underscore both anthropogenic pressure on vegetation **(Quézel and Barbero, 1989)** and the adverse impact of drought on the environment, leading to degradation, and loss of biodiversity **(Muluneh, 2021)**.

9.6 Ethnobotanical investigation

9.6.1 Age

The total number of people in our study was 130 interviewed with a deferent age stage distributing as follow: the young and moderate age {30-50} whit (31%), following by is greater than 70 was 15 %, and the last is less than 30 years (11 %), where the dominant category is {50-70} (43 %) depending on the result of **Guechi (2022)** in the Maadid region which get (53%) for 20 to 30 age group: Figure 22.

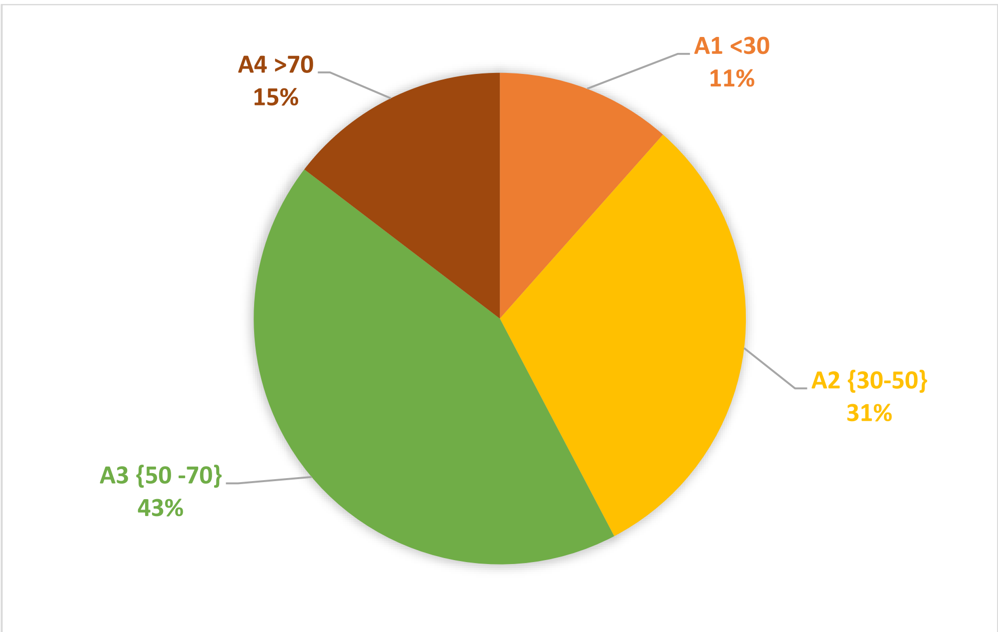


Figure 23: Age categories of informants

9.6.2 Gender

Our study touched on both genders, women and men, but we noted that the female gender is predominated by 59 % (77) compared to 41% (53) for male gender which prove that the women are more concerned with treatment, the preparation of recipes and they are responsible for the health of their families, as the same result for the ethnobotanical study of **Guechi (2022)** and **Marrouche *et al.* (2021)**, also because I am a woman, I was able to communicate with almost all the women of the region: Figure 23.

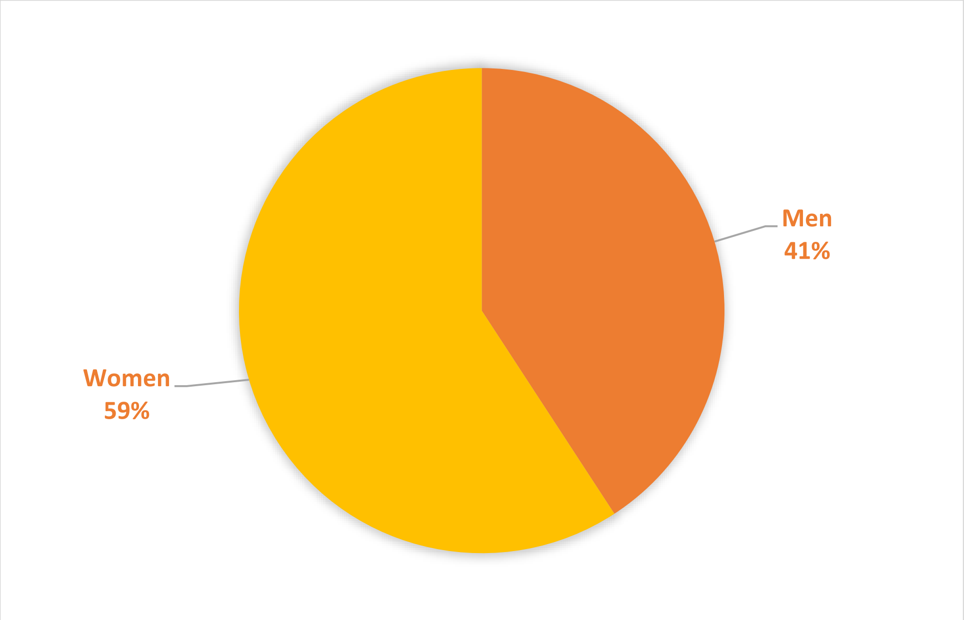


Figure 24: Gender of informants.

9.6.3 Education level

According to **Marrouche *et al.* (2021)**, the use of medicinal plants is most common among people with a primary level of education, accounting for 34% of users. This relatively high percentage is directly correlated with the education level of the local population using the plants. However, people with a secondary school education also have a significant percentage of medicinal plant use at 26%.

In contrast, in our study the dominate are illiterate 52 % because most of them were women over 50 years old, following by 19 % middle school ,11% primary and 10 % high school & those 8 % with a university-level education have a lower percentage of medicinal plant use. They depend on the modern treatment. This correlation between education level and medicinal plant use highlights the complex interplay between traditional and modern healthcare practices in the local population. (Figure 24)

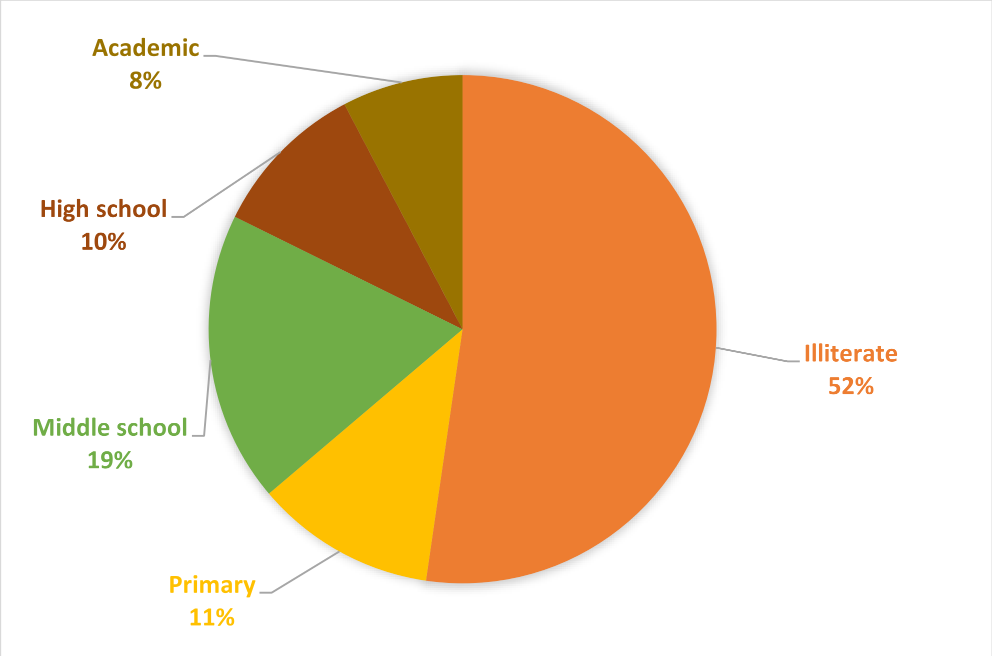


Figure 25: Education level categories of informants.

9.6.4 Profession

According to the population number affected by the investigation and taking the professional status into account, we obtained results indicating that the majority are common people whose profession is not related to plants 103 people out of 130 as a total (77%),14 as healers (11%) and 11 herbalists (8%) **Boucherit & Benaradj (2023)**: Figure 25

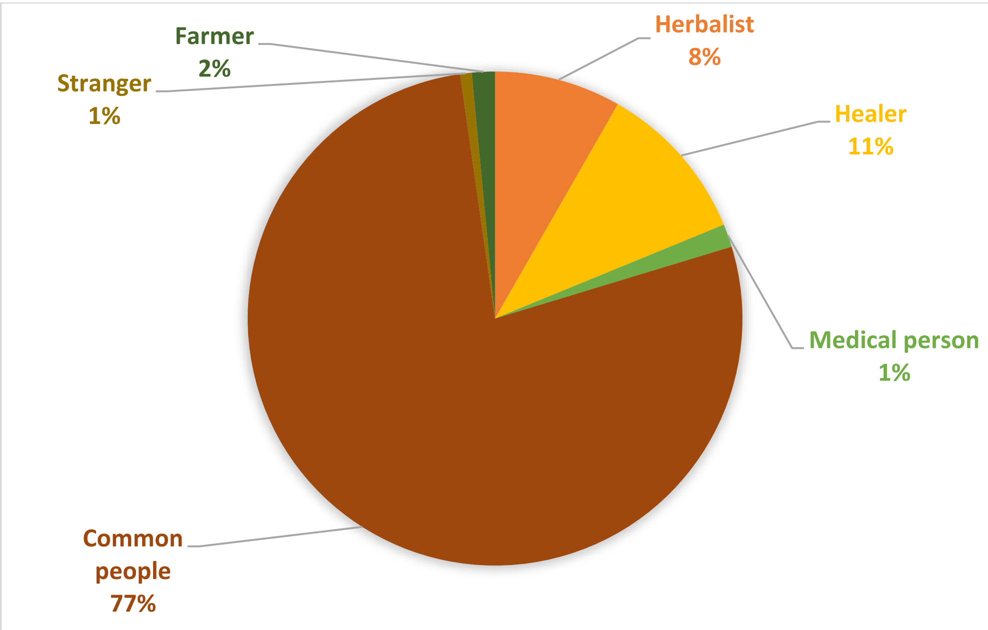


Figure 26: Deferent profession of informants.

