

Climate Change and Biodiversity in the Tropical Andes

Edited by

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Physical Geography and Ecosystems in the Tropical Andes

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Due to their fairly recent uplifting, the Northern and Central Andes have played a key role in the diversification of tropical South American biota (e.g., Heindl and Schuchmann 1998; Kattan et al. 2004). Several studies focusing on Andean biogeography (e.g., Roy et al. 1997; García-Moreno et al. 1999) showed that montane biota are the product of a combination of two important factors: (a) geological events with local to regional impacts on community structure and ecological processes, and (b) recent continental to global ecological changes caused by Croll-Milankovitch climatic cycles that last about 20,000 years and are determined by variations in the earth's orbit around the sun.

The tropical Andes top the list of worldwide hotspots for endemism and the number of species/area ratio (Myers et al. 2000). The snow capped peaks, steep slopes, deep canyons, and isolated valleys of these mountains have led to a large diversity of microhabitats favoring speciation. Moreover, their location between the lowlands of the Amazon, the Chiquitanía, and the Gran Chaco to the east and the Chocó, Tumbes-Guayaquil, and the arid systems of the Sechura Desert to the west determines complex dynamics of species exchange and isolation.

This biodiversity hotspot is also identified as one of the most severely threatened areas in the tropics (Mittermeier et al. 1999; Jetz et al. 2007). The long history of human occupation in the Andean region has transformed and re-shaped a significant proportion of its landscapes. Human occupation has contributed to the domestication of numerous species, turning this region into one of the world's 12 major centers of origin of plants cultivated for food, medicine, and industry (Saavedra and Freese 1986). During the last century, concentration of the human population in the inter-Andean valleys and the valleys of the Andean ridge has transformed an important part of the natural vegetation cover, causing losses in its biological richness, especially in the Northern Andes (Wassenar et al. 2007; Bruinsma 2003).

The threats to the tropical Andes' biodiversity are myriad, and in recent years they have been compounded by the manifold impacts of climate change. Given the complexity of these dynamics, tackling the challenges imposed by global change in the region requires a basic

understanding of its main geographic features and ecological systems. In this chapter we provide an overview.

Geographic Features

The tropical Andes are the longest and widest cool region in the tropics, as they extend over 1.5 million km², from 11° N to 23° S, occupying an elevation range from around 600–800 m up to some 6,000 m above sea level. Besides the characteristic Andean features of steep slopes, deep gorges, and wide valleys, a vast mountain plain, the Altiplano, extends at elevations above 3,500 m across much of southern Peru and western Bolivia. A large number of snow-capped peaks are found throughout the tropical Andes; the treeline occurs between 3,800–4,500 m near the equator and above 4,500 m from 15° S to the southern limit of the region.

Compared to the Central Andes, the Northern Andes are relatively small, extending from Venezuela to northern Peru. In Venezuela, the Andes form two branches that originate in the ‘Nudo de Pamplona’, in the Colombian territory. The northerly branch forms the Sierra de Perijá. The other branch is the main cordilleran massif, commonly called the ‘Cordillera de Mérida’. The Maracaibo Lake basin separates these two mountain ranges. In Colombia the Andes are divided into three main ridges, which stem from a massif located at 2°N, and are separated by two valleys running from south to north: the Magdalena valley separates the Eastern from the Central Cordillera, and the Cauca valley separates the Central from the Western Cordillera. The latter mountain chain is relatively low and lacks snow-covered peaks. The Central Cordillera is the highest of the three branches and contains several active strato volcanoes, some of them partially covered by snow (Fjeldså and Krabbe 1990).

To the south of the Colombian massif (Nudo de Los Pastos), and across Ecuador until 3°S, the Andes form two parallel mountain chains, the Eastern and Western cordilleras, which run from north to south forming a narrow (150–180 km wide) stretch of some 600 km (Clapperton 1993). These two branches of the Ecuadorian Andes are not completely defined as separate chains, but still give rise to a series of inter-Andean valleys above 2,000 m of elevation. South of the Paute–Cuenca–Girón Valley, the Northern Andes are lower. The tallest peaks are found southeast of Cuenca and reach 4,130 m, but all other areas are below 4,000 m.

