Chapter

Endemic Plant Species of Bolivia and Their Relationships with Vegetation

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Abstract

The inventory of Bolivia's vascular plants lists 2402 endemic species (ca. 20% of 12,339 of native flora). Among angiosperms, there are 2263 species from 124 families and 641 genera, whereas among pteridophytes, there are 139 species from 16 families and 29 genera. Seven families with the greatest number of endemic species are Orchidaceae (418), Asteraceae (246), Bromeliaceae (147), Cactaceae (127), Poaceae (92), and Piperaceae (81). *Cleistocactus* and *Puya* have 14 and 55 endemic species, respectively, so representing 82.3 and 84.6% of the species in these genera. Bolivia's endemic species show distribution patterns associated with past geological events, orographic dynamics (of the Andes and in the Cerrado), as well as areas of diversification. Dry xeric and humid regions host local and regional endemics in specific families and biogeographic regions of high conservation importance. Humid montane forests in the Yungas and dry inter-Andean valleys are rich in endemic species with 51 and 22% of the total recorded in the respective regions. Nevertheless, there are still many lesser known geographical areas that may generate new information in the short and medium term. Only 165 endemic species (6.9%) have been evaluated for their conservation status following IUCN categories with 49% assessed as endangered (EN).

Keywords: angiosperms, humid montane forests, ferns, dry valleys, Cerrado

1. Introduction

The Bolivian biota and its endemicity are derived from the influence of four biogeographic provinces, the Amazonian, the Andes, the Gran Chaco, and the Cerrado, generating several encounters of mixed elements [1]. For example, in the mountains of the Eastern Cordillera with the mixture of Andean and Amazonian flora, while in the Pantanal area (SE Bolivia) where there are Amazonian, Chaco and Cerrado elements took place. Amazonia is found in the alluvial plain from center to the north of the country, the Andes in mountain ranges in the west side, Cerrado on Precambrian shield in the east (in which it is also circumscribed to the Chiquitanía), and the Gran Chaco on plains and Andean foothills in the south.

These four biogeographical provinces together with the physiography of Bolivia combine in general opportunities for isolation, speciation, and restricted distribution, especially in geological periods, such as the uplift of the Andes and the conformation of valleys [1–3]. The floristic elements of each biogeographic province derive from radiation and dispersion processes during geological ages, whose adaptation has been consolidated in current landscapes.

Endemic species in Bolivia are associated with a wide range of diverse habitats and originated from different processes that have modeled the natural landscape in the past, particularly in the montane formations lying on the Andean and Brazilian lithospheres, specifically the uplift of the central Andes [4] 18 million years ago in the west and the slow weathering of the Precambrian Brazilian shield in the east, for example, through three biogeographical models of speciation in central Andes: vicariance of Andean uplifts, dispersal during the Pleistocene, and vicariance in both eastern and western slopes during glacial periods [5]. The rocky outcrops exposed in the Cerrado (or "brasileño-paranaense") of Bolivia have been identified as centers of plant endemism, where microhabitats are formed with specific microclimatic conditions [6, 7].

In the present contribution, we update the record of endemic vascular plants of Bolivia and evaluate general striking features and patterns of endemic plants and their relationships with vegetation types of the country, as a baseline for further studies.

2. Methodology

A large part of the information collected in the country is concentrated in databases and botanical collections of the National Herbarium of Bolivia (acronym, LPB in the Index Herbariorum). Due to a constant communication with experts and specialists from different groups of plants, publications and other valid and current scientific denominations about recent taxonomic works are available. This support constitutes our main source of references. Recently, an intense data compilation process has resulted from the information gathered for the "Catálogo de las Plantas Vasculares de Bolivia," published in 2014 [8] which mainly continues to be updated in Tropicos (www.tropicos.org, revised until November 7, 2018), as well as in other recent publications. The botanical inventory of Bolivia has been documented based on 650,000 herbarium specimens. The distribution of the collections covers a higher density in regions of the eastern slopes of the Andes, which includes the humid forests and the fragmented forests of the dry inter-Andean valleys (**Figure 1**). Recent publications and taxonomic updates to the Bolivian flora of vascular plants were the basis for this work [9–17].

In the highlands of the Andes toward the southwest and also in ravines and hills of the eastern Andean mountains, *Polylepis* (Rosaceae) forests (**Figure 2a**) are found, which are considered to be the highest in the world. However, they have been excluded here as a major vegetation formation because they are distributed in both a fragmented and azonal pattern in different vegetation formations, such as montane forests, dry puna, and humid puna. Therefore, a slightly modified map according to two vegetational classifications [8, 18] was elaborated (**Figure 3**).

The consideration of the endemic species follows in relation to the vegetation formations in which they are represented, which allows an evaluation on the distribution and striking characteristics of the families represented. This information is

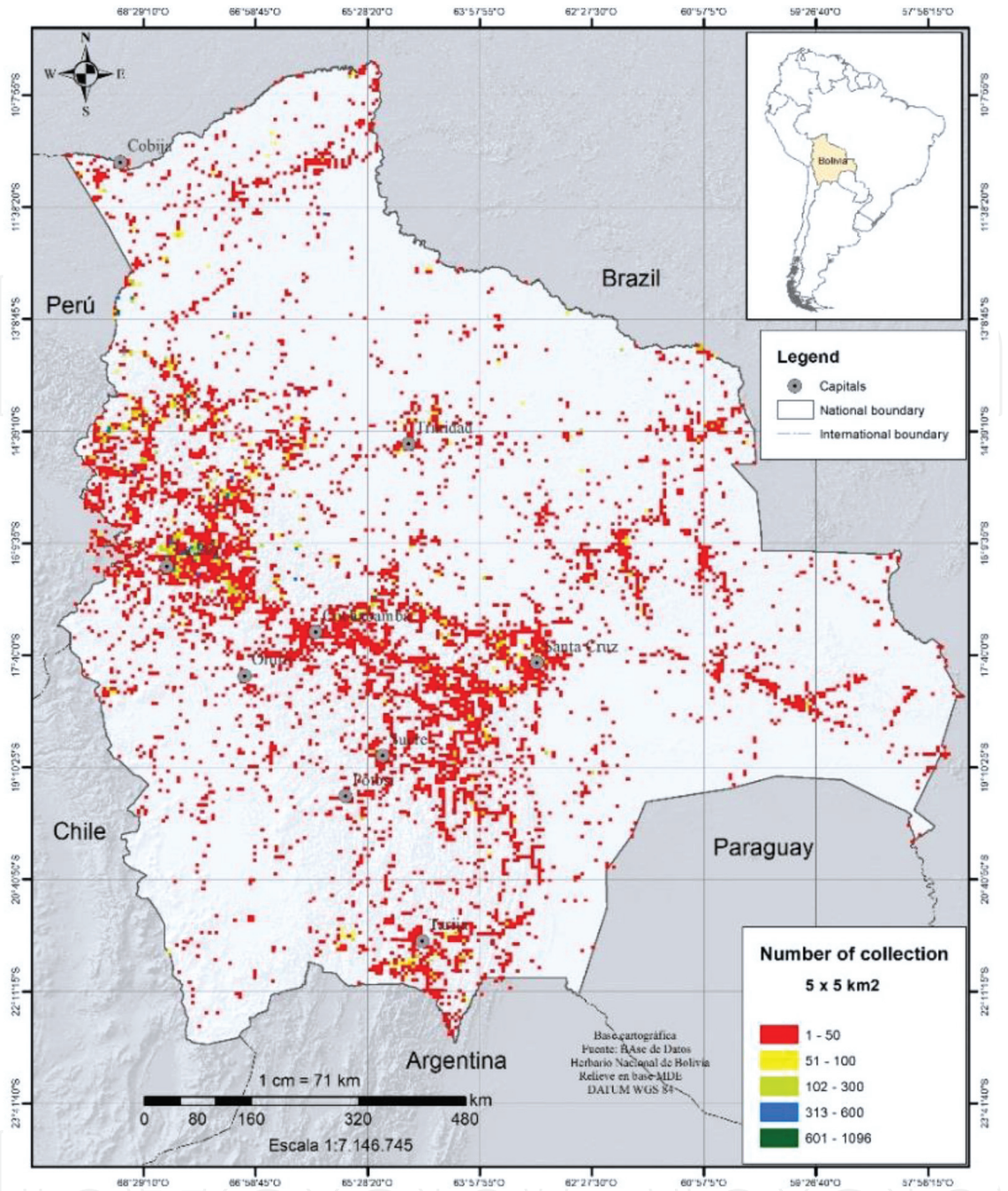

Figure 1.
Density cover of botanical collections in Bolivia at LPB (grid 5 × 5 km).

subsequently taken care of according to the biogeographical implications of the Bolivian flora. Finally, a number not exceeding to 200 endemic species occur in uncertain vegetation formations.

