





## Analysis of floristic diversity of the forest ecosystems of the Zat valley- High Atlas of Morocco: Valorization and conservation perspectives

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### ABSTRACT

From a management and conservation perspective, measuring the biodiversity of an ecosystem is an indispensable tool for assessing its health. Currently, scientists and authorities are giving great importance to the Zat valley because of its ecological, socio-economic and cultural importance. This study was carried out to assess the floristic biodiversity and to determine the different dominant plant groups in the Zat Valley. Based on 33 phyto-ecological surveys, the floristic diversity of the Zat valley revealed the existence of 114 species and subspecies distributed among 44 families and 96 genera, belonging to various biological types. As a first result, 9 taxa were reported as rare taxa according to the flora of Morocco, whereas 7 species were reported as rare and threatened species. A Correspondence Factor Analysis was performed in this study and allowed the individualization of five groups of plants: Pine formation, Thuja formation, Tamarix formation, Holm Oaks formation and Thuriferous formation, each of these formations was described by its geographical distribution, the biodiversity of its flora and its ecological conditions. This study provides an essential tool for the sustainable management of this valley through the implementation of a management and conservation plan.

### INTRODUCTION

Morocco is one of the rarest countries in North Africa to have a set of endemic ecosystems with remarkable biodiversity particularly in terms of forest areas [1-2-3]. It is composed of four major high mountains: Rif, Middle Atlas, High Atlas and Anti Atlas, which are important sectors regarding endemism of vascular plants [3]. The Zat valley is located within the High Atlas Mountains, it is mainly composed of wet grasslands and pozzines, which constitute a highly coveted pastoral resource due to the geomorphology and evolution of surrounding slopes. Its flora is characterized by a great specific richness [4], for instance, in the case of high Atlas meadows, 4200 species were recorded distributed in 940 genus and 135 families where 550 species are endemic to Morocco [5].

The Zat Valley is considered one of the most watered valleys in the High Atlas due to the contribution of solid precipitation allowing a rich vegetation cover. There are few studies about vegetation in Zat Valley where tree main forests have been quoted: holm oak, Juniper and Thuja which are highly exploited by local population due to their socio-economical assets [7]. Moreover, only a few scientific works have been carried out to describe the main floristic diversity of this ecosystem [8].

Since it provides several ecosystem services, the vegetation of Zat Valley is threatened by the expansion and development of anthropogenic factors such as agriculture, industry



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and urbanization, which climate change is expected to further exacerbate, thus jeopardizing their integrity and sustainability.

The aim of the present work is to construct a floristic checklist and to develop a typology of plant communities and an interpretation of the relationships existing between these later and environmental factors using floristic and ecological descriptors.

## MATERIALS AND METHODS

### Study area

The Zat valley is located between 31° 17' and 31° 32' North and 07° 29' and 07° 34' West, it is integrated into the Tensift watershed and overlaps with two rural communes, Ait Ourir and Arbia Tighdouine (Figure 1). It is bounded to the south by the axial zone of the High Atlas, to the north by the Haouz plain, to the east by R'Dat basin and to the west by Ourika basin.

From a pedological point of view, the Zat valley is composed of 46 % impermeable land, 40 % semi-permeable land and 14 % permeable land [9]. Consequently, these geological formations favor a sustained surface flow and possibly the development of important floods in case of heavy rains [9].

The hydrographic network of the studied area is characterized by the Zat River which has its source at the foot of Taska n'Zat (3905 m) on the right bank and Tougroudaden (3736 m) on the left bank. It drains a catchment area of about 525 Km<sup>2</sup> and flows from south to north to Ait Ourir where it branches into two parts, one joins the Oued Ourika, and the other the Oued Tensift.