In southern Ecuador and northern Peru the Andes form an intricate mosaic of mountain systems, some of them running from north to south and others from east to west. At this point, the Northern Andes not only get lower, but also lose humidity around the confluence of the Chinchipe River with the Marañón and Huancabamba rivers (Josse et al. 2009a). The Porculla Pass in the Huancabamba depression (6°S, 2,145 m) defines the limit between the northern and the central portions of the tropical Andes. South to the department of Cajamarca in Peru, the Marañón Valley separates the Central from the Western Cordillera. The Central Cordillera is continuous but lower than the Western Cordillera, crowned by snow peaks reaching more than 6,000 m, and separated into several discontinuous massifs (cordilleras Blanca, Huayhuash, and Raura).

In the Peruvian department of Junín the two cordilleras converge around Lake Junín. From this point to the south, the Andes are continuous and high, as there is not a single mountain pass lower than 4,000 m. From Cusco to central Bolivia the eastern Andes form a single mountain chain only interrupted by two deep canyons in La Paz (Josse et al. 2009a). West of the latter, the Peruvian-Bolivian altiplano is an area of wide, internally drained plains, containing

large lake complexes. The whole region was historically covered by a giant lake that after several cycles of flooding and subsequent glacial periods is currently fragmented into several lakes (Servant and Fontes 1978, Ballivian and Risacher 1981, Argollo and Mourguiart 1995). In the north, Lake Titicaca occupies 8,300 km² and drains to the south into the brackish Lake Poopó. At the southern limit of the Altiplano, the also brackish Uyuni and Coipasa lakes are annually flooded during the rainy season. These two lakes cover 10,000 and 2,220 km², respectively. The Cordillera Real and the Central Andes reach their southern limit in the Tunari-Cochabamba complex (Fjeldså and Krabbe 1990).

Plant Geography

The Northern Andes occupy approximately 490,000 km², from 11°N in the Sierra Nevada de Santa Marta Massif in northern Colombia to 6°S at the Porculla Pass of Peru (Van der Hammen 1974, Simpson 1975). They form a large phyto-geographic region divided into two subregions: the so called Páramos and the North-Andean forest ecosystems (Josse et al. 2009a; Figure 10.1). The latter show a mixture of several floristic elements from the surrounding lowlands, and regional variations of species composition in the montane (upper and lower) and sub-Andean altitudinal belts towards the Caribbean, Chocó, Orinoco, and Amazon.

The vegetation of the Northern Andes can be grouped into moist montane forests, seasonal and xerophytic scrubs, and páramo grasslands proper, including shrubby boundaries with the forest downslope and superpáramo above. Montane forests cover most of the region, whereas páramos are insular formations around the highest peaks. Scrub is restricted to the lower portion of the inter-Andean valleys, following the course of main rivers such as the Magdalena and Guayllabamba and smaller deep gorges and valleys throughout the region (Josse et al. 2009a). Páramos occupy the lower section of the high-Andean belt and form distinct plant communities; these ecosystems harbor the most diverse mountain flora in the world (Smith and Cleef 1988) and have high levels of endemism both for species and genera (Sklenár and Ramsay 2001). Northern Andean forests occur mostly between 3,000–3,300 m and 1,500 m above sea level, with sub-Andean forests further down to around 700 m elevation.

Physiographic features have created a natural barrier between the Northern and the Central Andes, expressed in differences in species composition of flora and fauna among both regions (Duellman 1979, 1999, Duellman and Wild 1993, Weigend 2002). The area between the Porculla Pass and the beginning of the Cordillera Negra in the Peruvian departments of La Libertad and Ancash (8°30'S) is considered a transitional zone, called “Jalca” by some authors, between these two subdivisions of the tropical Andes (Simpson and Todzia 1990; Gentry 1982). This biogeographically distinct zone occurs throughout the high elevations of the Andes in northern Peru west of the Marañón River (Sánchez-Vega and Dillon 2006; Weigend 2002, 2004).

The area north of the Porculla pass up to the Giron-Paute valley at 3°S in southern Ecuador constitutes another transitional zone inside the Northern Andes; this region is sharply delineated by the Paute Cuenca-Giron valley in an area where the Andes decrease in size and form a complex pattern of ridges and junctions that run east-west rather than north-south (Ulloa and Jorgensen 1993; Jorgensen et al. 1995). The fundamental difference between the north and south portion of the Northern Andes is the active volcanism present in the north during the last 2.5 million years, which has had a profound impact on topography and soils.