According to the Bolivian plant checklist [8], there are four major geographical regions in Bolivia: the Andes, Altiplano, lowlands, and uncertain. However this is an arbitrary delimitation that does not recognize local differences. The Andes, for example, has an altitude range of 500–3500 m and includes the Yungueñan "páramo" and both humid and dry forests in the Andean foothills. The Altiplano lies above 3500 m, whereas the lowlands include Amazonian rainforests, savannas, the Pantanal, and the Chaco xeric forest from 150 to 400 m, as well as the Precambrian mountain ranges of 600–1200 m altitude.

Figure 2.
Vegetation formations of Bolivia. (a) Polylepis *forest, (b) humid forest, (c) the Yungas, (d) Tucumanian-Bolivian forests, (e) "Campos cerrados," and (f) Chaqueñan foothills forests.*

The conservation status of endemic Bolivian plants has been evaluated in the four published red books [19–22] focused on plants of the Cerrado, wild relatives of cultivated plants, threatened plants of the Andean zone, and threatened plants of the lowlands.

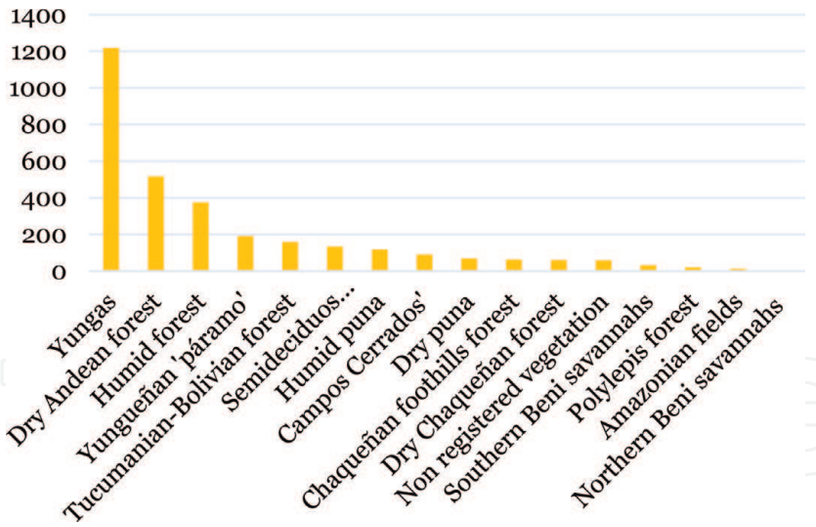

Figure 3.
Vegetation formations of Bolivia (modified from [18, 8]).

3. Results: what do we know to present?

3.1 Diversity and distribution

The endemic floristic elements represent biogeographic provinces that are found in Bolivia (**Table 1**). The highest representativeness comes from the Andes with 81% for the endemic plants of Bolivia, followed by the Amazon (16%), the Cerrado (9%), and the Gran Chaco (3%), whereas in four reported natural regions registered for each specimen in www.tropicos.com, trends in endemism are shown: the Andes (69.4%), lowlands (22.3%), Altiplano (6.6%), and uncertain (1.65%).

Although there are many mixtures of floristic elements in the country, it is generally recognized that certain vegetation formations are related to biogeographical affinities. The Amazonian province includes in general four vegetation types: northern and southern Beni savannahs, humid forest, and Amazonian camps, ranging from 100 to 400 m elevation. Both dry and humid "punas," *Polylepis* forests, dry inter-Andean valleys, Tucumanian-Bolivian forest, the Yungas, and the Yungueñan "páramo" make up the Andean province with 1500–5500 m elevation. For the Cerrado, the vegetation formations of the "campos cerrados" and the semideciduous Chiquitanian forest are included, between 400 and 1100 m elevation. And finally, both dry Chaqueñan forest and Chaqueñan foothills forest belong

	Floristic elements
Andean province	*Aa* (5), *Adesmia* (1), *Aspidosperma* (1), *Baccharis* (13), *Capsicum* (3), *Catasetum* (8), *Croton* (4), *Festuca* (17), *Nototriche* (8), *Passiflora* (22), *Protium* (1), *Solanum* (20), *Stevia* (25)
Amazonian province	*Annona* (1), *Andropogon* (3), *Attalea* (1), *Axonopus* (2), *Diospyros* (2), *Ficus* (1), *Heliconia* (1), *Machaerium* (3), *Nectandra* (2), *Neea* (5), *Paspalum* (4), *Sloanea* (1)
Cerrado province	*Acosium* (1), *Arachis* (7), *Borreria* (4), *Bromelia* (1), *Calea* (3), *Cordia* (1), *Discocactus* (2), *Frailea* (2), *Oxypetalum* (4), *Syagrus* (1), *Vellozia* (1)
Gran Chaco province	*Bulnesia* (1), *Cereus* (3), *Cnidoscolus* (2), *Gaya* (3), *Izozogia* (1), *Pereskia* (3), *Portulaca* (2)

Table 1.
Some characteristic genera of the four main biogeographic provinces in Bolivia. The number of endemic species is indicated in brackets.

to the Gran Chaco at 400–700 m. The meeting point of biogeographic Amazonian and Andean elements is mostly represented in the Yungas of the eastern slopes of the Andes, between 1500 and 3000 m elevation.

The endemic species of Bolivia make up a diverse group of life forms and taxonomic groups that contribute to the diversity of natural landscapes. Among these are trees (Annonaceae, Arecaceae, Erythroxylaceae, Fabaceae, and Lauraceae), tree ferns (Cyatheaceae), shrubs (Melastomataceae, Piperaceae), and subshrubs (Asteraceae and Ericaceae), as well as vines (Passifloraceae) and succulents (Cactaceae). There are also numerous herbaceous plants (Cyperaceae, Gesneriaceae, Iridaceae, and Poaceae), forbs (Heliconiaceae and Marantaceae), prostrate and scandent herbs (Aristolochiaceae, Convolvulaceae, and Cucurbitaceae), ferns (Dryopteridaceae and Polypodiaceae), aquatics (Eriocaulaceae and Isoëtaceae), and epiphytes (Loranthaceae and Orchidaceae).

Endemic plants were recorded from all 14 vegetation types known from Bolivia (see some examples in **Figure 2**). In terms of the richness of endemic species found in different vegetation formations, the trend is similar to that of plant families. The vegetation formation of the Yungas (humid mountains of the eastern Andes) hosts the highest concentration of endemic plant with 1218 (51% of the total number of endemic plants, **Figure 4**); it is followed by the dry inter-Andean valleys with 518 species and humid forests with 375. There are less than 50 endemic species found in vegetation formations in the alluvial plains of the lowlands (northern and southern Beni savannahs and "campos amazónicos"). Below is a synopsis of a sample on six vegetation formations represented in Bolivia with the largest number of endemic species recorded in relation to the ten families with highest level of endemism listed in in **Figure 5**. Most endemic species are restricted 1(−2) to a specific vegetation formation, but 1.26% are distributed in four or more contiguous formations (**Table 2**).

The Yungas: It is located along the eastern slopes of the Andean mountain ranging between 1000 m and 3500 m. It includes the timberline at higher elevations where it forms the Yungueñan "páramo" or cloud and humid montane forests at middle altitudes and sub-Andean and lowland forests at lower altitudes. The height of the forests decreases with increasing elevation, and, especially in cloud forests, the trees are covered with mosses and other epiphytic plants (**Figure 2c**). The diversity of tree species is higher at low elevations and decreases as altitude increases. Bamboos (*Chusquea* spp.) and tree ferns (*Cyathea* spp.) are also frequently found here.

