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Floristic Composition of the Mountainous Massif of Tessala (Algerian West): Biodiversity and Regressive Dynamics of the Forest Ecosystem

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Abstract

The aim of the present work is to assess the state of the forest ecosystem of the Tessala mountain (western Algeria) by highlighting the ecological factors that control its dynamics. Of the 10 stations sampled, 132 species from 44 botanical families and 5 biological types were identified. The dominance of plant formations is based on xeric species: Calycotome spinosa Link., Chamaerops humilis L. and Asparagus acutifolius L., reflecting a banalization of the floristic communities. The analysis of edaphic and biological data by the AFC revealed the main factors controlling the distribution of plant formations in the studied area and identified four clusters of stations according to the stage of degradation. Group 1 corresponds to the least degraded stations correlated with phanerophytes and attached to the most advanced edaphic conditions. Groups 2, 3 and 4 are represented by highly degraded stations, correlated with therophytes and chamephytes.

1. Introduction

For decades, the forest patrimony of western Algeria has undergone a perpetual regression, due to the combination of the constraining climate due to a prolonged summer drought and irregular rainfall [1], to human actions that are often unreflective (deforestation, overgrazing, fire) and the lack of rational management of green spaces [2]. This evolution has led to the substitution of original mesophytic vegetation by the xerophytes, confirmed in the works of [3-8]. The forest ecosystem of Mount Tessala, close to Sidi Bel Abbes, plays a considerable environmental and socio-economic role; however, it suffers from a gradual qualitative and quantitative loss of its interesting biodiversity [9].

The composition and the floristic organization of these natural woody formations impose a particular and remarkable physiognomy whose analysis makes it possible to show the importance of some types of vegetation in equilibrium with the habitat milieu.

The majority of the investigations carried out on the forest ecosystem of Mount Tessala concern the inventory of plants [10,11] and the biochemical valuation of certain medicinal taxa [12-14]. The work on the evaluation of the impact of anthropozoic action on the vegetation cover of the Tessala mountain range is limited [2].

The floristic composition is presented in this study as well as the negative consequences generated by human actions on the forest. Previous data [9] and [15] are used to complement this work in order to understand the functioning of the ecosystem and to determine the main ecological parameters that govern the dynamics and distribution of plant formations in this mountain massif.

2. Materials and methods

2.1. *Location of study area*

The Mount of Tessala is a mountain massif located to the north of the wilaya of Sidi Bel Abbés. It is limited to the north by the plain of Mleta and Sebkha of Oran, on the east by the mountains of Beni Chougrane, to the west by the mountains of Sebaa Chioukh and south by the plains of Sidi Bel Abbes. This mountain range of the Tellian Atlas reaches an altitude of 1061m (Fig. 1).

