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Assessment of vascular plant diversity and endemism in Venezuela

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Abstract

DUNO DE STEFANO, R., F. STAUFFER, R. RIINA, O. HUBER, G. AYMARD, O. HOKCHE, P. E. BERRY & W. MEIER (2009). Assessment of vascular plant diversity and endemism in Venezuela. *Candollea* 64: 203-212. In English, English and French abstracts.

A floristic update of Venezuelan vascular plants is proposed and includes 15 820 species, 2481 genera, and 275 families as native to the country. The total species number will probably increase to ca. 16 500 species when additional floristic inventories are completed. There are 2964 known endemic species of vascular plants in Venezuela, constituting 18.7% of the species in the flora. The highest vascular plant species diversity is centered in the Guayana region, followed by the Andes and the Coastal Cordillera. The extensive savanna region of the Llanos has the least number of endemic taxa. The coverage of floristic inventories is lowest in the Andes and Coastal Cordillera regions. The main causes determining current patterns of regional vascular plant richness and endemism in the country are geological, climatics, and historical.

Key-words

Venezuela – Neotropics – Flora – Endemism

Résumé

DUNO DE STEFANO, R., F. STAUFFER, R. RIINA, O. HUBER, G. AYMARD, O. HOKCHE, P. E. BERRY & W. MEIER (2009). Evaluation de la diversité des plantes vasculaires et de leur endémisme au Vénézuela. *Candollea* 64: 203-212. En anglais, résumés français et anglais.

Une mise à jour du nombre de plantes vasculaires au Vénézuéla est présentée et recense actuellement 15 820 espèces, 2481 genres et 275 familles. Le nombre total d'espèces s'élèvera vraisemblablement à environ 16 500 espèces lorsque des inventaires floristiques complémentaires auront été réalisés. Il y a 2964 espèces connues de plantes vasculaires endémiques au Venezuela, soit 18,7% du total des espèces de la flore. Le foyer le plus important de diversité pour les plantes vasculaires est centré dans la région de Guayana, suivi par les régions des Andes et de la Cordillère Côtière. La vaste région de savanne du Llanos présente le plus faible nombre de taxons endémiques. Les inventaires floristiques réalisés ne couvrent que faiblement les régions des Andes et de la Cordillère Côtière. Les principaux facteurs déterminant au niveau régional la richesse et le taux d'endémisme des plantes vasculaires sont de nature géologique, climatique, historique.

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Introduction

Phytogeographic studies show that the Neotropics, the region extending from southern Mexico to northern Argentina, and Chile, hosts a higher number of vascular plant species (ca. 110000 species) and is floristically richer than the Paleotropics (Africa and Asia) (ca. 90000 species) (GENTRY, 1993; HEYWOOD, 1997). Venezuela covers 916445 km^2 in northern South America (0°45'-15°40'N 59°45'-73°25'W). Its geographical position and landscape diversity, together with a tropical climate influenced mainly by the eastern trade winds and the Intertropical Convergence Zone (ITCZ), are probably the key factors determining its high vascular plant species diversity. The country's rich plant species diversity is also influenced by the convergence of three large mountain systems: the Andes in the west, the Coastal Cordillera in the north, and the Guayana Highlands south of the Orinoco River. Their different geology and geological histories, and their separation by extensive lowland plains, have allowed each system to develop distinct floristic assemblages. More detailed information on Venezuela's geography, topography, geology, climate, soil, and vegetation has been given in GONZÁLEZ DE JUANA & al. (1980), HUBER & ALARCÓN (1988), HUBER & FRAME (1989), HUBER (1997), PDVSA (1992), and DUNO DE STEFANO & al. (2003).

Analysis of vascular plant diversity and endemism in Venezuela is focused on its four main geographical regions:

1. the mostly forested high Andes with "páramo" shrublands;
2. the mid-elevation Coastal Cordillera mountains and adjacent Caribbean insular areas;
3. the lowlands, uplands and highlands of the ancient Guiana Shield with characteristic flat-topped mountains ("tepuis");
4. the extensive lowland grasslands and forests of the area known as the Llanos.