9.6.5 The treatment type

Depending on **Souilah *et al.* (2023), Wendimu et al (2024),** and through the interviews with the local people the results indicate that the treatment type is varies, and that's depends on their traditions or experience, even the personal experience interferes in this, some of them resort to herbs (phytotherapy treatment) 44 % as an effective treatment, and only 25 % they prefer modern medicine, while the rest 31%are the category that uses the phytotherapy and also the medicines: Figure 26

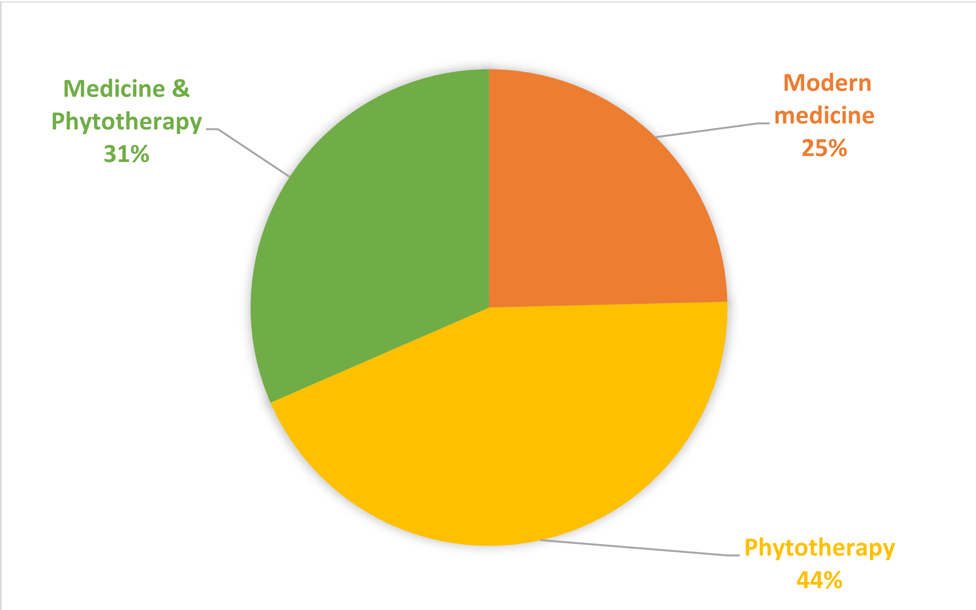


Figure 27: Dominant treatment type

9.6.6 Botanic diversity: Families and species

Nawash et al. (2014) and **Maamar Sameut *et al.* (2020)** refer to the diverse botanical families in the Mediterranean basin. It confirmed that the dominant is Lamiaceae. Accordingly, in our result indicates that in total of 12 species distributed over 10 families Lamiaceae were the most represented families with 3 species, and Asteraceae with 1 species, then Pinaceae (1 species), Rhamnaceae (1 species), Fagaceae, Paronychioideae, and Cupressaceae, Rosaceae, Buxaceae and Renonculaceae also 1 species for each one (Table 11 and figure 27).

Table 11: Families and medicinal plants in the study areas.

Familles	Medicinal plants
Lamiaceae	*Thymus algeriensis* Boiss. & Reut. *Ajuga chamaepitys* (L.) Schreb *Teucrium polium* L.
Cupressaceae	*Juniperus oxycedrus* L.
Paronychioideae	*Paronychia argentea* Lam.
Fagaceae	*Quercus ilex* L.
Pinaceae	*Cedrus atlantica* (Endl.) Manetti ex Carrière
Rosaceae	*Crataegus azarolus* L
Asteraceae	*Carthamus pinnatus* Desf.
Renonculaceae	*Ranunculus bulbosus* L.
Buxaceae	*Buxus sempervirens* L.
Rhamnaceae	*Rhamnus alaternus* L.

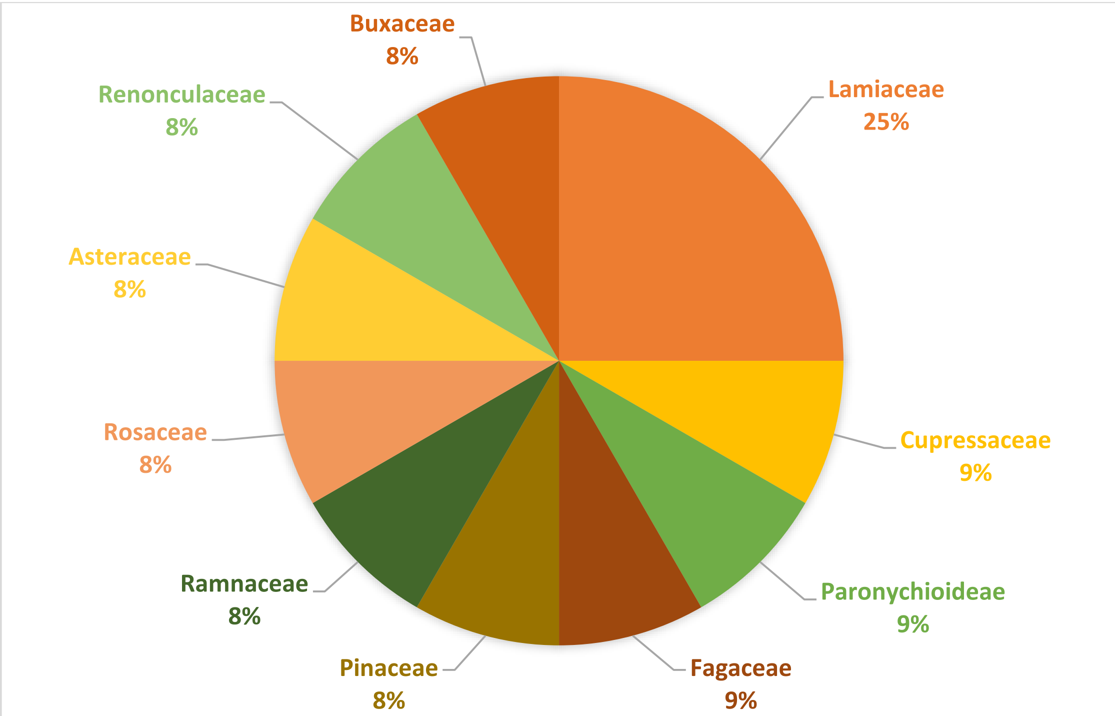


Figure 28: Dominant families

9.6.7 Used parts

According to **Khusna *et al.* (2023), Guechi (2022)** and **Marrouche *et al.* (2021),** the most commonly used parts of plants are leaves, which account for a significant percentage of plant usage. Other frequently used parts include roots, fruits, stems, bark, rhizomes, flowers, sap, branches, and tubers.

We registered that the most used part was the leaves (77%) more used than the other parts 23% include flower (6%), in a similar proportion the seeds (6%), followed by stem and roots (4%), fruit (3%): figure 28.

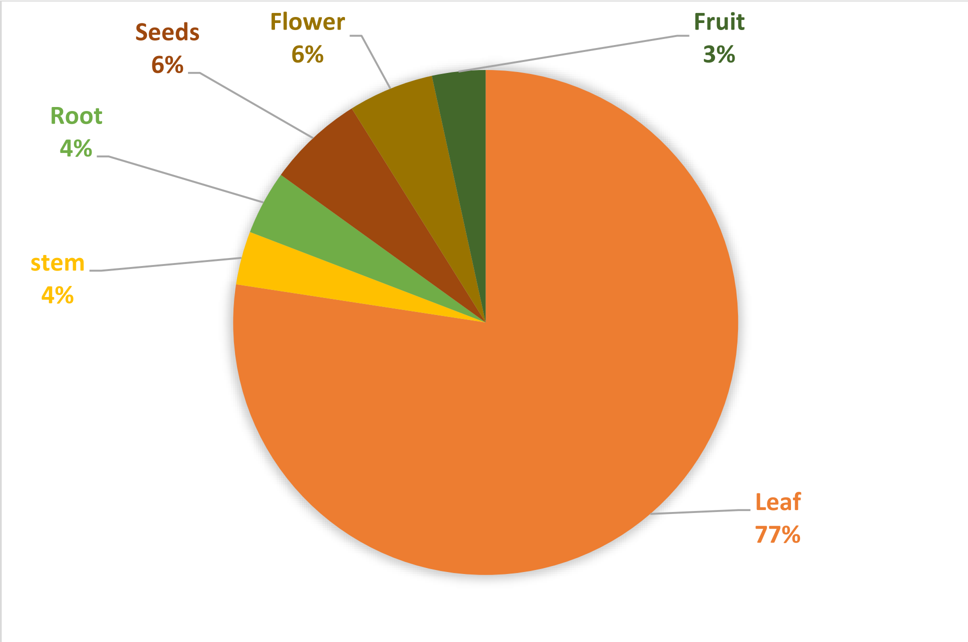


Figure 29: Dominant used parts.

9.6.8 Used purpose

This community and local population use the plants for a different purpose like treatment, they depending on it as a medicinal treatment (85%) where is the most common use, or for food (5%), in addition to other uses (aesthetic, aromatic) **Ndlovu et al (2024)**: figure 29.

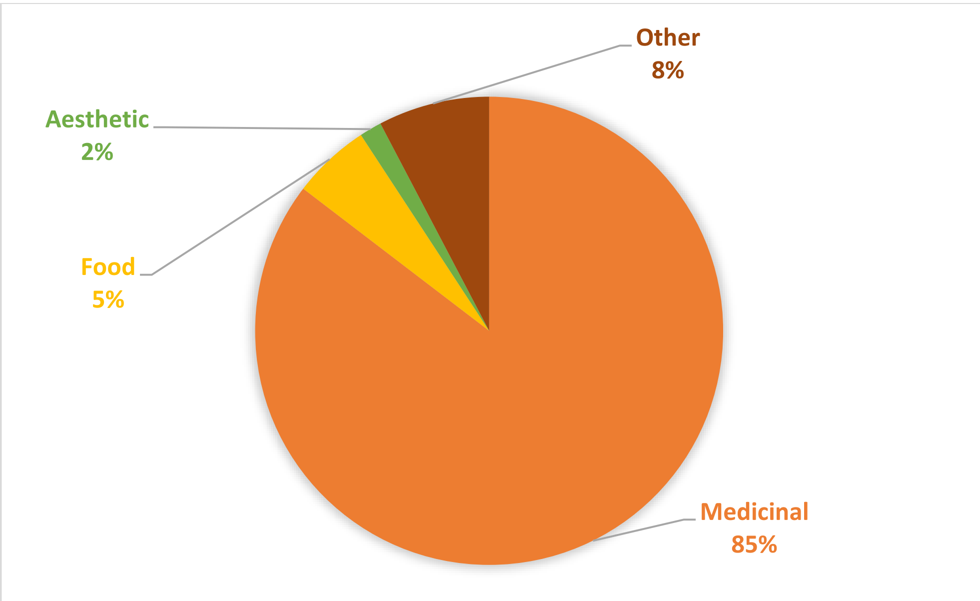


Figure 30: Dominant used purpose.

