Rodriguésia 66(4): 1025-1031. 2015
http://rodriguesia.jbrj.gov.br
DOI: 10.1590/2175-7860201566406

Flora of Bolivia - where do we stand?

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Abstract

The botanical exploration of Bolivia during the last two centuries did not leave a botanical legacy in the country. Only towards the end of the 20th century Bolivia saw the start of the biology careers at its universities and the development of its own herbaria. Nowadays there are important herbaria in La Paz, Santa Cruz, Cochabamba and Sucre with collections ranging between 40,000 and 350,000 specimens. In 2014 a catalogue of the vascular flora of Bolivia was published under the auspices of the Missouri Botanical Garden, recording 15,345 species, of which 12,165 are native and 2,343 are endemic, while 694 are cultivated, 267 adventitious and 221 are naturalized. Endemic species of vascular plants add up to 2,343 species. The 286 families listed follow the APG III classification system. There are about 150 botanists in Bolivia interested in studying the country's rich flora. During a workshop organized in 2013 to promote a Flora of Bolivia, the participants established jointly a preliminary format for the taxonomic treatments. The Flora of Bolivia is planned to be an electronic, open access publication with international participation. The World Flora represents a challenge that must be tackled by circumscribing, verifying and recording all species known within our territory, and it is expected that it will have positive repercussions from and towards the ongoing Flora of Bolivia, in a similar way as the long running series of the Flora Neotropica has provided a wider picture that can be adapted and modified to fit our particular country.

Key words: Flora, Bolivia, Chaco, Amazonia, endemics.

Resumo

A exploração botânica da Bolívia durante os últimos dois séculos não deixou um legado botânico no país. Apenas no final do século 20 o país começou a formar biólogos nas suas universidades e a desenvolver os seus acervos muselógicos. Atualmente existem herbários importantes em La Paz, Santa Cruz, Cochabamba e Sucre, com coleções acumulando entre 40 e 350 mil espécimes. O Catálogo da Flora Vascular da Bolívia, publicado em 2014 sob os auspícios do Missouri Botanical Garden, registrou 15.345 espécies de plantas, das quais 12.165 são nativas, enquanto 694 são cultivadas, 267 adventícias e 221 naturalizadas. Um total de 2.343 espécies de plantas vasculares endêmicas foi registrado para o país. As 286 famílias listadas seguem o sistema de classificação APG III. Existem cerca de 150 botânicos ativos na Bolívia, cujo interesse é estudar a rica flora do país. Uma oficina foi organizada em 2013 com intuito de promover a Flora da Bolívia, durante a qual um formato preliminar para os tratamentos taxonômicos foi estabelecido pelos participantes. O intuito é de apresentar a Flora da Bolívia como uma publicação eletrônica e de acesso aberto ao público contando com participantes internacionais. Enquanto representa um grande desafio para a comunidade botânica mundial, a Flora do Mundo objetiva circunscrever, verificar e registrar todas as espécies conhecidas em nosso território, e espera-se que esse ambicioso projeto tenha repercussão positiva em relação à Flora da Bolívia, da mesma forma na qual a longa série *Flora Neotropica* tem gerado um esquema mais amplo que pode ser adaptado e modificado para servir ao nosso país em particular.

Palavras-chave: Flora, Bolívia, Chaco, Amazônia, endêmica.

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Introduction

Bolivia is among one of the most biodiverse countries in the world, home to around 17,000 species of vascular plants (Beck 1998). Highlighted by Lack (2012) as the only South American country that did not attempt to compile a complete floristic account until the end of the past century, as the in-country study of the Bolivian flora has started particularly late (Meneses *et al.* 2013). As an example, the Biology Course at the Universidad Mayor de San Andrés, La Paz, started only in 1972, while the Herbario Nacional de Bolivia (LPB) was created in 1984 and is only 31 years old. Other herbaria in the country are in a similar situation, contrasting with herbaria in neighbouring countries, such as the Instituto de Botánica Darwinion (SI) and the Museo de La Plata (LP), in Argentina, and the Jardim Botânico do Rio de Janeiro (RB) and Museu Nacional (R) in Brazil, all with over a hundred years of age and continuously developing collection and research activities, as well as a long tradition of forming taxonomists. These countries have created diverse initiatives to prepare local and regional floras and vegetation surveys (Hoehne 1940-1965; Reitz 1965; Correa 1969-1999; Klein 1978; Zuloaga & Morrone 1996,1999; Wanderley *et al.* 2001).