However, this quadripartite subdivision does not cover the entire country; for instance, the complex, hilly landscape of Lara, Falcón and Yaracuy states in northwestern Venezuela has always been problematic in terms of its physiographic and floristic relationships because of its intermediate position between the Andes and the Coastal Cordillera regions.

The present study aims were:

a. to present updated richness and degree of endemism data for the vascular plant flora of Venezuela;
b. to analyze plant richness and endemism patterns in the country's principal biogeographic regions;
c. to compare this data with recently published data from other Western Hemisphere countries.

Vascular plant diversity in Venezuela

Interest in cataloguing the naturally occurring vascular plant species of Venezuela dates back to the early 20th century (Table 1). The body of botanical knowledge about Venezuela grew steadily during the latter half of the 20th century, although different authors have proposed widely divergent estimates of the country's total vascular plant species richness.

Table 1. – Previous published accounts of vascular plant diversity in Venezuela.

Author	Number of species cited
KNUTH (1926-1928)	3489
PITTIER (1931)	7658
PITTIER & WILLIAMS (1945)	12000
PITTIER (1945-1947)	9211
STEYERMARK (1977)	20000-30000
BERRY & al. (1995)	13400
HEYWOOD & DAVIS (1997)	21070
HUBER & al. (1998)	15440
MORILLO (2003); MOSTACERO & SMITH (2003); RAMIA & STAUFFER (2003)	15457

Based on more than 250 years of botanical exploration, floristic research, detailed inventories of existing herbarium specimens (i.e. MER, MO, MY, NY, PORT, US, VEN), and through literature research, a more accurate approximation of the actual vascular plant species richness in Venezuela has been developed and published recently in HOKCHE & al., 2008. This catalogue documents 275 families, 2480 genera and 15820 species of vascular plants in the country (Table 2), a total that encompasses 2964 endemic species, representing 18.7% of the country's vascular plant species. The ten most important vascular plant families in the country based on size (Table 3), account for approximately 43.6% of species. This coincides with a recent analysis of the most important worldwide vascular plant families (SMITH & al., 2003). For example, the three main families of flowering plants worldwide, based on

Table 2. – Total number of families, genera and species for the main vascular plant groups in Venezuela (HOKCHE & al., 2008).

Groups	Families	Genera	Species
Ferns	31	121	1155
Gymnosperms	3	5	29
Dicotyledons	193	1753	10505
Monocotyledons	48	601	4131
Total	275	2480	15820

Table 3. – The ten largest vascular plants families in Venezuela.

Family	Species
1. *Orchidaceae*	1506
2. *Leguminosae* s.l.	996
3. *Asteraceae*	784
4. *Rubiaceae*	777
5. *Poaceae*	740
6. *Melastomataceae*	650
7. *Cyperaceae*	430
8. *Bromeliaceae*	374
9. *Euphorbiaceae*	356
10. *Araceae*	281
Total (% of countrywide total: 15820)	6894 (43.6)

number of species, *Orchidaceae* (20000 species), *Leguminosae* s.l. (18000 species) and *Asteraceae* (23000-32000 species) are also the three largest families in Venezuela.

