ECOLOGICAL SYSTEMS

of the Amazon Basin of Peru and Bolivia

Clasification and Mapping

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Josse, C., G. Navarro, F. Encarnación, A. Tovar, P. Comer, W. Ferreira, F. Rodríguez, J. Saito, J. Sanjurjo, J. Dyson, E. Rubin de Celis, R. Zárate, J. Chang, M. Ahuite, C. Vargas, F. Paredes, W. Castro, J. Maco y F. Reátegui

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NatureServe is a non-profit organization dedicated to providing the scientific basis for effective conservation action.

The Instituto de Investigaciones de la Amazonía Peruana is an autonomous governmental entity, based in the Amazon Basin of Peru. Its mission is to support the betterment of the local communities' quality of life by dedicating research to sustainable development and conservation of the natural resources in the Amazon region.

The Conservation Data Center in the Facultad de Ciencias Forestales of the Universidad Nacional Agraria la Molina is an information management unity of the biological and ecological information of Peru. The unity keeps records of fauna and flora species as well as diminishing terrestrial and marine environments.

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Selva central, Peru. Jennifer Swenson

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Background and Objectives

NatureServe's experience in the development of ecological and vegetation classifications responds to the fact that natural vegetation communities are an important element of biodiversity in natural heritage methodology. Characteristics of natural communities such as richness, endemism, rarity and conservation status among others can be reported in order to better understand the condition of biodiversity in a particular location.

On the other hand, given the emphasis recently provided by the Convention on Biological Diversity to the ecosystem approach, planning for the conservation and sustainable use of natural resources requires maps of ecosystems that apply a unified classification with consistent criteria across political boundaries. These maps should provide a degree of conceptual and spatial resolution representative of the enormous biological and ecosystematic diversity of the Neotropics, in this particular case.

In 2001, we started to develop a scheme for the classification of ecological systems (see Section 1.1). This classification considers these circumstances and addresses the need to develop a standard classification unit for the whole continent that will facilitate mapping applications with an intermediate scale. Since we odeveloped a preliminary version with definitions for 750 terrestrial ecological systems in Latin America and the Caribbean, the classification has been applied in the production of ecosystems maps for several ecoregions and ecoregional compounds in Central and South America and the Caribbean.

These applications have not only made it possible to refine the classification, but also to improve the mapping aspect, adapting it to the resources available in each case. Studies that use ecoregions as the geographical context for spatial analysis and planning have become common in the last few years and, due to its finer grain, the standardized classification of ecological systems can play an important role in these regional studies to determine aspects such as the state of conservation of an ecosystem throughout its distribution range. Since ecological systems units are defined placing an emphasis on environmental characteristics and dynamic processes, they are ideal to evaluate the state and evolution of various ecological phenomena, from trends in the change of land use and natural habitats to the creation of repeatable metrics for landscape fragmentation.

When we started developing the proposal for the project "Mapping of Ecological Systems and Areas of Endemism for the Conservation of the Amazon Basin in Peru and Bolivia", we decided we would use the distribution of endemic species and ecological systems as the main information to determine conservation gaps in the study area. This area comprises the Eastern foothills of the Andes and the adjacent Amazon plains of Peru and Bolivia. With regards to the vegetation cover in the region, other mapping processes highly compatible with our approach were under way and we decided to integrate them into our proposal with the purpose of developing a unified classification and map for the whole study area.

As a result, we set ourselves the goal of mapping the 84 ecological systems identified in the study area using a scale of 1:250.000, with the participation of the Conservation Data Center / Universidad Nacional Agraria La Molina (CDC-UNALM), Instituto de Investigaciones de la Amazonía Peruana (IIAP) in Peru, and the team of Gonzalo Navarro and Wanderley Ferreira in Bolivia. Each system is represented with a brief description and picture in Appendix 1.

In addition to analyzing the gaps or identifying priority areas, there are several objectives involved in the development of a map with a standardized classification of ecological systems:

- Promoting the use of information on ecological systems in regional planning processes.
- Identifying rare or vulnerable ecological systems through spatial analysis.
- Researching species-habitat relationships, both in animal and vegetation species.
- Contributing to the understanding of actual and potential vegetation cover to facilitate ecological restoration processes and the adequate interpretation of the natural vegetation potentiality of each territory.
- Implementing monitoring and evaluation programs of the ecological integrity.

Throughout Latin America national vegetation maps have been prepared using different criteria, scales and degrees of precision and field validation. Thus, preventing the implementation of applications needed for biodiversity conservation and management of natural resources. In response to this, NatureServe is committed to create a standardized map throughout the continent.