A Flora is fundamental to enable a country to document its natural patrimony, be it as a guide for sustainable use of its plant resources or to inforce conservation measures to protect and manage plant diversity, being a data source for future basic or applied studies.

Brief history of Bolivian botany

The year of 1978 has marked the start of systematic floristic surveys in La Paz (LPB) through international collaboration between Bolivia, Germany and the United States, resulting in the collection of over 350,000 specimens of vascular plants (ferns, gymnosperms and angiosperms) and a smaller number of non vascular plants. These collections partially document the floristic richness of the country, while a group of more regional herbaria in Cochabamba, Santa Cruz and Sucre comprise respectively 60,000, 160,000 and 40,000 specimens (Tab. 1), complementing the overall picture.

It is important to understand that the Herbario Nacional de Bolivia (LPB) was created as part of an agreement between the Instituto de Ecología de la Universidad Mayor de San Andrés and the Museo Nacional de Historia Natural, therefore it aims to incorporate valuable ecologic information to the floristic inventories, comprising auto and synecology data regarding species, as well as etnobotanical data in the form of use references. Such integration allows for a wider appreciation of the floristic diversity and also of the different vegetation types found in Bolivia, resulting in many publications and in recent comments on biogeography and evolution (Fernández *et al.* 2015; Maldonado *et al.* 2015; Gallegos *et al.* 2014; Saavedra *et al.* 2014; Apaza-Quevedo *et al.* 2013; Cuesta *et al.* 2012; Beck *et al.* 2010; Zenteno-Ruiz *et al.* 2009; Fuentes Claros 2006; Moraes *et al.* 2006).

The recently published Catalogue of Vascular Plants (Jørgensen *et al*. 2014) represents an important milestone that will constitute the base for the preparation of the Flora of Bolivia. This publication took 15 years of intermittent work to be completed, and was carried under a broad collaboration from different institutions worldwide and published under the auspices of the Missouri Botanical Garden (MO), with the contribution of 221 specialists and 53 reviewers. The general plan for the Catalogue followed the system created for the Peru and Ecuador catalogues (Brako & Zarucchi 1993; Jørgensen & León-Yánez 1999). In Bolivia, 44 botanists from the Herbario Nacional de Bolivia (LPB), Herbario Nacional Forestal Martín Cárdenas (BOLV), Herbario Regional del Oriente (USZ) and the Herbario del Sur de Bolivia (HSB) were responsable for treatments at family or generic level.

Table 1 – Number of specimens deposited in major Bolivian Herbaria

Department	Herbaria	Acronym	Specimen
La Paz	Herbario Nacional de Bolivia	LPB	350,000
Cochabamba	Herbario Nacional Forestal Martín Cárdenas	BOLV	60,000
Santa Cruz	Herbario Regional del Oriente	USZ	160,000
Chuquisaca	Herbario del Sur de Bolivia	HSB	40,000

Preparation of the Flora of Bolivia

As a basis for the preparation of the Flora of Bolivia, the published catalogue (Jørgensen *et al.* 2014) contains a synopsis of the vascular flora of Bolivia as it is known today, providing synonymy for species, bibliographic references for Bolivia, life-forms, origin, regional distribution, vegetation zones, altitudinal distribution and by geopolitical division, infraspecific taxa and common names when available. It is possible to access the electronic version in the webpage of the Missouri Botanical Garden (TROPICOS 2015). The data is managed as part of the TROPICOS, therefore it can be updated, added to and corrected in a dynamic way.