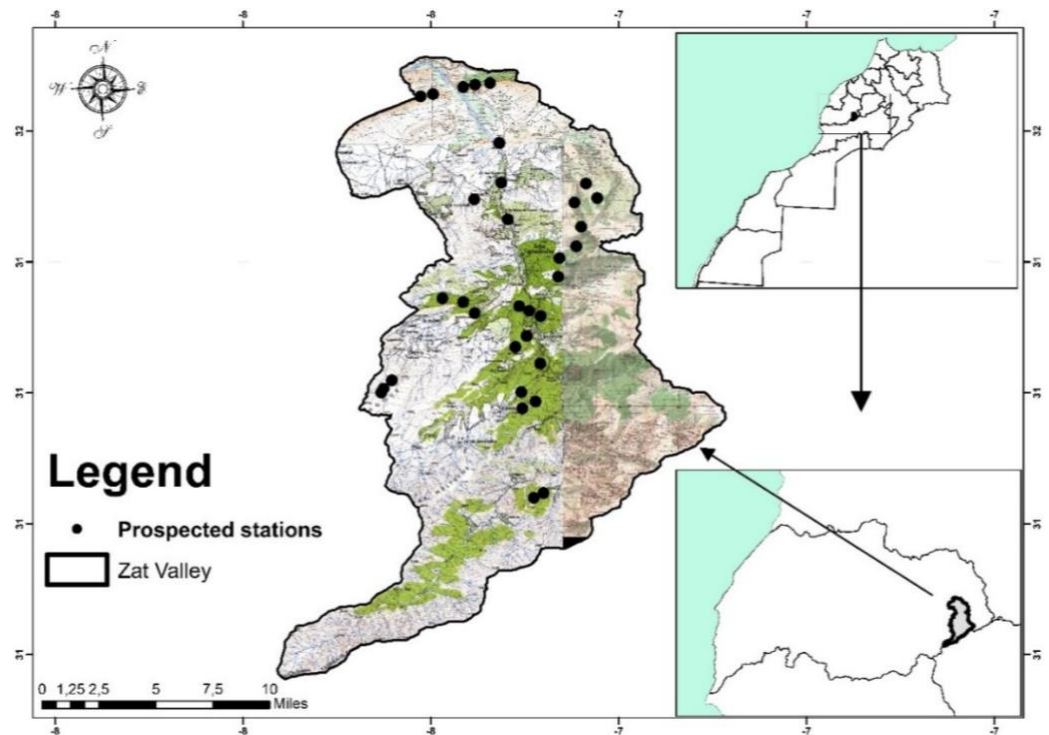


Figure 1. Geographical location of prospected stations in the Zat Valley.

## Sampling

33 localities were surveyed in order to cover the entire study area. Floristic sampling was carried out according to the phytocological approach described by Mueller-Dumbois and Ellenberg (1974) [10]. The principle of its establishment consisted in collecting data on physical environment and vegetation in the smallest area that contains almost all of a floristic homogenous surface (relevé) in order to have representative results of the entire study area. This method made it possible to define, analyze the different floristic groups and to highlight their relationships with the physical environment using fixed ecological and structural parameters. The main measured environmental parameters were altitude, slope and orientation, substrate and soil type, anthropogenic activities such as grazing intensity, fire and wood cutting.

As for the biological types, we adopted the life-forms of encountered species, according to the Raunkiaer classification system [11], as follows: phanerophytes, chamaephytes, hemicryptophytes, therophytes and geophytes.

The collected specimens were dried and pressed using the herbarium press of Museum of Natural History in Marrakesh. They were then identified using the Practical flora of Morocco: manual of the determination of vascular plants [12-13] and by consulting old collection of herbarium of Museum of Natural History of Marrakesh. The status of the studied taxa was based on the catalogue of rare, threatened or endemic vascular plants in Morocco [14].

The Correspondence Factor Analysis (CFA) was performed in this study using Past software (version 3.1) [15] based on a table of 33 surveys (R.1 to 33) and described by 26 dominant species. Indeed, for this analysis, we selected only those species with an abundance-dominance index greater than or equal to 2.

## RESULTS

### Floristic composition

As a result of the examination of 33 phyto-ecological surveys, the Zat valley is characterized by a great floristic richness estimated to 114 vascular species (Table 1). These species are distributed among 96 genera and 44 botanical families. The most dominant family was *Asteraceae* with 11 species (9.73%), followed by *Poaceae* with 10 species (8.75%), *Leguminosae* and *Labiatae* with 7 species (6.19%) each, and *Umbelliferae* with 5 species (4.42%). The following 17 families are represented by a single species: *Anacardiaceae*, *Apocynaceae*, *Convolvulaceae*, *Ericaceae*, *Fagaceae*, *Globulariaceae*, *Juglandaceae*, *Malvaceae*, *Moraceae*, *Myrtaceae*, *Papaveraceae*, *Punicaceae*, *Rosaceae*, *Rubiaceae*, *Tamaricaceae*, *Urticaceae*, *Zygophyllaceae* (Table 1).