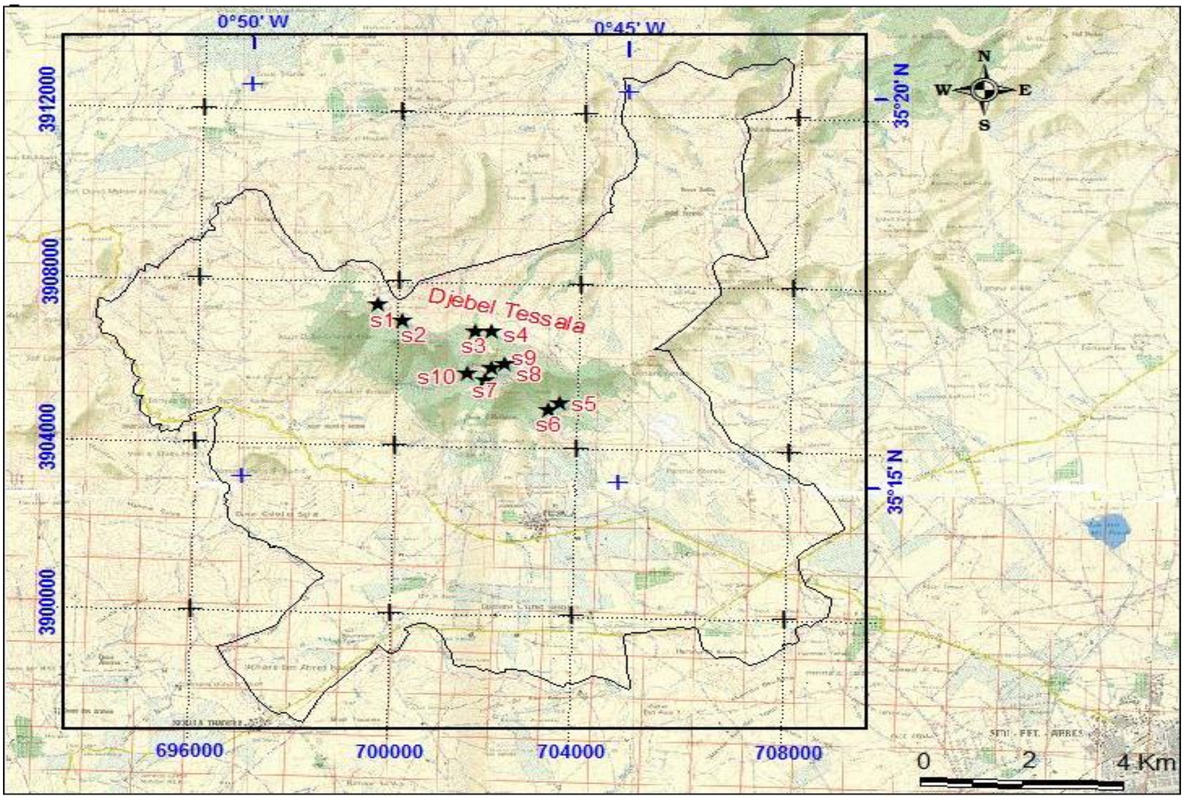

Figure 1: Location of the Tessala Mountain and location of sampling stations [9].

The Mount of Tessala is part of the central Tell of Oran. Its geological structure is marked by formations of bedrock of the Cretaceous-Oligocene complex and formations with limestone dominance little resistant to erosion. Outcrops of calcareous sandstones appear in places of gypsum soles of the Triassic [16].The climate is of semi-arid Mediterranean type, with a mean annual rainfall of 335-400 mm and an average annual temperature of 8-26 °C, 2 °C for December and 30 °C for August.

2.2. *Choice of stations and methodological approach*

Ten stations were selected on both the South and North slopes, taking into account exposure, vegetation physiognomy and anthropozoogenic action (Figure 1). The floristic surveys, covering an area of 100 m² (ten surveys per station), were carried out from March to June 2012, a period corresponding to optimum vegetation in the area studied. One hundred surveys were carried out according to the concepts of phytoecology and the floristic inventory, based on the tree, shrub, bushy and herbaceous strata. Each listed species was assigned a coefficient of abundance-dominance and sociability. The delimitation of a floristically homogeneous surface is respected in this study for the realization of floristic surveys. This important notion for the quality of the information has been associated with that of the minimal area [17]. It is a surface that does not offer appreciable differences in floristic composition between its different parts [18].

The technique of surveys thus adopted is careful to specify the stationary characteristics of the survey selected for analysis, namely: altitude, slope, exposure, nature of substrate and average recovery rate. The identification of species is completed according to the flora of [19], [20], APG III (2009) and Tela Botanica (2015). For each station, physicochemical analyzes were carried out on a sample of soil taken from the surface horizon, whose properties are often related to human, agricultural or pastoral disturbances [21]. This analyzes concern texture, moisture, electrical conductivity, pH, calcareous content and organic matter content. The values relating to these various physicochemical parameters correspond to average values per station.