A total of 139 families are found in the Yungas (**Figure 5a**). Orchidaceae is the most abundant in species numbers (with 294), followed by Asteraceae (130) and Piperaceae (51). Among the more important genera are *Lepanthes* (Orchidaceae) with 50 species, *Peperomia* (Piperaceae) with 35, and *Elaphoglossum* (Dryopteridaceae) with 29.

Dry Andean forest: The vegetation is often deciduous as a result of the long dry season. Most of the native vegetation occurs in isolated populations due to an intensive agricultural expansion or the widespread plantation of exotic species, such as *Eucalyptus* spp., *Phragmites* spp., and *Pinus radiata* D. Don.

Of more than 3000 species recorded for this region, almost 16% are endemic. A total of 139 families are represented with Asteraceae having the highest number of species (97) followed by Cactaceae (83) and Bromeliaceae (52) (**Figure 5b**). Among the most important genera are *Stevia* (Asteraceae), *Tillandsia* (Bromeliaceae) with 24 species, and *Puya* (Bromeliaceae) with 20.

Humid forest: It mostly covers the alluvial plains in the lowlands of Bolivia. The topography is relatively flat from about 500 m at the lower limits of the Yungas forests down to 100 m elevation in the north, mostly evergreen with continuous

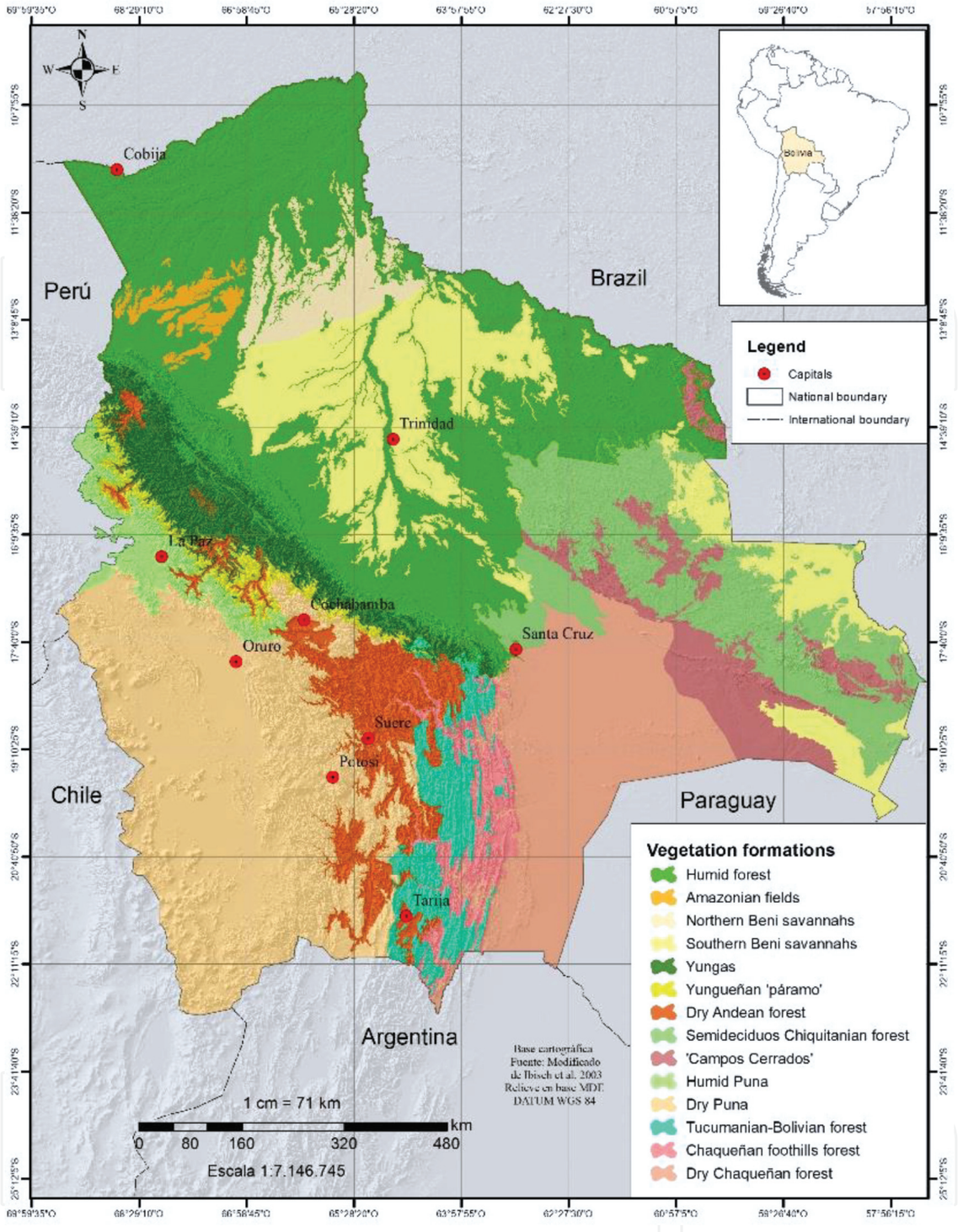

Figure 4.
Distribution of a number of endemic plants of Bolivia in major vegetation types, including highlands and lowlands.

tree canopy and characterized by their high diversity (**Figure 2b**). Associations of monotypic or impoverished forests dominated by large bamboos (*Guadua* spp.) or palm trees (*Mauritia flexuosa* L.f., *Oenocarpus bataua* Mart.) that successfully suppress the growth of other species are also found here.

Of the 5663 species recorded, almost 6% are endemic coming from 138 families. Orchidaceae is the most important family (with 57 species) followed by Piperaceae (35) and Bromeliaceae (24) (**Figure 5c**). *Piper* and *Peperomia* (Piperaceae) are the genera with more endemic species, 18 and 17 species, respectively. *Fosterella* (Bromeliaceae) is another genus with several (10) endemic species.

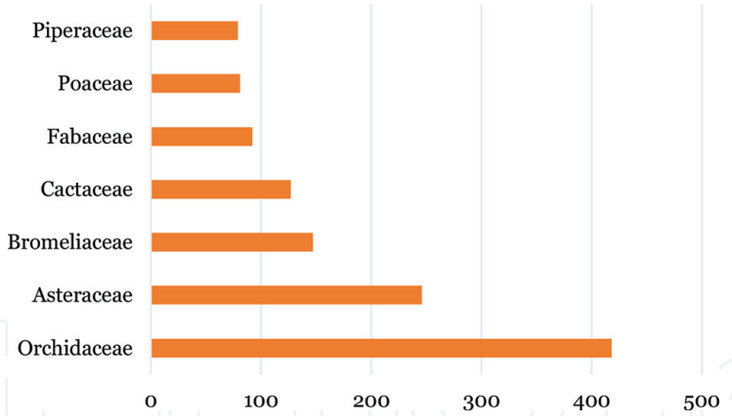

Figure 5.
The ten families with the largest number of endemic species in six vegetation formations of Bolivia.

	Endemic species
With four contiguous vegetation types	*Acianthera boliviana* (Rchb. F.) Pridgeon & M.W. Chase, *Aechmea kuntzeana* Mez, *Aegiphila herzogii* Moldenke, *Aristida friesii* Hack. Ex Henrard, *Bellucia beckii* S.S. Renner, *Cleistocactus samaipatanus* (Cárdenas) D.R. Hunt, *Croton abutilifolius* Croizat, *Furcraea boliviensis* Ravenna, *Gentianella inaequicalyx* (Gilg) J.S. Pringle, *Hippeastrum evansiae* (Traub & I.S. Nelson) H.E. Moore, *Lepidaploa tarijensis* (Griseb.) H. Rob., *Lonchocarpus pluvialis* Rusby, *Lupinus buchtienii* Rusby, *Maytenus tunarina* Loes. ex Kuntze, *Nassella holwayii* (Hitchc.) Barkworth, *Paranephelius asperifolius* (Muschl.) H. Rob. & Brettell, *Pitcairnia cardenasii* L.B. Sm., *Schoepfia tetramera* Herzog, *Steinbachiella leptoclada* Harms, *Stevia sarensis* B.L. Rob., *Tillandsia hegeri* Ehlers, *Trichogonia capitata* (Rusby) B.L. Rob.
With five contiguous vegetation types	*Festuca fiebrigii* Pilg., *Gentianella silenoides* (Gilg) Fabris, *Machaerium latifolium* Rusby, *Recordia boliviana* Moldenke, *Stevia setifera* Rusby ex B.L. Rob.
With six types	*Bougainvillea* modesta Heimerl, *Paspalum ekmanianum* Henrard

Table 2.
List of endemic species represented in less geographically restricted sites.