Study area

The study area comprises the hydrographic basin of the Amazon River in Peru and Bolivia, from the headwaters of affluent rivers in the eastern slope of the Andes to the northern and eastern political boundaries of each country. The altitudinal limit of the continuous tree line located at approximately 3.500 m was used in this geographical space as the specific criteria to delimit the area to the west. One of the main reasons to avoid the using of the water divide to delimit the study area was to avoid from including vegetation communities and endemic species representative of the Puna region, whose distribution range extends considerably towards the west of the water divide.

The purpose of this project was to develop distribution maps of endemic species and ecological systems for one of the planet's most diverse regions: the eastern slopes of the Tropical Andes and the adjacent Amazonian forest. Since the publication of "Terrestrial Ecoregions of Latin American and the Caribbean" (Dinerstein et al. 1995), the Andean portion of the study area has been generally known as the Yungas, a usage that has considerably simplified a definition of a more complex origin, and its northern boundary roughly corresponds with the course of the Maranon River. It was initially considered to use this river as the northwestern boundary of the study area, with the purpose of including only complete biogeographical regions in the project. The area north of the Marañon River is characterized by the subhumid and xeric systems of the Marañon and Chamaya valleys which, thanks to a decline in the Andes mountain range in the area bordering the Huancabamba Depression (2145 a.s.l.), comprise distributions both to the north and south of this milestone, with clear biogeographical relations to dry ecosystems present in the western slope of the mountain range (Weigend 2002, Duellman 1979 en Weigend 2002). In spite of recognizing that a biogeographically different region would be partially included (Amotape-Huancabamba), we finally decided to take the northern border of the ecological systems map all the way to the political boundary with Ecuador. However, from the endemism study's standpoint, it was decided to exclude species representative of this biogeographical area to focus this component of the project in the complex region of rainforests of the eastern slope or Yungas. In this context, the Bolivian Yungas are included, establishing the southern boundary of the map's Andean area, approximately at latitude 18º south, in the "Codo de Santa Cruz". At this point, in addition to a change in the orientation of the mountain range to north south, there is also the limit between two biogeographical provinces, Yungas and Tucumano-Bolivian (Navarro and Maldonado 2002) with the consequent changes in the biocenosis.

A similar situation regarding the northwestern extreme takes place in the southeastern extreme of the study area, because of the gradual transition of Amazon forests towards seasonally dry forests of the biogeographic province of Bolivian Chiquitania and Brazilian Cerrado. Although the Bolivian Chiquitania is part of the Amazon basin, it was decided to exclude it from the study due to biogeographical reasons.

The Amazon savannahs in Bolivia and southern Peru were included in the study area, since they are part of the Heath, Beni, Mamoré and Guaporé rivers' basins, which occupy a great proportion of the hydrographic basin of the Amazon River in Bolivia.

The study area comprises 1.249.281 km^2 (Fig. 1) where 84 different ecological systems have been identified. This ecosystem richness can be attributed to the vast latitudinal gradient and the diversity of ecological habitats included in this geography, such as: Andean rainy and cloudy mountainsides, inter-Andean xeric valleys, sedimentary mesas and Sub-Andean hills, the Amazon peneplains with its alluvial flood plains, rocky outcrops of diverse origin and the complex mosaic of well drained, flood savannahs and gallery forests, typical of the enormous alluvial plains of the Mamoré and Beni rivers basin.

Together these environments cover most tropical bioclimates and occur on the most varied geomorphologies and geologies. Some of the most outstanding characteristics of this area of the Andes and the Amazon are worth emphasizing within this context.

Andes

Here your attention will be drawn to the strong northwest-southeast trend and its close relation to a Sub-Andean mountain range rising east in a discontinuous manner, causing major rivers that flow from the eastern mountain range not to take a typical eastward trend. Instead they make a detour to the north, forming vast valleys parallel to the mountain range orientation before flowing to the Amazon. In addition, the relatively low elevation of this Sub-Andean mountain range causes the eastern most peaks to have very particular habitats where species and ecosystems typical of the Andes and Amazon create a mosaic where alluvial valleys of meandric rivers at 1000 m elevation are surrounded by mountain ranges covered by cloud forests.

This physiography also has an important influence in the climate, location and extension of dry valleys. The rain shadow effect resulting from the interaction between wind circulation patterns and topography has been the most widely accepted and used explanation to justify the presence of dry valleys. However, the presence of xeric habitats in the beds of deep canyons seems to be explained by a different phenomenon involving the interaction of topography with the daily sun warming cycle (Killeen et al., in press).

Finally, another characteristic is the extreme slope of the mountainside, with altitudinal changes of three or four thousand meters in horizontal distances of 50 or 100 km.