2.3. *Data processing*

The similarity indices of Sorensen [17] and the specific diversity are used to compare the similarity of the floristic composition and the specific richness of the studied stations. The treatment of floristic and soil data was carried out by factorial correspondence analysis (AFC) and ascending hierarchical classification (CHA). This approach is well adapted to phytosociological studies and allows treating the floristic and pedological variables [22]. It is a tool that objectively discriminates particular entities or compares stations in pairs [23]. The hierarchical ascending classification makes it possible to better individualize the boundaries between the different groups [24]; [15]. The CFA matrix crosses all edaphic variables (13 parameters) with 05 biological types, recover vegetation, altitude and slope for the identification of the main ecological gradients for the 10 selected stations in this study.

3. Results and Discussion

3.1. *Vegetation analysis*

After analyzing the data on the different floristic surveys carried out on the selected stations, a synthetic table regrouping the different species per stratum is drawn up (Table 1). These analyzes revealed certain characteristics relating to the biological spectra of the 132 plant species listed and the characteristics of the different families to which they belong.

3.1.1. *Biological Spectrum of Species*

Analysis of the biological spectrum of the inventoried species shows the dominance of therophytes in all the studied sites, with rates of 38 to 45%, followed by hemicryptophytes with 27-33%. Phanerophytes are better developed in stations S2, S6, S9 and S10 with an average rate of 11%. The area is less represented in the 10 stations (7 - 10%) and the geophytes are at the bottom with a rate between 2.5% and 5.45% (Figure 2).

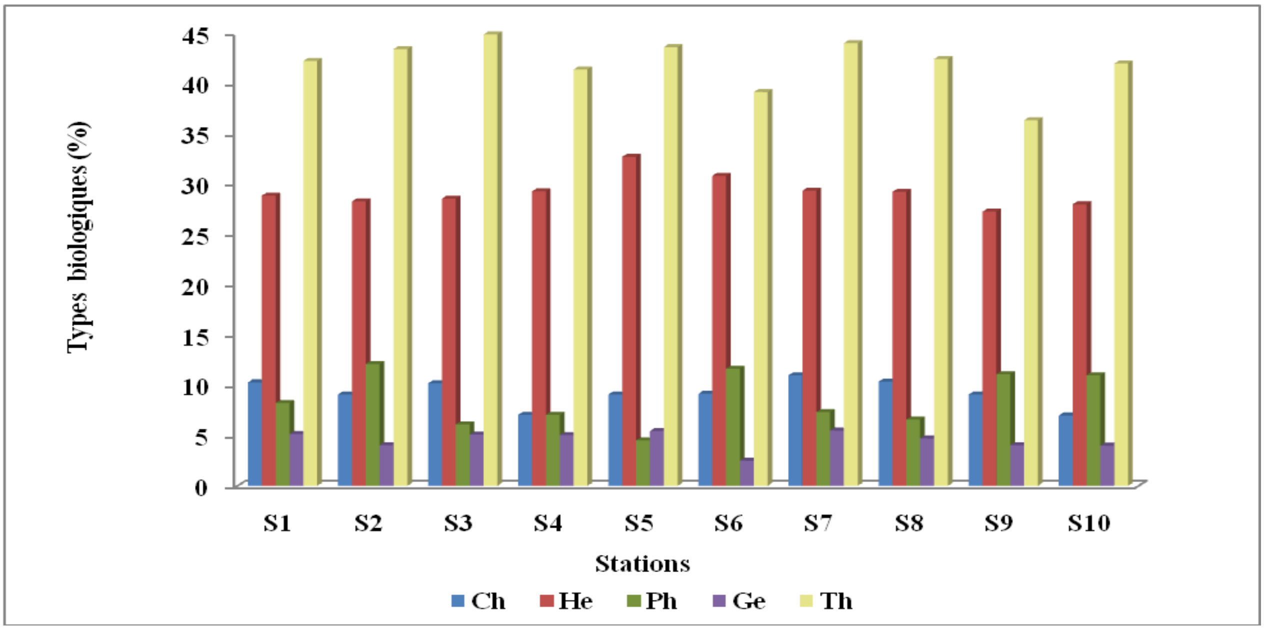

Figure 2: Percentages of biological types by station.