9.6.9 Method of preparation

To streamline drug administration, various preparation methods are utilized like: infusion, powder, fumigation, decoction, poultice, maceration and basting. Individuals consistently seek the most convenient approaches for preparing herbal remedies **Marrouche *et al.* (2021).**

Those preparation methods of herbs are differing and depending on the population's knowledge and the targeted treatment.

Accordingly, in our study area, the results indicated that the concerned community uses the most typical methods as follow: the (68%) use of drugs the preparation is carried out by boiling, and infusion 3 % which is they are considered easier and more effective by domestic community who consider both methods for the same purpose according to their culture **(Khusna *et al.*, 2023) ,Boucherit & Benaradj (2023),** following by powder (12 %), the rest of the people chose other methods of use, such as maceration (8%), infusion, vaporation, and cataplasme 3% for each beside other traditional methods. See the figure 30 below.

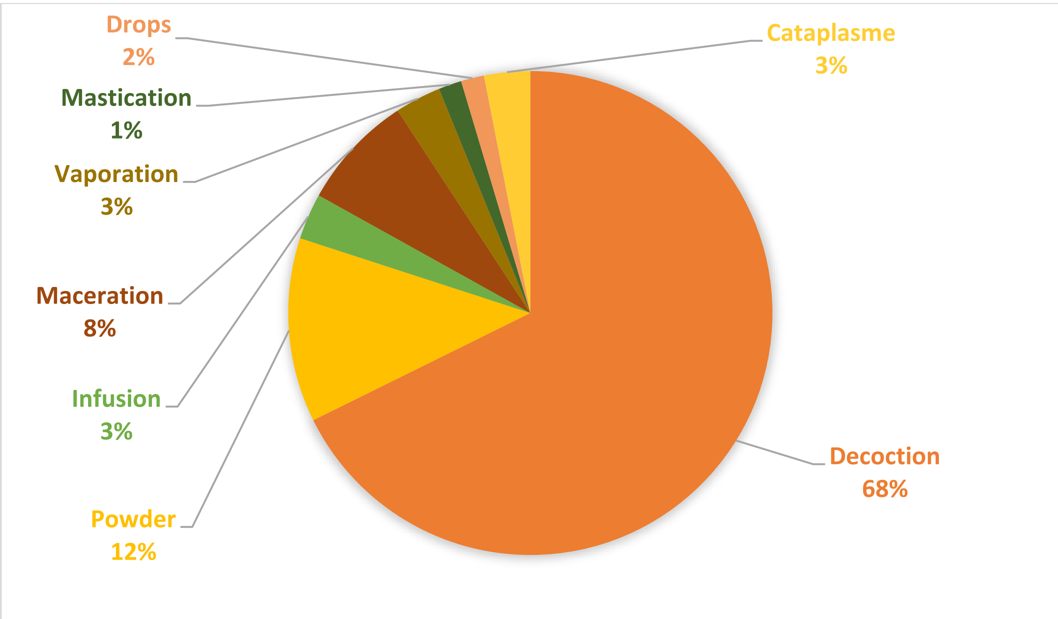


Figure 31: Dominant method of preparation.

10 Numerical analysis

10.1 Sørensen-Dice's similarity index

The similarity, using the Sørensen-Dice's index, which its values ranging from 0 to 1, can reveals the possible link or connections between species groups **(Marcon, 2024)** and the possibility to show species associations according to certain ecological affinities **(Hammer *et***

***al.*, 2001)**. In the same context a high similarity value suggests that two groups share a similar floristic composition or ecological conditions **(Walter, 2006)**.

Our analysis shows three distinct groups labeled as 1, 2, and 3 as shown in the figure 31 below.

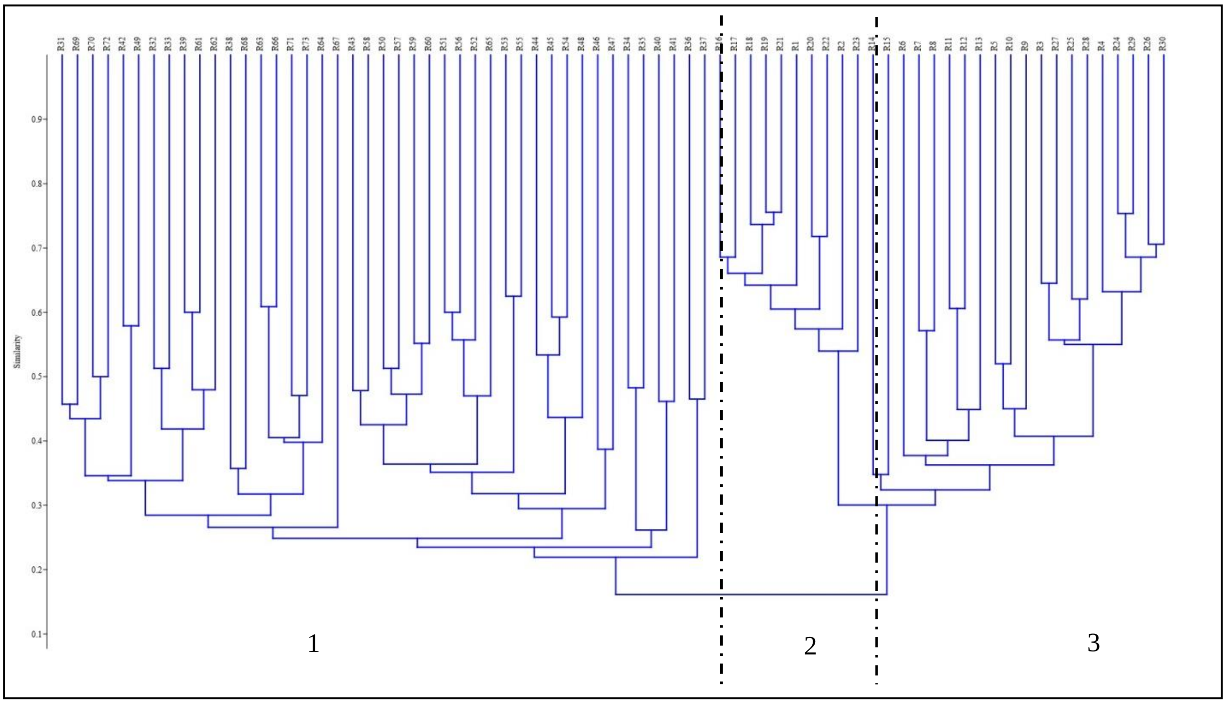


Figure 32: Samples similarity of Djebel Maadid cedar forest

The first group (1) which is located in the centre of our study area and brings the following samples: R31 ,R32 ,R33 ,R34 ,R35 ,R36 ,R37 ,R38 ,R39 ,R40 ,R41 ,R42 ,R43 ,R44 ,R45 ,R46 ,R47, R48 ,R49 ,R50 ,R51 ,R52 ,R53 ,R54 ,R55 ,R56 ,R56 ,R57 ,R58 ,R59 ,R60 ,R61 ,R62 ,R63, R64, R65, R66, R67, R68, R69, R70, R71, R72, and R73 ,this group clearly appears a strong similarity between the surveys, the group occupies a microclimatic zone in the North and West Exposure with high altitude, its characterized by a rainy and cold climate in the winter which makes it the richest area in biodiversity and the most productive forest of wood .And it’s the case in the second group (2) which is next to the group (1) from the east and brings the samples :R1, R2, R16, R17, R18, R19, R20, R21, R22, and R23. This state reflects a strong similarity in this group **(Koleff *et al.*, 2003**; **Gonzalez Herrera, 2009**; **Marcon, 2024)**. This group occupies a microclimate area protected in East and West by high altitude ridge lines and headed towards the North exposure. This situation leaves it greatly rainy with cool winters. Note that **Zedam (1991)** has mentioned that this part of forest is located in the highest class part of wood production. These sample's areas can play an important role for the conservation of plant biodiversity and be the most important zone of preservation in the cedar forest specifically against overgrazing.

The group (3) which is more important in number and very heterogeneous where **Jenny *et al.* (1990)** indicate that the cluster analysis takes into account species variation and therefore clearly separates study stations: R3, R4, R5, R7, R8, R9, R10, R11, R12, R13, R14, R15, R24, R25, R26, R27, R28, R29, and R30. Its surveys belong to east and west exposures, at a medium to low altitude which makes it vulnerable to overgrazing, even though have cold season in winter and less precipitation compared to the first group, also **Zedam (1991)** has mentioned that this zone is a wood production forest that divided into two classes, the eastern one is the moderate.

10.2 Detrended correspondence analysis (DCA)

As **Zedam (2015)** provide the performation of the multivariate analysis techniques (DCA) for the transformation of data "samples-species" based on the distribution of the species, depending on the figures 28 and 29 the samples and species regrouped in 3 major groups due to the similar characteristic of species, the first group "A" includes the following samples: R31, R31, R32, R33, R34, R35, R36, R37, R38, R39, R40, R41, R42, R43, R44, R45, R46, R47, R48, R49, R50, R51, R52, R53, R54, R55, R56, R56, R57, R58, R59, R60, R61, R62, R63, R64, R65, R66, R67, R68, R69, R70, R71, R72, and R73 with a serval species such as *Cedrus atlantica* Manetti, according to **Maire (1926)** the atlas cedar supporting the dry climate in summer and the cold in winter as an xerophilous species, and **Kaabeche (1996)** declared that it occupies the northern slopes of the highest massif of Hodna and Bibans , Righa and Maadid, and developed in a bioclimatic atmosphere between the semi-arid to sub-humid bioclimates, characterized by annual precipitation ranging from 500 to 800 mm. The Atlas cedar prefers a substrate characterized by limestone but as an opinion it already has a regressive evolution especially within the Djebel Maadid, in addition to the presence of *Crataegus azarolus* L, *Juniperus oxycedrus* L, and *Quercus ilex*; this floristic formation is very poor compared to the cedars formation related to the humid bioclimate of the sub-coastal Tell and indicate ecologically only that belong to sylvatic physiognomy.

Crepis foetida L., *Crepis vesicaria* L., *Echinaria capitata* L., *Cirsium echinatum (Desf). DC*, *Inula montana* L., *Senecio leucanthemifolus Poir*., and *Carduus nutans* L., *Carthamus pinnatus L*,*Jurinea humilis* L., *Carlina lanata* L and *Catananche caerulea* L., *Centaurea pullata* L., *Centaurea acaulis* L., all this species belong to Asteraceae family which is recognized for their resistance to the rigor of environmental conditions **(El Bouhissi *et al.*, 2021)**

The samples: R1, R2, R3, R4, R5, R6, R7, R8, R9, R10, R11, R12, R13, R14, R15, R16, R17, R18, R19, R20, R21, R22, R23, R24, R25, R26, R27, R28, R29, and R30 where the species distribution depending on their ecological characteristics and floristic composition, specially the altitude, according that this group can be split to groups "B" and "C".