The Bolivian catalogue documents 286 families arranged following the APG III (2009) classification system, comprising 15,345 species of which 12,165 are native species, while 694 are cultivated, 267 adventitious and 221 naturalized (Tab. 2), and 112 further putative species records not yet confirmed for the country. The number of endemic species currently recorded for Bolivia is 2,343, slightly less than 16% of the total species number. The present count departed from an initial total of 47,974 names recorded for Bolivia, amalgamating information from the catalogue of ferns and flowering plants of Bolivia (Foster 1958) and the *Guía de árboles de Bolivia* (Killeen *et al.* 1993) with records from Tropicos (2015) and The International Plant Names Index (IPNI 2015) either published from or with distribution referred to Bolivia. The major groups (Tab. 3) are 14,157 angiosperms, 1,145 ferns and 43 gymnosperms, most of the last introduced and/or cultivated. Orchidaceae, Asteraceae and Fabaceae contribute over 1,000 species and six of the largest genera (over 100 species) , where *Solanum* alone comprises 192 species (Tab. 4, 5).

Considering the 9 major geopolitical subdivisions, or departments (Fig. 1) of Bolivia, the four southwestern ones, La Paz, Oruro, Potosi and partly Cochabamba include the majority of the Andean highlands, while Chuquisaca, the eastern part of Cochabamba and La Paz are also home to the interandean valleys, Tarija, Chuquisaca and Santa Cruz are home to the Chaco (related to the Brazilian Pantanal), while Santa Cruz spans from Chaco in the south, Savanna in the far east, and transitional rainforest reaching the mostly Amazonian departments of Pando and Beni (CEDIB 2015). At present, La Paz features the highest number of species, while the entirely Amazonian department of Pando, with meagre 2,000 species records (Tab. 6), is likely to be undercollected. The same is true in the case of the vast Beni department (Tab. 5, Fig. 2) and the Andean highlands in Oruro and Potosi (Fig. 2), just to exemplify the areas showing sparse collecting activities in the map prepared from databased herbarium records. Even considering the harsh climatic conditions at high altitudes,

Table 2 – Vascular plants of Bolivia summarized according to category

Category	Nº species
Accepted	15,345
Native	12,165
Endemic	2,343
Cultivated	694
Adventicious	267
Naturalized	221

*Several species are recorded in different categories, therefore the total number is higher than the accepted species number. Categorization according to Jørgensen *et al.* 2014

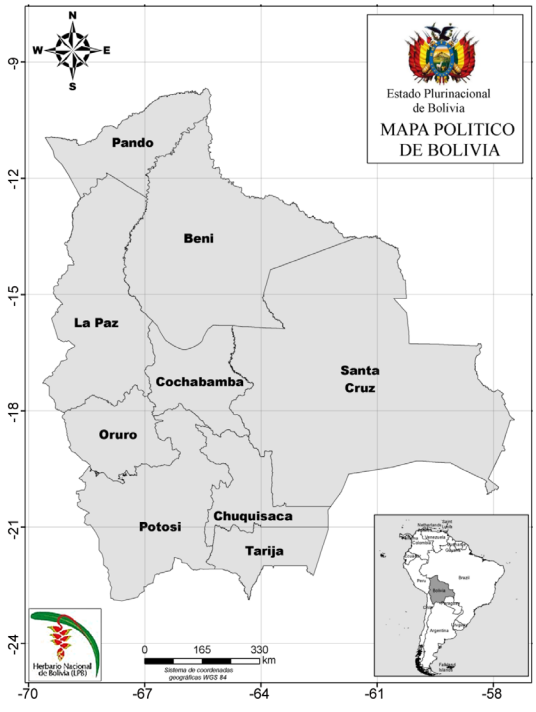

Figure 1 – Map of Bolivia highlighting the departaments.