According to the catalogue of rare, threatened or endemic vascular plants of Morocco [18], the endemic flora in Zat valley is represented by nine species; seven of them are endemic to Morocco while two species are reported as sub-endemic (Table 2) whereas 7 taxa are reported as rare and threatened species, namely: *Juniperus communis* L; *Juniperus thurifera* subsp. *africana*. Maire; *Matricaria aurea* (Loefl.) Sch. Bip; *Trifolium cernuum* Brot; *Diplotaxis ollivieri* Maire; *Poa pratensis* L; and *Rumex ginii* Jahandiez and Maire.

According to Raunkiaer's classification [11], this floristic list is dominated by Phanerophytes with 36 species (31.86%), followed by Therophytes with 29 species (25.66%), then Hemicryptophytes with 24 species (21.24%), Chamaephytes with 20 species (16.81%) and Geophytes with five species (4.42%) (Figure 2).

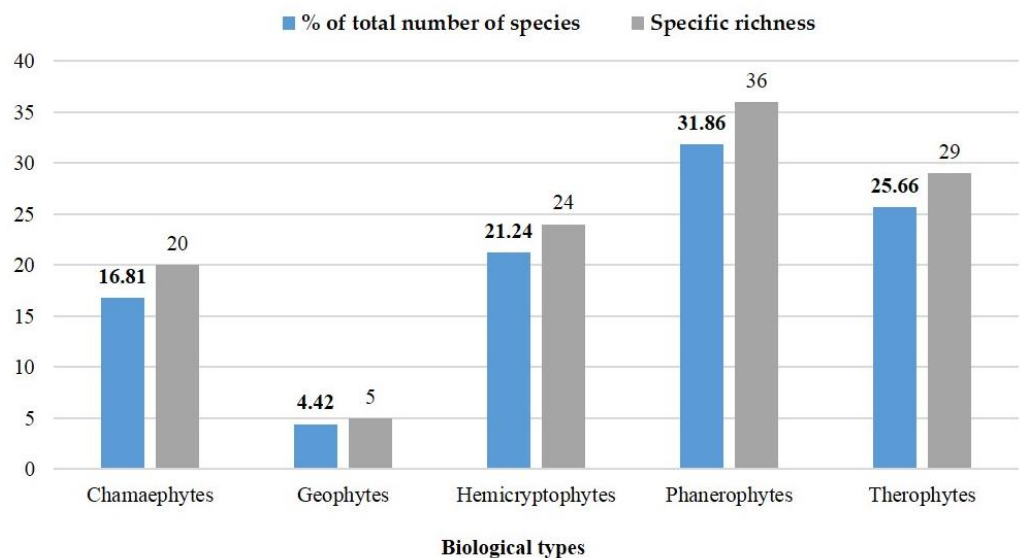
The sampled area has 6 halophilic species belonging to 4 different families according to the halophile flora [21]. We quote: *Juncus acutus* L., *Salsola vermiculata* L., *Atreplex halimus* L., *Frankenia* sp, *Plantago coronopus* L and *Phragmite australis* L. These species are located mostly in the Amassine River in the northwestern part of the study area.