Yungueñan "páramo": Between 3500 and 4200 m elevation, this formation forms belts of grass and scrubs fed by nearly permanent precipitation. The most common genera include *Jarava, Festuca, Brachyotum, Clinopodium, Mutisia, Chuquiraga, Baccharis, Calceolaria*, and *Gnaphalium*. Other notable species include communities of *Puya raimondii* Harms and many species of the Ericaceae family.

Here a total of 846 species with ca. 22% endemics is found. The largest number of endemic species belongs to the family Orchidaceae (with 52 species), followed by Asteraceae (19) and Bromeliaceae (15) (**Figure 5d**). Among genera with the most numerous endemic species are *Puya* (Bromeliaceae) and *Gentianella* (Gentianaceae) with 15 and 13 species, respectively.

Tucumanian-Bolivian forest: Both humid to semi-humid forests cover the eastern slopes of the Andes in southern Bolivia between 500 and 1300 m elevation (**Figure 3d**). Among the more important elements are patches of *Polylepis hieronymi* Pilger (Rosaceae) and *Podocarpus parlatorei* Pilg. (Podocarpaceae) at higher altitudes; also are characteristic *Polylepis crista-galli* Ruiz & Pav., *Alnus acuminata* Kunth (Betulaceae) and *Juglans australis* Griseb. (Juglandaceae).

A total of 1647 species has been recorded here, of which close to 10% are endemic. Among the 130 families reported with endemic species, the most speciose are Orchidaceae (with 25), Asteraceae, and Bromeliaceae (21) (**Figure 5e**).

Begonia (Begoniaceae) and *Puya* (Bromeliaceae) are the genera with most endemic species (nine and eight, respectively).

Semideciduous Chiquitanian forest: It includes deciduous and semideciduous forests that are located throughout the Chiquitanian region in the department of Santa Cruz, between 400 and 700 m of elevation. Some characteristic species of the Chiquitania are *Machaerium nyctitans* (Vell.) Benth. (Fabaceae), *M. acutifolium* Vogel, *Amburana cearensis* (Allemão) A.C.Sm., *Schinopsis brasiliensis* Engel (Anacardiaceae), *Handroanthus lapacho* (K. Schumann) Sandwith (Bignoniaceae), and *Pseudobombax marginatum* (A. St.-Hil., A. Juss. & Cambess.) A. Robyns (Malvaceae).

Almost 6% are endemic, and the most common families with endemic species are Fabaceae (with 27 species), Asteraceae (16), and Malvaceae (14) (**Figure 5f**). Within the Fabaceae, the genus *Arachis* has the highest level of endemism with seven species.

3.1.1 Taxonomic groups

Among ferns and fern allies (Pteridophyta) together with the angiosperms of Bolivia, there are 2396 endemic species, in 670 genera and 141 families (**Table 3**). Seven angiosperm families account for 50% of the total (**Figure 6**): Orchidaceae, Asteraceae, Bromeliaceae, Cactaceae, Fabaceae, Poaceae, and Piperaceae. In the case of the Pteridophyta, two families comprise slightly less than 50% of the total: Dryopteridaceae with 43 species and Polypodiaceae with 26. Among the genera with the highest number of endemic species are *Puya* (Bromeliaceae, 55 species), *Lepanthes* (Orchidaceae, 52), *Peperomia* (Piperaceae, 51), *Solanum* (Solanaceae, 44), and *Tillandsia* (Bromeliaceae, 37), among others (**Figure 7**). In any case, the representation of four genera of the Orchidaceae has in total 134 endemic species.

If we relate the number of endemic species per family to the total numbers represented in Bolivia, the patterns show different percentages (**Table 4**). Orchids comprise the family with the highest number of endemic species, but this represents only 32.5% of the total; in Asteraceae the figure is 20.2%, whereas in the Bromeliaceae the endemic species amount to 45.8% of the total, and in the Cactaceae it rises to 55.9%. In Triuridaceae and Tropaeolaceae, the number of endemics amounts to about 50%, but the first has only 2 native species with 1 endemic, while the second has 14 species with 7 endemic. In addition there is another group where the percentage of endemism is low, ranging from 9 to 20% in families such as Fabaceae, Arecaceae, Poaceae, Amaranthaceae, and others.

In the case of species sorted by genera, various trends can be discerned (**Table 5**) as follows: 84.6% of *Puya* spp. (Bromeliaceae) are endemic, whereas in *Begonia* (Begoniaceae) the figure is 48.1%, *Piper* (Piperaceae) 30.1%, *Solanum* (Solanaceae) only the 23.7%, and *Trichilia* (Meliaceae) a mere 5.3%. Three genera, each with 25 endemic species, show very different trends in endemism, such as for *Masdevallia* (Orchidaceae) 78.1%, for *Siphocampylus* (Campanulaceae) 56.8%, and for *Miconia* (Melastomataceae) 17.7% (**Figure 8**).

	Families/genera/species	**% from the total**
Angiosperms	125/641/2263	89/96/94
Pteridophyta	16/29/139	11/4/6

Table 3.
Bolivian endemic vascular families, genera, and species and percentage from the total.

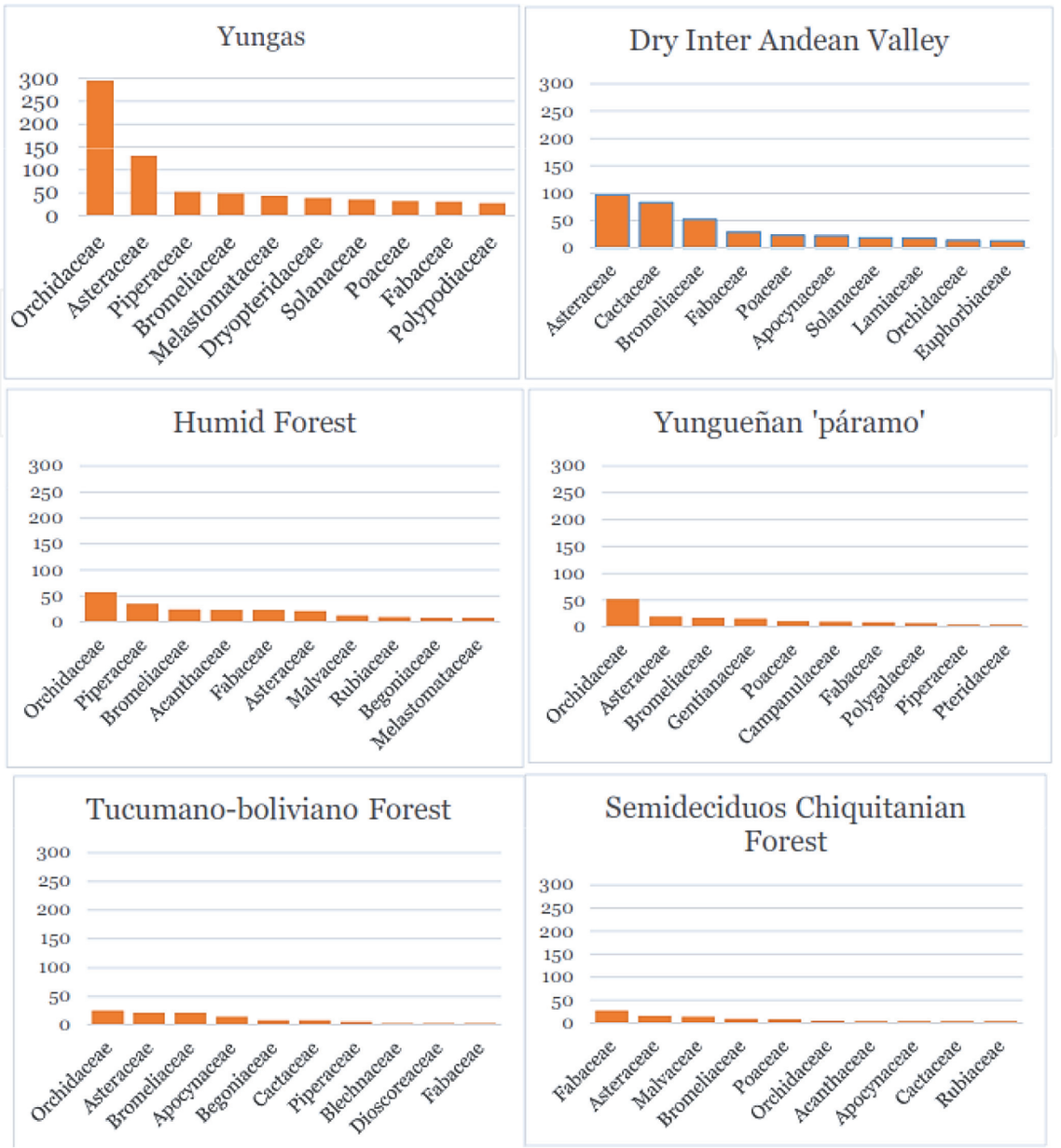

Figure 6.
Angiosperm plant families with the highest number of endemic species in Bolivia.

