

Checklist of the native tree flora of Algeria: diversity, distribution, and conservation

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Background and aims – Trees represent an important component of many ecosystems of the world. The knowledge of their diversity and geographic distribution is of great theoretical and practical importance. This paper aims to provide the first comprehensive checklist of native tree taxa in Algeria.

Material and methods – The checklist was based on the analysis of published data and has been improved with own field observations. Statistical analysis has been performed on the taxonomic richness, life forms, and chorological spectra in terms of diversity, endemism, habitats, and distribution of the tree flora in Algeria. The conservation status following IUCN and the protection status at national level have been presented.

Key results – The checklist comprises 120 native tree taxa currently known in Algeria, including 106 species, one hybrid species, and 13 subspecies, belonging to 63 genera and 35 families. The four most species-rich families are Rosaceae (13 spp.), Fabaceae (12 spp.), Salicaceae (9 spp.), and Tamaricaceae (9 spp.). The richest genus is *Tamarix* (9 spp.), followed by *Quercus* (7 taxa in 6 spp.). We found that trees are more often single-stemmed (45%), and are small or medium-sized. Mediterranean element is dominant (46%), followed by Saharo-arabic (17%), wide distribution element (15%), and European elements (12%). Furthermore, 11% of all tree taxa are endemics or subendemics. The highest number of taxa (71%) is found in the Tellian area, whereas the lowest number (36%) occurs in the Saharan area. Only nine taxa are considered to be threatened or near threatened, while 36 taxa are yet not assessed. This analysis highlights 33 taxa with patrimonial value, both endemics and range-restricted. Out of these taxa, only 18 are protected by national legislation.

Conclusion – This work shows that a relatively rich tree flora is found in Algeria. It aims to be used as a tool for managing tree species diversity. Some of the tree taxa need appropriate measures for their in situ conservation, a challenging but worth pursuing target.

Keywords – Checklist; endemic plants; life forms; North Africa; Sahara; taxonomic richness; threatened species; trees.

INTRODUCTION

Algeria is one of the most biodiverse countries in North Africa because of its unique biogeography with a transition between tropical and temperate climates (Véla & Benhouhou 2007). In terms of phytogeography, Algeria is indeed an interesting

country, belonging to both the Mediterranean and Saharo-Arabian regions, and therefore to the Holarctic kingdom (Quézel 1978). The interaction of the Mediterranean climate with the relief of the Atlas results in a strong environmental gradient, creating a north-south decrease in rainfall and an increase in dry season length, that determines huge changes

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in the floristic composition of ecosystems and a high plant diversity (Meddour 2010). Therefore, considerable habitat diversity exists on this territory, explaining its high level of endemism and species diversity (Véla & Benhouhou 2007). Recent studies showed that there are 3951 species (and subspecies) with 10.9% of them (430) endemics to Algeria (Dobignard & Chatelain 2010–2013). However, the floristic diversity is still imperfectly known, even for the tree flora. Indeed, knowledge about the number and distribution of trees, and more generally, woody species, remains limited for several regions of the world (Beech et al. 2017; Médail et al. 2019), especially in areas with limited data availability, such as arid and semi-arid areas (e.g. Brandt et al. 2020).

In the Mediterranean region, trees represent an important component of the ecosystems (Quézel & Médail 2003), and they are the keystone species of several forests and woody matorrals, considering the important place that they occupy in landscapes (Médail et al. 2019). The knowledge of their diversity and geographic distribution is of great theoretical and practical importance (Roma-Marzio et al. 2016). Tree flora have been shown to be important biodiversity surrogates for highly heterogeneous areas (Latini et al. 2017), like Algeria. A recent study indicated that some Mediterranean areas contain a disproportionately high phylogenetic diversity with a concentration of palaeo-endemic species (Cheikh Albassatneh et al. 2021). Hence, a focus on tree species constitutes a key issue to assess floristic diversity and develop proper conservation strategies (Médail et al. 2019).

Several researchers in the Mediterranean region have been involved with inventorying tree flora at local, regional, or national scales, e.g. Abbate et al. (2012), Roma-Marzio et al. (2016), and Médail et al. (2019). An effective assessment can be based on richness and level of endemism of the tree plants (Macía 2008), as did Barbero et al. (2001) for the Mediterranean forests. The entire Mediterranean Basin comprises a high tree richness estimated to 290 native taxa (species and subspecies) including 201 endemics (Quézel & Médail 2003; Médail 2008).

Historically, the tree flora of Algeria was the subject of two important contributions over a century ago (Letourneux 1887; Lapie & Maige 1914), wherein trees growing wild in the country were first listed. Apart from these historical contributions, there are few studies focusing on tree species in the country. Khelifi (2002) and Harfouche et al. (2005) briefly listed the native tree species present in the Algerian territory, counting 70–71 main and secondary species. There are also partial studies like the recent analysis of the influence of environmental vs anthropic factors for explaining the distribution of the four major coniferous species in North West Algeria (Ayache et al. 2020). For the Sahara region, Sahki & Sahki (2004), Benchelah et al. (2006), Kaabeche et al. (2011), and Sahki et al. (2017) mention the existence of 35 to 40 native tree species growing in the whole Algerian Sahara (Great South). On the other hand, the GlobalTreeSearch database (BGCI 2020) provides an overall list of 103 tree species for the country.

However, to date, there is no overall inventory of the tree flora of Algeria. Moreover, there is a lack of data for a considerable number of trees, notably on their life forms,

geographic distribution, rarity, endemism, and threats. In this context, our work arises from the necessity to update and improve the available information and filling in the knowledge gaps on native trees of Algeria, a country with limited data availability. This study aims to provide the first comprehensive checklist of the native tree flora of Algeria growing in the wild and to describe their taxonomical and chorological diversity, to estimate their distribution within the Algerian floristic regions, and to highlight narrow endemic and threatened taxa.

MATERIAL AND METHODS

Definitions

Due to the lack of consensus on a clear definition of tree species, a review of the literature to search for objective definitions for tree, relevant for the goal of our study, was necessary. In their study on the diversity of trees in the Mediterranean Basin, Médail et al. (2019) defined as tree “a species with a single stem and a well individualized crown, with a height that can potentially reach 3 m”. The tree definition agreed by IUCN’s Global Tree Specialist Group is less restrictive for the height: “a woody plant with usually a single stem growing to a height of at least 2 m, or if multistemmed, then at least one vertical stem 5 cm in diameter at breast height” (Beech et al. 2017; Rivers et al. 2019).