The group "B" includes the R1, R2, R16, R17, R18, R19, R20, R21, R22, and R23 specialized by the presence of *Daphne laureola* L., *Phlomis bovei* de Noé, *Rosa canina* L., *Bellis sylvestris* , *Festuca atlantica* L., and *Viola munbyana* Boiss. et Reut which indicate the humid atmosphere and less altitude as mentioned by **Zedam (1991)**.

The group "C" encountered the following samples: R3, R4, R5, R6, R7, R8, R9, R10, R11, R12, R13, R14, R15, R4, R25, R26, R27, R28, R29, and R30. This group specified by the various grass species along with the resistant species to low temperature like *Bupleurum montanum* Coss. & Durieu, & Durieu, an endemic species which is threatened and must be protected urgently as suggested by **Bounar *et al.* (2021)**, and the presence of *Eryngium campestre* L. Which is considered by **Jalobă *et al.* (2018)** as a problem on the pastoral value in Baicoi (Romania) and next to the annual herbaceous plant: *Hordeum murinum* L. considered a problematic weed in cereal crops **(Baghestani *et al.*, 2008)** where it can be argued that it is an anthropized environment. (Figure 32)

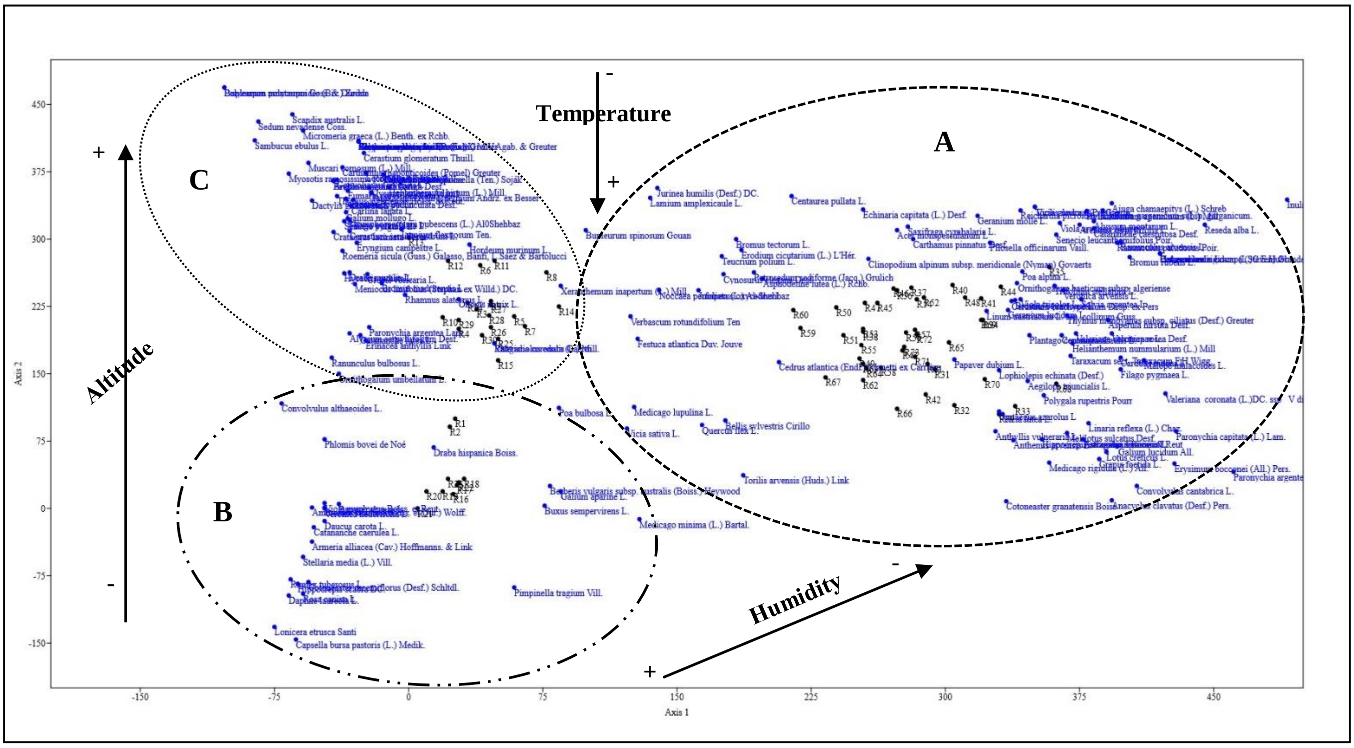


Figure 33: DCA ordination of samples and species of Djebel Maadid cedar forest

The multivariate analysis of the DCA in the figure 32 shows three gradients which manifest themselves through our species - samples records: altitude, temperatures, and humidity.

The gradient revealed by axis 1 in the DCA graph shows a decrease in humidity from group "B" to group "C" and then to group "A". This demonstrates the existence of a humid microclimate in the center of the study area, which is in a lower region, unlike the upper region that experiences frequent air currents and is subject to drying southern winds.

On the other hand, the axis 2 (Figure 32) shown two opposite gradients: altitude and temperatures. The temperature decreases with altitude **(Arnould *et al.*, 2021)** which is the same case in our study. It leaves the lower altitude group "B" warmer and the groups "A" and "C" relatively colder, respectively.

These three gradients leave our study stations in particular ecological conditions specific to each group.

10.3 An overwiew of a floristic analysis and the species conservation of the cedar vascular flora of Djebel Maadid (Cenral part).

10.3.1 Cenral part of Djebel Maadid presentation

This overwiew study focuses on a biodiversity assessment and spatial distribution of the cedar flora in the cenral part of Djebel Maadid forest in the southern Bordj-Bou-Arreridj province (Figure 33).

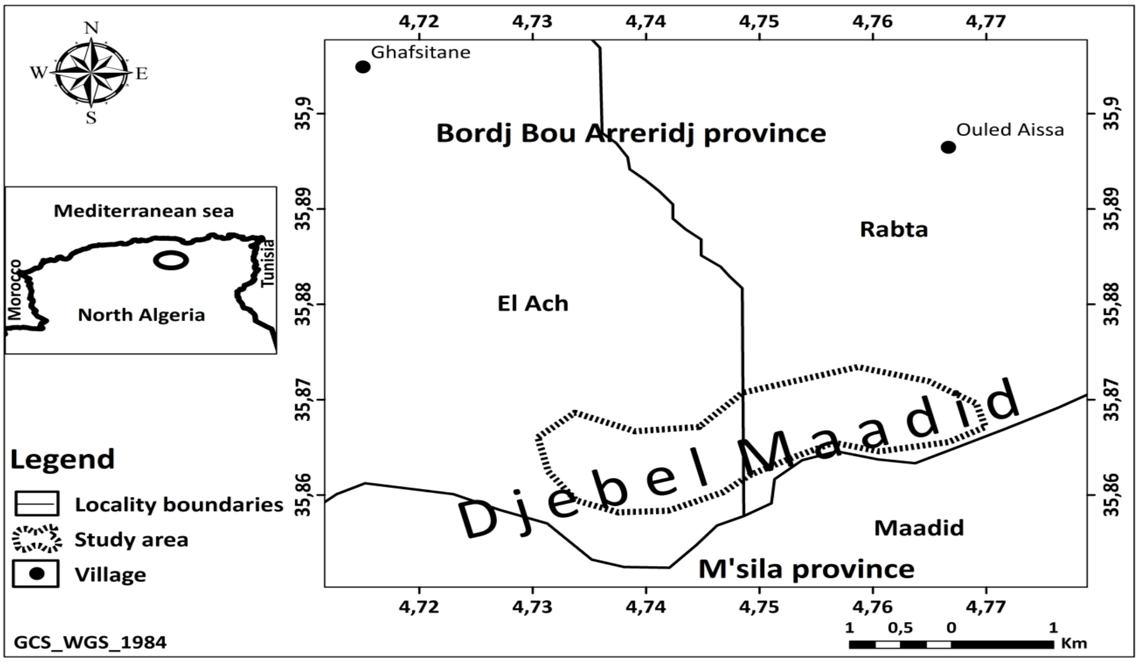


Figure 34 : Location of the cenral part of Djebel Maadid cedar forest.

The floristic importance of the central zone of the cedar forest of Djebel Maadid is undeniable. Naturally protected by surrounding rocky escarpments and cliffs, it contrasts with the periphery, which is constantly sought after by local residents. In fact, this area boasts a specific richness of 108 taxa, representing 62.07% of the total richness, and is distributed across 34 botanical families, accounting for 87.18%, which is quite substantial (Table 12).

Table 12: The importance of the central part of Djebel Maadid cedar forest

	Djebel Maadid cedar forest		
Area	Study area	Central part	Rate (%)
Surveys number	73	30	41,10
Total richness	174	108	62.07
Families	39	34	87.18

The analysis, including similarity and detrended correspondence analysis, identified various groups of plants-samples that demonstrate different environmental states linked to distinct stationarity. The species richness in particular sites can play a local role in the in-situ conservation of plants and habitats and must be registered for an urgent awareness situation.

This aims to evaluate the ecological conditions for plant protection and conservation by conducting an inventory and proposing a method to protect the existing flora.

10.3.2 Surveys characteristics

After exploring our region, we conducted 30 samples with altitudes ranging from 1510 m to 1830 m. We carried out an inventory of the entire vascular flora present in each sample (Table 13).

Table 13: Surveys characteristics of the central part of Djebel Maadid cedar forest

Samples	Exposure	Altitude (m)	Samples	Exposure	Altitude (m)
R1	North	1580	R16	North	1630
R2	North	1600	R17	North	1670
R3	West	1780	R18	North	1690
R4	West	1630	R19	North	1590
R5	East	1630	R20	North	1650
R6	East	1540	R21	North	1630
R7	East	1760	R22	North	1690
R8	East	1830	R23	North	1690
R9	East	1650	R24	West	1690
R10	East	1600	R25	West	1750
R11	East	1630	R26	West	1800
R12	East	1630	R27	West	1800
R13	East	1690	R28	West	1740
R14	East	1510	R29	West	1720
R15	East	1670	R30	West	1670

Our surveys are depicted in the studied area map (Figure 34), where the exploration covered homogeneous forest areas. In these areas, samples were collected and the existing flora was collected.