**Table 1.** Specific richness and proportion relative of 37 families of Zat valley.

Families (44)	Number of genera (96)	Number of Species (114)	Genera frequency (%)	Species frequency (%)
<b><u>S/E Gymnospermes</u></b>	<b>5</b>	<b>8</b>	<b>5,21</b>	<b>7,08</b>
<i>Cupressaceae</i>	2	5	2,08	4,42
<i>Pinaceae</i>	2	2	2,08	1,77
<i>Ephedraceae</i>	1	1	1,04	0,88
<b><u>Cl/ Monocotyledone</u></b>	<b>16</b>	<b>20</b>	<b>16,67</b>	<b>17,70</b>
<i>Poaceae</i>	7	10	7,29	8,85
<i>Arecaceae</i>	3	4	3,13	3,54
<i>Asparagaceae</i>	2	2	2,08	1,77
<i>Amaryllidaceae</i>	2	2	2,08	1,77
<i>Cyperaceae</i>	1	1	1,04	0,88
<i>Juncaceae</i>	1	1	1,04	0,88
<b><u>Cl/ Dicotyledone</u></b>	<b>75</b>	<b>86</b>	<b>78,13</b>	<b>75,22</b>
<i>Asteraceae</i>	11	11	11,46	9,73
<i>Leguminosae</i>	5	7	5,21	6,19
<i>Labiatae</i>	5	7	5,21	6,19
<i>Umbellifereae</i>	4	5	4,17	4,42
<i>Brassicaceae</i>	3	4	3,13	3,54
<i>Chenopodiaceae</i>	4	4	4,17	3,54
<i>Cistaceae</i>	2	3	2,08	2,65
<i>Polygalaceae</i>	3	3	3,13	2,65
<i>Geraniaceae</i>	3	3	3,13	2,65
<i>Oleaceae</i>	3	3	3,13	2,65
<i>Crassulaceae</i>	2	3	2,08	2,65
<i>Salicaceae</i>	2	3	2,08	2,65
<i>Caryophyllaceae</i>	2	2	2,08	1,77
<i>Euphorbiaceae</i>	2	2	2,08	1,77
<i>Plantaginaceae</i>	1	2	1,04	1,77
<i>Rhamnaceae</i>	2	2	2,08	1,77
<i>Scrophulariaceae</i>	2	2	2,08	1,77
<i>Solanaceae</i>	2	2	2,08	1,77
<i>Anacardiaceae</i>	1	1	1,04	0,88
<i>Apocynaceae</i>	1	1	1,04	0,88
<i>Convolvulaceae</i>	1	1	1,04	0,88
<i>Ericaceae</i>	1	1	1,04	0,88
<i>Fagaceae</i>	1	1	1,04	0,88
<i>Globulariaceae</i>	1	1	1,04	0,88
<i>Juglandaceae</i>	1	1	1,04	0,88
<i>Malvaceae</i>	1	1	1,04	0,88
<i>Moraceae</i>	1	1	1,04	0,88
<i>Myrtaceae</i>	1	1	1,04	0,88
<i>Papaveraceae</i>	1	1	1,04	0,88
<i>Punicaceae</i>	1	1	1,04	0,88
<i>Rosaceae</i>	1	1	1,04	0,88
<i>Rubiaceae</i>	1	1	1,04	0,88
<i>Tamaricaceae</i>	1	1	1,04	0,88
<i>Urticaceae</i>	1	1	1,04	0,88
<i>Zygophyllaceae</i>	1	1	1,04	0,88

**Table 2.** List of endemic species of the Zat Valley "E: Moroccan endemic, A: endemic to Morocco and Algeria, I: Moroccan-Iberian

Species	Endemism
<i>Bellis caerulea</i> Cosson ex Ball	E
<i>Genista florida</i> L. ssp. <i>maroccana</i> Ball	
<i>Macrochloa antiatlantica</i> (Barrena et al) H. Scholz and Valdes	
<i>Eryngium varifolium</i> Cosson	
<i>Stipa nitens</i> Ball	
<i>Retama dasycarpa</i> Cosson	
<i>Thymus satureioides</i> Cosson	A
<i>Juniperus thurifera</i> subsp. <i>africana</i> . Maire	
<i>Polygala balansae</i> Cosson	I



**Figure 2.** Biological types and relative proportion of vascular plants recorded in the Zat Valley.

### Typology of plant groups

The processing of the CFA results showed the differentiation of five groups of plants (Figure 3), Pine formation, Tamarix formation, Thuja formation, Holm oaks formation and Thuriferous formation. Each type of these formations is defined by its geographical distribution, floristic biodiversity and ecological conditions.

Aleppo pine formation is located in the low altitudes between 600 and 800 m, often developed on a sandy clay soil poor in organic matter, with a low specific richness estimated by 9 taxa. This formation occupies a privileged space of the downstream part of the Zat valley (Figure 4), it shows the abundance of the following characteristic species: *Pinus halepensis* L, *Juniperus phoenicea* L, *Chamaerops humilis* L., *Drimia maritima* L., *Asparagus albus* L., *Lygeum spartum* L., *Stipa capensis* Thumb.