The Central Andes encompass four phyto-regions: Yungas, Moist Puna, Xeric Puna and Bolivian-Tucuman (Josse et al. 2009a). The Yungas are found throughout the eastern side of the Central Andes following the eastern versant of the Marañon river in Peru to central Bolivia, between the Moist Puna to the west and the lowlands of the Amazon to the east (Cabrera and Willink 1973). From 6° to 13°S, the Yungas are associated with a discontinuous sub-Andean mountain system which causes rivers descending the Eastern Cordillera to run in a northerly direction, forming wide valleys parallel to the cordillera, before continuing towards the Amazon lowlands (Josse et al. 2009a). The ecological conditions at the highest eastern peaks of this low sub-Andean belt are very peculiar; Andean and Amazonian species and ecosystems form spatial mosaics in the alluvial valleys above 1,000 m, surrounded by slopes covered by montane forests. The altitudinal range occupied by the Yungas is very wide (500–4,000 m). Because of the steep slopes of these mountains, it is possible to find altitudinal gradients of three to four thousand meters in a horizontal distance of only 50–100 km. These forests are distributed in two altitudinal belts that run along the eastern slopes of the Andes: the sub-Andean belt below 2,000 m of elevation and the cordilleran belt proper, which runs above 2,000 m and includes three ecological subdivisions: the montane, the upper-montane, and the lower portion of the high Andean zone.

The Moist Puna occurs from northern Peru to the central portion of the eastern cordillera in Bolivia, including the high-Andean basin of Lake Titicaca. This almost flat basin was filled up several times during the Holocene by sediments of fluviolacustrine and fluvio-glacial origin. This biogeographic unit also covers a wide altitudinal range, from 2,000 m in the inter-Andean valleys to more than 6,000 m on the high peaks of the cordillera. Most of the original vegetation of the upper-montane and high Andean belts of the Moist Puna was probably formed by forests of *Polylepis* spp., dominated in each mountain massif by endemic species (Josse et al. 2009a). However, the ancestral land uses by the human settlers of this landscape have significantly reduced these forests, replacing them with grasslands and scrub which, too, harbor important diversity. In the topographic depressions, as well as surrounding lakes and other water courses, there are numerous wetlands and peat bogs, some of them of considerable size.

The Xeric Puna occurs mainly in the central-southern portion of western Bolivia and northwestern Argentina, and sparsely in adjacent areas of southwestern Peru and northeastern Chile. As the previous biogeographic units, this formation occupies a wide altitudinal belt, from approximately 2,000 m in the high eastern valleys (also called Pre-Puna) up to 6,000 m on the tall snow-capped peaks and volcanoes of the western cordillera. The Andean Altiplano, one of the largest mountain plains in the world, is part of the Xeric Puna. This vast plain has a mean altitude of 3,650 m and is located in the widest sector of the Andean chain. Vegetation of the Xeric Puna is highly diversified and forms several unique ecosystems, such as the salt flats, which comprise the largest saline mountain ecosystem on Earth.

The Bolivian-Tucuman biogeographic province extends beyond the Yungas to the south along the slopes of the eastern ridges of the Andean Cordillera, from central Bolivia to northwestern Argentina between 600 m and almost 4,000 m of elevation. To the west, it is bounded by the Xeric Puna and to the east by the Bolivian Chiquitanía and the Gran Chaco. Most of the Bolivian-Tucuman province occupies the sub-Andean belt below 2,000 m of elevation. Although the vegetation of this province shares some elements with these neighboring floristic provinces, it also contains a large number of endemics (Josse et al. 2009a).



Figure 10. 1. Map of floristic regions of the tropical Andes (Josse et al. 2009a). This map does not represent official information of any of the five countries, but rather represents an exercise in information integration and analysis.

Ecosystems of the Tropical Andes

Classifying the wealth of ecosystems of the tropical Andes has proved to be a difficult task, especially because of the different approaches taken by researchers and institutions of the different countries and the lack of a coherent effort to unify criteria for classification. Josse et al. (2009a, b) made the most recent attempt to address this problem and produced an ecosystem map for the whole region (http://www.comunidadandina.org/public/libro_92.htm), integrating earlier maps for the different countries (Navarro and Ferreira 2007 for Bolivia; Rodríguez et al. 2004 for Colombia; Peralvo et al. 2006 for Ecuador; Josse et al. 2007 and INRENA 2000 for Peru; Ataroff and Sarmiento 2003 for Venezuela).