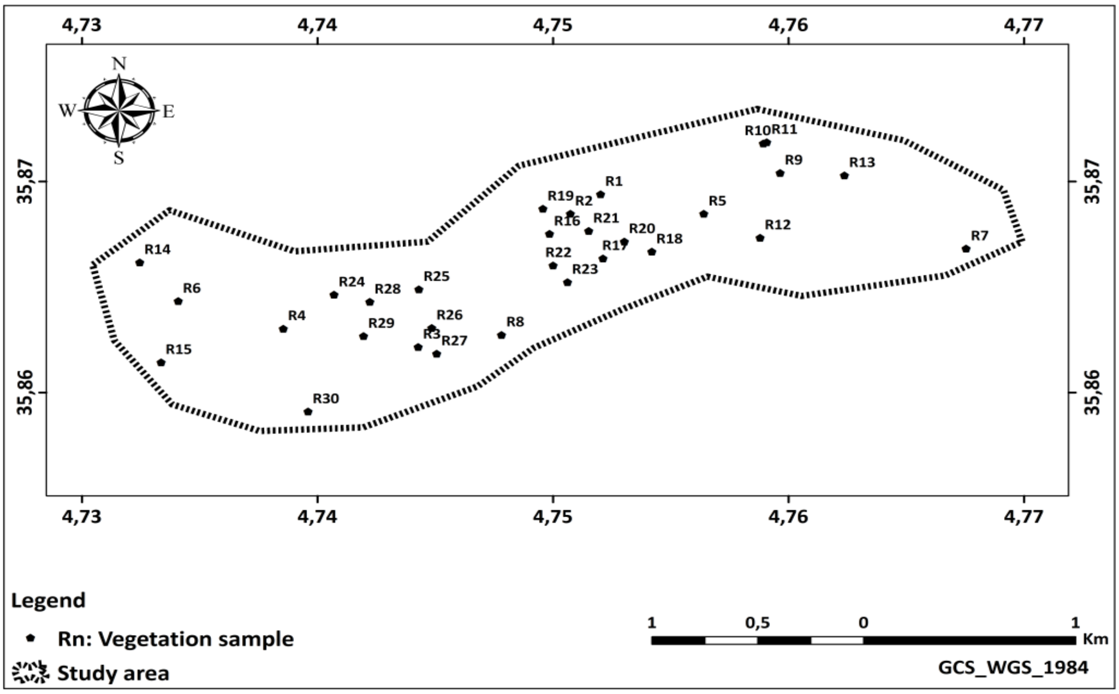


Figure 35: Cedar's samples of the central part of Djebel Maadid cedar forest.

10.3.3 Floristic analysis

10.3.3.1 Taxonomic richness

The results revealed that the samples yielded **108** species, belonging to over **91** genera and **34** botanical families. The majority of families, seven in total, encompass more than 65% (71 species) of the entire flora: Asteraceae (22 species), Brassicaceae (12 species), Poaceae (10 species), Apiaceae (08 species), Lamiaceae (07 species), Caryophyllaceae, and Fabaceae (06 species each). The remaining families each have between 1 to 3 species (Figure 35).

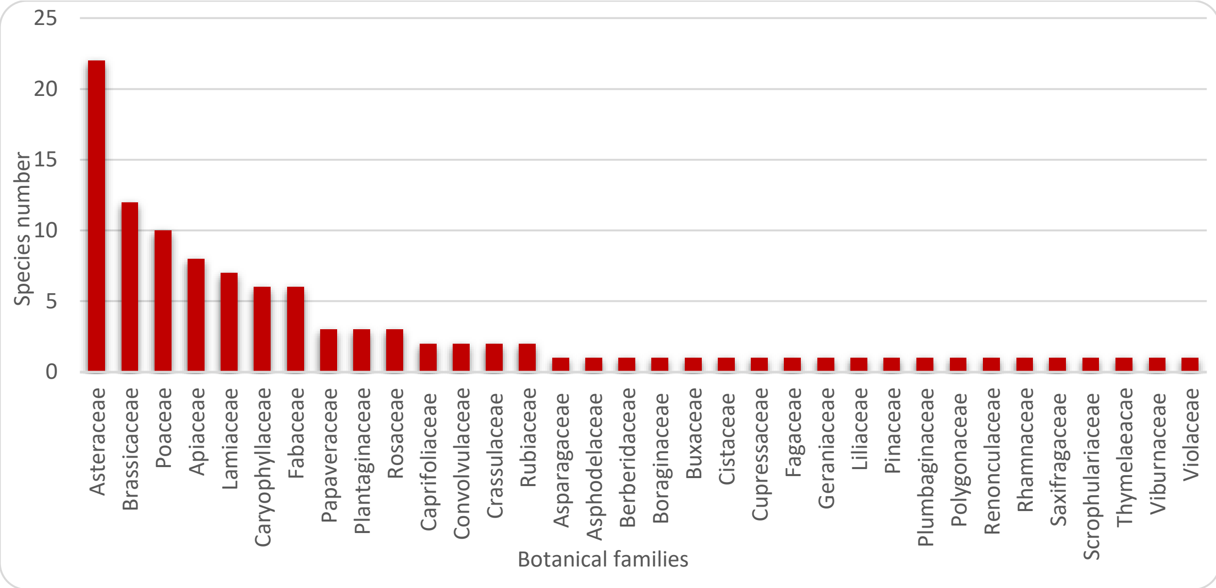


Figure 36: Botanical families distribution of the central part of Djebel Maadid cedar forest

10.3.3.2 Chorology

If we consider the Mediterranean element in its broad sense, the species encountered in our study amount to 53, representing more than 49% of the total flora. The remaining species are from other origins, numerically less significant. The Transition group comprises 36 species (33.33%), while the Nordic and Cosmopolitan groups each have 15 (13.89%) and 04 species (3.70%), respectively.

The dominance of the Mediterranean origin, as observed in our study, has been reported in numerous works conducted in neighboring regions as **Guechi (2022)**, **Yaici (2020)**, **Bounab (2020)**, and **Sedjar (2012)**.

It is important to note that the most xeric cedar forests in Algeria, such as the cedars of Aurès, Belezma, and Hodna, are situated in the Mauretanian Steppe Domain, where rainfall is very irregular and varies from 450 to 950 mm **(Yahi *et al.*, 2008)**.

10.3.3.3 Life-form

The results of our species life-form are grouped as follows: Therophyte "Th" (46 species), Hemicryptophyte "He" (29 species), Chamaephyte "Ch" (14 species), Phanerophyte "Ph" (10 species), and Geophyte "Ge" (09 species). The most dominant life form is the therophyte, representing more than 42% of all species. The less represented life-forms are the Phanerophyte and the Geophyte.

The distribution of life-forms of the central part of the Djebel Maadid area follows the pattern:

Th > He > Ch > Ph > Ge.

However, in the main forest of the studied cedar's stations (Tellian and Saharan Atlas), as reported by **Yahi et al. (2008)**, the pattern is: He > Th > Ch > Ph >Ge. The dominance of the life-forms Therophyte and Hemicryptophyte in our case study aligns with the findings of **Beghami *et al.* (2013)** in their work on thuriferous Juniper (*Juniperus thurifera* L.) in the Aurès area (Algeria), specifically concerning the species of the forestry community Cedar-Thuriferous Juniper localized at high altitudes. This observation reflects the specific characteristics of the species and the prevailing ecological conditions in our study area.

The observations reported by **Yahi *et al.* (2008)** regarding the high frequency of therophytes in Algerian cedar forests, indicating disturbance through activities like clearing and grazing, are notable. This dominance of the therophyte life-form is often seen as an adaptive response in arid areas, as noted by Negre (1966). This fact translates the aridity of the environment, as highlighted by **Negadi *et al.* (2014)**. **Zedam (2015)** explains the abundance of "therophytes" reflecting a pioneer stage linked to the climate. The prevalence of therophytes serves as an ecological indicator of human activities and local climatic conditions. Understanding these dynamics is crucial for formulating effective conservation and management strategies for these unique ecosystems.

In the Hodna Mountains and nearby areas, the dominance of the therophytes is apparent as reported by **Kaabeche (1990)**; **Sedjar (2012)**; **Zedam (2015)**; **Bounab (2020)**; **Yaici (2020)** and **Zedam and Fenni (2021)**.

10.3.3.4 Perturbation index

The Perturbation Index (PI) is a measure that depends on the number of therophytes and chamaephytes, providing a quantification of therophytization in an environment **(Loisel and Gomila, 1993)**. In our case study, with 46 therophytes and 14 chamaephytes, the calculated PI is 55.56%. This value is higher compared to some works:

- **Beghami et al. (2013)**: PI= 55,26 to 61,86 % for the degraded formations and 28,13 to 45,50 % for the least ones;
- **Bounab (2020)**: PI= 57,75 ± 1,48 %;

- **Yaici (2020)**: PI = 40%;
- **Guechi (2022)**: PI = 40%;
- **Larbi et al. (2021)**: PI= 27%.

These differences may be explaining the local conditions, the management practices, and the ecological contexts.

When the perturbation index (PI) is higher, the plant group is more degraded and results from a high proportion of identified therophytic and chamaephytic species and this state reflects the opening of plant formations **(Hebrard *et al.*, 1995**; **Belhacini *et al.*, 2016)**.

It is important to note that the sylvatic formation represented specifically by the phanerophytes is less in our case study.

This fact reveals, in first an anthropogenic pressure on the vegetation **(Quézel and Barbero, 1990)**, and on the other the drought which affects negatively the environment and reflects degradation and biodiversity loss **(Muluneh, 2021)**.

10.3.4 Numerical analysis

10.3.4.1 Sørensen-Dice's similarity index

The similarity, with values ranging from 0 to 1, shows the possible link or connections between species groups **(Marcon, 2024)** or to compare associations **(Hammer *et al.*, 2001)**. A high similarity value suggests that two groups share a similar floristic composition or ecological conditions **(Walter, 2006)**. Our analysis shows two distinct groups labeled as "1" and "2" (Figure 36). Each group may have high similarity in floristic composition or the same ecological characteristics that distinguish it from the other.