The records of endemic species of Bolivia are accompanied by a brief photographic synopsis that illustrates the characteristics of selected taxa (**Figures 9–12**). We present four groups of photographs: endemic palms [11], endemic plants of the Madidi region [10], endemic plants of the Bolivian Cerrado [16], and inter-Andean valleys with dry forests [23]. Tree palms and acaulescent species are represented here by *Attalea blepharopus* Mart. that grows in very humid forests in central Bolivia (**Figure 9a**) and then three species of the genus *Syagrus*: *S. petraea* (Mart.) Becc. from the plains and rocky hills of the Cerrado (**Figure 9b**), *S. yungasensis* M. Moraes from the drier montane forests (**Figure 9c**), and *S. cardenasii* Glassman from the alluvial plains, as well as in sub-Andean highlands (**Figure 9d**).

Among endemic Bolivian plants of the Madidi National Park in the NW of the country (mostly comprising Yungas vegetation), *Prestonia leco* A. Fuentes & J. F. Morales (Apocynaceae) is a liana found in the humid submontane forest (**Figure 10a**). *Passiflora madidiana* P. Jørg., Cayola & Araujo-Murak. (Passifloraceae) is an endemic climber of the dry forests of the Tuichi river basin (**Figure 10b**). *Stenostephanus suburceolatus* J.R.I.Wood (Acanthaceae) is a terrestrial

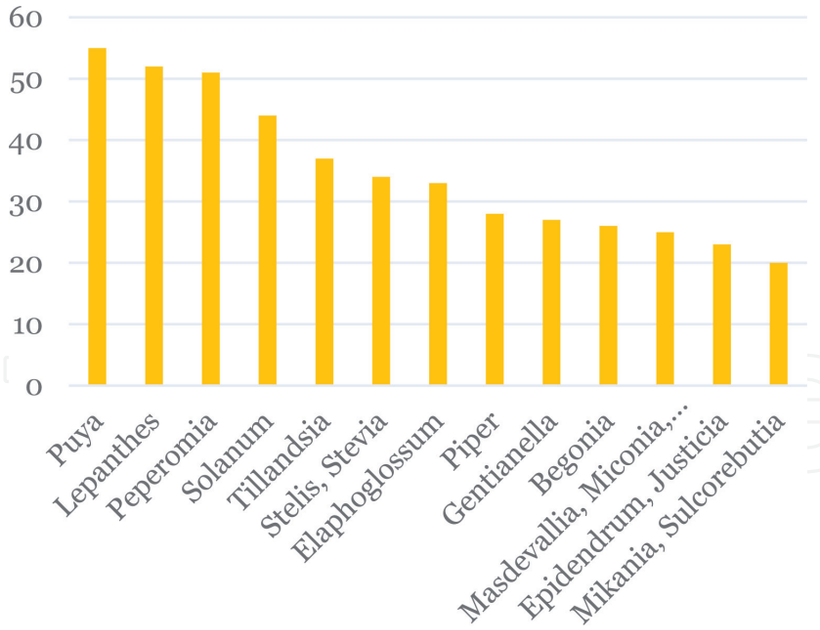

Figure 7.
Genera with the highest number of endemic species in Bolivia.

Plant family	Endemic species	Representativeness in the family (%)
Cactaceae	127	55.9
Triuridaceae, Tropaeolaceae	1, 7	50.0
Begoniaceae	26	48.1
Bromeliaceae	147	45.8
Zygophyllaceae	3	40.0
Proteaceae	5	38.5
Piperaceae	79	36.6
Orchidaceae	415	32.5
Acanthaceae	49	28.3
Dioscoreaceae	11	23.9
Asteraceae	243	20.2
Solanaceae	61	19.2
Euphorbiaceae	39	13.0
Amaranthaceae	14	11.4
Poaceae	81	9.5
Arecaceae	9	9.3
Fabaceae	92	8.9

Table 4.
Comparison of the level of endemism in some families of Bolivian native plants.

herb (**Figure 10c**), known from a single population of seasonally moist low altitude Andean forest. Finally, *Tristerix rhodanthus* Kuijt (Loranthaceae) is a hemiparasite collected in cloud forest fragments (**Figure 10d**).

The Chiquitanian endemic examples are as follows: *Blepharodon crabrorum* Goyder (Apocynaceae), a subshrub that blooms all the year and is found in rock

Plant genus	Endemic species	Representativeness in the genus (%)
Cleistocactus	14	82.3
Puya	55	84.6
Masdevallia	25	78.1
Lepanthes	52	74.3
Monnina	16	69.6
Arachis	12	63.1
Siphocampylus	25	56.8
Gentianella	27	50.0
Begonia	26	48.1
Peperomia	51	41.5
Tillandsia	37	35.2
Piper	28	30.1
Elaphoglossum	33	26.0
Solanum	44	23.7
Miconia	25	17.7
Pavonia	6	13.0
Trichilia	1	5.3

Table 5.
Comparison of the level endemism in some genera of Bolivian native plants.

crevices on vertical cliff faces (**Figure 11a**); *Mimosa crasspedisetosa* Fortunato & Palese (Fabaceae) a branched shrub or subshrub in scattered places in the plains of "campos cerrados" (**Figure 11b**); *Frailea chiquitana* Cárdenas (Cactaceae), a small and wooly cactus common in the slabs (**Figure 11c**); *Centratherum cardenasii* (I.S. Nelson & Traub) Van Scheepen (Amaryllidaceae), a perennial herb that grows in sandy Cerrado (**Figure 11d**); *Hippeastrum starkiorum* (I.S.Nelson & Traub) Van Scheepen (Amaryllidaceae), a rare bulbous herb that grows in rock crevices in campo rupestre and on hills (**Figure 11e**); and *Pitcairnia chiquitana* R. Vásquez & Ibisch (Bromeliaceae), cespitose plant, which is locally abundant on rock platforms and in campo rupestre (**Figure 11f**).

Endemic plants from dry forests in Andean valleys are as follows: *Cardenasiodendron brachypterum* (Loes.) F.A. Barkley (Anacardiaceae) (**Figure 12a**), a tree that grows on dry hillsides on rocky soils below 2600 m; *Mastigostyla cardenasii* R.C. Foster (Iridaceae) (**Figure 12b**), an herb of these valleys that reaches the humid puna; *Ipomoea exerta* Goyder & Fontella (Apocynaceae), a very rare herb and grows in dispersed zones at 2500 m (**Figure 12c**); *Oxypetalum fuscum* Epling (Lamiaceae), a short vine that is frequent in thickets (**Figure 12d**); *Lepechinia bella*, a small shrub that grows on rocky slopes (**Figure 12e**); and *Puya weddelliana* (Baker) Mez (Bromeliaceae) (**Figure 12f**), a rosette plant, which grows in groups on rocky slopes.

The most endangered species fall into three categories: critically endangered (CR) with 19 endemic species, followed by threatened (EN) with 80, and vulnerable (VU) with 66 (**Figure 12**). The total of 165 endemic plants that have been evaluated as threatened in Bolivia indicates that only 6.9% of the total number of endemic species has been assessed. A sample of 14 endemic species from Bolivia along with the category they belong to is shown in **Table 6**.