The thematic homologation of the cartographic information made by these authors was based on NatureServe's classification of ecological systems of the Western Hemisphere (Comer et al. 2003; Josse et al. 2003) (<http://www.natureserve.org/infonatura>). According to this classification, a terrestrial ecological system is defined as a group of local-scale plant communities that co-occur in a given landscape, thus sharing ecological processes (e.g., fire cycles, floods), substrates (e.g., superficial soils, parent rock), and/or environmental gradients (e.g., bioclimate, elevation, hydrologic patterns) (Josse et al. 2003).

Classification Framework

Historically, terrestrial ecosystems have been defined in a variety of ways. Some approaches focus on biotic components like vegetation, either as 'existing vegetation' – what one observes in the field (e.g., Rodwell et al. 2002) – or as 'potential vegetation' – what the presence of plant species indicate for successional sequences and potential biomass productivity of a site (Daubenmire 1966). Other approaches focus directly on abiotic components: the physical features of landscapes that define recurrent ecologically-relevant patterns (e.g., Rowe and Barnes 1994; Bailey 1995; Racey et al. 1996; USDA Forest Service 2006).

The NatureServe ecological systems classification borrows elements of each of these approaches to describe integrated units of recurring vegetative assemblages that depend on recurrent local-scaled physical features and dynamic processes. This approach is not unlike many previous efforts to characterize natural community types (e.g., Whittaker 1962; 1975). Whereas vegetation classifications provide a conceptual/taxonomic hierarchy to organize existing vegetation classification units, terrestrial ecological systems describe the common co-occurrence of local-scale vegetation units on the ground. Both forms of classification serve as practical tools for ecological mapping and assessment.

The ecological systems classification and derivative maps aim to provide comprehensive local-scale ecosystem information to natural resource managers. The approach of linking existing vegetation communities based on the similarity of their biophysical setting, environmental gradients and/or dynamic processes tends to produce more realistic interpretations of a given landscape, compared to many vegetation classification types. The modular structure of the NatureServe terrestrial ecological systems classification is a result of the core assumption that plant communities tend to co-occur in a given landscape and that the landscape can be characterized by particular combinations of environmental factors, with varying diagnostic classifiers depending upon the geography.

The complex topography, altitudinal and latitudinal gradients of the tropical Andes result in a significant climatic heterogeneity that must be taken into account in a classification of the numerous ecosystems in this region. To this end, Josse et al. (2009a) followed the system of bioclimatic classification developed by Rivas-Martínez et al. (1999), based on comparative analyses of primary data from meteorological stations and the types of vegetation present in a given area. This protocol allowed the homologation of existing classifications for the different countries, as well as grouping the ecosystems at a higher hierarchical level (macro-groups). Floristic composition is another key criterion in this classification approach, thus systems that otherwise share similar vegetation structure, environmental settings, and ecological processes, are distinguished based on their composition.

Classification Results and Discussion

Josse et al. (2009b) mapped 56 macro-groups and 133 ecosystems for the Tropical Andes (Table 10.1; descriptions for each type can be found at:

<http://www.natureserve.org/publications/pubs/EcosistemasAndesNorteYCentro.pdf>. Most of the identified ecosystems have a limited/restricted distribution; for instance, 102 ecosystems have extensions of less than 1 million hectares, and only 31 (23%) present a broad distribution. This asymmetry in the spatial distribution of ecosystems reflects the high level of beta diversity (geographical species turnover) that characterize the Andean region.

Both the Northern Andes and the Bolivian - Tucuman floristic regions encompass the largest number of altitudinal belts in the region, as they span from the lower tropical thermal zone (~700 m) to the cryotropical zone (>4.500 m) in the Northern Andes, and from the tropical thermal zone to the supratropical in the Bolivian-Tucuman region. This explains why these two phytogeographic regions contain the largest number of ecosystems and macrogroups (Table 10.2). The highest number of forest ecosystems (beta diversity) is found in the Bolivian-Tucuman region, and the largest number of non forested ecosystems (grasslands, salt plains, high elevation wetlands) is found in the Xeric Puna and the Moist Puna. These latter two provinces also have several ecosystems with restricted distribution, which explains their high levels of endemism.

The distribution patterns of macro-groups among phytogeographic areas clearly show that both the Xeric Puna and the Moist Puna have the most widely distributed ecosystems in the tropical Andes. This is due, to a large extent, to the vastness of the Altiplano between Peru and Bolivia in the widest portion of the Andean range (450 km in southern Bolivia). The Northern Andes, on the other hand, contain the largest number of macro-groups with less than 2 million hectares, with the exception of the sub-Andean moist forest and the humid montane forest. The famed ecosystem diversity of this phytogeographic region is thus explained by the high turnover of environmental conditions across short distances.