For the purpose of this checklist, we considered a tree as a normally single-stemmed ligneous plant (or multistemmed trunks after disturbance like fire or cutting) that can attain a height of at least 2 m at maturity. Furthermore, a naturally multistemmed woody plant is not a tree (e.g. various *Adenocarpus*, *Cytisus*, *Genista*, *Retama*, *Viburnum*). We included in our checklist tree-like plants such as some palms, which are usually considered trees (Richardson & Rejmánek 2011). This definition fits the characteristics of species that comprise the tree flora of Algeria, mainly because trees of the region tend to be small. However, some plant species vary in habit from shrub to tree across their range (Basak & Alam 2016), and setting a minimum height at maturity to separate trees from shrubs proved difficult, as also mentioned by Richardson & Rejmánek (2011). We also follow the proposal of Médail et al. (2019) to integrate as a tree those species that are generally shrubby but that can form true trees in optimal growth conditions, sheltered from frequent disturbances; this is for example the case for *Myrtus communis* and *Spartium junceum*.

Data collection and sources

Based on available literature and own field observations on native trees in Algeria, we gathered a comprehensive list of all the native trees with a potential height equal to or greater than 2 m at maturity (Quézel et al. 1999; Latini et al. 2017). The information sources for compiling data on the tree flora of Algeria were various and heterogeneous. The bibliographic research started with the Nouvelle Flore de l’Algérie by Quézel & Santa (1962–1963), which has served as an important starting point for our inventory. This flora remains up to now the main source of information for any

floristic study in Algeria. Tree species data were also gathered from other relevant primary sources, such as the Flore d'Algérie (Battandier & Trabut 1888–1895, 1985, 1902), the Flore de l'Afrique du Nord (Maire 1952–1987), the Flore et végétation du Sahara (Ozenda 2004), and the eflora Maghreb (eflora Maghreb 2019–2020). However, several knowledge gaps exist at different levels (e.g. height of the tree plants, life forms, distribution, etc.). To fill in these gaps, we have considered several documents dealing especially with the tree flora of Algeria (Letourneux 1887; Lapie & Maige 1914; Somon 1987) or Sahara (Benchelah et al. 2006; Kaabeche et al. 2011; Sahki et al. 2017), and we have supplemented this data with numerous field observations. Some major databases and taxonomic sources, such as GlobalTreeSearch database (BGCI 2020), the African Plant Database (APD

2012–2020), the Euro+Med PlantBase (The Euro+Med PlantBase 2006–2020), the Global Biodiversity Information Facility (GBIF 2020), and the Plants of the World Online (POWO 2019), have been consulted, in particular, to confirm life form, native status, and to decide inclusion in the present checklist.

Taxonomy, data management, and analysis

For each taxon, we give the following data: family, accepted scientific name according to APD (2012–2020), local name, life form and subform, height class, chorological category and endemism, habitat, distribution in Algeria, conservation status, and national protection. The family classification follows APG IV (2016) for the angiosperms and Christenhusz et al. (2011) for the gymnosperms. The nomenclature is