The predominance of therophytes in the ten stations reflects the degraded state of the forest ecosystem of the Tessala massif. Periods of prolonged drought in this zone during the last two decades are at the origin of the dominance of this biological type [1]. Indeed, therophytisation is described as a form of resistance to drought and represents an ultimate stage of degradation [25]; [26]. Variations in the biological spectrum of listed species can be explained by altitudinal stratification, local fluctuations in bioclimatic parameters and the multiple pressures exerted by man and his cattle [27].

3.1.2. *Characterization of families*

The percentages of the 44 census families show that Asteraceae (13.74%) are represented by 13 genera and 18 species. The Poaceae (12.21%) have 10 genera and 16 species, the Fabaceae with 10.68%, 8 genera and 14 species, the Lamiaceae with 8 genera and 9 species and the Apiaceae with 5 genera and 6 species. Brassicaceae and Oleaceae are present at rates of 3.05%, 3 genera and 4 species. The other families share rates of 0.76% - 2.29%. Generally the most generically diverse families are richer in species. The diversity of order one is increased because, in addition to the large number of species, the number of families is also [28].

Table 1: Plant surveys carried out in the field

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
Texture	La	La	La	Ls	As	Sl	Sl	Al	Al	Sl
Structure	G	G	G	G	G	Gr	G	G	Gr	Gr
SG- Coarse sand (%)	40,07	31,82	21,61	23,19	19,43	31,23	24,68	34,95	39,37	32,98
SF - Soft sand (%)	11,89	21,59	53,37	33,46	59,04	37,82	43,90	16,29	15,93	37,80
A - Clay (%)	02,28	03,52	03,51	01,68	03,74	01,31	01,62	11,51	05,53	02,20
LF- Fine limon (%)	16,00	20,63	23.17	13,71	12,43	12,23	13,83	26,02	21,94	19,82
LG Coarse limon (%)	09,85	14,02	13,94	06,72	05,48	02,46	04,68	17,23	16,02	05,78
Humidity (%)	11,39	10,27	10,03	09,62	7,34	11,60	07,65	07,59	11,43	11,59
pH	07,56	07,00	08,01	07,96	07,74	08,02	07,13	08,03	08,04	08,02
Conductivity (ms/cm)	00,12	00,10	00,13	00,09	00,14	00,10	00,39	00,17	00,23	00,15
MO Organic matter (%)	03,60	02,01	03,92	02,02	03,06	01,20	02,90	01,88	03,48	02,82
Total Calcareous (%)	30,85	13,40	18,50	10,70	20,00	02,50	03,33	15,40	20,57	01,70
Active calcareous (%)	09,25	08,15	03,20	03,52	02,27	01,59	02,26	01,44	06,20	01,04

3.2. *Soil analysis*

The mean values for the various physicochemical parameters, characteristic of the surface horizon of the soil, are shown in table 2.

All soil samples show appreciable levels of sand and silt. This elementary composition varies from one station to another. Three stations are of silty-clay texture (S1, S2 and S3), three others are of sandy loam texture (S6, S7 and S10), S8 and S9 are of clay-silty texture whereas S5 is clayey-sandy texture and S4 limono-sandy. The organic matter contents range from 1.2% to 3.92% and the highest levels are noted in stations S1, S3 and S9. S6 and S8 are relatively low in organic matter (1.2% and 1.88%).

Table 2: Physicochemical characteristics of the surface horizon of the stations

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
Texture	La	La	La	Ls	As	Sl	Sl	Al	Al	Sl
Structure	G	G	G	G	G	Gr	G	G	Gr	Gr
SG- Coarse sand (%)	40,07	31,82	21,61	23,19	19,43	31,23	24,68	34,95	39,37	32,98
SF - Soft sand (%)	11,89	21,59	53,37	33,46	59,04	37,82	43,90	16,29	15,93	37,80
A - Clay (%)	02,28	03,52	03,51	01,68	03,74	01,31	01,62	11,51	05,53	02,20
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Active calcareous (%)	09,25	08,15	03,20	03,52	02,27	01,59	02,26	01,44	06,20	01,04

The total calcareous content ranges from 1.7 to 30.85%. According to the norms established by [29], we distinguish three classes of soils:

- Class 1: strongly calcareous soil for station S1 with a rate of 30.85%,
- Class 2: medium calcareous soil (S2, S3, S4, S5, S8 and S9) with rates of 10-20%
- Class 3: slightly calcareous soil (S6, S7 and S10) with rates between 1.7% and 3.33%.