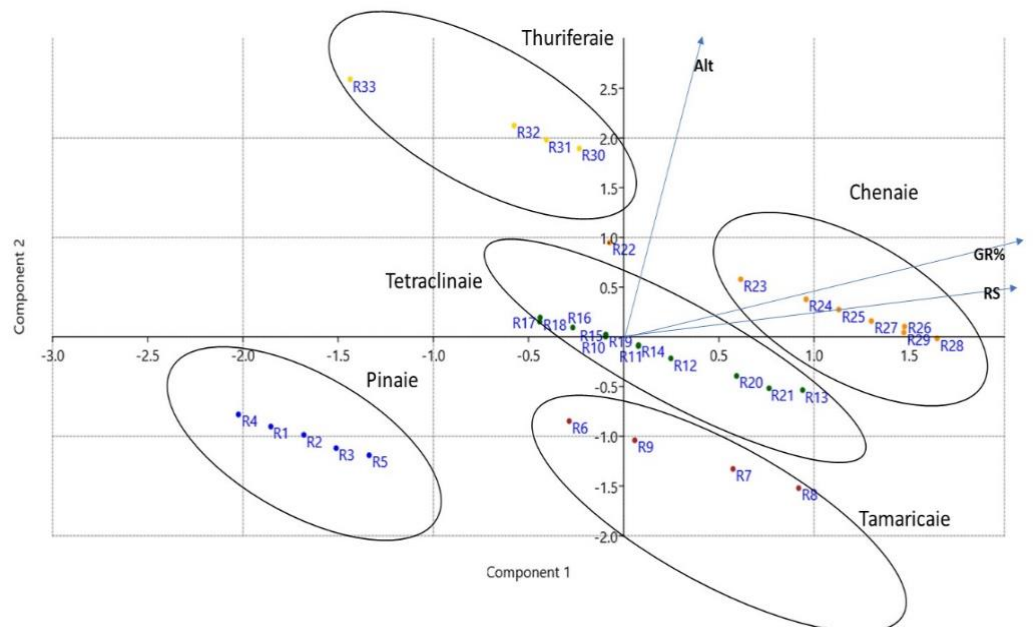
Tamarix formation is located in the alluvial zones of Zat River and its tributaries; it is along the river in Zat valley (Figure 4). It is generally narrow and forms a fringe about 100 m wide in which epiphytes, creepers and riparian plants are found. Tamarix

formation includes: *Tamarix africana* L., *Populus alba* L., *Salix pedicellata* Desf., *Nerium oleander* L., *Dittrichia viscosa* L., *Phragmite australis* L., *Arundo donax* L., *Juncus acutus* L., we also noticed the presence of four rare and threatened species: *Matricaria aurea* (Loefl.) Sch. Bip. *Trifolium cernuum* Brot; *Diplotaxis ollivieri* Maire and *Poa pratensis* L.

Thuja formation is characterized by an estimated high species richness of 21 species and a general cover of more than 60%. Two types of facies can be distinguished in the Zat valley, which differ according to the exposure of the slopes, the most frequent species in this formation are: *Tetraclinia articulata* (Vahl) Mast., *Juniperus phoenicea* L., *Pestacia lentiscus* L., *Olea europea* L., *Ceratonia siliqua* (L.) Willk, *Macrochloa antiatlantica* (Barrena et al) H. Scholz and Valdes., *Thymus satureioides* Cosson., and *Polygala balansana* Cosson. These last three species are endemic according to the catalogue of endemic vascular plants of Morocco [21].

Holm oaks formation holds a special place in the central part of the Zat valley (Figure 4), it is located in high altitudes ranging from 1800 to 2550 m, especially in the upstream of Tighadouine village. This formation is home to a rich and diverse flora, it is composed of 23 species and subspecies, of which 7 are endemic. We witnessed the abundance of *Quercus rotundifolia* L., *Juniperus oxycedrus* L., *Pestacia lentiscus* L., *Thymus satureioides*, *Cistus monspeliensis* L., *Lavendula dentata* L., *Cistus salvifolius* L.

Thuriferous formation is little represented in the study area, it represents 7% of the Zat valley and is located in the high-altitude zones which can reach up to 3500 m of altitude (Yagour plateau) (Figure 4), it grows on a schistous soil and is characterized by the presence of the following characteristic species: *Juniperus thurifera subsp. africana*. Maire, *Alyssum spinosum* L., *Bupleurum spinosum* (Gouan) O. Bolòs and Vigo., *Festuca maroccana* L., *Genista florida* L. ssp. *maroccana* Ball, *Retama dasycarpa* L., *Stipa nitens* Ball.



**Figure 3.** Ordination plots of CFA illustrating the relationship between environmental factors and surveys prospected. Abbreviations (Alt: Altitude; GR%: General recovering%; RS: Richness species).



**Figure 4.** Different plant formations recorded in the Zat valley (a. Aleppo pine formation; b. Riparian vegetation; c. Holm oaks formation; d. Thuriferous formation).

## DISCUSSION

The geographical location of the Zat Valley and its special environmental characteristics such as geomorphology, soil humidity, slope exposure and the presence of an anthropic pressure have led to a local diversification of the floristic composition; estimated at 114 species and subspecies. In fact, the importance of the first range families (*Asteraceae*, *Poaceae*, *Leguminosae* and *Labiatae*) is explained by their adaptability to the local conditions of the environment [1-4-5]. This interpretation is in agreement with the conclusions of previous works on the valleys of the high atlas of Morocco, in particular Ait Bou Guemmaz valley [16] and Ourika valley [5].