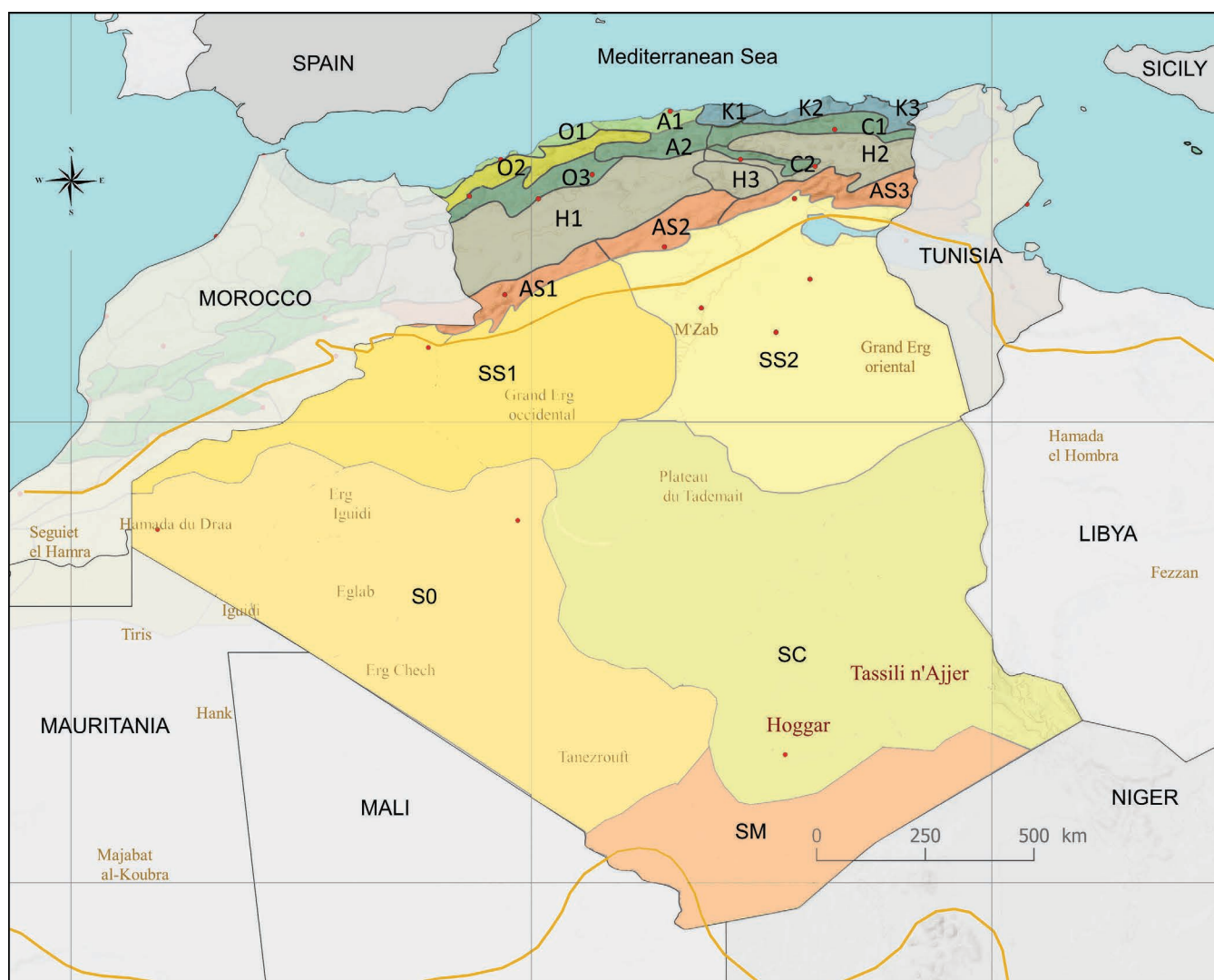


Figure 1 – The phytogeographical sectors and subsectors of Algeria (Quézel & Santa 1962–1963), modified by Quézel (1978) for the Saharan area, and slightly modified for the Tellian area by Meddour (2010). O1, Sahel and Oran coast; O2, coastal plains and hills of Oran; O3, Tellian Atlas of Oran; A1, Algiers Coast; A2, Tellian Atlas of Algiers; K1, Grande Kabylie (including Djurdjura); K2, Petite Kabylie (including Babors); K3, Numidia (from Skikda to El Kala); C1, Constantine's Tell and Biban mountains; C2, Hodna Mountains and Belezma; H1, Western High Plateaus; H2, Eastern High Plateaus; H3, Hodna Plain; AS1, Western Saharan Atlas; AS2, Central Saharan Atlas; AS3, Eastern Saharan Atlas (including Aurès); SS1, Northwestern Saharan; SS2, Northern Saharan; S0, Western Saharan; SC, Central Saharan (including Saharan High Mountains: Hoggar and Tassili n'Ajjer); SM, Southern Saharan. Map created with QGIS v.3.10.3 (QGIS 2020).

according to Dobignard & Chatelain (2010–2013) and updated by the African Plant Database (APD 2012–2020). The taxonomic richness of the flora is expressed in number of taxa in a given area (Altamirano et al. 2010), and provides information on the number of genera and species per family, and species by genus (Nyasiri et al. 2020). This is both the simplest and most easily interpreted measure of taxonomic diversity (Whittaker et al. 2001). Most tree species have local names and are used traditionally (Gillet & Doucet 2012). These local names originate from the Arab and Amazigh (Berber) languages and are given according to Letourneux (1887), Lapie & Maige (1914), and Trabut (2015); their transcription follow the mentioned sources.

Several taxonomic databases use the system of Raunkiaer (1934) for categorizing life forms, with trees mainly corresponding to the phanerophytes (Beech et al. 2017; Médail et al. 2019). We distinguish an important characteristic in the phanerophytes according to Ellenberg & Mueller-Dombois (1966): single-stemmed (scapose) or branched from near the base (caespitose). Hereafter, the tree taxa were classified as phanerophytes (P), with subforms scapose (P scap) and caespitose (P caesp). We assigned to each tree species one of the these two subforms, according to Carazo-Montijano & Fernandez-Lopez (2006), and in some cases, based on field observations rather than literature. Additionally, phanerophytes are conventionally subdivided into height classes (Ellenberg & Mueller-Dombois 1966), with a classification in tall, medium-sized, and small trees. These subdivisions have been formalized with more or less arbitrary boundaries as follows (Soulé et al. 2016): the tall trees or megaphanerophytes (Mg), over 30 m tall; the medium-sized trees or mesophanerophytes (Ms), between 8 and 30 m tall; the small trees or microphanerophytes (Mc), between 2 and 8 m tall.

The five main chorological categories (Endemic element, Mediterranean element, European element, wide distribution element, Saharo-arabic element) include 26 subcategories. This classification tries to combine the purely geographical aspect and the biogeographic one (Carazo-Montijano 2006; Carazo-Montijano & Fernandez-Lopez (2006). This information is completed with chorological data extracted from the APD, Euro+Med, and POWO databases, to fill in the gaps, especially in distribution of the endemic or Saharan trees. The term “endemic” is used here in a wide sense, to include endemics *sensu stricto*, taxa strictly localized to Algeria, and subendemics, taxa present in Algeria but shared with bordering countries (e.g. Morocco, Tunisia, Libya, Niger, or even Sudan). According to Meerts (2016), species with most of the distribution range in a region and limited extensions to adjacent regions are recognized as subendemics.

To assess species richness of trees at the habitat scale, we used existing data on habitats extracted from the main floras cited above. According to the global typology of habitat types in Algeria (Géhu et al. 1998), we summarized the six main habitat types (hereafter ‘habitats’) as follows (with their acronyms): F: forest habitat (woodlands and shrublands), W: freshwater habitat (or wetlands), R: rocky habitat, G: pastures and grasslands, S: sandy habitat (coastal

or continental), and A: synanthropic habitat (oasis, gardens, and hedges).

The distribution of tree species across the floristic regions of Algeria is not well known. We therefore collected the occurrences of each tree taxon according to the phytogeographical sectors and subsectors recognized by Quézel & Santa (1962–1963), modified by Quézel (1978) for the Saharan area, and slightly modified for the Tellian area by Meddour (2010), who split the initial C sector into two smaller subsectors, C1 and a new C2 subsector. The phytogeographical (sub)sectors ($n = 21$) are organised into the following three areas (fig. 1): Tellian area (K1, K2, K3, A1, A2, O1, O2, O3, C1, C2), Steppic area (H1, H2, H3, previously Hd, AS1, AS2, AS3), and Saharan area (SS1, SS2, SO, SC, SM). The main publications consulted to get data about their distribution in Algeria were the floras of Algeria, North Africa, and Sahara mentioned above. This bibliographical information was consolidated by field observations of the authors, the data provided by eflora Maghreb, and species occurrences records available at the Global Biodiversity Information Facility (GBIF 2020).

This distribution analysis of tree flora allows us to identify the taxa with the most restricted range, i.e. present in only one subsector within Algeria (or exclusive to this). In this sense, these plants, usually represented by few individuals or a small population, are labelled as ‘rare’ (Gillet & Doucet 2012). In the same way, Fennane & Ibn Tattou (1999) considered as rare the taxa present in one or two phytogeographic divisions of Morocco. We know, following Rabinowitz (1981), that one of the three attributes defining rarity is the size of the species range (large vs small).