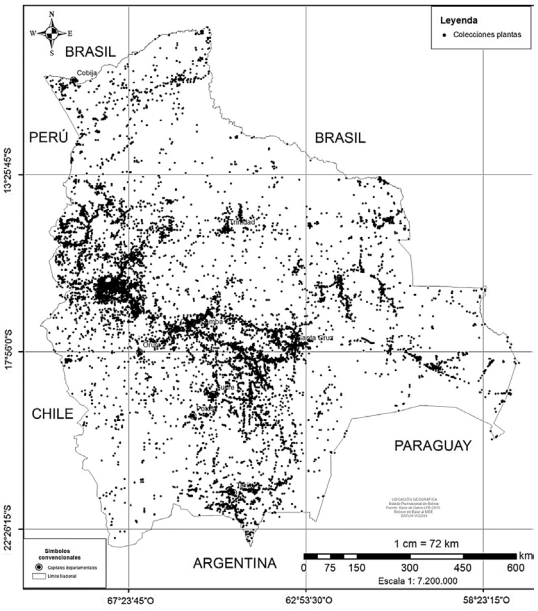

Figure 2 – Vascular specimen collections according to the LPB herbarium database, July 2015.

Table 3 – Vascular plant groups in Bolivia

Groups	Families	Genera	Species
Ferns	33	126	1,145
Gymnosperms	8*	20	43
Angiosperms	245	2,636	14,157
Total	286	2,782	15,345

* including 4 introduced families

Table 4 – Ten top families of vascular plants in Bolivia

Families	Nº species
Orchidaceae	1,263
Asteraceae	1,256
Fabaceae	1,114
Poaceae	962
Malvaceae	445
Rubiaceae	429
Cyperaceae	348
Solanaceae	341
Melastomataceae	325
Euphorbiaceae	322

Andean altiplano highlands feature 1,565 species, while the Andean slopes 9,253 species, more than in the lowlands with 8,453 species (Jørgensen *et al.* 2014). A breakdown of species numbers by altitudinal quota (Tab. 7) shows the decrease in species number with altitude above two thousand meters and that, at the upper limit (above 5,000 m), 33 species have been recorded.

Bolivia currently counts with approximately 150 botanists, mostly Biology graduates from the state universities of the Departments of La Paz, Cochabamba and Santa Cruz, but also agronomists and foresters from the universities in Beni, Chuquisaca and Tarija.

Towards a Flora of Bolivia

The publication of the Bolivian catalogue edited by Jørgensen *et al.* (2014) has motivated the country's herbaria to pursue the organization of knowledge regarding botanical richness and diversity. These tasks are gaining momentum as it is understood that a Flora is important and most necessary as the baseline for basic and applied plant studies.

A workshop "Towards a Flora of Bolivia" was organized in April 2013, with the participation of 40 botanists from Bolivia and other countries. The curators and representatives of the herbaria of Cochabamba (BOLV), Sucre (HSB), La Paz (LPB), Santa Cruz (USZ), Cobija, Oruro and Potosí were present alongside botanists that have supported the study of the Bolivian Flora for many years: the coordinator of the Madidi Project from the Missouri Botanical Garden (MBG), the author and editor of the Flora de Amboró from the New York Botanical Garden (NY), the coordinator of several Darwin Initiative projects from the Royal Botanic Gardens, Kew (K) and Oxford University and the Director of the Berlin Botanical Garden (BGBM).

The results from the workshop were published by Meneses *et al.* (2013) to increase their visibility. Some of the conclusions from this meeting are summarized below.

By consensus of all participants the Flora of Bolivia must be a publication of the highest scientific rigour and involving collaboration and communication with specialists worldwide.

The task of preparing a flora is arduous for the botanists; the existence of a Flora of Bolivia will create the opportunity to develop and gather the scientific knowledge regarding the species,

Table 5 – Ten top genera of vascular plants in Bolivia

Genera	Nº species
Solanum	192
Miconia	141
Epidendrum	128
Elaphoglossum	127
Peperomia	123
Tillandsia	104
Senecio	99
Thelypteris	96
Paspalum	95
Piper	93

Table 6 – Species number and area of the 9 departments of Bolivia

Departament	Species number	Approx. area (km^2)
La Paz	9,272	120,000
Santa Cruz	7,817	357,000
Cochabamba	5,888	52,000
Beni	3,626	288,00
Chuquisaca	2,577	46,000
Tarija	2,554	35,000
Pando	2,001	60,000
Potosí	997	98,000
Oruro	442	43,000

thus facilitating future species identification, knowledge dissemination towards conservation and sustainable management of the plant resources.