According to Josse et al. (2009a), 78% of the area of the tropical Andes still maintains a natural vegetation cover. The distribution of the areas transformed by human intervention is asymmetrical and highly concentrated in the Northern Andes (Table 10.3), where anthropogenic areas (236,689 km²) surpass natural vegetation (197,635 km²) in extent. However, the identification of “natural” ecosystems in this complex region is still a matter of debate among specialists, remarkably so the classification of the high Andean grasslands in Peru and Bolivia, which in spite of mainly being composed of native species, are cultural landscapes that have

been managed for centuries. The development of new methods using high resolution optical remote sensing data, together with ground-truthing should be seen as a main research priority to overcome this problem and reduce the omission error of classifying degraded puna areas as natural systems.

In spite of the unresolved discussion of which classification system should be used to represent the enormous biodiversity of the tropical Andes at the ecosystem level, this work presents a solid approach to produce an integrated regional ecosystem map for the five Andean countries. The map takes into account the single effort of each country and creates an integrated and coherent map that will be used for conservation planning at the regional level. Further, the presented ecosystem map represents a baseline to produce further climate change vulnerability analyses as well as a reference to develop deforestation analyses and other related research topics in the tropical Andes.

This exercise allowed the analysis of existing information on ecosystems and vegetation at national level. A need was identified to integrate methodological approaches to more accurately represent the current state of ecosystems at a regional scale since maps of the five countries were developed based on information of varying quality, particularly with respect to remnant natural vegetation

Table 10.1a. List of ecological systems by floristic region - **Northern Andes**

Sistema Ecologico	Ecological System
Arbustal montano xerico interandino de los Andes del Norte	Northern Andes inter-Andean montane xeric shrubland
Vegetacion saxicola montana interandina de los Andes del Norte	Northern Andes inter-Andean montane saxicolous vegetation
Arbustal saxicola montano de las cordilleras subandinas orientales	Eastern sub-Andean ridge montane saxicolous shrubland
Arbustal y herbazal sobre mesetas subandinas orientales	Eastern sub-Andean plateau shrubland and grassland
Arbustal montano de los Andes del Norte	Northern Andes montane shrubland
Arbustal montano bajo xerico interandino de los Andes del Norte	Northern Andes inter-Andean lower montane xeric shrubland
Bosque altimontano siempreverde de los Andes del Norte	Northern Andes upper montane evergreen forest
Bosque de <i>Polylepis</i> altimontano pluvial de los Andes del Norte	Northern Andes upper montane <i>Polylepis</i> pluvial forest
Bosques bajos y arbustales altoandinos paramunos	High Andean paramo dwarf shrubland
Bosque altimontano de las cordilleras subandinas orientales	Eastern sub-Andean ridge upper montane forest
Bosque montano bajo pluvial de la cordillera del Condor	Cordillera del Condor lower montane pluvial forest
Bosque montano pluvial de las cordilleras subandinas orientales	Eastern sub-Andean ridge montane pluvial forest
Bosque pluvial sobre mesetas de arenisca de la Cordillera del Condor	Cordillera del Condor sandstone plateau pluvial forest
Bosque montano pluviestacional de los Andes del Norte	Northern Andes montane seasonal evergreen forest
Bosque montano pluvial de los Andes del Norte	Northern Andes montane pluvial forest
Bosque montano bajo pluviestacional subhumedo de los Andes del Norte	Northern Andes lower montane semideciduous forest
Bosque piemontano pluviestacional subhumedo de los Andes del Norte	Northern Andes foothill semideciduous forest
Bosque montano bajo pluvial de los Andes del Norte	Northern Andes lower montane pluvial forest
Bosque montano bajo pluviestacional humedo de los Andes del Norte	Northern Andes lower montane seasonal evergreen forest
Bosque piemontano pluvial de los Andes del Norte	Northern Andes foothill pluvial forest
Bosque montano bajo xerico de los Andes del Norte	Northern Andes lower montane xeric forest
Bosque piemontano xerico de los Andes del Norte	Northern Andes foothill xeric forest
Bofedales altimontanos paramunos	Upper montane paramo bogs
Bofedales altoandinos paramunos (Turberas)	High-Andean paramo bogs
Arbustales bajos y matorrales altoandinos paramunos	High-Andean shrubby paramo
Arbustales y frailejonales altimontanos Paramunos	Upper montane paramo shrublands and frailejonales
Matorral edafoxerofilo en cojin altoandino paramuno	High-Andean paramo cushion vegetation
Pajonal altimontano y montano paramuno	Upper montane and montane paramo grassland
Pajonal arbustivo altimontano paramuno	Upper montane shrubby paramo
Pajonal edafoxerofilo altimontano paramuno	Upper montane subhumid paramo grassland
Sabana arbolada montano baja de los Andes del Norte	Northern Andes lower montane treed savanna
Vegetacion geliturbada y edafoxerofila subnival paramuna	High Andean fell fields