Data regarding the global status of threatened tree taxa, according to IUCN (2020), have been collected, although this status has not been assessed for all taxa, nor specifically for Algeria. The IUCN (2012) classification system consider three categories of threatened tree taxa, having a high risk of extinction: critically endangered (CR), endangered (EN), or vulnerable (VU). The other categories are near threatened (NT), least concern (LC) or not threatened, and data deficient (DD) for the taxa deemed not to have sufficient information available to assign a Red List category.

Tree taxa protected by the national legislation in Algeria are indicated according to the “List of non-cultivated plant species protected throughout Algeria”, set by Executive Decree No. 12-03 of January 4, 2012 (JORA 2012).

RESULTS

Checklist, taxonomic pattern, and diversity

The checklist of the tree flora of Algeria includes 120 tree taxa, i.e. 106 species (including 12 autonyms), one putative hybrid species, and 13 subspecies, belonging to 63 genera and 35 families (supplementary file 1). Only few taxa (13, i.e. 12% of the overall tree flora) are gymnosperms, which are distributed within seven genera and three families. Angiosperms comprise the largest group of tree species, with 107 taxa (88%), belonging to 56 genera and 32 families.

Table 1 – The number of taxa per family in the tree flora of Algeria.

Family	Number of taxa	Proportion (%)
Rosaceae	13	10.8
Fabaceae	12	10.0
Salicaceae	9	7.5
Tamaricaceae	9	7.5
Cupressaceae	7	5.8
Fagaceae	7	5.8
Anacardiaceae	6	5.0
Oleaceae	6	5.0
Pinaceae	5	4.2
Rhamnaceae	5	4.2
Sapindaceae	5	4.2
Moraceae	4	3.3
Capparaceae	3	2.5
Apocynaceae	2	1.7
Arecaceae	2	1.7
Buxaceae	2	1.7
Caprifoliaceae	2	1.7
Celastraceae	2	1.7
Ericaceae	2	1.7
Polygonaceae	2	1.7
Adoxaceae	1	0.8
Aquifoliaceae	1	0.8
Betulaceae	1	0.8
Boraginaceae	1	0.8
Cannabaceae	1	0.8
Lamiaceae	1	0.8
Lauraceae	1	0.8
Malvaceae	1	0.8
Myrtaceae	1	0.8
Salvadoraceae	1	0.8
Santalaceae	1	0.8
Sapotaceae	1	0.8
Taxaceae	1	0.8
Ulmaceae	1	0.8
Zygophyllaceae	1	0.8
Total	120	100

Among them, dicots are the most numerous with 105 taxa (98%), while monocots include only two palms (2%).

According to the taxa number, 20 families have between 13 and two taxa in the country (table 1), while 15 families are only represented by one species. The most diverse families are Rosaceae (13 spp.), followed by Fabaceae (12 spp.), Salicaceae (9 spp.), Tamaricaceae (9 spp.), Cupressaceae (7 taxa in 5 spp.) and Fagaceae (7 spp.). Oleaceae and Anacardiaceae are also significantly represented with six

Table 2 – List of families and genera by number of taxa ($n \geq 2$) in the tree flora of Algeria.

Family	Genus	Number of taxa	Number of species
Tamaricaceae	<i>Tamarix</i>	9	9
Fagaceae	<i>Quercus</i>	7	6
Fabaceae	<i>Acacia</i>	5	5
Salicaceae	<i>Salix</i>	5	5
Sapindaceae	<i>Acer</i>	5	4
Cupressaceae	<i>Juniperus</i>	5	3
Rosaceae	<i>Crataegus</i>	4	4
Moraceae	<i>Ficus</i>	4	4
Salicaceae	<i>Populus</i>	4	4
Rosaceae	<i>Sorbus</i>	4	4
Pinaceae	<i>Pinus</i>	3	3
Anacardiaceae	<i>Pistacia</i>	3	3
Rosaceae	<i>Prunus</i>	3	3
Buxaceae	<i>Buxus</i>	2	2
Polygonaceae	<i>Calligonum</i>	2	2
Oleaceae	<i>Fraxinus</i>	2	2
Oleaceae	<i>Olea</i>	2	2
Oleaceae	<i>Phillyrea</i>	2	2
Rhamnaceae	<i>Rhamnus</i>	2	2
Anacardiaceae	<i>Searsia</i>	2	2
Rhamnaceae	<i>Ziziphus</i>	2	2
Caprifoliaceae	<i>Lonicera</i>	2	1

species each. These eight richest families include 69 taxa altogether, accounting for 58% of all tree taxa in the Algerian flora.

Among the genera, *Tamarix* comprises the highest number of taxa (9 spp.), followed by *Quercus* (7 taxa in 6 spp.), and *Acacia*, *Acer*, *Juniperus*, and *Salix* (5 taxa each) (table 2). This means that 30% of the tree flora is grouped within these six genera. Then, 16 genera encompass between four and two taxa, while 34% of all genera (41) are monospecific in the tree flora of Algeria.

Life forms and subforms

Phanerophytes are more often single-stemmed (scapose), than multistemmed (caespitose), with 54 taxa (45%) versus 41 (34%) respectively, while 25 taxa (21%) are represented by the two subforms. The distribution of the trees based on the height class highlights the co-dominance of microphanerophytes (small trees, 2–8 m), with 58 taxa (48%) and the mesophanerophytes (medium-sized trees, 8–30 m), with 61 taxa (51%). Only *Cedrus atlantica*, which quite often exceeds 30 m in height under optimal conditions, is classified as a megaphanerophyte (tall tree).

Table 3 – The number of taxa per chorological category in the tree flora of Algeria.