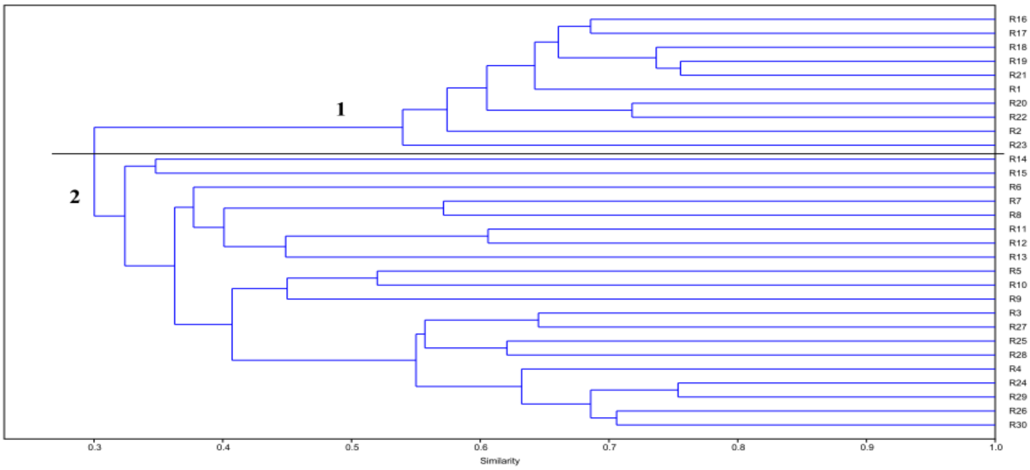


Figure 37: Samples similarity of the central part of Djebel Maadid cedar forest

The first group (1) comprises samples with values exceeding 0.50, extending well beyond. These samples include: R1, R2, R16, R17, R18, R19, R20, R21, R22, and R23. This state indicates a strong similarity within this group **(Koleff *et al.*, 2003; Marcon, 2024)**. The group occupies a microclimate area protected to the east and west by high-altitude ridge lines and faces northward. This positioning results in significant rainfall and cool winters. It's worth noting that **Zedam (1991)** has identified this part of the forest as belonging to the highest class of wood production. These areas of the samples can play a crucial role in conserving plant biodiversity, particularly given the existing threat in the cedar forest, primarily from overgrazing.

The second group (2), more numerous and highly heterogeneous. **Basyuni and Jayusman (2019)** highlight that the cluster analysis considers species variation, serving as an ecological indicator for the community. This group comprises samples with lower similarity compared to the first group, recording values below 0.40. Noteworthy samples in this group include: R3, R4, R5, R6, R7, R8, R9, R10, R11, R12, R13, R14, R15, R24, R25, R26, R27, R28, R29, and R30. The samples are situated in areas with two exposures (East and West) and are located in an overgrazed region. In one part, they rest on rocky and superficial terrain, while in the other, they receive less precipitation and experience cold winters. According to **Zedam (1991)**, this part of the forest falls into two wood production zones: the east area in the moderately productive class and the west area in the least productive one.

10.3.4.2 Detrended correspondence analysis (DCA)

As stipulated by Cano et al. (2019), the Figure 37 below indicates the presence of two "Species-Samples" groups.

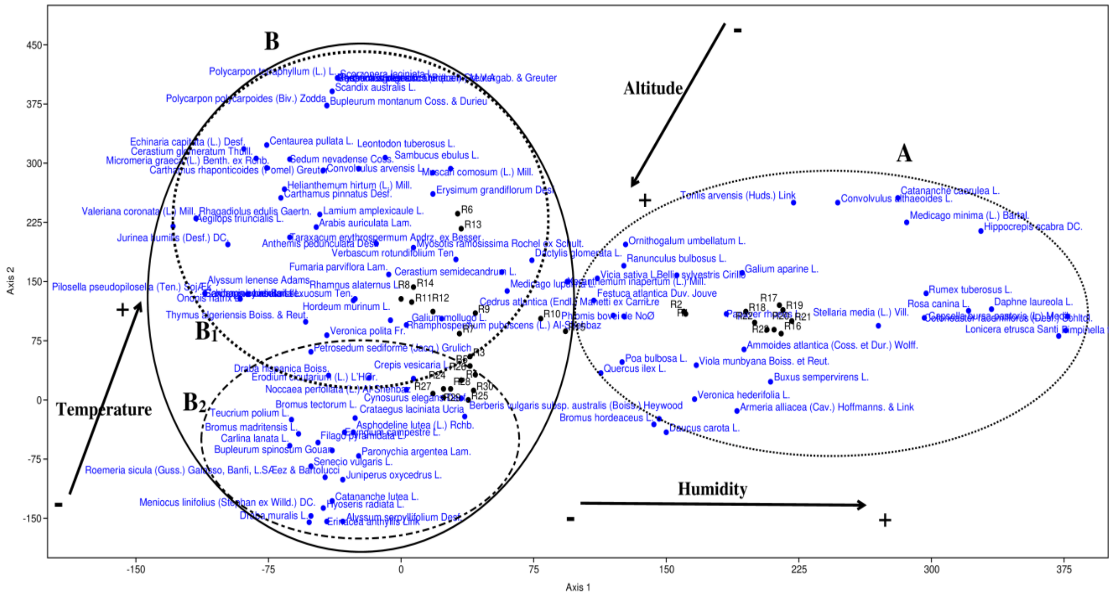


Figure 38: DCA ordination of samples and species of the central part of Djebel Maadid cedar forest.

This occurrence arises from the characteristic species associated with each group **(Fennane, 1988)**. The first group (A) encompasses the following samples: R1, R2, R16, R17, R18, R19, R20, R21, R22, and R23, featuring species dependent on ecologically specific stations. The floristic composition of this group is specialized and belongs to sylvatic physiognomy, including species such as *Daphne laureola* L., *Viola munbyana* Boiss. et Reut., and *Phlomis bovei* de Noé. These species indicate a humid atmosphere and fairly deep soil **(Mediouni and Yahi, 1989)**, as specified by **Zedam (1991)**, this part of the forest provides potential conditions for the cedar's trees to yield more wood production than other areas. On the other hand, **Solomou *et al.* (2023)** note that *Bellis sylvestris* Cirillo characterizes a state of ecological condition in which it adapts to grow in well-lit but also partially shaded positions, as well as in habitats with moderate nutrient availability. Additionally, **Karahan (2020)** reports that the genus "Bellis" colonizes moist habitats, often localized in forests. This group of samples is considered a sylvatic set, where its species are relatively more preserved from overgrazing and human aggression.

The second group (B) of "Species-Samples" comprises the samples: R3, R4, R5, R6, R7, R8, R9, R10, R11, R12, R13, R14, R15, R24, R25, R26, R27, R28, R29, and R30, where particular species are encountered, exhibiting unique ecology in response to altitude variation. This group can be divided into two subgroups: B_1 and B_2. Subgroup B_1, including the samples R5, R6, R7, R8, R9, R10, R11, R12, R13, R14, and R15, forms two smaller subgroups, all oriented towards the East. The first is located in the eastern study area with the samples R5, R7, R8, R9, R10, R11, R12, and R13; the other includes the samples R6, R14, and R15 situated in the western part of the study area. Firstly, this subgroup contains forest species such as *Bupleurum montanum* Coss. & Durieu, an endemic species that is threatened and requires urgent protection, as suggested by **Bounar *et al.* (2021)**. *Rhamnus alaternus* L., a sclerophyll shrub characterizing Mediterranean evergreen oak woodland, is mentioned by **Ciccarelli *et al.* (2016)**. *Sambucus ebulus* L., a species indicating disturbed areas, is highlighted by **Fanelli *et al.* (2008)**. Secondly, there are ruderal-weed species like *Hordeum murinum* L., identified by **Baghestani *et al.* (2008)** as a problematic weed affecting cereal crops, and *Muscari comosum* (L.) Mill., a perennial weed in North Africa. **Haliniarz *et al.* (2021)** considered it an endangered species in Poland. This subgroup is regarded as a sylvatic set, with its area subject to various forms of human aggression.

The subgroup B_2 includes species typically considered as weeds and those specific to a particular ecosystem. These species are found in the following samples: R3, R4, R24, R25, R26, R27, R28, R29, and R30, all oriented toward the West exposure.

Among the weed species, *Senecio vulgaris* L. is encountered, occurring in both ruderal and agricultural habitats **(Leiss and Müller-Schärer, 2001)**. *Eryngium campestre* L. is considered a problem for pastoral value in Baicoi, Romania, as noted by **Jalobã *et al.* (2018)**. Regarding *Bromus tectorum* L., it is identified as a winter annual invasive species in the Great Basin site (USA) by **Bradford and Lauenroth (2006)**. Lastly, *Erodium cicutarium* (L.) L'Hér. requires weed management due to its invasive potential of lands **(Hien Le *et al.*, 2021)**.

Finally, species dependent on a particular ecosystem at high altitude, often open or semi-open with groves of sylvatic physiognomy, include *Erinacea anthyllis* Link and *Bupleurum spinosum* Gouan, identified as spiny xerophytic plants by **Taleb and Fennane (2016)**. *Juniperus oxycedrus* L., reported by **Cano-Ortiz *et al.* (2021)**, is a shrub found in dry, sunny, and rocky environments. This subgroup is considered a sub-sylvatic set, with its area subject to overgrazing.

The figure 37 allows us to observe three ecological gradients concerning executive samples, encountered species, and characteristics of the prospect areas. The first gradient is humidity, increasing from subgroup B_2, situated in the west exposure, to group A, located in the north exposure. The second gradient is altitude, ascending from group A at low altitude (with an altitudinal average of 1642 m) and subgroup B_1 at moderate altitude (with an altitudinal average exceeding 1649 m) to subgroup B_2, found at high altitude (with an altitudinal average exceeding 1731 m). The last gradient is temperature, decreasing from group A to group B, which encompasses the high-altitude areas.

10.3.5 Perspective of plant conservation

The analysis of plant distribution in the study area and the ecological characteristics of the corresponding samples reveals three areas of plant biodiversity that strive to be preserved from overgrazing, human aggression, and other negative impacts (figures 38,39).

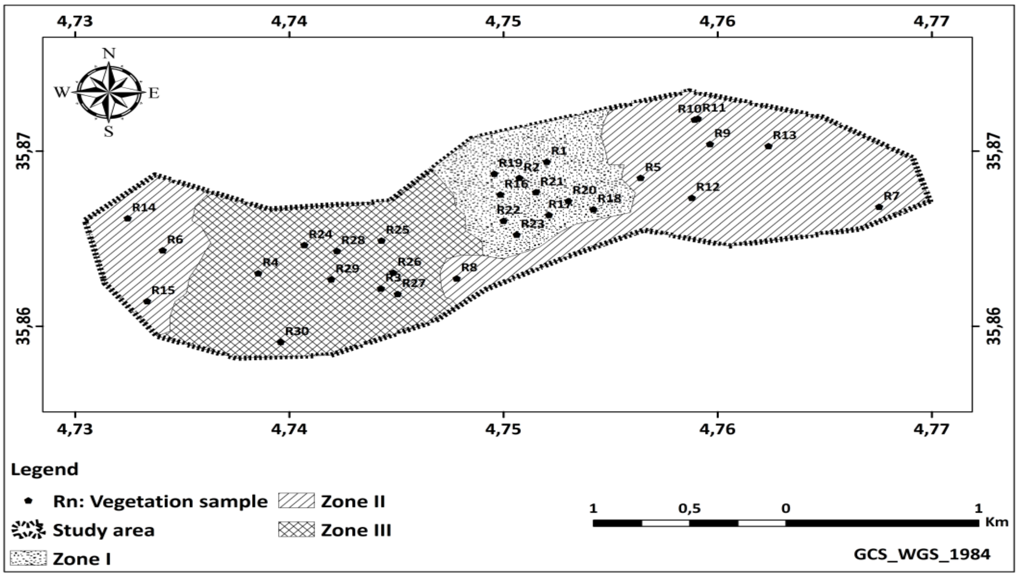


Figure 39:Flora zones to preserve in the central part of Djebel Maadid cedar forest.