Vascular plant diversity statistics for most tropical countries are still strongly dependent on the coverage of the botanical exploration, and new systematic research and concepts are constantly changing vascular plant inventories. This is definitely the case in Venezuela, where during the last 80 years each successive attempt at quantifying the country's floristic richness has quickly been outdated by new research results (see Table 1). For instance, a detailed flora addressing almost 10000 species of the Venezuelan Guayana region was recently concluded and published (STEYERMARK & al., 1995-2005). However, this region still contains many unexplored areas, such as the Sierra de Unturán, Serranía Tapirapecó, Sierra Curupira, some sectors of the Sierra Parima, and areas of very limited access in the lowlands of Amazonas and Bolívar states. In other words, there is still a high potential for new discoveries despite the fact that botanical research in the region began with Humboldt and Bonpland in the early 19th century and was continued by many subsequent botanists (HUBER, 1995a). Another example is the northwestern state of Zulia, perhaps the state with least amount of botanical research coverage. Zulia includes the Sierra de Perijá, a large Andean mountain range covering approximately 3000 km^2, for which a preliminary checklist published by ARISTEGUIETA & al. (1985) indicated the presence of 1348 vascular plants. It is most probable, however, that given its physiographic and ecological diversity, this area contains at least 3000 vascular plant species. Likewise, the orchids are the most diverse flowering plant family in the country with 1506 known species, but Carnevali & Romero (*pers. comm.*) consider that future botanical exploration will probably increase this number to at least 1600 species. As the case of Venezuela illustrates, extensive botanical exploration and collection is clearly needed to improve floristic knowledge in the megadiverse countries of the tropics (PRANCE, 2001).

Regional plant diversity and endemism

Vascular plant richness and endemism in Venezuela have been grouped by the country's four main biogeographical regions (Table 4). Although the total number of endemic species in Venezuela is 3056, however, the list in Table 4 includes only the species endemic to each region, for a total of 2994 species. STEYERMARK (1979) stated that the causes determining current plant distribution patterns in Venezuela are historic, geological, physiographic, and climatic (especially in response to climate changes since the Neogene began). He also mentioned that the main centres of endemism in the country are the Guayana Highlands, the Andes, and the Coastal Cordillera, each of which hosts high plant diversity caused by speciation in response to geographical isolation (Table 4). In the more homogeneous climatic, geographic and ecological conditions of the Llanos and other lowland areas, plant diversity and endemism levels are lower (DUNO DE STEFANO & al., 2007: 107-122). The exceptions are some areas with unique edaphic or ecological conditions (e.g., the Caatinga forests and "banas" in the Upper Rio Negro region) that favor isolation and speciation, thus producing local endemic populations.

1. Guayana

The Guayana region of Venezuela covers approximately 500000 km^2, including all the area south of the Orinoco River and the intricate Orinoco Delta fluvial system in eastern Venezuela. It is a topographically complex region encompassing extensive lowlands, divided plateaus, and the Sierra Neblina highlands (highest point: 3014 m). This largely undisturbed region contains a great diversity of vegetation communities, ranging from tierra firme forests to flooded forests such as the Rio Negro or Amazonian Caatinga forests, to balsa-like woodlands ("boyales"), shrublands, savannas, montane grasslands, meadows, pioneer formations, and various types of aquatic vegetation (HUBER, 1995b).

Floristics

The floristics of the region is amply covered in STEYERMARK & al. (1995-2005). This project includes almost 10000 species and is one of the seminal floras for the Neotropics.

Endemism

There are no vascular plant families strictly endemic to the Venezuelan Guayana, although there are several Guayana-centred families with all or most of their genera and/or species growing in this region. These include the *Hymenophyllopsidaceae* (8 species), *Bonnetiaceae,* and *Rapateaceae*. As a result of ongoing taxonomic realignment based on molecular systematics, three families traditionally considered Guayana

Table 4. – Estimated number of vascular plant species and endemics in the four main geographical regions of Venezuela, in relation to the total number of taxa in each region

Region	Number of species	Endemic species	%R	%V	References
Guayana	10300	2136	20	14	Berry & al. (1995)
Andes	7000	506	10	3.3	Estrada (pers. comm.)
Coastal Cordillera	4000	322	8.5	2.1	Meier (pers. comm.)
Llanos	3200	30	1	< 1	Duno & al. (2007)

[**Abbreviations: %R** = in percent, regionally endemic taxa; **%V** = in percent, Venezuelan taxa (based on national total = 15820 taxa)]

endemics *(Euphroniaceae, Saccifoliaceae, Tepuianthaceae)* have been transferred to *Chrysobalanaceae, Gentianaceae,* and *Thymelaeaceae,* respectively (APG, 2003). However, Kubitzki (2003) and Thorne & Reveal (2007) have maintained the *Tepuianthaceae* as a separate family endemic to the Guiana Shield flora.