Chorological categories	Subcategories	Number of taxa	Proportion (%)
Endemic element	End Alg	4	3.3
	End Alg-Mor	4	3.3
	End Alg-Tun	2	1.7
	End Alg-Tun-Lib	2	1.7
	End Alg-Niger-Sudan	1	0.8
Mediterranean element	Circummediterranean	12	10.0
	W-Mediterranean	11	9.2
	Mediterranean-Macaronesian	5	4.2
	Mediterranean-Turanian	5	4.2
	S-Mediterranean	4	3.3
	W-Mediterranean-Macaronesian	4	3.3
	S-Mediterranean-Macaronesian	2	1.7
	N-Mediterranean	2	1.7
	E-Mediterranean	1	0.8
	SW-Mediterranean	1	0.8
	W-Mediterranean-Atlantic	1	0.8
	Ibero-Maghrebian	7	5.8
European element	European	6	5.0
	European-Caucasian	5	4.2
	Eurosiberian	2	1.7
	Eurasiatic	1	0.8
Wide distribution element	Paleotemperate	11	9.2
	Paleotropical	5	4.2
	Paleosubtropical	2	1.7
Saharo-arabic element	Tropical-Saharo-arabic	16	13.3
	Saharo-arabic	4	3.3
Total		120	100

Table 4 – Relative proportion of the six habitat types in which the tree flora occurs in Algeria. Note that the sum of the proportions is greater than 100% because the same plant can occur in multiple habitat types.

Habitat types	Number of taxa	Proportion (%)
Forest habitat	68	56.7
Freshwater habitat	46	38.3
Pastures and grasslands	13	10.8
Rocky habitat	37	30.8
Sandy habitat	17	14.2
Synanthropic habitat	8	6.7

Chorological categories and endemism

The distribution of the chorological categories is highly diverse since it includes five main elements, with 26 subelements (table 3). The majority of trees belong to the Mediterranean element with 55 taxa (46%), including seven Ibero-Maghrebian taxa. Besides typical Mediterranean taxa, the Algerian tree flora also includes 14 taxa (12%) belonging to the European element that occur especially in the mountainous region of Northern Algeria. Another group of 18 taxa (15%) with a wide distribution is also well represented. The Saharo-arabic element includes 20 taxa (16%). The Endemic element is represented by 13 taxa (11%), i.e. nine species and four subspecies, of which three North-African or Saharan endemics (occurring in more than two countries), six subendemics (present in two countries, Algeria with Morocco or Tunisia), and four Algerian endemics *sensu stricto* (*Abies numidica*, *Cupressus dupreziana*, *Juniperus thurifera* subsp. *aurasiaca*, and *Lonicera kabylica*) (table 6).

Habitat types

Tree taxa clearly prevail in forest habitats: 68 taxa were recorded in both woodlands and shrublands (table 4). The rocky habitats (rocky ridges of the mountains and the coastal cliffs), which offer favourable settings (refuges) for tree taxa, far from anthropogenic factors (fires, grazing), host a significant amount of 37 taxa. A remarkable diversity of 46 tree taxa occur in wetlands (fresh, salty, or brackish watercourses), e.g. Tamaricaceae and Salicaceae; these are the species that form riparian forests, usually at the edge of temporary rivers (wadis). The other habitats harbour fewer taxa: sandy habitat (17), pastures and grasslands (13), and synanthropic habitat (8).

Table 5 – Distribution of the tree taxa richness in the floristic regions (phytogeographical sectors) of Algeria, organized according to the 3 main areas. Abbreviations. K: Kabylia-Numidian sector; A: Algiers sector; O: Oran's sector; C: Constantine's sector; H: High Plateaus sector; AS: Saharan Atlas sector; SS: Northern Saharan sector; SO: Western Saharan sector; SC: Central Saharan sector; SM: Southern Saharan sector.

Main areas	Tellian area				Steppic area		Saharan area			
Phytogeographical sectors	K	A	O	C	H	AS	SS	SO	SC	SM
Number of taxa	71	63	51	47	21	49	23	16	33	17

Table 6 – List of the tree taxa with patrimonial value (endemics and/or exclusives) that are threatened and protected at national level or not. Abbreviations. End: Endemic; Alg: Algeria; Mor: Morocco; Tun: Tunisia; Lib: Libya; Nig: Niger; Sud: Sudan; Sah: Saharan. *According to Aissi et al. (2021).

Taxa	Endemics and subendemics	Exclusives (locations)	IUCN (2020) status	Protection
<i>Abies numidica</i> Carrière	End Alg	K2 (Babors)	CR	P
<i>Acacia laeta</i> R.Br. ex Benth.		SC (Ahaggar)	LC	P
<i>Acer campestre</i> L.		K2 (Babors, Guerrouch)	LC	P
<i>Argania spinosa</i> (L.) Skeels	End Alg-Mor (Sah)	SO (Hamada of Tindouf)		P
<i>Bauhinia rufescens</i> Lam.		SM (Tin Zaouatin)	LC	
<i>Buxus balearica</i> Lam.		AS1 (Djebel Grouz)		P
<i>Calligonum arich</i> Le Houérou	End Sah (Alg-Tun-Lib)	SS2 (Grand Erg oriental)		
<i>Calligonum azel</i> Maire	End Sah (Alg-Tun-Lib)			
<i>Capparis decidua</i> (Forssk.) Edgew.		SM (?)	LC	
<i>Cedrus atlantica</i> (Endl.) Carrière	End Alg-Mor		EN	P
<i>Cordia sinensis</i> Lam.		SC (Tassili n'Ajjer)	LC	P
<i>Crataegus granatensis</i> Boiss.		AS3 (Aurès)		
<i>Cupressus dupreziana</i> A.Camus	End Alg (Sah)	SC (Tassili n'Ajjer)	EN	P
<i>Ficus cordata</i> subsp. <i>salicifolia</i> (Vahl) C.C.Berg		SC (Ahaggar, Tassili n'Ajjer)		P
<i>Ficus ingens</i> (Miq.) Miq.		SC (Ahaggar, Tassili n'Ajjer)	LC	
<i>Ficus sycomorus</i> L.		SC (Ahaggar)	LC	
<i>Frangula alnus</i> Mill. subsp. <i>alnus</i>		K3 (El Kala)	LC	
<i>Fraxinus dimorpha</i> Cosson & Durieu	End Alg-Mor		EN	P
<i>Juniperus phoenicea</i> subsp. <i>turbinata</i> (Guss.) Arcang.			NT	P
<i>Juniperus thurifera</i> subsp. <i>aurasiaca</i> (Véla & P.Schäff.) Véla	End Alg	AS3 (Aurès)		P
<i>Lonicera kabylica</i> (Batt.) Rehder	End Alg			P
<i>Olea europaea</i> subsp. <i>laperrinei</i> (Batt. & Trab.) Cif.	End Sah (Alg-Nig-Sud)	SC (Ahaggar, Tassili n'Ajjer)		P
<i>Pinus nigra</i> subsp. <i>mauretanica</i> (Maire & Peyerimh.) Heywood	End Alg-Mor	K1 (Djurdjura)		P
<i>Pinus pinaster</i> subsp. <i>renouii</i> (Villar) Maire	End Alg-Tun		EN	
<i>Pistacia atlantica</i> Desf.			NT	P
<i>Populus tremula</i> L.		K2 (Babors)	LC	P
<i>Prosopis farcta</i> (Banks & Sol. ex Russell) J.F.Macbr.		SS2 (Ayata Lake, oued Righ)		
<i>Quercus afares</i> Pomel	End Alg-Tun		VU	P
<i>Quercus faginea</i> subsp. <i>broteroi</i> (Cout.) A.Camus*		O3 (Terni, Balloul, Safalou)		
<i>Quercus faginea</i> Lam. subsp. <i>faginea</i> *		AS3 (Chélia)		
<i>Sorbus latifolia</i> (Lam.) Pers.		O3 (Tlemcen Mts)		
<i>Tamarix boveana</i> Bunge			VU	
<i>Tamarix parviflora</i> DC.		AS3 (Batna)		