Active calcareous contents are often less than 6.20%. They reached 8.15% at S2 and 9.25% at S1. Electrical conductivity reveals unsalted soils for most samples. The measurements carried out give values fluctuating between 0.09 ms / cm (S4) and 0.39 ms / cm (S7). The pH remains slightly alkaline, between 7 and 8.04 with a very insignificant difference between the different samples analyzed. Soil moisture levels range from 7.34% to 11.60%. S1, S2, S9 and S10 stations in the northern slope have the highest rates (10.27% and 11.60%). An average grade (9.62% and 10.03%) is noted at stations S3 and S4, while a very low grade (7.34% and 7.65%) characterizes the stations on the southern slope, In this case stations S5, S7 and S8. The station S6 has a high humidity (11.60%). This moisture level is explained by the type of vegetation formation characterizing this station (light forest) and the importance of the recovery rate (35%). The southern slope is subject to prolonged drought while the northern slope benefits from milder climatic conditions, a sea breeze with its softening effects in summer [30].

3.3. ***Data processing***

3.3.1. ***Sorensen Similarity Coefficient***

The similarity coefficient of Sorensen (Is) evaluates the floristic affinity between two stations. If Is> 0.5, the two stations belong to the same plants community. The results show that the similarity coiefficients of the stations are important (Is> 0.73). The similarity dendrogram (Fig. 3) reveals five homogeneous groups. The G1 and G2 have an important similarity in the floristic composition with respectively 0.75 and 0.80. A strong similarity is noted for the three groups G3, G4 and G5 with respectively 0.85, 0.90 and 0.95. The group G3 is represented by the stations S1, S3, S4, S5, S7 and S8. This group has a strong similarity belonging to the same plants community. On the physiognomic level, these stations are represented by highly degraded scrublands based on *Calycotome spinosa, Chamaerops humilis* and *Ampelodesmos mauritanica*. Groups G4 and G5 correspond to the most degraded habitats (S3, S4, S5, S7 and S8). The most balanced stations consist of S2, S6, S9 and S10. Habitats that are less influenced by humans correspond to *Quercus ilex* (S2, S9 and S10) woody matorrals and *Pinus halepensis* (S6).

This strong similarity means that the ten sampled stations are homogeneous from the point of view of floristic composition. This homogeneity is the consequence of the different environmental conditions and the levels exploitation to which the vegetation cover is subjected in each station.