There are 34 accepted endemic genera and 2136 endemic species in this region (Berry & al., 1995). The latter figure represents 22.7% of the total species (9411 species) in this region's flora, as well as 13.5% of the total species included in Venezuela's flora (15820 species). The genera considered endemic to the Venezuelan Guayana are *Salpinctes* Woodson *(Apocynaceae); Achnopogon* Maguire, Steyerm. & Wurdack, *Chimantaea* Maguire, Steyerm. & Wurdack, *Duidaea* S. F. Blake, *Huberopappus* Pruski, *Quelchia* N. E. Br., *Siapaea* Pruski, *Tuberculocarpus* Pruski, and *Tyleropappus* Greenm. *(Asteraceae); Brewcaria* L. B. Sm., Steyerm. & H. Rob. and *Steyerbromelia* L. B. Sm. *(Bromeliaceae); Mycerinus* A. C. Sm. and *Tepuia* Maguire & Steyerm. *(Ericaceae); Celianella* Jabl. *(Euphorbiaceae); Neblinantha* Maguire and *Sipapoantha* Maguire & B. M. Boom *(Gentianaceae); Pyrrorhiza* Maguire & Wurdack *(Haemodoraceae); Uladendron* Marc.-Berti *(Malvaceae); Mallophyton* Wurdack *(Melastomataceae); Aracamunia* Carnevali & I. Ramírez *(Orchidaceae); Amphiphyllum* Gleason, *Kunhardtia* Maguire, *Marahuacaea* Maguire, and *Phelpsiella* Maguire *(Rapateaceae); Aphanocarpus* Steyerm., *Cephalodendron* Steyerm., *Coccochondra* Rauschert, *Coryphothamnus* Steyerm., *Duidania* Standl., *Holstianthus* Steyerm., and *Yutajea* Steyerm. *(Rubiaceae); Apocaulon* R. S. Cowan, and *Rutaneblina* Steyerm. & Luteyn *(Rutaceae);* and *Achlyphila* Maguire & Wurdack *(Xyridaceae).*

The highest levels of endemism are found in the most species-diverse families in the region: *Rubiaceae* (124 endemic species), *Bromeliaceae* (114), *Melastomataceae* (78), *Asteraceae* (56), and *Araceae* (48). High levels of endemism are also associated with the main mountain ranges or massifs, especially in Amazonas state (highlands above 1500 m; 428 endemic species; areas include Aracamuni, Duida, Huachamacari, Neblina, Marahuaca, and Sipapo) (Berry & al., 1995). Another 189 endemic species have been documented in unique white-sand ecosystems found in the lowlands of Amazonas state (areas include Cerro Yapacana, Río Atabapo, Río Guainía, Río Pasimoni, and San Carlos de Río Negro) (Berry & al., 1995; Huber & al., 1998; Clark & al., 2000). In contrast to Amazonas state, the landscape of Bolívar state is a diversified sequence of hills, plateaus, and high plains at different altitudes, and geographical isolation between the various mountain systems is less pronounced. To date, only 99 endemic species are reported from the highlands (mainly Chimantá) and 37 from the uplands (between 500 and 1500 m in Imataca, Sierra de Lema, and Cerro Venamo). The very low level of endemism in Delta Amacuro state is probably due to its uniform topography: mostly extensive plains formed by fluvial, fluvial-marine, and marine sediments. The resulting homogeneous landscape has ecologically uniform conditions that do not favor effective geographical isolation and have kept speciation at much lowers levels than in the highlands.

2. The Andes

The northernmost extension of the South American Andean Cordillera consists of two main branches in northwestern Venezuela. One is the Sierra de Perijá, which stretches north along the Colombia / Venezuela border in western Zulia state, and the other is the Sierra de Mérida, which extends northeast toward the Caribbean Sea and is located in the states of Táchira, Mérida, Trujillo, portions of Portuguesa, and Lara. This extensive mountain system has steep slopes and deep valleys. It reaches its highest elevations (just over 5000 m) near the city of Mérida. This region originally hosted a great diversity of ecosystems, including several kinds of montane forests, high-Andean shrub and grasslands (páramos), as well as xerophytic vegetation in some inter-Andean valleys. Over the past century many of these ecosystems have been replaced by extensive anthropogenic secondary vegetation.