In addition, the number of rare and endemic species recorded was proportionally similar to other Moroccan valleys previously studied, such as Ourika valley with 6 species [19]; Ait Bou Guemmaz with 8 species [16]; and the lower valley of wadi Drâa with 18 taxa [17]. Our finding makes this site more valuable in terms of biodiversity. The high level of Phanerophytes observed (31.86%) reflecting the semi-arid bioclimate that prevails in the territory of the valley, which is in agreement with the work described previously in Beni Bousera (northern Morocco) [20] and Ourika valley [5].

This article notes that the Zat valley is mainly composed of five different plant groups according to the results of the CFA. First, the Aleppo pine formation located in the the downstream of the Zat valley and characterized by a low specific richness. In Morocco this formation is rare [3], however, it constitutes a few isolated stands on the periphery of the major mountain ranges and particularly in the Rif where it is relatively common on the Mediterranean slope of the Middle Atlas (regions and Moulouyen slope of the high "eastern" ranges), and also in the High Atlas where it is quite widespread in the internal valleys northwest of Marrakesh. Due to their plasticity, yield and economic importance, Aleppo pine is the main group of resinous species reforested in Morocco [21-22].

Also, it can be seen that Tamarix formation was individualized by their high specific richness and a fairly high rarity rate [23], this alluvial zone has been demonstrated by several authors as a biodiversity hotspot area [24-25]. In fact, detailed studies [24] show that the environmental parameters, such as dissolved oxygen, elevation, salinity and nitrate concentration, are considered as one of the most important factors that are capable of influencing the abundance and distribution of riparian plants along the Zat River and its tributaries.

In addition, the presence of two facies of Thuja is explained by the fact of the change of the slopes exposure. The botanical characteristics of the thuja formation were described by [2-3-26]. Indeed, detailed studies [5] point out the existence of a high density of *Tetraclinis articulata* in the adrets and a greater average coverage per foot in the more shaded orientations (of eastern and northern component).

On the other hand, Holm oaks formation is characterized by their ecological plasticity, which can extend from the thermo-mediterranean to the supra-mediterranean stage [27]. It corresponds to the internal, intra-mountainous domains located in the valleys and the sub-basins of the river basins. This observation is in concordance with the work carried out in this zone [1-3-5]. This formation has also been reported by [5-27], in two main blocks of the High Atlas: Azzaden and high Ourika, with a high density observed in the reserve of Takhrkhourte which belongs to the Toubkal National Park.

Finally, our results showed that the geographical distribution of Thuriferous formation clearly depends on the continental semi-internal domains of high altitude, it essentially occupies the mediterranean mountainous stage, upper semi-arid variant to lower and middle sub-humid variant [1-5-26]. In Morocco, this formation exists mainly in the Middle Atlas, the High Atlas and the Anti-Atlas of Saghro and can reach altitudes exceeding 3000 meters. In the Toubkal National Park, the thuriferous forest reaches 3520 m but it can be found at 3300 m which is more frequent [5]. Indeed, [28] considers that this forest species is threatened by extinction due to strong anthropogenic pressure limiting its natural regeneration and accelerating the aging of its stands.

## CONCLUSIONS

Rarity, Endemism and number of species of plants are of great importance in the Zat Valley. The list of the flora of the Zat Valley includes 114 species of vascular plants. The study of the vegetation was made by a preliminary global analysis of 33 phytocological surveys carried out during numerous missions. This analysis based on the floristic composition allowed the identification of five plants formations: Pine formation, Tamarix formation, Thuja formation, Holm oaks formation and Thuriferous formation.

For a better conservation and efficient management of this valley, it is recommended to deepen the knowledge of this environment and its natural resources, as well as to identify the different existing and potential threats, mainly due to human activities.

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## AUTHOR CONTRIBUTIONS

Mostakim L. and Guennoun F.Z. were involved in the conception and design of the experiments. Mostakim L. and Fetnassi N. collected the samples, analyzed data and prepared a draft of manuscript. Mostakim L., Guennoun F.Z. and Fetnassi N. contributed to revising it critically for important intellectual content. Ghamizi M. supervised the research work. The final manuscript was approved by all authors.

## CONFLICTS OF INTEREST

There is no conflict of interest among the authors.

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