Geographic distribution in Algeria

Most of the tree taxa (85, 71%) occur in the Tellian area, grouping the sectors O, A, K, and C, while only 52 taxa (43%) have their distribution in the Steppic area (sectors H and AS), less favourable for trees (table 5). These two areas of the northern part of Algeria share 38 taxa (32%). A surprisingly high number of 43 tree taxa (36%) occur in the Saharan area (sectors SS, SO, SC, and SM), despite the fact that it is a desert area dominated by drylands. A smaller group of 13 taxa (11%) is present in all these three areas of Algeria.

Taxa with narrow-range distribution

Most tree taxa have large distribution ranges in Algeria, as they are present at least in two floristic regions (i.e. subsectors). Nevertheless, our analysis highlights the presence of 24 rare taxa (20%), as well as endemic and non-endemic, with a narrow-range distribution, occurring within only one floristic region of Algeria (table 6). Among them, seven taxa are present in the Tellian Atlas Mountains (Babors, Djurdjura, or Tlemcen Mountains) or in the coastal region (El Kala), with some individuals or a small population. Another group of five rare plants is present exclusively in the steppic mountainous area (Saharan Atlas), mainly in the Aurès. An unexpectedly high number of tree taxa (12, ca 10%), with tropical affinity, is special to the sectors of Algerian Sahara. They occur especially in the Central Sahara Mountains (Ahaggar and Tassili n'Ajjer).

Threatened taxa

Currently for Algeria, 84 tree species are included in the IUCN Red List of Threatened Species database, of which seven are considered threatened (1 CR, 4 EN, 2 VU), and two others are classified as near threatened (NT) at the global level (table 6). On the other hand, 71 tree taxa are classified as least concern (LC), and four species are data lacking for an assessment (DD). Accordingly, the proportion of threatened and near threatened tree taxa in Algeria is about 7.5% of all tree taxa (9 taxa). Moreover, our results indicate a significant percentage (46%) of endemics and subendemic taxa classified as threatened and near threatened. However, 36 tree taxa (30% of all taxa) are not yet assessed.

Taxa protected by the law

In total, 41 tree taxa (34% of the total) are included in the “List of non-cultivated plant species protected throughout Algeria”, and are protected by the law, of which only 18 have a patrimonial value (endemic, rare, and/or threatened). Conservation decisions, such as the creation of a national red list, are made with only limited data available for Algeria. Therefore, the national legislation does not protect 15 endemic or rare taxa out of the 33 that we have highlighted (table 6).

DISCUSSION

Global tree richness in Algeria

We identified 120 native tree taxa in total that included 106 species, one putative hybrid species, one variety, and 12 subspecies, belonging to 63 genera and 35 families, thus attesting the remarkable diversity of the Algerian tree flora. Our analysis shows that there are a few extra species compared to the GlobalTreeSearch database (BGCI 2020), which only gives 103 tree species in Algeria. This tree species diversity is mainly due to the particular climatic conditions and habitat heterogeneity in Algeria, and its geological, palaeogeographic, palaeoclimatic, and historical factors that have helped to create highly diverse environments, similar to the rest of the Mediterranean region (Quézel 1978; Quézel & Médail 2003).

Due to the large literature survey and our own field observations in various parts of the country since several decades, our species list can therefore be considered as a comprehensive checklist of the tree taxa in the Algerian territory. However, the information for some taxonomic groups (e.g. *Tamarix*, *Acacia*) remains incomplete due to the taxonomic complexity and the cryptic diversity in these genera in North Africa (Kyalangalilwa et al. 2013; Bihaoui et al. 2020) and the rarity of observations, especially in the southern Sahara. Therefore, some new species may be added to the current checklist in the future.

Families with the greatest number of taxa are Rosaceae (13 spp.) and Fabaceae (12 spp.). This finding is consistent with other studies on tree floras. Indeed, many authors in temperate biomes (e.g. Palgrave et al. 2007; Gillet & Doucet 2012; Beech et al. 2017) reported high Fabaceae species diversity in their studies. Fabaceae is one of the most diverse families in the world (Beech et al. 2017), so the chance of finding a Fabaceae member is highly likely. As well, Rosaceae is the richest family for species in Mediterranean-European countries (Yurukov & Zhelev 2001; Abbate et al. 2012; Roma-Marzio et al. 2016; Médail et al. 2019).

The distribution of tree taxa based on the height class highlights a high proportion (49%) of microphanerophytes (small trees, 2–8 m). Moreover, these trees are often multistemmed or single/multistemmed (56%). In fact, this habit indicates that Algerian “forests” are frequently small and multi-branched, corresponding to the “maquis, matorral, or bush”, very widespread in the country, with 58.7% of the woodlands (FAO 2012). In arid areas of North Africa, many true trees generally occur as shrubs under certain environmental conditions or in situations where the disturbances are intense, particularly herbivory (Zaafouri & Chaïeb 1999; Médail et al. 2019). This is the case for *Ziziphus lotus* and *Searsia tripartita* in arid and hyperarid areas or for *Spartium junceum* in more temperate areas. Moreover, 23 “cryptic trees” (19%), i.e. trees usually with a shrubby form, occurring in the Mediterranean-European region (Médail et al. 2019), are recorded in our checklist.