Floristics

Only one sizable floristic publication (Bono, 1996) has covered this region. It consists of a vascular plant flora of the state of Táchira (ca. 11000 km^2) with over 4000 species, although a supplement containing an additional 600 species is

in press. On a more local scale, a catalogue of the vascular flora of Guaramacal National Park in the states of Trujillo and Portuguesa was published by DORR & al. (2000), and another catalogue of the Venezuelan páramos was published by BRICEÑO & MORILLO (2002, 2006). Reviews of recent publications on Venezuelan Andean floristics can be found in HUBER & al. (1998), AZÓCAR & M. FARIÑAS (2003), and SKLENÁR & al. (2005).

Endemism

STEYERMARK (1979) estimated that 506 endemic vascular plant species existed in the Venezuelan Andes distributed in numerous, often very small subcentrers. At the generic level, the Andean flora has a considerably lower level of endemism than the Guayana region. Endemic genera in the Venezuelan Andes include the *Asteraceae* (*Coespeletia* Cuatrec., *Carramboa* Cuatrec., and *Ruilopezia* Cuatrec. (all three segregated from *Espeletia* Bonpl., the monotypic genus *Freya* Badillo (LUTEYN, 1999), and the *Orchidaceae* (*Stalkya* Garay)). In the most recent floristic catalogue of the páramos, which represents only a small portion of the total area of the Venezuelan Andes (highlands above 2800-3400 m), BRICEÑO & MORILLO (2002, 2006) reported 1437 flowering plant species of which 387 were endemic. The authors mentioned no endemic genera for this area. These new endemic species figures for the páramos suggest that Steyermark's estimate for the Andes was low and that the final number of endemic species will be higher once data for montane forests is incorporated.

The Guaramacal area is an excellent example of how intensive botanical exploration produces significant changes in botanical knowledge: endemic species estimates for the area have increased from five (STEYERMARK, 1979) to at least 30 (AYMARD, 1999; DORR & al., 2000). Other unexpected botanical discoveries include documentation of genera or species in the Andes that were previously regarded as endemic to the Coastal Cordillera (STEYERMARK & HUBER, 1978). Such is the case of the genera *Croizatia* Steyerm. *(Euphorbiaceae)* (CUELLO, 2002), *Caracasia* Szyszyl. *(Marcgraviaceae)*, the species *Ladenbergia buntingii* Steyerm. *(Rubiaceae),* and *Byrsonima karstenii* W. R. Anderson *(Malpighiaceae)*.

For the Sierra de Perijá, MORILLO (2003) reported 17 endemic species, with the *Asteraceae* (8 species) and *Apiaceae* (5 species) families containing the largest number of endemics.

3. Coastal Cordillera

This mountain system runs east-west along the northern Caribbean coast of Venezuela. In the west it begins in the Yaracuy Depression north of the Andes in northwestern Venezuela and continues east to the tip of the Paria Peninsula in front of Trinidad. The Coastal Cordillera's high points are Pico Naiguatá (2765 m) in its central section and Cerro Turimiquire (2630 m) in the east. This region also includes what is called the "Serranía del Interior" range, which has generally lower elevations and a drier climate, as well as the Venezuelan islands, of which Isla Margarita is the largest.

Floristics

Floristic data for this densely populated region of Venezuela is rather fragmentary in that it is limited to a number of protected areas such as Avila National Park near Caracas (STEYERMARK & HUBER, 1978; MEIER, 1998), Henri Pittier National Park in Aragua state (BADILLO & al., 1984; CARDOZO, 1993, 2001) and Morrocoy National Park on the coast in Falcón state (STEYERMARK, 1994). Important floras for the region are "Flora de la Isla de Margarita" (HOYOS, 1985), "Flora de Monagas" (LÁREZ, 2005), and a series of papers have been published over the last 30 years reporting floristic inventories of many montane and other localities in the Coastal Cordillera (for a detailed bibliography, see HUBER & al., 1998; MEIER, 2005).