Table 10.1b. List of ecological systems by floristic region - **Bolivian - Tucuman**

Sistema Ecologico	Ecological System
Matorral xerico montano Boliviano-Tucumano	Bolivian-Tucuman montane xeric scrub
Bosque altimontano pluviestacional Boliviano-Tucumano	Bolivian-Tucuman upper montane seasonal evergreen forest
Bosque freatofilo del piso montano xerofitico	Bolivian-Tucuman dry montane riparian forest
Bosque freatofilo subandino interandino Boliviano-Tucumano	Bolivian-Tucuman inter-Andean foothill wash woodland
Bosque ribereño subandino interandino Boliviano-Tucumano	Bolivian-Tucuman inter-Andean foothill riparian forest
Vegetacion ribereña del piso montano xerofitico	Bolivian-Tucuman xeric montane riparian vegetation
Bosque montano Boliviano-Tucumano de Pino de Monte	Bolivian-Tucuman montane Podocarpus forest
Bosque montano subhumedo Boliviano-Tucumano	Bolivian-Tucuman montane semideciduous forest
Bosque subhumedo ribereño montano Boliviano-Tucumano	Bolivian-Tucuman dry montane riparian forest
Bosque humedo montano Boliviano-Tucumano de Aliso	Bolivian-Tucuman montane Alder forest
Bosque montano xerico interandino Boliviano-Tucumano	Bolivian-Tucuman inter-Andean montane xeric forest
Bosque subandino Boliviano-Tucumano de transicion con los Yungas	Transitional sub-Andean Bolivian-Tucuman Yungas forest
Bosque subhumedo Boliviano-Tucumano del subandino inferior	Lower sub-Andean Bolivian-Tucuman semideciduous forest
Bosque subhumedo Boliviano-Tucumano del subandino superior	Upper sub-Andean Bolivian-Tucuman semideciduous forest
Bosques bajos edafoxerofilos montanos y basimontanos Boliviano-Tucumanos	Bolivian-Tucuman montane and lower montane forests
Bosque subandino humedo Boliviano-Tucumano	Sub-Andean Bolivian-Tucuman moist forest
Bosque interandino subandino xerofitico Boliviano-Tucumano	Bolivian-Tucuman inter-Andean foothill xeric forest
Matorral altimontano secundario Boliviano-Tucumano	Bolivian-Tucuman upper montane shrubland
Pajonal altimontano Boliviano-Tucumano	Bolivian-Tucumane upper montane grassland
Matorral pluviestacional montano Boliviano-Tucumano	Bolivian-Tucuman montane dry mesic scrub
Pajonal pluviestacional montano Boliviano-Tucumano	Bolivian-Tucuman montane dry mesic grassland