Distribution in Algeria

If several tree taxa are present everywhere in Algeria, most of them (71%) occur in the Tellian area. There is a gradual decrease in species richness from the Tellian area to the inner Sahara (36%), via the Steppic area (43%). Therefore, the distribution of the tree flora reveals a north-to-south decreasing in species richness, linked to an aridity gradient, being lowest in hyperarid to arid areas and highest in subhumid to humid areas in Algeria. This latitudinal decrease reflects the progressive impoverishment of the entire vascular flora as one progresses towards the most deprived areas from a climatic point of view (Quézel 1978). Elsewhere, O'Brien (1993) have demonstrated a similar relationship between woody plant species richness and a climatic gradient in Southern Africa. Xystrakis et al. (2019) showed that woody plants diversity was higher along a north-western to south-eastern gradient, which was related to a dominant climatic gradient throughout Greece. In China, Qian (2013) showed that woody plant species richness varies greatly along environmental gradients at the regional scale, and climatic variables are important forces driving gradients of species richness. Indeed, current climatic factors heavily shape the distribution patterns of plant taxa in arid areas (Mehrabian et al. 2020).

Chorological diversity of the tree flora

A remarkable chorological diversity (5 elements and 26 subelements) structures the woody flora of Algeria. This reflects largely the palaeogeographic and palaeoclimatic history of the region linked to its geographical position in the Mediterranean Basin, at the crossroads of several biogeographical regions (Eurasian, Saharan-Arabian, and Tropical) (Quézel 1978).

The Mediterranean element as a whole represents the largest part of the tree flora, with 46% of the taxa. According to Quézel (1978), in the northern part of the Maghreb, there is a predominance of the Mediterranean element; this is the case in particular for tree species, e.g. *Arbutus unedo*, *Ceratonia siliqua*, *Laurus nobilis*, *Myrtus communis*, *Olea europaea*, *Pistacia lentiscus*, *Quercus coccifera*, and *Q. ilex* (Quézel 1995).

The European element represents a significant proportion of 12% of the tree flora. This cool-temperate Eurasian and European flora represents often-relict species that have survived the Last Glacial Maximum (Médail & Diadema 2009; Husemann et al. 2014). They are mostly located in mountain forests at higher elevations, viz. in the Atlas (refugium area), or in wetlands, where they found suitable ecological conditions (Quézel 2000). Most of them are located at their southern range-limit in Northern Africa, such as *Acer* spp., *Alnus glutinosa*, *Salix* spp., *Ulmus minor*, *Populus* spp., *Prunus* spp., *Sorbus* spp., *Ilex aquifolium*, and *Taxus baccata* (Quézel 2000). The wide distribution element (Paleotemperate, Palaeo(sub)tropical) represents an important proportion of 15%.

Within the Saharo-arabic element, the proportion of the Saharo-arabic-Tropical taxa (13.3%) reveal a strong affinity of the Algerian tree flora with tropical floras, as it was previously reported for the overall flora (Quézel 1978). The

spread in North Africa of the Tropical flora of Sahelian type occur during interglacial phases (African pluvial), especially in desert savannah landscapes of the Sahara, where the vast majority of trees are of tropical origin, especially in the Central Sahara mountains (Quézel & Barbero 1993; Médail & Quézel 2018). Among them, we can mention *Acacia* spp., *Balanites aegyptiaca*, *Boscia senegalensis*, *Capparis decidua*, *Ficus cordata* subsp. *salicifolia*, *Grewia tenax*, *Maerua crassifolia*, and *Salvadora persica*.

The Algerian tree flora contains a lesser but noteworthy number of endemic and subendemic taxa (11%) (fig. 2). In the Maghreb, as in the Mediterranean Basin, this endemism can be explained as a result of isolation phenomena in some areas (mountains, desert) and by the complex historical biogeography combined with several crucial environmental changes, notably the contrasted climatic episodes of the Quaternary (e.g. Médail & Diadema 2009; Thompson 2020). The most interesting cases are undoubtedly those of the flagship species *Abies numidica* and *Cupressus dupreziana*, two strictly endemic conifers, with a restricted area on mountains, where isolation has resulted in speciation. The Algerian Fir is restricted to Babor and Tababor Mountain, where it occurs in humid montane mixed forests on calcareous slopes, and is highly scattered (Yahi et al. 2011). The actual area of occupancy is estimated to be less than one km² (Yahi et al. 2011). The Tassili cypress, with a total known population of 233 living trees (Abdoun & Beddief 2002), is limited to the Tassili Plateau (Central Sahara), within the regions of Maddak, Tassili-Hedjrit and Amiok, where the trees grow on high plateaus (tassili) or in the bottoms of valleys and gorges (Abdoun et al. 2013). These two endemic tree species, endangered or critically endangered, meet all the rarity criteria of Rabinowitz (1981), i.e. reduced populations, restricted area, and specialized habitat; their conservation needs to be prioritized.

Threats and conservation of the tree taxa

The number of threatened and near threatened tree species in Algeria is currently nine (7.5% of all taxa). Nevertheless, since several trees are yet not assessed (36 tree taxa, 30%), the number of threatened tree taxa in Algeria is obviously incomplete in the IUCN Red List database. Actually, the proportion of threatened tree taxa in Algeria is low, considering that Quézel & Médail (2003) identified 61 threatened trees out of the 290 present in the Mediterranean basin, i.e. 21%, and in Morocco, Fennane (2017–2018) recorded 17.5% of threatened tree taxa (n = 97). Some of our taxa classified as least concern (at specific rank over their entire range) or not evaluated by IUCN (2020) are worth mentioning: *Pinus nigra* subsp. *mauretanica* and *Juniperus thurifera* subsp. *aurasiaca*. Based on our own observations, we consider these rare endemic taxa, which occupy tiny parts of the entire range of the species, as really threatened in Algeria. Indeed, they are declining due to their small populations and the strong anthropogenic disturbances (human pressure, overexploitation due to logging and wood harvesting, overgrazing, recurrent fires) they are increasingly facing in Algeria (Meddour et al. 2011; Taib et al. 2020). Nevertheless, without knowing which of the unassessed tree taxa (species, subspecies, and varieties) are threatened

and what the threats are, we cannot effectively protect them. Hence, we highlight the need to conduct a complete assessment of the threat status of all known tree taxa of Algeria, as an urgent priority to guide future conservation actions.