Amazon

The study area includes three large Amazon units or biogeographical provinces: Western Amazon, Southwestern Amazon and South Central Amazon. This division in zones has been recognized and described in their areas by different authors (Ducke & Black 1953, Rizzini 1963, Hueck 1966, Prance 1973, 1977, Rivas Martínez & Navarro 1994). These zones are mainly associated with the progressively seasonal weather that comes from Pucallpa, Peru, to the south and central south and a water deficit for most of the year in the plains, not necessarily in the Andean piedmont. In addition to the climatic aspect, differences between the western and southwestern sector of the Amazon in Peru are expressed in the extension of the flood plains, bigger in the north (Western Amazon) than in the south. The plains also have different ebb and flood periods due to the influence of the precipitation regimes, which are different in the north and south.Other landscape elements that differentiate the two regions are the Andes mountain range and its predominance of high hills and low mountains in the western edge. The low hills, plains and terraces with diverse drainage capacity define the eastern landscape. An additional effect of the Andes rising is the diversity of sediments corresponding to different deposition environments, ranging from deposits with marine influence prior to the rising to fluvial and lake deposits.

Finally, the Bolivian Amazon constitutes the southern extreme of the Amazon region, thus having the biogeographic character of transition towards the Cerrado and Chiquitania provinces, characterized by the rising of the Precambric Shield already present in northeastern Bolivia near the Brazilian border.