Table 10.1c. List of ecological systems by floristic region - **Yungas**

Sistema Ecológico	Ecological System
Matorral xerico interandino de Yungas	Yungas inter-Andean xeric scrub
Vegetacion saxicola montana de Yungas	Yungas montane saxicolous vegetation
Bosque altimontano pluvial de Yungas	Yungas upper montane pluvial forest
Bosque altimontano pluviestacional de Yungas	Yungas upper montane seasonal evergreen forest
Bosque de <i>Polylepis</i> altimontano pluvial de Yungas	Yungas upper montane <i>Polylepis</i> pluvial forest
Bosque de <i>Polylepis</i> altimontano pluviestacional de Yungas	Yungas upper montane <i>Polylepis</i> seasonal evergreen forest
Bosque de <i>Polylepis</i> altoandino pluvial de Yungas	High Andean Yungas <i>Polylepis</i> pluvial forest
Bosque montano pluviestacional subhúmedo de Yungas	Yungas montane semideciduous forest
Bosque montano pluvial de Yungas	Yungas montane pluvial forest
Bosque montano pluviestacional humedo de Yungas	Yungas montane seasonal evergreen forest
Bosque y arbustal montano xerico interandino de Yungas	Yungas inter-Andean montane xeric forest and shrubland
Bosque basimontano pluviestacional subhúmedo de Yungas del Norte	Northern Yungas lower montane semideciduous forest
Bosque basimontano pluviestacional subhúmedo de Yungas del Sur	Southern Yungas lower montane semideciduous forest
Bosque bajo de crestas pluviestacional de Yungas	Yungas ridge seasonal evergreen dwarf forest
Bosque basimontano pluviestacional humedo de Yungas	Yungas lower montane seasonal evergreen forest
Bosque y palmar basimontano pluvial de Yungas	Yungas lower montane pluvial (palm dominated) forest
Vegetacion ribereña basimontana de Yungas	Yungas lower montane riparian vegetation
Bosque basimontano xerico de Yungas del sur	Southern Yungas lower montane xeric forest
Bosque y arbustal basimontano xerico de Yungas del Norte	Northern Yungas lower montane xeric forest and shrubland
Complejo submontano seco de Yungas del norte	Northern Yungas lower montane dry vegetation complex
Complejo submontano y montano seco de Yungas del norte	Northern Yungas montane and lower montane dry vegetation complex
Pajonal arbustivo altoandino y altimontano pluviestacional de Yungas	Yungas upper montane dry mesic shrubland and grassland
Pajonal arbustivo altoandino y altimontano pluvial de Yungas	Yungas upper montane pluvial shrubland and grassland
Sabana arbolada montana y basimontana de Yungas	Yungas montane and lower montane treed savanna

Table 10.1d. List of ecological systems by floristic region - **Moist Puna**

Sistema Ecologico	Ecological System
Arbustales montanos xericos interandinos de la Puna Humeda	Moist Puna inter-Andean montane xeric shrubland
Bosques y arbustales montanos xericos interandinos de la Puna Humeda	Moist Puna inter-Andean montane xeric forest and shrubland
Matorrales y herbazales xericos internadinos de la Puna Humeda	Moist Puna inter-Andean xeric steppe
Bosques bajos y arbustales altimontanos de la Puna Humeda	Moist Puna upper montane dwarf forest and shrubland
Bosque bajo altoandino de la Puna Humeda	Moist Puna high Andean dwarf forest
Cardonales deserticos del piedemonte occidental de la Puna Humeda	Moist Puna western foothill succulent desert scrub
Cardonales y matorrales montanos deserticos occidentales de la Puna Humeda	Moist Puna western montane succulent desert scrub
Matorrales deserticos montanos noroccidentales	Puna northwestern montane desert scrub
Rosetales deserticos basimontanos	Pacific desert foothill rosetales
Bofedales altoandinos de la Puna Humeda	Moist Puna high-Andean bogs
Pajonal higrofitico altimontano de la Puna Humeda	Moist Puna upper montane wet meadow
Pajonal higrofitico altoandino de la Puna Humeda	Moist Puna high-Andean wet meadow
Vegetacion acuatica y palustre altoandina de la Puna Humeda	Moist Puna high-Andean marsh and aquatic vegetation
Pajonales y matorrales altimontanos de la Puna Humeda	Moist Puna upper montane grassland and shrubland
Matorral edafoxerofilo en cojin altoandino de la Puna Humeda	Moist Puna high-Andean cushion vegetation
Pajonal altoandino de la Puna Humeda	Moist Puna high-Andean grassland
Vegetacion saxicola altoandina de la Puna Humeda	Moist Puna high-Andean saxicolous vegetation
Vegetacion geliturbada subnival de la Puna Humeda	Moist Puna snow fields