From the thorough analysis of taxa with patrimonial value, we have highlighted 13 endemic taxa in a broad sense, 24 rare or exclusive taxa, and nine threatened and near threatened taxa, i.e. 33 taxa in total. Among exclusive taxa, *Crataegus granatensis* is probably often under-observed, and often confused with *C. monogyna* (Dobignard 2009). Of these high-value taxa, around 14 are not protected by the legislation in Algeria, particularly *Pinus pinaster* subsp. *renoui*, an Algerian-Tunisian endemic with restricted area, and *Tamarix boveana*, which are threatened since many subpopulations of these taxa are in decline according to Farjon (2013) and Beech (2018), respectively. In particular, *T. boveana* seems to have regressed around the Grand Erg occidental following the increase in human activity (Selkh 2012). On the other hand, the highest level of protection is

recommended for the stands of *Pinus pinaster* subsp. *renoui* in the El Kala coastal dunes (Stevenson et al. 1988), and especially on the coastal mountain of Bougaroun Cape in the Collo Peninsula (Maire 1952–1987; Yahia et al. 2012).

A focus on the tree-like *Calligonum*, in particular *C. arich* and *C. azel* that are unknown and threatened in the Saharan area, would be useful. These two endemic species, present in the large dune complexes of the Sahara in Algeria, Tunisia, and Libya, are not evaluated by IUCN (2020) and are not protected in Algeria. *Calligonum azel* has a wide distribution in the Northern and Western Sahara and stretches across the dunes to the northern borders of the Tassili, while *C. arich* is located only in the Northern Sahara (Ozenda 2004; Benchelah et al. 2006). The latter species is distinguished by its always arborescent habit (8–10 m tall). It is therefore one of the very rare endemic trees of the Sahara, present in the Grand Erg oriental (Médail & Quézel 2018). These two *Calligonum* species were present in the dunes of the Grand Erg oriental, until World War II, when they were destroyed by coal mining and represented by their last vestiges in the



Figure 2 – Photographs of a few endemic and subendemic tree species in Algeria. **A.** *Argania spinosa*, introduced at Chlef, 16 Oct. 2013. **B.** *Lonicera kabylica*, Tikjda at Djurdjura National Park, 27 Jan. 2013. **C.** *Abies numidica*, introduced in Chréa National Park, 8 May 2016. **D.** *Pinus nigra* subsp. *mauretanica*, Tigounatine at Djurdjura National Park, 10 Nov. 2009. **E.** *Fraxinus dimorpha*, Aurès, 9 Dec. 2015. **F.** *Quercus afares*, Guerrouch forest at Taza National Park, 12 Jun. 2019. **G.** *Cupressus dupreziana*, Tassili n'Ajjer, 13 May 2007. **H.** *Pinus pinaster* subsp. *renoui*, Jijel, 12 Jun. 2019. **I.** *Cedrus atlantica*, Tikjda at Djurdjura National Park, 10 May 2014. **J.** *Juniperus thurifera* subsp. *aursiaca*, djebel Chélia at Aurès, 29 Nov. 2018. All photos by Rachid Meddour.

1950s (Le Houérou 1995). Since then, *C. arich* has become considerably scarce in Saharan Tunisia (Chaïeb in Médail & Quézel 2018). Moreover, Zaafouri & Chaïeb (1999) already considered *C. arich* as extinct or in the process of extinction and *C. azel* as endangered in Southern Tunisia, victims of frantic logging. In the Hamada of Guir in Algeria, *C. azel*, abundant in the erg in the 1950s, has also almost disappeared: only five heavily grazed individuals have been recorded in the Béni Abbès-Ougarta region (Benhouhou 1991). In the Grand Erg occidental, anthropogenic pressure resulted in the total disappearance of *C. azel*, which was used as fuel (Kaabeche et al. 2011). Thus, the information presented above on these endemic *Calligonum* provides a plea for their inclusion in the IUCN Red List and for the development of rapid conservation action.

We recommend adding all these tree taxa to the Algerian List of protected vascular plants, even if their threat status is globally least concern (or not yet evaluated). On the other hand, all the taxa with patrimonial value require further data (distribution area, population size, habitat specificity, assessment of threats) with the application of quantitative criteria in order to assign a suitable threat category (IUCN 2012). These tree taxa deserve a special consideration for their in situ conservation. The rarest ones, with restricted-range distribution and small populations, should be the focus of species-specific conservation strategies implemented at the regional or local scale, inside and outside the network of protected areas (Eilu et al. 2004).

CONCLUSION

Checklists of plants have an important role because they serve as foundations for the inventory and the conservation of plant biodiversity in given areas. The present checklist demonstrates the diversity of tree species in Algeria. This comprehensive compilation of data is also an important contribution to filling the knowledge gap on this component, particularly on lesser-known species in Algeria, an area with limited data availability. Otherwise, knowing that the relative lack of knowledge hinders practical measures for conservation, this study could be a valuable tool to select the most endangered and interesting tree species from a biogeographical point of view for future monitoring and conservation planning. Some of these tree taxa need appropriate management and rapid actions for their real conservation, a challenging but worth pursuing target.

Finally, further research is required to collect more data in order to fill the several gaps that remain in our knowledge of the Algerian tree flora, especially on their distribution and conservation status. In particular, the distribution data will stimulate future studies to reevaluate the phytogeographical subdivision of Algeria.

SUPPLEMENTARY FILE

Supplementary file 1 – Checklist of the native tree flora of Algeria. Abbreviations: life forms: P: Phanerophyte, scap: scapose, caesp: caespitose; tree types: Mg: megaphanerophyte, Ms: mesophanerophyte, Mc: microphanerophyte; chorological categories: End: Endemic,

Alg: Algeria, Mor: Morocco, Tun: Tunisia, Lib: Libya; habitat: F: forest, W: freshwater, R: rocky, G: pastures and grasslands, S: sandy, A: synanthropic.

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