The workshop also provided an opportunity for the participants to establish the format for the taxonomic treatments, that was prepared in collaboration and accepted as a joint decision. The treatments of the Flora will include the accepted scientific name and selected synonyms according to the International Code for Nomenclature of Algae, Fungi and Plants (McNeill *et al.* 2012). The morphologic descriptions will be based in Bolivian specimens and include the most relevant characters compiled in a relatively short text (200-300 words). Additional data will include habitat information, autoecologic information regarding the taxa (phenology, pollinators when known, etc.), the common names and known uses. Identification keys will include representative morphologic characters of vegetative and reproductive parts. Complementary ecologic information may be given in order to subsidise the species identification. A representative selection of up to 20 specimens will be used to fundament the specific or infraspecific taxonomic circumscription used in the flora. Distribution maps will contain georeferenced points based on specimens found in the available national and international databases containing Bolivian records after being examined by authors of the treatments. Illustrations will be provided to depict at least each genus, and may be either photographs or line-drawings.

The classification will be based on up to date phylogenetic knowledge (APG III 2009) to order and plant family level. Generic classification will preferably consider monophyletic groups, bearing in mind that this level of information is not yet available for all plant groups.

The Flora of Bolivia has been planned as an electronic, open access publication. The first fascicles will be prepared with groups comprising relatively few species, for which there are already Bolivian and foreign specialists engaged in studies, as for example families Amaranthaceae, Arecaceae, Lentibulariaceae, and selected groups of Orchidaceae and Poaceae. The participation of Bolivian botanists is strongly encouraged, however

Table 7 – Altitudinal distribution of the vascular plants of Bolivia

Altitude (m a.s.l.)	Species number
0–500	7,150
500–1,000	4,972
1,000–1,500	4,316
1,500-2,000	3,902
2,000–2,500	3,536
2,500–3,000	3,331
3,000–3,500	2,650
3,500–4,000	1,855
4,000–4,500	881
4,500–5,000	410
>5000	33

we are aware that they are very few when taking into account the size of the task ahead.

Bolivia has a positive track record with the Flora Neotropica Organization that helped the country, back in 1984, to found the Herbario Nacional de Bolivia (LPB), uniting collections, human capacity and infrastructure. The annual Flora Neotropica meeting in the Andes supported local herbaria and created new regional ones, enhancing the profile of botanical research in the country.

Conclusion

As all other tropical countries that are part of the World Flora, Bolivia needs to engage in the preparation of its national flora in order to contribute towards the final account at a global level. We do hope that the international scientific community and the national authorities are able to support the preparation of our Flora alongside the World Flora Project (Jackson & Miller 2015). Bolivian taxonomists could also contribute directly towards the World Flora, especially in particular groups such as the high-andean plants from the humid slopes of the Andes, highland wetlands and of the mostly endemic groups with a centre of diversity in the region, such as the Chloranthaceae, Cunoniaceae and Hypseocharitaceae.

The contribution to the World Flora is seen as a positive challenge by the Bolivian botanical community. As the verification and recording of species started by the Bolivian Catalogue (Jørgensen *et al.* 2014) continues to be improved and the Bolivian taxa are better circumscribed, we seek to unite our knowledge across the borders into neighbouring countries. Our relatively young botanical institutions and community are keen to participate in the elaboration of widely accessible documents for all stakeholders interested in contributing towards the survival of humankind that is today threatened by the increasing loss of habitats, biodiversity and compromising of the Earth's ecologic processes.

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Artigo recebido em 03/09/2015. Aceito para publicação em 25/09/2015.