Zone I: Center of the studied area

Zone II a: East of the studied area

Zone II b: West of the studied area

Zone III: Center West of the studied area

Figure 40: Forest zones in the central part of Djebel Maadid cedar forest (Photos: Radjai, 2022).

These forest zones of flora are delimited, illustrated, and characterized as follows:

Zone I: This middle zone of the studied area is oriented to the North. It features a sylvatic physiognomy, with its species predominantly found in this part rather than others. These species are relatively more preserved from human pressure due to the challenging access to this area, attributed to the North-South orientation cliffs situated in the East and West, along with the dense green oak scrub located at the bottom (North side). In this context, **Angelstam *et al.* (2023)** assert that biodiversity conservation can be achieved by establishing protected forest areas. This zone can play a role as a promoter of plant species to the bordering zones.

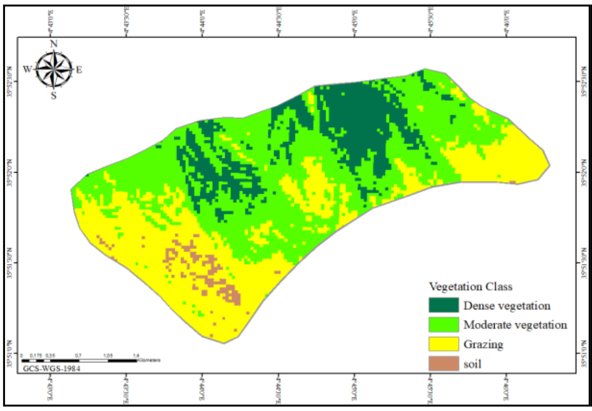
Zone II: It is situated in the East (Zone IIa) and West (Zone IIb) of the studied area. This zone exhibits a sylvatic physiognomy, with its exposure oriented to the East, and its area is subjected to anthropogenic activities. It is crucial to acknowledge that among the threats to biodiversity, the loss of "habitat" is associated with human activity **(Verma *et al.*, 2020)**. In this zone, we propose to prioritize preservation initially and subsequently advocate for overgrazing regulation in specific areas, especially those identified as vulnerable.

Zone III: A final zone located in the center-west with a west orientation. The surveyed area exhibits a sub-sylvatic physiognomy on one hand, and on the other, it is often open or semi-open with groves of sylvatic physiognomy growing on a soil that is frequently skeletal, with rocks outcropping. The local biodiversity in this area is susceptible to overgrazing and human aggression. It's important to note that overgrazing, defined as the disrespect for the animal load, leads to the loss of plant protection from climate aggressiveness, and land use practices are also considered partial causes of biodiversity loss **(Soulé, 1991)**. The floral richness of this zone and its biotope must be urgently preserved to ensure its sustainability because conservation of biodiversity in such environments will result in protected areas that welcome and maintain unmodified sites **(Sergio and Pedrini, 2007)**. As recommended by **Shaheen *et al.* (2023)**, for effective *in-situ* conservation, it is necessary to establish wild nurseries to retain the potential of threatened plants in their natural habitats initially and then plan future reforestation to create the desired forest atmosphere.

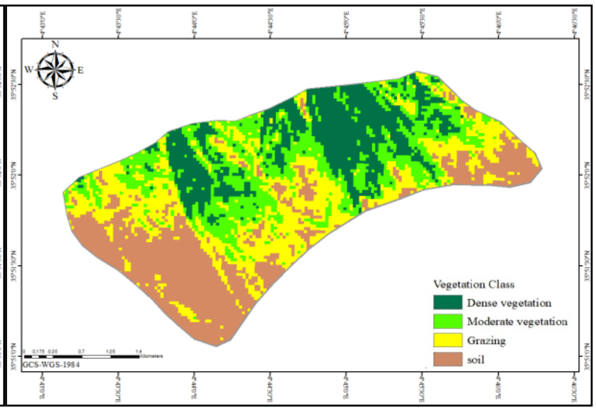
10.4 Vegetation mapping of Djebel Maadid forest

For the purpose of monitoring and analysing the dynamic change of vegetation cover at its various levels and studying the relationship between it and a several influential external factors, the most important are climate change and the diverse human activities **(Ariane *et al*., 2018)**. The following study presents the use of **Google Earth** pictures and satellite images (Landsat LTO5 and Landsat LTO8) in different years (2009, 2017 and 2022) and additional terrain data for mapping vegetation in a Honda high mountain environment. The methodology used based on combination of knowledge and the classification of the cedar forest to four different vegetation cover which are depending on the abundance of woody class, this classification is applied to generate a vegetation map of the south of Bordj-Bou-Arreridj province over the period of 13 years from 2009 to 2022 it focused on the available data map for the 2009, 2017, and 2022 to achieve a comparison of the vegetation cover state's after exposure to several variable factors **(Xu, 2019)**.

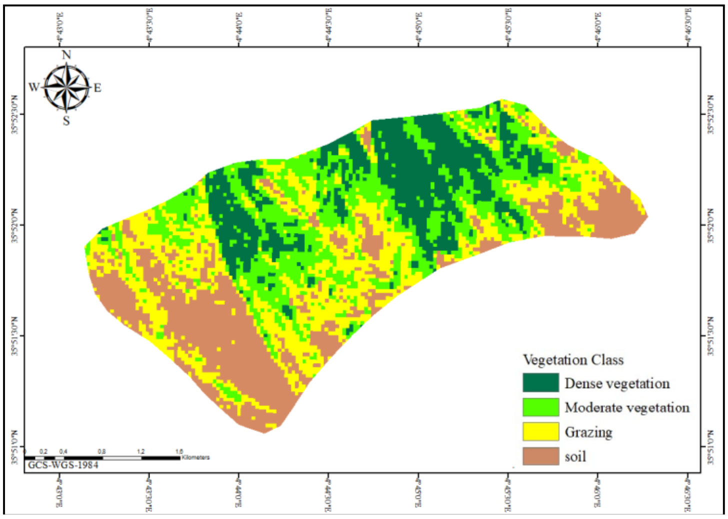
The NDVI is extensively employed in analysing the connection between spectral changes and variations in vegetation growth rates. It serves as a valuable tool for assessing green production and identifying alterations in vegetation. This is particularly relevant when examining the vegetation cover of Djebel Maadid **(Khallef & Zennir, 2023)** and **(Carpenter, *et al.*, 1999)** uses vegetation maps that categorize plant life into fundamental forms, including the conifer, hardwood, water, and barren ,these categories are often broken down into more specific subgroups based on species associations, and, where relevant, by tree size and density such as dense vegetation (woody vegetation), moderate vegetation, grazing, and bare ground :soil (Figure 40)



Year 2009



Year 2017



Year 2022

Figure 41: Vegetation classes of the studied area of Djebel Maadid cedar forest

To summarize the situation illustrated by the figure 40 which depict the state of the area for the years 2009, 2017, and 2022 respectively, we present the relevant surface areas for each mapped category: dense vegetation, moderate vegetation, grazing, and bare ground (Table 14).

Table 14: Classification area of vegetation classes for the year 2009 ,2017 and 2022.

Area (ha)	**2009**	**2017**	**2022**
- Dense vegetation	300,03	412,51	163,80
- Moderate vegetation	504,28	273,04	433,98
- Grazing	149,40	268,17	335,24
- Bare ground (soil)	0,13	0,13	20,80
Total (ha)	953,80	953,80	953,80

The Figure 41 below illustrates the area proportions clearly with increasing or decreasing.

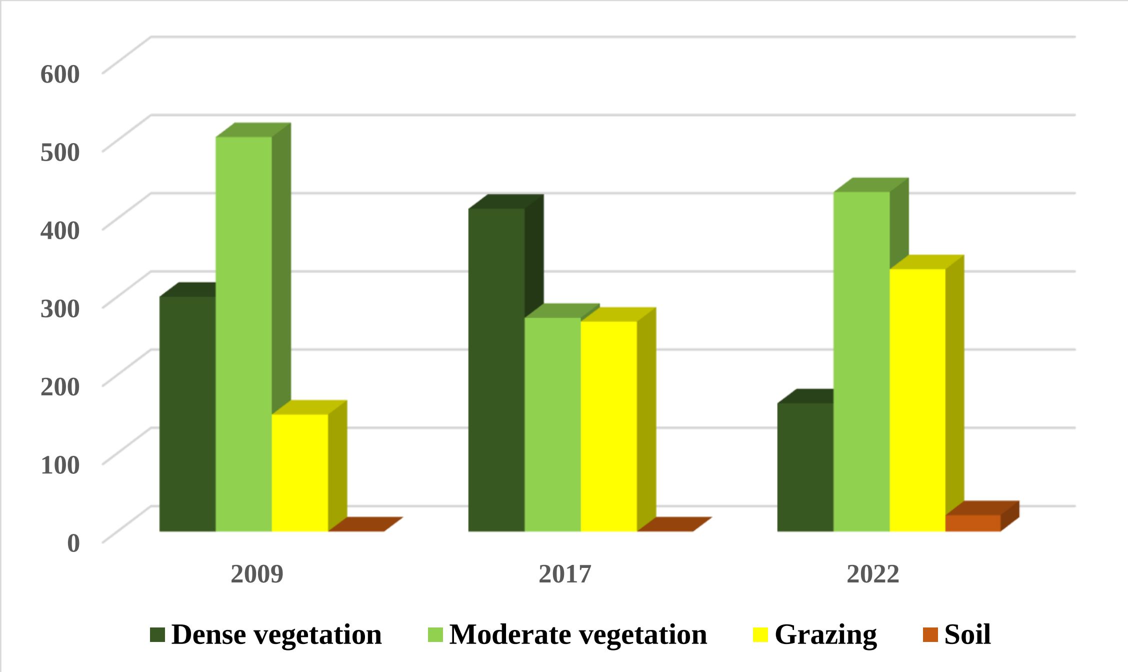


Figure 42: Vegetation classes for the years : 2009, 2017, and 2022.