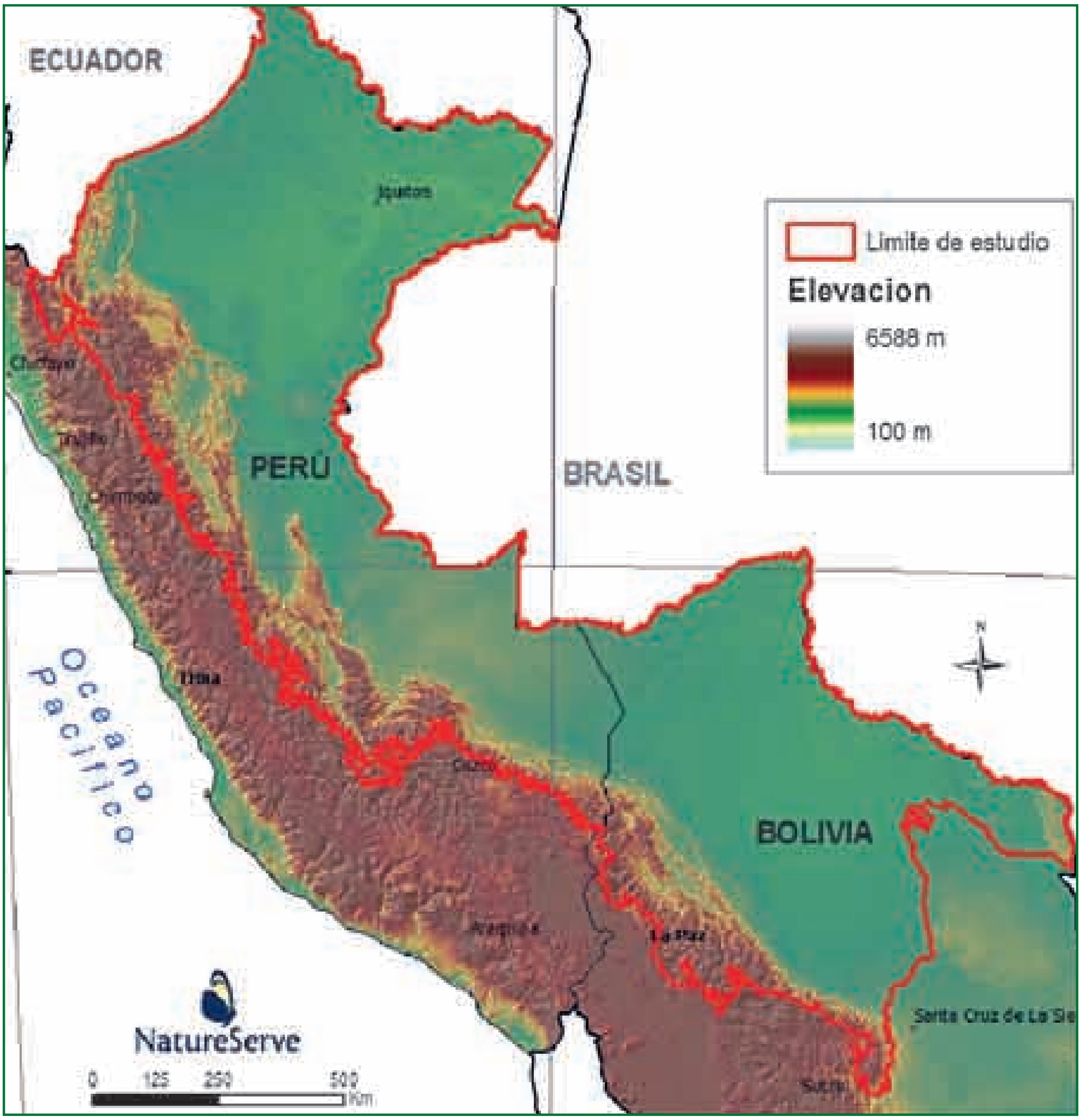
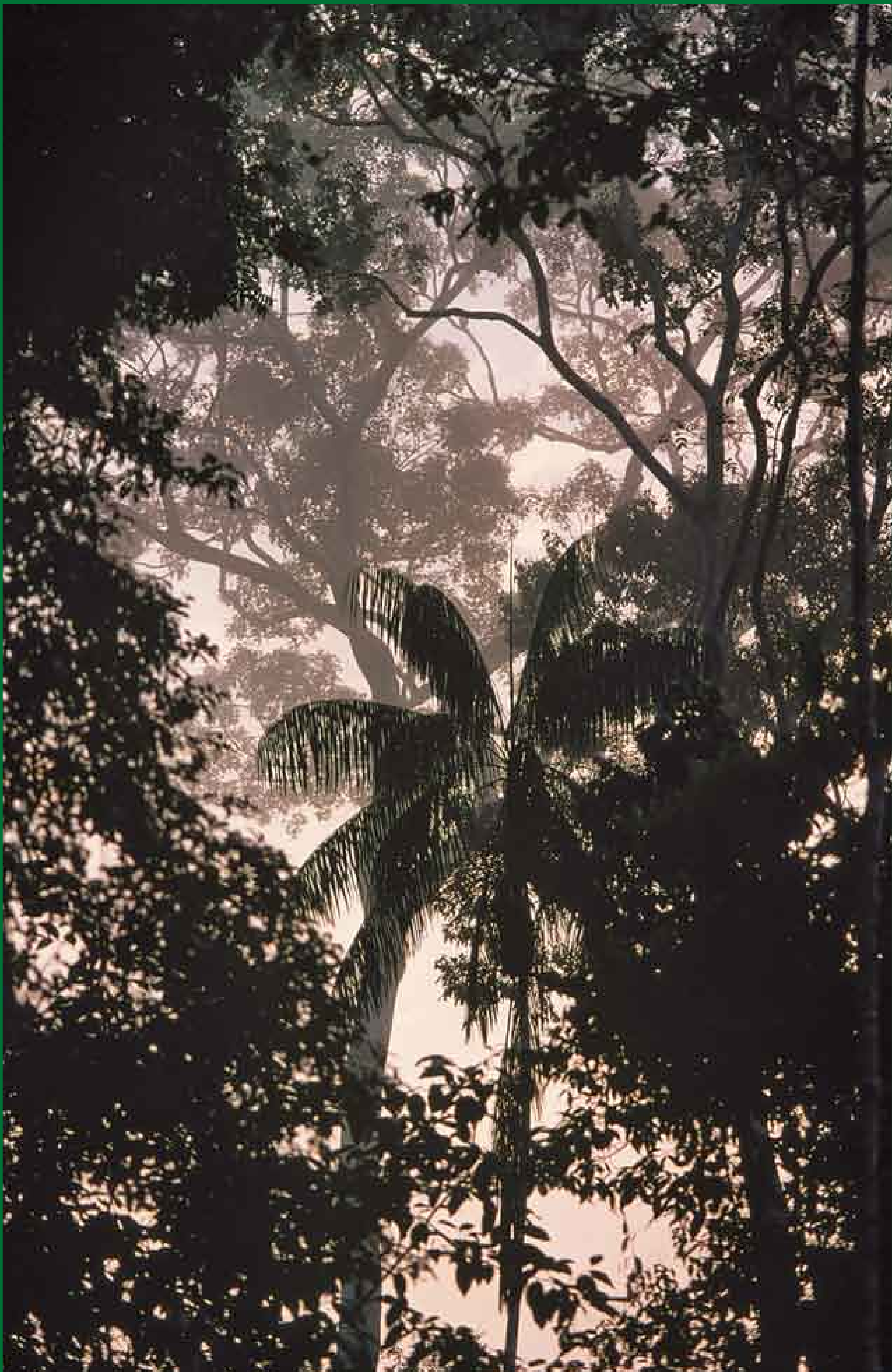


Figure 1. Ecological Systems Map study area of the Project Ecological Systems and Endemic Species Mapping to Support Conservation Planning of the Upper Basin of the Amazon River in Peru and Bolivia.



National Park Manu, Madre de Dios. Walter H. Wust

1. Conceptual and methodological framework

1.1. THE CLASSIFICATION SYSTEM

The experience acquired in the North American vegetation mapping helped NatureServe understand that the best way to represent the diversity of vegetation communities at medium scales is through the combination of physical habitat and vegetation physiognomy parameters. In a like manner, we learned that the group of criteria that best discriminate communities would vary depending on the landscape. Thus, for example, in a montane area altitudinal belts and bioclimate are determining criteria, while topography, hydrography and flooding dynamics are the factors determining the distribution of communities in an alluvial plain. This might seem obvious, but often times classification schemes are quite rigid in the use of a group of criteria, in order to preserve consistency. Based on this experience, NatureServe developed the International Terrestrial Ecological System Classification.