Endemism

STEYERMARK (1979) reported 247 endemic vascular plant species in the Coastal Cordillera region, which is approximately half the number of known endemic species (506) in the Venezuelan Andes. The number of endemic genera, however, is much lower than reported for the Andes. Only four endemic genera (all monotypic) are found in this area: *Margaritolobium* Harms *(Fabaceae), Rojasimalva* Fryxell *(Malvaceae), Llewelynia* Pittier *(Melastomataceae)*, and *Neoblakea* Standl. *(Rubiaceae)*. This difference in the degree of generic endemism may result from the overall lower elevations of the Coastal Cordillera; indeed, typical high mountain ecosystems above 2800 m are lacking. Most hills and lower mountains range from 500 to 1500 m.

A realistic estimate of the number of endemic species in the Coastal Cordillera region is probably close to 400 species (Meier, *pers. comm.*). Many areas in the Coastal Cordillera have not been adequately and systematically explored, especially the Serranía del Interior, and less floristic data exists for some mountains (e.g., the densely-forested Golfo Triste massif south of Caracas) than for some of the tepui summits in the Venezuelan Guayana. Recent intensive botanical exploration in the region has yielded interesting new botanical data. STEYERMARK (1979) reported a total of 14 endemic species for Cerro La Chapa, a small cloud forest area between 1000-1400 m in Yaracuy state, but new intensive inventories by Meier and colleagues during the past ten years have increased overall species inventory to at least 900 species, including 130 (14.4%) species endemic to Venezuela (Meier, *pers. comm.*). Of these, 11 are strictly endemic to Cerro La Chapa, 82 are endemic to the

Coastal Cordillera (including Falcón state), 26 are endemic to the Coastal Cordillera and the Andes, four are endemic to the Coastal Cordillera and Venezuelan Guayana, and seven are endemic to the Coastal Cordillera, the Andes, and Venezuelan Guayana (Meier, *pers. comm.*). This clearly illustrates that current endemism figures for the Andes, and the Coastal Cordillera are probably underestimates attributable to incomplete floristic inventory.

4. The Llanos

The Venezuelan Llanos is an extensive macro-thermic lowland region covering approximately 240000 km² (26% of the country) and characterized by wide, partly flooded, alluvial Quaternary sedimentary plains alternating with slightly inclined piedmont glacis, and low Tertiary sandstone mesas. The region is bordered by the Coastal Cordillera to the north, the Andes to the west and the Guayana massif to the south. A wide belt of flooded lands stretches east along the Orinoco River from Apure state in the southwest and transitions into the marshy plains of the Orinoco River delta and adjacent Monagas state (included in the Guayana region here, see above) (Duno de Stefano & al., 2007).

The region is generally covered by a variety of savanna ecosystems interrupted by several types of dry to evergreen forests, gallery forests, and shrublands locally called "chaparrales", and dominated by *Curatella americana* L. *(Dilleniaceae)*. More restricted plant communities characteristic of this region include palm swamps ("palmares", dominated by *Copernicia tectorum* (Kunth) Mart., and "morichales", dominated by *Mauritia flexuosa* L. f.), as well as flooded shrublands ("congriales"), dominated by *Acosmium nitens* (Vogel) Yakovlev *(Fabaceae)* and flooded woodlands ("saladillales"), dominated by *Caraipa llanorum* Cuatrec. *(Clusiaceae)* (Aymard, 2003; Huber & al., 2006).

Floristics

In their annotated and illustrated catalogue of vascular plants for the entire Llanos region, Duno de Stefano & al. (2007) reported approximately 3200 species. Herbaceous ecosystems, especially savannas and other wetlands, predominate in the region, and the most important families are *Poaceae* (274 species), *Fabaceae* (204 species), and *Cyperaceae* (175 species).