Table 10.1e. List of ecological systems by floristic region - **Xeric Puna**

Sistema Ecologico	Ecological System
Bosque bajo altimontano de la Puna Xerofitica central	Central Xeric Puna upper montane forest
Bosque bajo xerofitico interandino de la Prepuna superior oriental	Eastern Prepuna upper inter-Andean xerophytic low forest
Bosque bajo altoandino de la Puna Xerofitica occidental	High-Andean western Xeric Puna low forest
Bosque bajo altoandino de la Puna Xerofitica oriental	High-Andean eastern Xeric Puna low forest
Cardonal altoandino de la Puna Xerofitica occidental	High-Andean western Xeric Puna succulent scrub
Matorral altimontano de la Puna Xerofitica desertica	Xeric Puna upper montane desert scrub
Cardonales deserticos montanos suroccidentales	Southwestern Xeric Puna montane succulent desert scrub
Matorrales deserticos montanos suroccidentales	Southwestern Xeric Puna montane desert scrub
Bofedales altoandinos de la Puna Xerofitica	High-Andean Xeric Puna bog
Pajonal higrofitico altoandino de la Puna Xerofitica	High-Andean Xeric Puna wet meadow
Vegetacion acuatica y palustre altoandina de la Puna Xerofitica	High-Andean Xeric Puna marsh and aquatic vegetation
Arbustal xerofitico interandino de la Prepuna inferior oriental	Eastern Prepuna lower inter-Andean xerophytic shrubland
Arbustal espinoso altimontano de la Puna Xerofitica	Xeric Puna upper montane thorn scrub
Matorral altimontano de la Puna Xerofitica noroccidental	Northwestern Xeric Puna upper montane scrub
Matorral altimontano y altoandino psamofilo de la Puna Xerofitica	Xeric Puna sand scrub
Matorral higrofilo altoandino de la Puna Xerofitica ("tholares")	High-Andean Xeric Puna hygrophilous scrub (tholares)
Matorrales y herbazales altimontanos y altoandinos de la Puna Xerofitica oriental	Eastern Xeric Puna shrublands and steppe
Pajonales y matorrales altoandinos de la Puna Xerofitica norte	High-Andean northern Xeric Puna grassland and scrub
Pajonales y matorrales altoandinos de la Puna Xerofitica suroccidental	High-Andean southwestern Xeric Puna grassland and scrub
Vegetacion de los salares altoandinos de la Puna Xerofitica	High-Andean Xeric Puna salt pan vegetation
Vegetacion abierta geliturbada altoandina de la Puna Xerofitica septentrional y oriental	High-Andean northeastern Xeric Puna open snow fields
Vegetacion abierta geliturbada altoandina de la Puna Xerofitica suroccidental	High-Andean southwestern Xeric Puna open snow fields
Glaciares	Glaciers

Table 10.1f. List of ecological systems by floristic region - **Transition or adjacent lowland**

Sistema Ecológico	Ecological system
Bosque del piedemonte del oeste de la Amazonia	Western Amazon foothill forest
Bosque del piedemonte del suroeste de la Amazonia	Southwestern Amazon foothill forest
Bosque inundable de la llanura aluvial de rios de aguas blancas del suroeste de Amazonia	Southwestern Amazon whitewater flooded forest
Bosque siempreverde estacional subandino del suroeste de Amazonia	Sub-Andean seasonal evergreen forest of southwestern Amazonia
Bosque siempreverde subandino del oeste de Amazonia	Sub-Andean evergreen forest of western Amazonia
Bosque siempreverde subandino del suroeste de Amazonia	Sub-Andean evergreen forests of southwestern Amazonia
Bosque humedo de tierras bajas y submontano del suroccidente Caribeño	Southwestern Caribbean foothill and lowland moist forest
Bosque transicional preandino del Chaco noroccidental	Sub-Andean transitional forest of the Northwest Chaco
Bosques freatofíticos del Chaco (Algarrobales)	Chaco hygrophilous forests (ground water Algarrobales)
Bosque subhumedo semideciduo de la Chiquitania sobre suelos bien drenados	Chiquitano semideciduous forest on well-drained soils
Bosque pluvial premontano del Choco-Darien	Sub-Andean Choco-Darien rain forest
Bosque transicional preandino de los Llanos del Orinoco	Sub-Andean transitional forest of the Llanos del Orinoco
Bosque Tumbesino deciduo de tierras bajas	Tumbesian lowland deciduous forest
Bosque Tumbesino deciduo espinoso	Tumbesian deciduous thorn forest
Bosque Tumbesino deciduo premontano	Tumbesian premontane deciduous forest

Table 10.2. Ecosystems, macro-groups and floristic regions included in the map of the Northern and Central Andes (Josse et al. 2009b).

Floristic region	Ecosystems	Macro-groups
Northern Andes	32	15
Yungas	22	11
Moist Puna	18	8
Xeric Puna	19	8
Bolivian-Tucumano	22	11
Total	113	53

Table 10.3. Extent of natural and anthropogenic areas in the Northern and Central Andes (Josse et al. 2009b).

Region	Anthropogenic Areas (km ²)	Natural Vegetation (km ²)
Northern Andes	236,689	197,635
Central Andes	96,733	983,492
Total	333,422	1,181,127

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