Terrestrial ecological systems are defined as groups of vegetation communities that tend to co-occur in the landscape because of their relation with common and determinant factors, such as ecological processes, substrates and/or environmental gradients. A given terrestrial ecological system will typically manifest itself in a landscape at intermediate geographic scales of dozens to thousands of hectares and persist for 50 or more years. This temporal scale allows the incorporation of the typical succession dynamics to each unit's concept. With these temporal and spatial scales delimiting the concept of ecological systems, we then integrate multiple ecological factors –or diagnostic parameters- to define each unit. These multiple ecological factors are evaluated and combined in different ways to explain vegetation spatial patterns.

On the other hand, when creating units that will constitute elements for conservation planning, our purpose is for these units to represent different suites of species in the best way possible. This is the reason why the floristic composition also plays a determining role in our approach. Considering the great diversity of species in the Neotropic and the relative lack of systematized floristic information, we use the different phytogeographic classifications existing at floristic region and province scale (Udvardy 1975, Prance 1977, Cabrera y Willink 1980, Takhtajan 1986, Rizzini 1997, Rivas Martínez y Navarro 1994, Rivas Martínez 2000) to separate systems that otherwise share the same type of landscape, physical habitat and ecological processes.

Another goal of the ecological systems classification is to capture the effect of ecological processes. This is why communities constantly alternating between early to midsuccessional stages due to seasonal flooding, constitute a system different to that formed by mature forests that, despite having some degree of seasonal flood have a different disturbance regime due to topography and distance from the river.

Another factor of this approach is the spatial pattern. In our classification, a system constituting the matrix, extending over square kilometers, has the same place as another with a very restricted distribution resulting from the localized outcrop of a substrate, which determines the presence of a very particular community.

Finally, the classification of ecological systems is based on the actual and not the potential vegetation coverage. With respect to the process, the classification was developed by using the whole continent as the physical framework for the selection of spatial stratification criteria, such as bioclimate, geoforms, geomorphology, hydrogeomorphology, combined with phytogeographic units as a way to represent the biotic component with its floristic discontinuities. These criteria were used at different levels of spatial resolution, obtaining a more general first level of units, which we called Ecological Divisions (Fig. 2). They provided a more manageable spatial context to identify and apply the group of criteria or parameters that would best explain the distribution of natural communities at a higher spatial resolution.

Vegetation plays a preponderant two fold role in this approach: on one hand its physiognomic or structural expression is captured by remote sensors that are the source of information necessary for the mapping of large areas. On the other hand it reflects the biological response to different ecological processes and environmental characteristics present in a specific site.

This classification was carried out with the contribution of numerous vegetation experts, using hundreds of bibliographic and cartographic references that allowed for the identification and description of 758 classes of