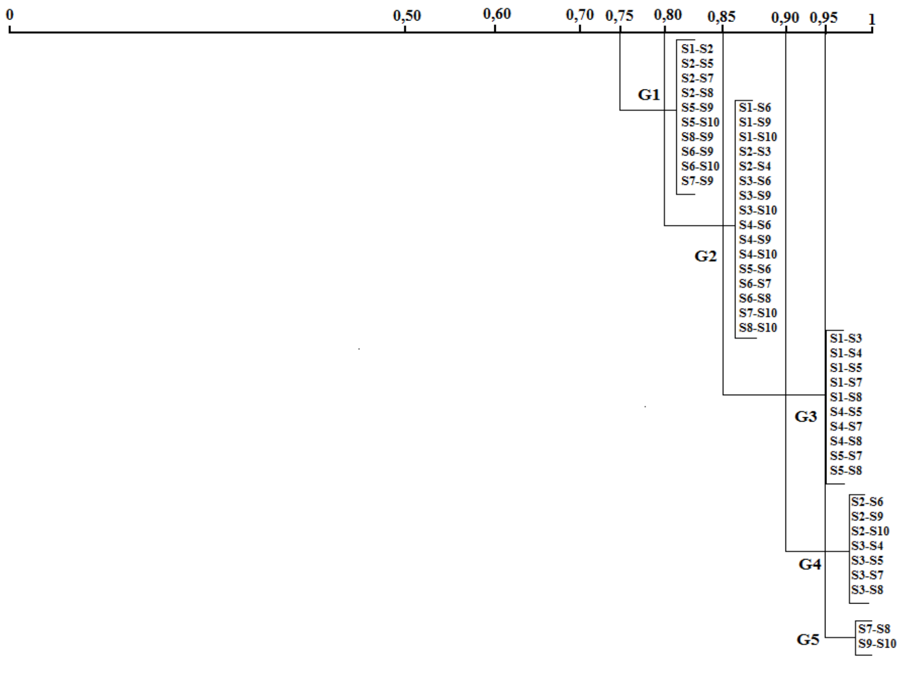


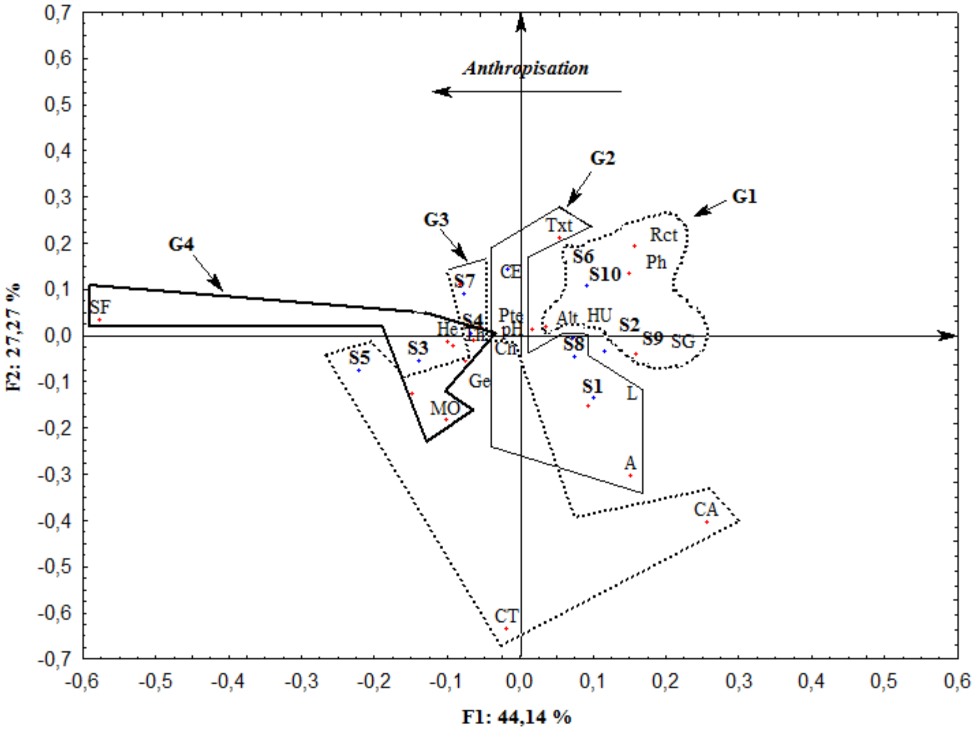
Figure 3: Dendrogram of similarity between the ten studied stations.