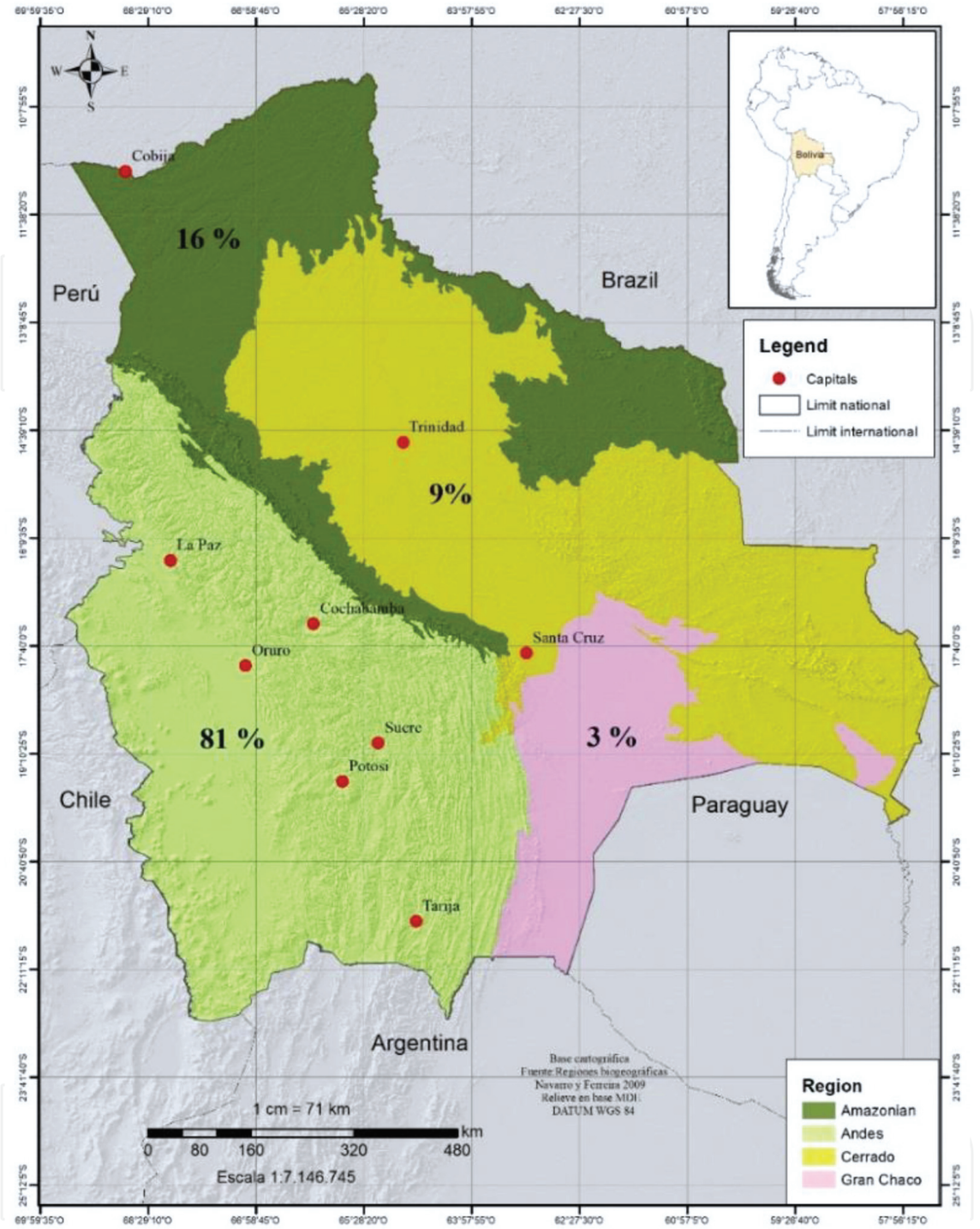

Figure 8.
Major biogeographic regions represented in Bolivia (adapted from [3]).

4. Discussion

Our knowledge of the floristic composition of Bolivia and its richness has increased in the last 20 years although there are still changes, such as new species and endemics; in addition, the level of our understanding has resulted from the intensification of botanical collections and fieldwork in geographical areas that are botanically less known. Until 1992, a list of 20 endemic monotypic genera of Bolivia in 13 families of vascular plants that existed was the first basis and a large number of herbarium specimens that had not been identified [1]; in the case of mosses, Bolivia has an

Figure 9.
Endemic palms of Bolivia. (a) Attalea blepharopus*, (b)* Syagrus petraea*, (c)* Syagrus yungasensis*, and (d)* Syagrus cardenasii *(Arecaceae). Photographs: Mónica Moraes R.*

inventory of 920 species, of which 55 are endemic [24]. In contrast in 2014, 2343 species of vascular plants were reported as endemic to Bolivia from a total of 12,165 species in 286 families [8], and 13.6% endemics were reported in the fern family Polypodiaceae and 33% for orchids but in the gymnosperms and in the angiosperms. Currently the number has risen to 12,239 native species of vascular plants (www.

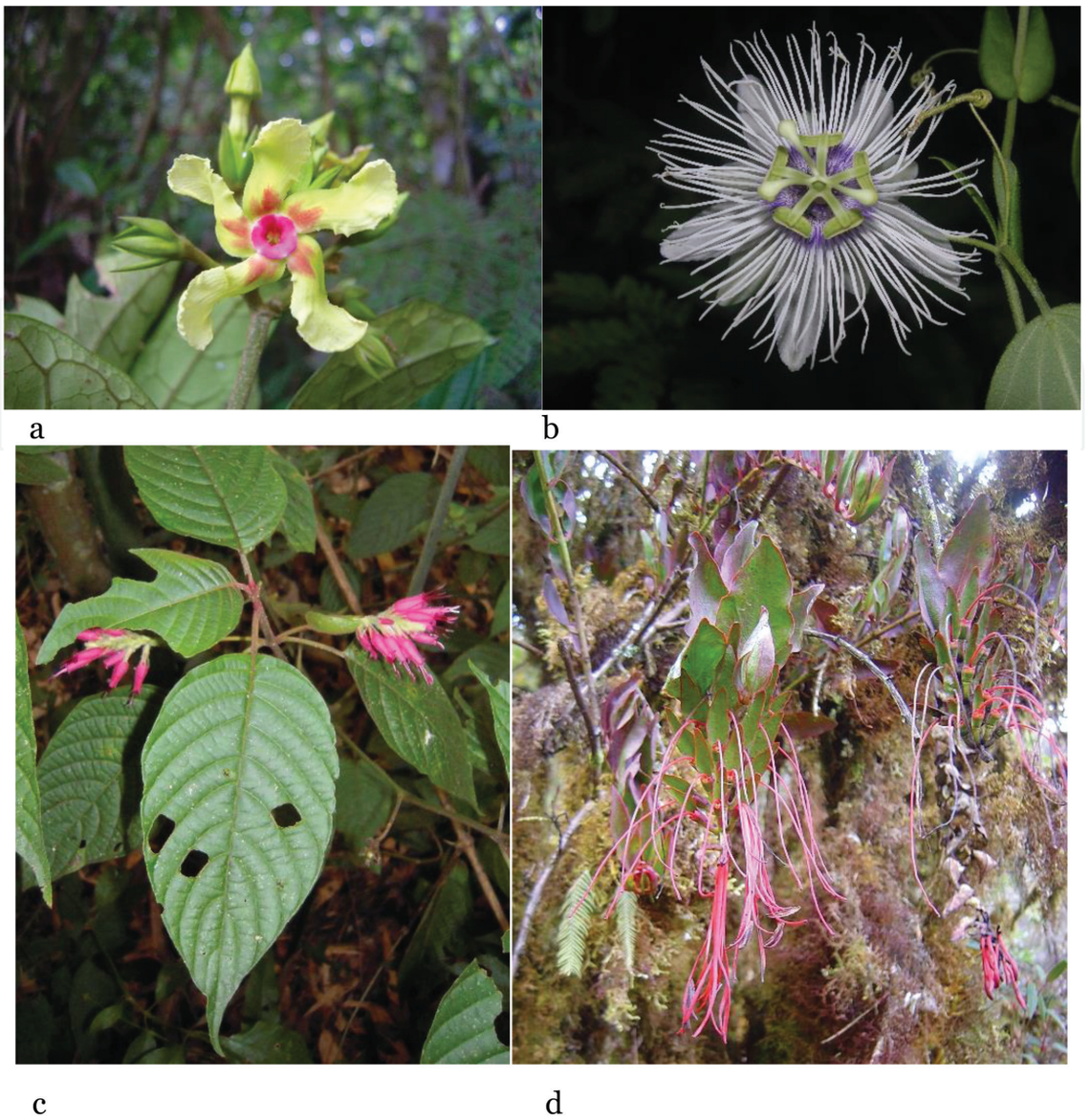

Figure 10.
Endemic plants of Madidi National Park. a. Prestonia leco *(Apocynaceae), b.* Passiflora madidiana *(Passifloraceae), c.* Stenostephanus suburceolatus *(Acanthaceae) and d.* Tristerix rhodanthus *(Loranthaceae). Photographs, a,c-d: Alfredo Fuentes, b: Alejandro Araujo-Murakami.*