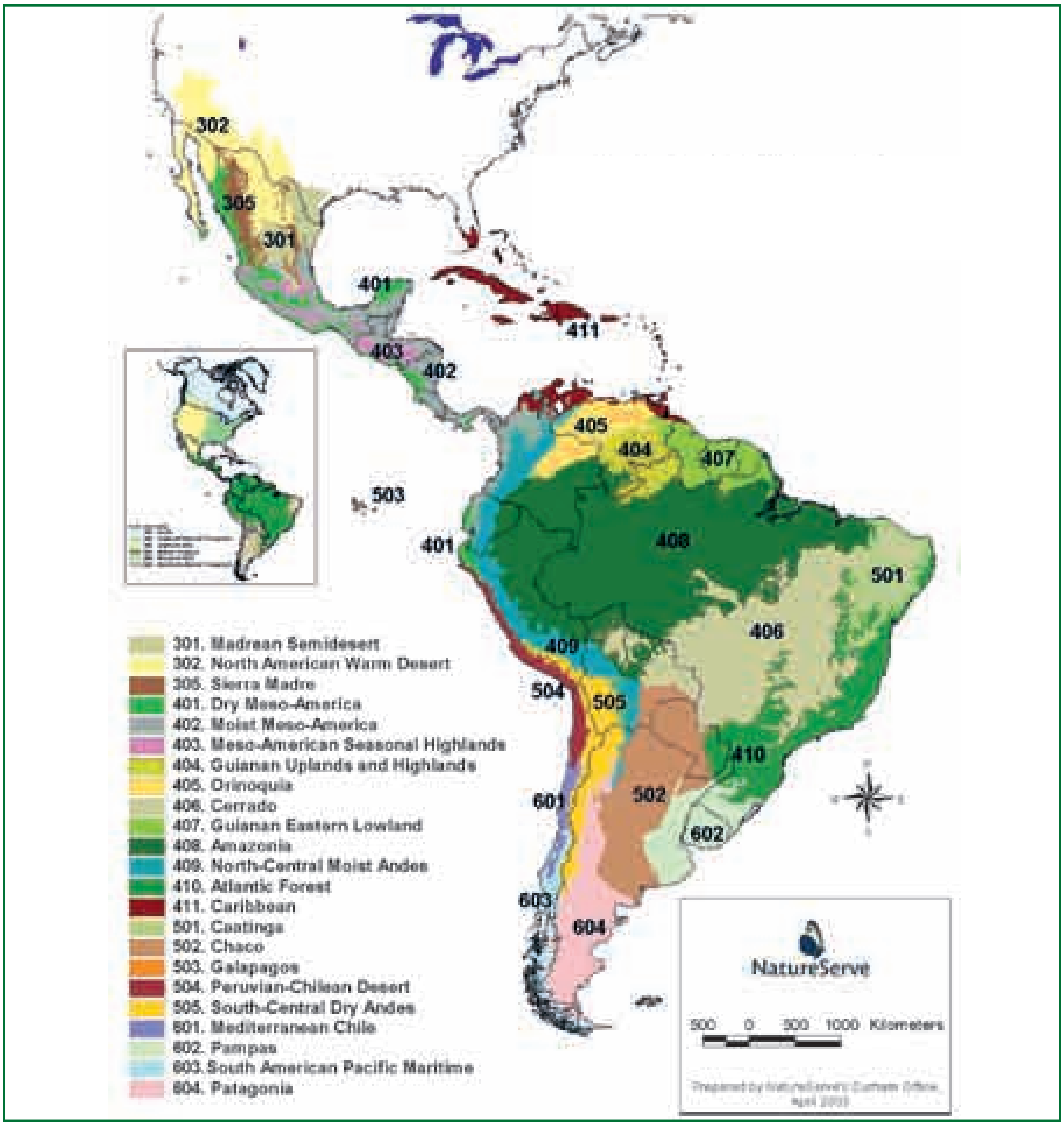


Figure 2. Map of Ecological Division of Latin America and the Caribbean.

ecological systems from Mexico to Tierra del Fuego (Josse *et al.* 2003). This classification is always under review, being refined and enriched with each mapping exercise that takes place, generally at ecoregional and multinational scales.

The legend of the Amazon basin of Peru and Bolivia represented on the ecological systems map (Table 1 and Appendix 1) is the result of refining the list of ecological systems identified for this region as part of the classification developed for the whole hemisphere. This adjustment implied the creation of some new classes, elimination of others and refinement of concepts. Thanks to consistent application of established criteria and the conceptual framework adopted for the classification, the final list of ecological systems for the project's region, along with their respective descriptions, is part of the terrestrial ecological systems classification of Latin America and the Caribbean.

The spatial representation of this *a priori* classification constitutes a relatively independent process where the most appropriate means to delimit the identified units are sought. Depending on the spatial scale chosen and the spatial information available, this process could originate legend adjustments, in the sense that there are systems that cannot be represented or there is the need to map complexes, since physical conditions in determined areas of the landscape create mosaics of natural systems impossible to separate. This has been the case for most of the Beni savannahs, and the Amazon riparian systems.

1.2 OTHER CLASSIFICATION APPROACHES AND THEIR COMPATIBILITY

Among international classification systems applied in Latin America that have resulted in vegetation cover maps, the most important are: the classification of Holdridge life zones based on bioclimatic parameters, the UNESCO physiognomic-ecological classification (1973) and the Hueck and Seibert vegetation map (1988). The first is a potential vegetation classification scheme based on the effects of precipitation, temperature and evapotranspiration on the vegetation (Holdridge, 1967) that was applied by J. Tosi to develop the Ecological Map of Peru, originally published using a 1:1.000.000 scale (Tosi, 1957). A map using this scheme was also published for Bolivia (Unzueta, 1975).

The South American UNESCO map was published in 1981 at a 1:5.000.000 scale and is based on the International Classification and Cartography system proposed by UNESCO (1973). Aside from the map published by UNESCO, this classification system has been used, with some adaptations or just as reference, for diverse vegetation cover maps, since the vegetation's structure and phenology criteria it uses are convenient to interpret remote sensors images.

The South America map by Hueck and Seibert (1988) was published at a 1:8.000.000 and its legend is a combination of vegetation formations with a regionalization based on phytogeographic patterns that, considering technical resources and knowledge as of date, constitutes an admirable synthesis.

There are also some digital land coverage maps recently produced by diverse groups of researchers, at very coarse spatial resolutions according to the use purpose of this information. The vegetation map of South America created by the Joint Research Centre (Eva *et al.* 2002) stands out among them for having a detailed legend considering the 1km spatial resolution in which the map was produced.