Endemism

Steyermark (1979) mentioned eight endemic species for the Llanos region, while Huber & al. (1998) mentioned 13, Aymard (2003) 15, and Riina (2003) ca. 20 species. The most recent checklist includes at least 30 endemic species in this region (Huber & al., 2006; Duno de Stefano & al., 2007: 107-122). Eighteen of the vascular plant species endemic to Venezuela co-occur in the Llanos and Guayana regions, meaning they are not reported as endemic to either region: *Alternanthera pulchella* Kunth *(Amaranthaceae)*; *Justicia parguazensis* Wassh. *(Acanthaceae)*; *Duguetia riberensis* Maas & Boon and *Xylopia plowmanii* P. E. Berry & D. Johnson *(Annonaceae)*; *Mandevilla caurensis* Markgr. *(Apocynaceae)*; *Jacaranda orinocensis* Sandwith *(Bignoniaceae)*; *Campsiandra taphornii* Stergios *(Caesalpiniaceae)*; *Diospyros gallo* B. Walln. *(Ebenaceae)*; *Croton bolivarensis* Croizat *(Euphorbiaceae)*; *Machaerium dubium* (Kunth) Rudd, *Lonchocarpus crucisrubierae* Pittier and *Myrocarpus venezuelensis* Rudd *(Fabaceae)*; *Nectandra aurea* Rohwer *(Lauraceae)*; *Strychnos davidsei* Krukoff & Barneby *(Loganiaceae)*; *Eugenia amblyosepala* McVaugh and *E. pachystachya* McVaugh *(Myrtaceae)*; *Ouratea davidsei* Sastre *(Ochnaceae)*; and *Zanthoxylum syncarpum* Tul. *(Rutaceae)*. Other cases of Venezuelan endemics occurring in more than one physiographic area are the 26 species shared by the Coastal Cordillera and the Andes, the seven reported in both the Coastal Cordillera and Guayana regions, and the 11 species found in the Coastal Cordillera, the Andes, and Guayana regions.

Venezuela as a floristically diverse country

Official reports (e.g., Huber & al., 1998; Marn, 2000) frequently state that Venezuela has one of the highest plant diversities in the Neotropics. Plant diversity and endemism data for the entire New World are far from complete, but it is quite probable that Venezuela hosts the highest vascular plant diversity of any country from Central America and the Caribbean Basin. Among the countries of South America, it ranks sixth in vascular plant diversity after Brazil, Colombia, Peru, Ecuador, and Bolivia (see Table 5).

Climate (mainly precipitation), orography, size, and geographic position are key factors in determining overall vascular plant diversity in any given country. Small countries such as Costa Rica and Panama, both with areas of less than 100000 km², have areas that receive high precipitation and have complex orography, resulting in relatively high vascular plant diversity. In addition, both countries are geographically located where the floras of two continents intermix, another factor which increases their plant diversity. Compared to other South American countries, Venezuela has a large area of plains, the Llanos, which covers approximately 25% of its territory with a flat, dry area of very low diversity and endemism.

In contrast, Colombia, Ecuador, Peru, and Bolivia cover the core of the Andes, which has highly diverse and complex orography and climate conditions (including areas with some of the highest rainfall on the planet), and is probably the most

Table 5. – Estimates of the total number of vascular plant species for some neotropical countries.

Country	Area [km²]	Number of species	References
Central America & Mexico			
Mexico (only flowering plants)	1972250	30000	Delgadillo & al. (2003)
Belize	22966	3408	Balick & al. (2000)
Nicaragua	13000	5354	Stevens & al. (2001)
Panama	75517	9520	Correa & al. (2004)
Caribbean Region			
Cuba	110860	6505	Heywood & Davis (1997)
Jamaica	10991	3247	Adams (1972)
Dominican Republic	48730	5600	Bolay (1997)
South America			
Argentina	2791810	8409	Zuloaga & al. (2008)
Bolivia	1098580	17350	Heywood & Davis (1997)
Brazil	8511965	56000	Heywood & Davis (1997)
Colombia	1138910	24783	Bernal & al. (2007)
Chile	756206	4985	Zuloaga & al. (2008)
Ecuador	283000	15306	Jorgensen & León-Yanez (1999)
Guianas (Guyana Suriname and French Guiana)	493880	9200	Boggan & al. (1997)
Paraguay	406635	5099	Zuloaga & al. (2008)
Peru	1285220	17143	Brako & Zarucchi (1993)
Uruguay	175016	2770	Zuloaga & al. (2008)
Venezuela	916445	15820	Hokche & al. (2008)