tropicos.org), and the present work reports a total of 2402 endemic plants of Bolivia; this means that in 4 years it has increased by 2.5%.

As in other botanical cases, it is very important to update the knowledge about the endemic flora. With the example of the 20 species in monotypic genera reported by Moraes and Beck [1], the number of endemisms for Bolivia was reduced to 14, and only 5 are monotypic: *Cardenasiodendron brachypterum* (Loes.) F.A. Barkley, *Polyclita turbinata* (Kuntze) A.C. Sm., *Rusbya taxifolia* Britton, *Boelckea beckii* Rossow, and *Recordia boliviana* Moldenke; only *Cardenasiodendron brachypterum* (Loes.) F.A. Barkley was assessed as VU by Navarro et al. [21].

On the eastern slope of the Andes and in the Amazon basin in Peru and Bolivia, 435 species in four plant groups, Anacardiaceae, Chrysobalanaceae, *Inga* (Fabaceae), and Malpighiaceae, were found to be endemic in the lowlands [25]. Acanthaceae presented its highest point of endemism at medium elevations, and nine plant groups, Aquifoliaceae, Brunelliaceae, Campanulaceae, Ericaceae, Loasaceae, Marcgraviaceae, *Fuchsia* (Onagraceae), and Passifloraceae, presented their highest point of endemism at elevations above 2000 m. Probably 20–25% of

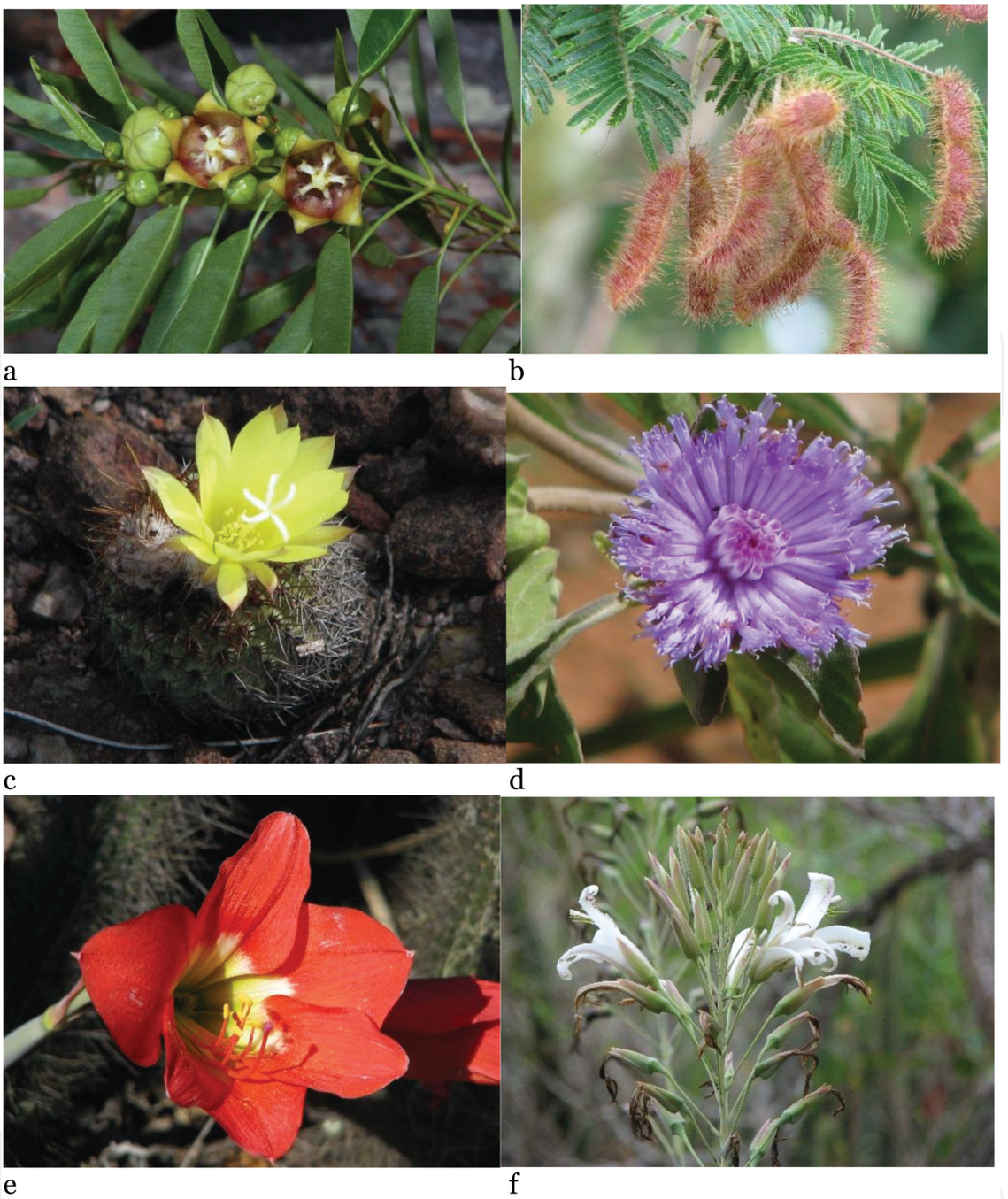

Figure 11.
Endemic plants of the Chiquitano and Cerrado region. (a) Blepharodon crabrorum *(Apocynaceae), (b)* Mimosa crasspedisetosa *(Fabaceae), (c)* Frailea chiquitana *(Cactaceae), (d)* Centratherum cardenasii *(Asteraceae), (e)* Hippeastrum starkiorum *(Amaryllidaceae), and (f)* Pitcairnia chiquitana *(Bromeliaceae). Photographs: John Wood.*

the total vascular plants of Bolivia could be restricted to the country [26], the family with the highest number of endemic species being the Orchidaceae (35%, [27]). Plant endemism ranges between 59 and 85% of the species sampled in three areas of the Bolivian Chaco region [28], whereas only 18% of species in dry inter-Andean valleys of the western side of the country are endemic [29].