Peru

There are two official maps of vegetation coverage for the complete national territory: the Ecological Map of Peru (ONERN, 1976) and the Forest Map (INRENA, 1995). The first one applies the Holdridge (1967) classification scheme of potential vegetation or life zones based on rainfall, temperature and evotranspiration effects on vegetation. The forest map classifies vegetation formations based on an ad-hoc system that incorporates climatic, physiognomic, physiographic and floristic elements applied when interpreting Landsat images.

Vegetation formations identified in the Forest Map can, in general terms, have a certain degree of correspondence with ecological systems, but not a specific correspondence, due to the conceptual and spatial resolution, much coarser in the case of the forest map.

In addition to these two national maps, there were maps of the two regions included in this project, the Andes and the Amazon lowlands. The Andean region was covered by ecological systems maps developed within the framework of two Ecoregional Conservation Planning's projects, sponsored by the Nature Conservancy; one for the Ecoregion of the Eastern Cordillera Real Oriental, carried out by the Ecuadorian Foundation of Ecological Studies (EcoCiencia), comprising a relatively small extension of the Peruvian territory north of the Maranon river. The second one corresponds to the map of terrestrial ecological systems of the Peruvian Yungas, executed by the Conservation Data Center (CDC–UNALM). Both maps have been improved within the context of the present project, thanks to field samples taken for validation and adjustment of the bioclimatic map used as a resource.

With regards to the Amazon lowlands, the Instituto de Investigaciones de la Amazonía Peruana (IIAP) had been working on the preparation of a mosaic of Landsat TM images (BIODAMAZ, 2004), which was visually interpreted in terms of the 19 types of natural vegetation identified and described by F. Encarnación for the Peruvian Amazon (BIODAMAZ, 2004b). Even though it is not a map, it was an important input in the preparation of the ecological systems map, both because the use of the mosaic and the contribution vegetation types described by Encarnación (BIODAMAZ, 2004b) meant for the classification of ecological systems as well.

Bolivia

There are also forest maps at national level in Bolivia, and similar to Peru, the applied classification is ad-hoc and is adjusted to the use purposes of these products, which means that conceptual resolution of the classes is quite coarse.

A map of the Bolivian vegetation was published in 1994 (Ribera *et al.* 1994), and ever since, other approximations for the classification of ecological units or ecoregions have been produced, which correspond to exercises of ecological regionalization of the national territory, more than land cover or vegetation maps in the formal sense.

A new vegetation map of Bolivia is about to be published, at a 1:250.000 scale, where the mapping unit is the vegetation community (vegetation series). This unit has a higher conceptual resolution than ecological systems, but starts from a very similar approach and thus, its correspondence with the classification of ecological systems is attained from the grouping of vegetation series units. G. Navarro and W. Ferreira have prepared this map, with the support of The Nature Conservancy and NatureServe. Existing inputs that have facilitated the preparation of this map are next mentioned and they constitute products of prior consulting, carried out in protected areas or project intervention areas.

- Vegetation map of the Amboró/Madidi Corridor (WWF-CISTEL), covering all the Yungas area and the southernmost area of the Beni
- Vegetation map of the Pando department (WWF-HERENCIA)
- Vegetation map of the Amboró National Park (FAN-WCS)
- Vegetation map of the northern area of the Isiboro Secure National Park, Beni (CIDDEBENI)

Table 1. Groups of ecological systems and their distribution in the study area.

UPLAND VEGETATION		
1. Andean moist forests		
CES409.920	High-Andean Polylepis pluvial forest of the Yungas	Pe, Bo
CES409.043	Upper montane pluvial forest of the Yungas	Pe, Bo
CES409.044	Upper montane pluviseasonal forest of the Yungas	Pe, Bo
CES409.045	Upper montane pluvial Polylepis forest of the Yungas	Pe, Bo
CES409.046	Upper montane pluviseasonal Polylepis forest of the Yungas	Pe, Bo
CES409.105	Northern Andes upper montane evergreen forest	Pe
CES409.050	Montane pluvial forest of the Yungas	Pe, Bo
CES409.110	Northern Andes montane pluvial forest	Pe
CES409.913	Montane pluvial forest of the Condor Mountain Range	Pe
CES409.051	Montane humid pluviseasonal forest of the Yungas	Pe, Bo
CES409.197	Boliviano-Tucumane montane Podocarpus forest	Bo
CES409.903	Lower montane pluvial forest of the Condor Mountain Range	Pe
CES409.054	Lower montane humid pluviseasonal forest of the Yungas	Pe, Bo
CES409.048	Lower montane pluvial forest and palm grove of the Yungas	Pe, Bo
2. Amazonian moist forests		
CES408.565	Western Amazon subandean evergreen forest	Pe
CES408.572	Western Amazon piedmont forest	Pe
CES408.543	Southwestern Amazon subandean evergreen forest	Pe, Bo
CES408.545	Southwestern Amazon subandean evergreen seasonal forest	Pe, Bo
CES408.570	Southwestern Amazon piedmont forest	Pe, Bo
CES408.523	Western Amazon evergreen forest of the peneplain	Pe
CES408.548	Western Amazon isolated ridges forest	Pe
CES408.544	Southwestern Amazon evergreen seasonal forest of the peneplain	Pe, Bo
CES408.549	Southwestern Amazon Bamboo forest	Pe, Bo
CES408.518	Central-south Amazon Palm dominated forest	Bo
CES408.566	Central-south Amazon isolated ridges forest	Bo
CES406.235	Chiquitanian precambrian shield evergreen seasonal Amazonian forest	Bo
3. Andean dry forests and xeric scrub		
CES409.921	Montane subhumid pluviseasonal forest of the Yungas	Pe, Bo
CES409.075	Montane interandean xeric forest and shrubland of the Yungas	Pe, Bo