biodiverse region on Earth (Gentry & Dodson, 1987). In many of these countries, the flora of the eastern slope of the Andes gradually merges into that of the western Amazon Basin, further increasing species richness.

Endemism in Venezuela (18.7%) is lower than in neighboring countries such as Colombia, Ecuador, and Peru (25-30%) (Jørgensen & León-Yanez, 1999; Bernal & al., 2007), but higher than in Central American countries (1,2-12%) (Balick & al., 2000; Stevens & al., 2001; Correa & al., 2004). Three of Venezuela's four principal geographical regions (the Andes, Guayana, and the Llanos) are also shared with two or more countries; only the Coastal Cordillera is completely within Venezuela. The diverse and complex orography, and climate of the Andean core in Colombia, Ecuador, Peru, and Bolivia are also fundamental in producing the high endemism values reported for these countries. In terms of species numbers and endemism, two other New World countries stand out. Mexico has about 30000 reported vascular plant species, 50-60% of which are endemic (Delgadillo & al., 2003). Although Mexico is not particularly humid, it covers an enormous area containing complex mountain ranges and is located in a unique geographical situation (latitudinal range, 32°-14° N) where Nearctic and Neotropical botanical elements intermix. Cuba is another extraordinary case in that it is only slightly larger than 100000 km² but contains 6505 reported vascular plant species, of which approximately half are endemic due to unique ecological conditions (i.e. geology and soil diversity) and the island's isolation (Borhidi, 1991).

Conclusion

The catalogue of Hokche & al. (2008) includes 15820 native vascular plant species in Venezuela (6.2 % of the world's vascular flora) of which 2964 species (18.7%) are endemic. There are 28 herbaria in the country housing about 750000 botanical specimens (Huber & al., 1998); yielding a collection index of about 82 (number of botanical collection stored in the herbaria of the country divided by its surface), which is below the minimal value considered appropriate for a reasonably thorough botanical understanding of a tropical country (Campbell, 1989). Botanical exploration of Venezuela is still incomplete, and it is therefore quite likely that the total number of vascular plant species in the country could surpass 16500 once future research is incorporated into the overall species count. Intensive and systematic botanical exploration

is needed in inadequately covered areas and/or in areas threatened by destruction, such as northern Amazonas state, the Sierra Perijá in Zulia state, and all the montane forests in the Andes (particularly the states of Lara, Mérida, Portuguesa, Táchira and Trujillo), and the Coastal Cordillera. Regional diversity and endemism data are relatively complete for the Guayana and Llanos regions, the vascular plant diversity of which has been well-documented in two major floristic projects: the "Flora of the Venezuelan Guayana" (STEYERMARK & al., 1995-2005), and the "Catalogue of the Venezuelan Llanos" (DUNO DE STEFANO & al., 2007). No such projects have yet been completed for the Andes or the Coastal Cordillera regions, both of which still lack large-scale floristic documentation, but research on these areas is currently underway. A major floristic inventory was begun by Winfried Meier in the Coastal Cordillera that will eventually produce more accurate diversity data for this region. A similar effort is underway in the Venezuelan Andes and to date has produced a checklist of the páramos of South America (LUTEYN, 1999; SKLENÁR & al., 2005), and Venezuela (BRICEÑO & MORILLO, 2002, 2006). Floristic research in the forests of the Venezuelan Andes and the Coastal Cordillera should clearly be a top priority for biodiversity research in the country.

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