Our results support former conclusions by other authors. According to [26, 30], the highest concentration of plant endemism is registered in the Andean mountains, where both the Yungas (humid forests) and inter-Andean dry forests are found. Moreover, the major record of scientific collections and knowledge comes from the eastern slopes of the Andes from the NW toward the center of the country, where Bolivia's greatest biodiversity is higher [31]. Also the distribution of endemic palms

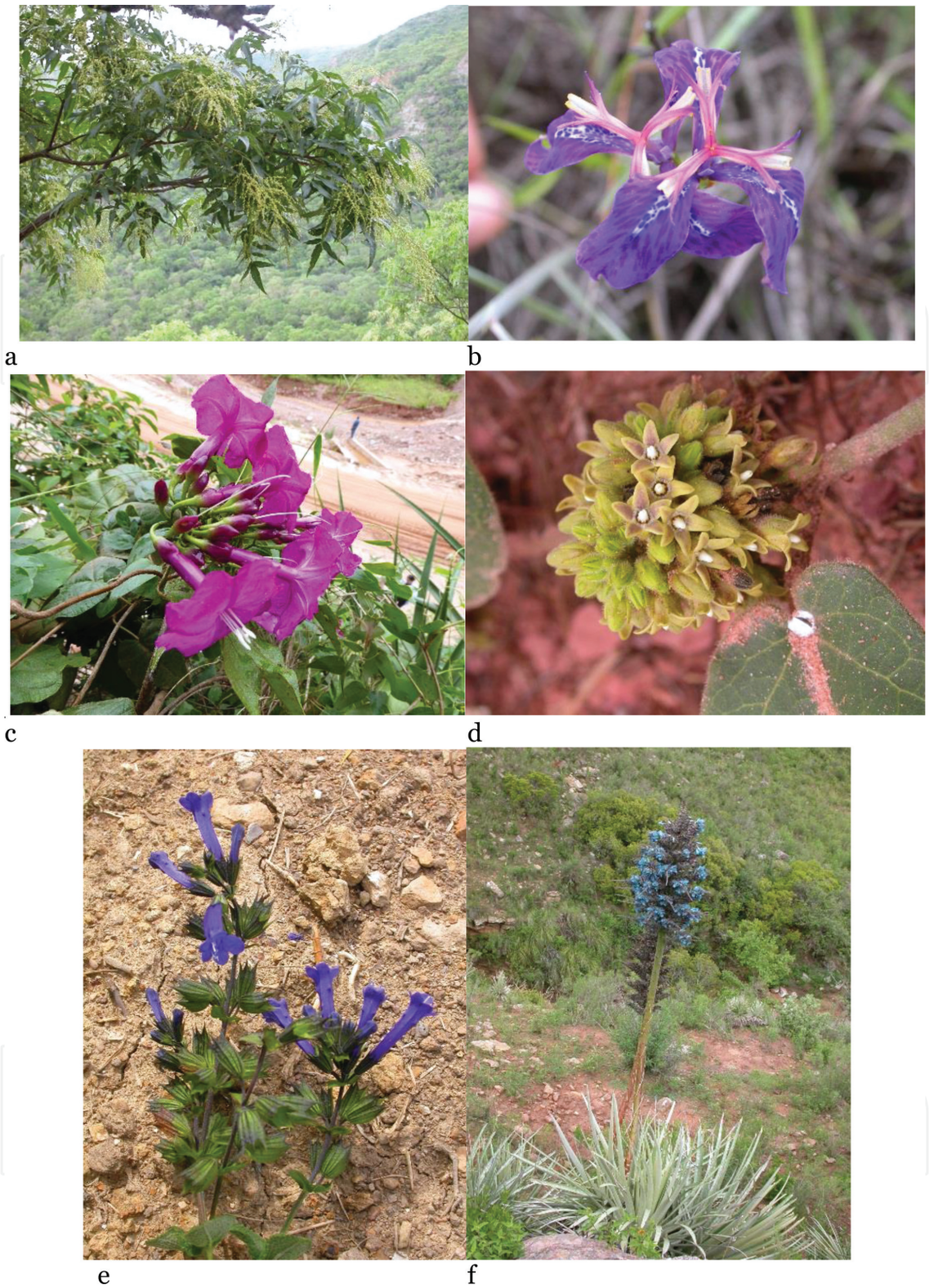

Figure 12.
Endemic plants of dry forests in inter-Andean valleys. (a) Cardenasiodendron brachypterum *(Anacardiaceae), (b)* Mastigostyla cardenasii *(Iridaceae), (c)* Ipomoea exerta *(Convolvulaceae), (d)* Oxypetalum fuscum *& Fontella (Apocynaceae), (e)* Lepechinia bella *(Lamiaceae), and (f)* Puya weddelliana *(Bromeliaceae). Photographs: John Wood.*

(Arecaceae) is associated with the eastern Andes [32]. But high-priority areas for representativeness of ecosystems and species, the Yungas forests, stand out as the main center of biological diversity in Bolivia due to the greater richness of species and better state of conservation with local centers of endemism, in addition to the Tucumano-Bolivian forest, Llanos de Moxos, and Amazonian forests with up to

Endemic species	Family	Category
Abarema centiflora Barneby & J.W. Grimes	Fabaceae	EN
Acanthosyris asipapote M. Nee	Santalaceae	CR
Arachis ipaensis Krapov. & W.C. Greg.	Fabaceae	EN
Begonia baumannii Lemoine	Begoniaceae	VU
Brunellia boliviana Britton ex Rusby	Brunelliaceae	VU
Nasa herzogii (Urb. & Gilg) Weigend	Loasaceae	EN
Passiflora chaparensis R. Vásquez	Passifloraceae	CR
Philibertia zongoensis Goyder	Apocynaceae	CR
Polylepis neglecta M. Kessler	Rosaceae	VU
Parajubaea sunkha M. Moraes	Arecaceae	EN
Roupala filiflora K.S. Edwards & Prance	Proteaceae	CR
Siphocampylus reflexus Rusby	Campanulaceae	EN
Trichocereus werdermannianus Backeb.	Cactaceae	VU
Zanthoxylum aculeatissimum Engl.	Rutaceae	EN

Table 6.
Endemic plants of Bolivia and UICN categories, based on [21, 22].

15% representativeness, while in the Altiplano, more fragmented and dispersed areas were identified [30].

Worldwide there is increasing evidence confirming that endemism is a powerful tool for use in global conservation efforts: hotspots based on levels of endemism cover more number of species than richness-based hotspots and are closely related to the degree of threat [33]. Therefore, a positive relationship between endemism and species richness might be expected [34]. Although Bolivia has not been completely surveyed floristically, 2403 endemic species have been recognized, and this may indicate that species richness may be greater than it has been documented. However, it is essential to establish the state of conservation of these species in order to increase efforts and generate more responsible actions to safeguard the natural heritage.

The confirmation on the presence of species and their status as endemics represents a greater effort by scientists and is an ongoing work. Each study and botanical survey contributes to the documentation of the flora of Bolivia. To develop an adequate conservation strategy, it will be necessary to assess this large residue to understand the threat level they face. However, there is very limited information and few collections of most endemic species. The humid montane forests are a hotspot in the tropical Andes that constitute a very rich region in endemism and would be supported by a greater total richness of plants. Therefore, it is essential to intensify the survey of species throughout their range, especially when there are still a large percentage of well-conserved landscapes and the threats are more locally concentrated, but the incidence of global warming against them with consequences can be catastrophic.

5. Conclusions

In terms of the concentration of the botanical collections made in Bolivia, there are large areas that still need to complete the surveys and records of species.

Therefore, it is expected that the total of endemic species will increase, especially in inter-Andean valleys with humid forests, as well as in the different formations that are represented in the east on Precambrian rocks of the Cerrado region in the country.

At the moment, the trends that have been interpreted according to the 2402 endemic plants are indicative with respect to the families and genera with the greatest number of species. 50% is represented by seven families; among them the Orchidaceae (418 spp.), Asteraceae (246 spp.), and Bromeliaceae (147) stand out. The representativeness on the total of native species is the following: Orchidaceae with 32.5%, Asteraceae 20.2%, and Bromeliaceae 45.8%, while among the genera, *Puya* (Bromeliaceae) presents 55 endemic species (representing 85% of the total native species of Bolivia), *Lepanthes* (Orchidaceae) with 52 (means 74%), and *Peperomia* (Piperaceae) with 51 (41.5%).

Although more than 80% of the plants come from the biogeographic region of the Andes, the landscape with the largest number of species (69%) is restricted to the eastern slopes (from 500 to 3500 m altitude), leaving the altiplanic landscape with only 7%. The geographical pattern that concentrates the 51% of endemisms in the humid montane forests of Yungas, where both Andean and Amazonian elements converge, is also fundamental. This feature of endemic plants also has relevance for the 22% that is represented in dry forests in Andean valleys, which corresponds to one-fifth of the total represented in Bolivia.

Finally, regarding the evaluation of the state of conservation of endemic plants in Bolivia, the efforts are still incipient. A total of 154 endemic species (6.9%) were evaluated in their conservation status according to IUCN categories, with the majority in threatened state (EN, 48.5%), followed by the vulnerable (VU, 40%) and in critical condition (CR, 11.5%).

Conflict of interest

The authors of this contribution indicate that they have no conflicts of interest that affect the content and information of this publication.

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