3.3.2. *Shannon Diversity Index*

The Shannon Diversity Index, evaluated for the ten stations, ranges from 0.56 to 0.90. It is between 0.56 and 0.86 bits / individual at S1, S3, S4, S5, S7 and S8 which have a specific richness ranging from 97 to 101 species. The high value (0.90 bits / individual) is recorded in stations S2, S6, S9 and S10 for a specific richness of 99 to 120 species. These are favorable stations for the installation of many species represented by a small number of individuals. The stations S2, S6, S9 and S10 have relatively high values (0.36 to 0.39) whereas S1, S3, S4, S5, S7 and S8 show low values (0.30 to 0.36) indicating a state of disturbance and spatial disorganization of the species. These changes in the index are linked to pressures exerted by humans and by livestock [31]. The low values correspond to the dominance of *Calycotome spinosa* and *Chamaerops humilis* which show significant abundance-dominance in the stations S1, S3, S4, S5, S7 and S8

3.3.3. *Factor analysis of correspondence*

The factor analysis of the correspondences identified four groups of plant formations (Figure 4). The F1 axis (44.14% inertia) and the F2 axis (27.27%) visualize the spatial arrangement of the groups. The axis F1 expresses a gradient of evolution of the balanced habitats towards the degraded stations. The automatic hierarchical classification clearly distinguishes the individualization of these four groups.



Legend: SG: Coarse sand, SF: Fine sand, L: Limons, A: Clay, OM: Organic matter, EC: Electrical conductivity, CT: Total calcareous, Alt: Altitude, Hu: Humidity, Txt: Texture, Pte: Slope, Nf: Number of families, Ne: Number of species, Ph: Phanerophytes, Ch: Chamephytes, Ge: Geophytes, He: Hemicryptophytes, Rr: Recovery rate, S: Station.

Figure 4: Graphical representation of the factorial plane F1xF2.

On the basis of the contributions made by the stations, soil and floristic parameters, the group G1 (S2, S6, S9 and S10) corresponds to habitats dominated by phanerophytes. This biological type is related to the recovery rate (Rr), altitude (Alt), soil moisture (Hu) and coarse sand (CS). The tree and shrub strata have a high recovery rate characterizing the least degraded stations. These habitats are represented by dense matorrals based on *Quercus ilex* (S2, S9 and S10) and *Pinus halepensis* (S6) light forest with a recovery rate of 30% to 35%. The high density of these vegetation formations protects them from overgrazing (difficult access).

The group G2 is represented by S1 and S8, characterized by dominance of chamephytes on a clay (A) and limonous (L) soil. The type of vegetation formation characterizing these two stations is the garrigues based on *Quercus ilex*, Quercus coccifera and Pistacia lentiscus, with a recovery rate of 20% to 15%. The Kermes oak is the dominant species in the shrub stratum and the *Calycotome spinosa* in the bushy and herbaceous stratum in the S1 station. Green oak, present only in the shrub stratum at S8, reflects the degradation of this station, whereas the bushy and herbaceous strata are composed of species resistant to various aggressions (*Calycotome spinosa* and *Chamaerops humilis*).

The group G3 (S4, S5 and S7) is distinguished by the dominance of therophytes and the chamephytes. These two biological types are associated with the total calcareous rate (CT), the active calcareous rate (AC) and the organic matter content average (OM). These habitats are clear matorrals area (S7) and heavily degraded scrublands (S4 and S5) based on *Calycotome spinosa* and *Chamaerops humilis*. According to [31], ovine and bovine overgrazing leads to the development of chamaephytes represented by *Calycotome spinosa*, *Chamaerops*