According to **Kiringe and Okello (2007); Eldridge *et al.* (2011); Taylor and Atkinson (2012); Sanbi (2013); Haddad *et al.* (2015); Reisch *et al.* (2017); Haddad *et al.* (2019) ; Carrasco *et al.* (2020); Vukeya *et al.* (2023)** and based on our research findings, the analysis conducted using remote sensing and GIS's investigation on the vegetation cover of Cedar Forest in the Maadid area supports our study predictions. The study revealed significant changes in the woody vegetation cover over a 13 years period. From 2009 to 2022, there was a decrease in the dense vegetation area 300,03 ha to 163,80 ha in 2022 but with a notable growth occurred between 2009 and 2017, with an increase of 300,03 ha, reaching an evolution peak of 412,51 hectares during this period and similarly, the moderate vegetation cover also has the same situation in evolution peak in 2009 with 504,28 ha but the 2017 was an intensive regression year: 273,04 ha.

The conservation stage where we have as detection of grazing impact a high decrease in 2009 (149,396 ha) due to the absence of human activity in the forest during the mentioned period according to the grazing type which was impeded stabling. It's the regeneration stage where we have the progressive of dense and moderate vegetation although the increased human pressure, overgrazing from 2009 to 2022 149,40 ha, 268,17 ha, 335,24 ha, which increased by 185,84 ha.

The NDVI factor shows that the impact of the anthropic pressure on vegetation cover is negative in last 5 years, that the integrity of the natural vegetation in Maadid has been decreasing even there is a guaranteed regeneration of plants and vegetation biodiversity which suggests a naturel conservation but it style depending on the overgrazing pressure. It is constantly increasing and widespread in preserving areas (high diversity), which threat to local biodiversity

10.5 Biodiversity and the conservation methods

According to **Costion (2011)**, the one of the most prominent problems facing biodiversity is a severe extinction, especially in the richest areas on the planet, despite the interest in this topic and discussion all biology’s fields, its impact is currently strong and worrying issue due to the absence of a systematic and effective method for measuring the biodiversity, that’s why our approach to identifying and prioritizing protected areas for Atlas cedar is based on a strategy that considers the ability of a suite of populations to survive locally and the effective cost of their protection over the long term to develop such a strategy, we assess both the suitability of the habitat and the adaptive capacity of the populations that make up the species' range in the face of ongoing climate change **(Cheddadi *et al.*, 2022)**.

The examination of plant distribution in the study area and the ecological traits of the samples reveal in addition to the NDVI results get three distinct areas of plant biodiversity that are being conserved to prevent overgrazing, human disturbances, and other detrimental effects. These forest zones dedicated to preserving flora are clearly defined, depicted, and described as shown in figures 42.

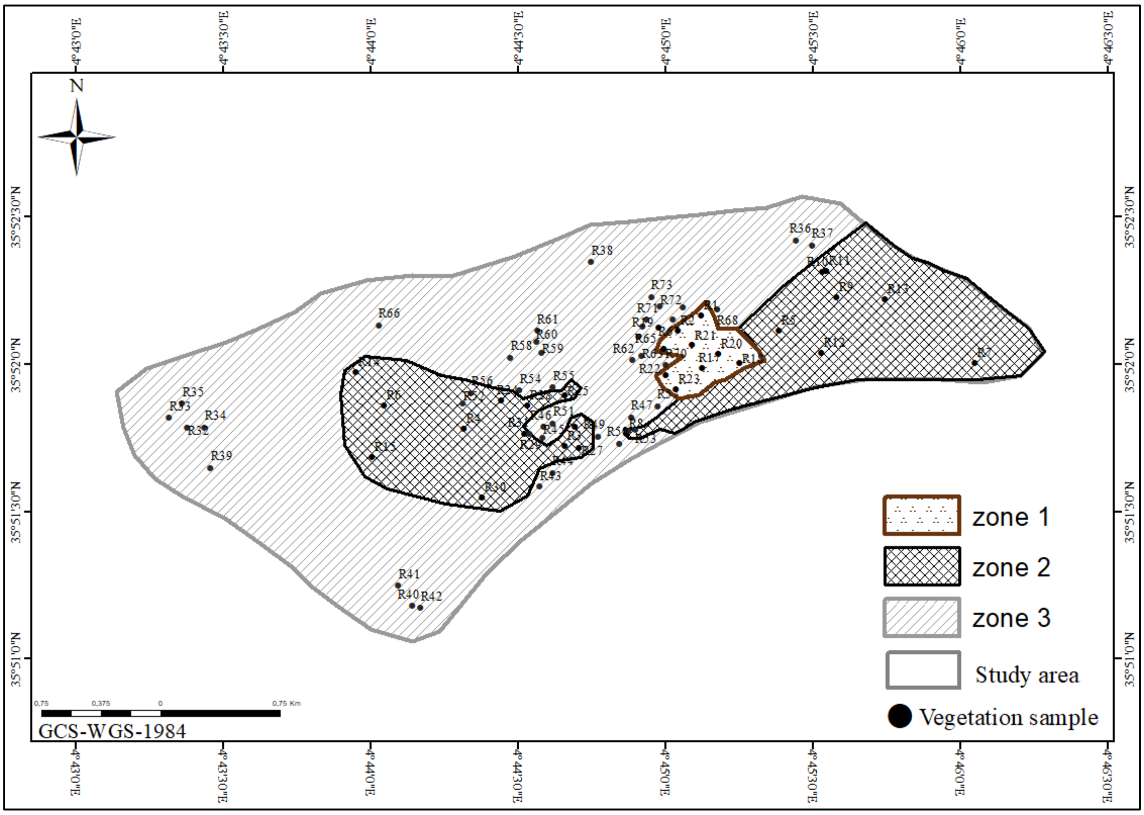


Figure 43: Delimitation of the preserving flora zones in Djebel Maadid cedar forest.

- Zone 1: A focal area within the research site, facing north, exhibits a woodland appearance with a concentration of species unique to this region: a sylvatic area relatively preserved. It is relatively shielded from human impact due to challenging access, attributed to the presence of nine cliffs oriented along the North-South axis to the East and West, as well as dense green oak scrub at the base on the northern side. This zone potentially serves as a catalyst for the spread of plant species to nearby areas **(Radjai *et al.*, 2023)**.

- Zone 2: Located in the eastern (zone II a) and western (zone II b) parts of the surveyed region, this area exhibits a forested landscape: a sylvatic area relatively less preserved. Facing eastward, it is impacted by human activities. Notably, biodiversity in this zone is threatened by habitat loss due to human intervention. Our recommendation is to prioritize conservation initially and subsequently implement controlled grazing, particularly in vulnerable areas." **(Radjai *et al.*, 2023)**.

- Zone 3: according to the recommendations of **Soulé (1991), Sergio & Pedrini (2007). Shaheen *et al.* (2023)**, the third zone (the rest parts of the forest area) is: an anthropized pre-sylvatic area. It showcases a mix of sub-forest-like vegetation alongside open or semi-open spaces, often featuring groves with rocky outcrops on a predominantly skeletal soil.

Unfortunately, the local biodiversity faces challenges from overgrazing and human disturbances. Overgrazing, defined as the excessive pressure on vegetation by animals, leads to the loss of plant cover, leaving the soil vulnerable to environmental stresses. Additionally, unsustainable land use practices contribute to the decline in biodiversity, to safeguards the floral diversity and ecosystem integrity of this region, urgent action is required. Preserving the rich flora and biotope of this area is crucial for its long-term sustainability, as conservation efforts in such environments provide havens for biodiversity and untouched natural landscapes effective in-situ conservation strategies should include establishing wild nurseries to protect endangered plant species within their natural habitats. Furthermore, planning for future reforestation initiatives is essential to restore the desired forest ecosystem and ensure the continuity of this unique ecological zone **(Radjai *et al.*, 2023)**

Conclusion

Conclusion

The vascular flora inventory in the study area of the cedar forest at Djebel Maadid, located in southern Bordj-Bou-Arreridj province and at the Northern face of the Hodna Mountains (North Algeria), operated in 73 samples, yielded and carried out in the cedar forest; over an altitude ranging from 1510m to 1850 m; got as results 174 species, spanning over 91 genera and **39** botanical families. The dominant family was the Asteraceae.

The most marked biological type is that of therophytes with a biological spectrum: **Th > He > Ch > Ph > Ge. C**horologically the Djebel presents a significant proportion of Mediterranean species, some of which are endemic. In the ethnobotanical context, through the execution of 130 surveys, it has been shown that the exploitation of medicinal plants is carried out in an anarchic manner and does not have a negative impact on the conservation of taxa. In this fact a rigor on the part of the forestry administration must be demonstrated.

For the endemism in the study area we have inventoried 14 endemic taxa of which 5 species are north African endemic, 4 Algerian -Moroccan endemic, 4 Algerian endemic and 1 Algerian -Tunisian endemic species.

The perturbation Index (PI) relies the abundance of therophytes and chamaephytes and offering a quantification of therophytization within the environment. The calculated PI stands at 57.47% which is higher compared for other national cedar formations. It can qualified our study area as degraded. This index reveals an anthropogenic pressure on this plant formation with other factors such as drought which affect negatively the environment and causes a biodiversity loss.

The numerical data analysis of this flora gets two sets of plants-samples that demonstrate different environmental states such as temperature and humidity in relation with altitude, and linked to the samples characteristics.

The special and the characteristic species with the rate of richness encountered in plants-sample groups and particularly in subgroups gave three areas where the first is considered as a sylvatic set where its species are relatively more preserved from human pressure, the second is as a sylvatic set where its area is submitted to anthropogenic activities, and the last is as a sub-sylvatic set where its local biodiversity is subject to overgrazing and human aggression.

The floristic significance of the central part of Djebel Maadid cedar forest is undeniable, as it is naturally protected by the surrounding rocky escarpments and cliffs. This contrasts sharply with the periphery, which is constantly under pressure from anthropogenic actions by local residents. Indeed, this central part has a significant species richness compared to the rest of the study area. It can act as a reservoir of plant species, promoting their spread to neighboring areas that are partially or completely affected by negative human activities, particularly overgrazing. The conservation of "*in situ*" biodiversity can be particularly achieved through the creation of protected forest areas.

To conserve in-situ the whole existing flora, the first and the second areas (if the second will be preserved rapidly from the negative impacts) can promote, uphold, and invade the neighbouring areas with their richness and special species. The third area must be preserved from anthropogenic activities. Management must be applied and directed towards to guarantee their continuing existence and their sustainability for the future generations.

In addition to the result of the normalized difference vegetation index (NDVI) detection which considerate the vegetation cover serves as a vital indicator of environmental change, reflecting the health of an ecosystem. Indicator species, sensitive to environmental shifts, are early responders to ecosystem changes.

Monitoring these species and vegetation cover offers valuable insights into ecosystem health. By assessing vegetation cover, impacts of factors like pollution, climate change, and land use alterations can be evaluated effectively, therefore the conservation efforts should prioritize the preservation of the first and second areas to safeguard their biodiversity and unique species.

Simultaneously, the third area necessitates protection from human-induced activities. Implementing robust management strategies is essential to guarantee the longevity and viability of these plant species for the benefit of future generations.

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