humilis, Daphne gnidium and *Thymus ciliatus*. Their proportion increases as soon as there is degradation of pre-forest habitats. This biological type adapts better to prolonged drought and light than phanerophytes [32].
The group G4 is represented by S3 where the therophytes and hemicryptophytes dominate. This set is correlated with fine sands (FS) and a high organic matter content (OM). The place occupied by hemicryptophytes in station S3 is due to its high richness in organic matter, soil moisture and altitude. This observation was noted by [33]. Station S3 constitutes a heavily degraded scrubland dominated by *Ampelodesmos mauritanica*, *Calycotome spinosa* and *Chamaerops humilis*, which emerge as the most dominant species of the bushy and herbaceous stratum.
The F1 axis expresses the degree of opening of the environment due to an anthropogenic gradient (regressive dynamics) and reflects a gradient of recovery rate (Rr) or density of vegetation, since it contrasts dense formations (light forest and Matorrals trees) to the open formations (garrigues). The phanerophytic species are composed of *Pinus halepensis* L., *Ceratonia siliqua* L., *Quercus ilex* L., *Quercus coccifera* L., *Pistacia terebinthus* L., *Pistacia lentiscus* L., *Olea europaea* Var. *Oleaster*) et les espèces chamaephytiques et thérophytiques correspondant aux *Calycotome spinosa* Link., *Chamaerops humilis* L., *Daphne gnidium* L., *Ruta montana* L., *Thymus ciliatus* Desf., *Anagallis arvensis* L., *Anagallis Monelli* L., *Bromus rubens* L., *Lobularia maritima* (L.) Desv., *Papaver rhoeas* L., and *Reseda alba* L.). This change in the physiognomy of vegetation would be linked to the high human impact and grazing promoting the acceleration of erosion processes and recurrent and persistent drought [34]. A difference is noted between the vegetation for ten stations and found that there is a regressive dynamics in different facies of the southern and northern slopes of the study area. In the stations S1, S3, S4, S5, S7 and S8, dominates a very advanced degradation facies where thorny Mediterranean thermophilic species dominate, they are *Chamaerops humilis*, *Asphodelus microcarpus, Calycotome spinosa, Ampelodesmos mauritanica Urginea and maritima*. These taxa are present in degraded matorral and scrubland, constituting a final stage of degradation characterizing bushy herbaceous strata and dominated chamaerops, witnessed the opening of the vegetation favored by anthropozoogène action [35]. This species is an indicator of degradation of green oak formations [36]. Under the combined action of man and his cattle, all plant groups are disturbed in their dynamics and then in their floristic composition. This change in the physiognomy of vegetation could cause forest loss, genetic potential and therefore a loss of biodiversity [9] and [15].

Conclusion

The obtained results show the very advanced state of degradation of some forest vegetation structures on Tessala Mount to give way to shrub formations forming mainly matorrals, associated in the best case with some forest species, witnesses of the original forests. In this fragile ecosystem, anthropogenic action remains the main factor of degradation. We consider the floristic indicator in this study as a guiding factor in the diagnosis of vegetation dynamics. The plant formations are mainly light forests based on *Pinus halepensis*, woody (dense and light) matorrals based on *Quercus ilex* and heavily degraded scrubs based on *Calycotome spinosa* and *Chamaerops humilis*. The state of the vegetation cover is seriously threatened and the analysis shows the extent of the man and herds impact.
Phytoecological surveys showed 132 species belonging to 44 families where Asteraceae are the most diverse, followed by Poaceae, Fabaceae, Lamiaceae, and Brassicaceae. The Mediterranean floristic element clearly dominates the flora of Tessala Mount, with a clear importance of therophytes largely dominating the biological spectrum throughout the study area. The progressive importance of biological types is schematized as follows: Th > He > Ph > Ch > Ge.
The factor analysis of the correspondences showed the discrimination of the pedobiological variables and the demonstration of the major ecological gradients. Four groups of stations are differentiated according to their state of degradation: the group containing the best balanced habitats (S2, S6, S9 and S10) correlated with the phanerophytes linked to the most advanced edaphic conditions (soil moisture). The three other groups have well-developed ecological degradation and are correlated with therophytes and chaméphytes characterizing a calcareous substratum. Overgrazing coupled with fires and woodcutting; govern the distribution of the main vegetation formations across the area
These synthesized ecological data explain the regressive dynamics of the forest ecosystem of the Tessala Mountain and its evolution towards a therophyte-based ecosystem. This mountain massif shelters an important plant biodiversity and an arrangement that protects and conserves its biological resources not yet valued in terms of biotechnology. The area is an undeniable asset for scientific and tourism activities, as it is threatened by agricultural clearing, permanent overgrazing of livestock, illegal logging and harvesting of timber that hinders the renewal of biological resources [9].

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