Bo = Bolivia; Pe = Peru

CES409.057	Interandean xeric scrub of the Yungas	Pe
CES409.117	Lower montane subhumid pluviseasonal forest of the northern Yungas	Pe
CES409.053	Low montane subhumid pluviseasonal forest of the southern Yungas	Pe, Bo
CES409.207	Low montane subhumid pluviseasonal forest of Bolivia-Tucuman	Bo
CES409.079	Lower montane xeric forest and shrubland of the northern Yungas	Pe
CES409.056	Lower montane xeric forest of the southern Yungas	Pe, Bo
4. Chiquitano dry forests		
CES406.238	Chiquitania and Beni semideciduous subhumid forest	Bo
CES406.240	Chiquitania and Beni "Cerradão"	Bo
5. Andean azonal vegetation (edaphically conditioned)		
CES409.912	Upper montane lithomorphic shrubland of the Condor Mountain Range	Pe
CES409.914	Pluvial forest on plateaus of the Condor Mountain Range	Pe
CES409.039	Shrubland and meadows on eastern subandean plateaus	Pe
CES409.049	Yungas ridge pluviseasonal forest	Pe, Bo
CES409.067	Montane lithomorphic vegetation of the Yungas	Pe, Bo
CES409.195	Boliviano-Tucumano low edaphoxerophilous forest	Bo
6. Amazonian azonal vegetation (edaphically conditioned)		
CES408.546	Western Amazon semideciduous azonal forest	Pe
CES408.562	Western Amazon white-sand sclerophyllous vegetation	Pe
CES408.554	Central-south Amazon ridges lithomorphic scrub	Bo
CES408.557	Savannah of the central-south Amazon transitional to the Cerrado	Bo
7. Andean grassland and shrubland		
CES409.063	High-Andean and high-montane aquatic and palustrine vegetation of the Yungas	Pe, Bo
CES409.123	Upper montane and montane paramo grassland	Pe
CES409.124	Upper montane paramo grassland and shrubland	Pe
CES409.058	High-Andean and upper montane pluvial grassland and shrubland of the Yungas	Pe, Bo
CES409.059	High-Andean and upper montane pluviseasonal grassland and shrubland of the Yungas	Pe, Bo
CES409.062	Yungas montane and lower montane savanna	Pe, Bo
AMAZONIAN WETLANDS		
8. White water floodplain forests		
CES409.047	Montane and upper montane riparian vegetation of the Yungas	Pe, Bo
CES409.065	Lower montane riparian vegetation of the Yungas	Pe, Bo
CES409.061	Subandean palm swamp of the Yungas	Pe
CES408.532	Western Amazon white-water floodplain forest the	Pe
CES408.531	Southwestern Amazon white-water floodplain forest	Pe, Bo
CES408.578	Southwestern Amazon stagnant white-water flooded forest	Pe, Bo
CES408.550	Amazon white-water riparian successional vegetation complex	Pe, Bo
Co02 Amazon	Amazon white-water successional flooded forest complex	Pe, Bo
Co05 Beni	Beni white-water riparian forests and vegetation complex	Bo
9. Black water floodplain forests		
CES408.536	Western Amazon black-water floodplain forest and riparian vegetation	Pe
CES408.535	Southwestern Amazon black-water floodplain forest and riparian vegetation	Pe, Bo
CES408.538	Western Amazon alluvial plains palm swamp	Pe
CES408.573	Southern Amazon alluvial plains palm swamp	Pe, Bo
CES408.526	Southern Amazon stagnant black-water alluvial forest	Pe, Bo
CES408.574	Central-south Amazon black-water floodplain forest	Bo
CES408.576	Southern Amazon upland depression forest	Bo
Co08 Beni	Beni clear and dark-water riparian forests and vegetation complex	Bo

Bo = Bolivia; Pe = Peru

10. Amazonian clear water floodplain forests		
CES408.528	Southwestern Amazon clear-water stream forest	Pe, Bo
CES408.567	Central-south Amazon clear-water stream forest	Bo
11. White or black water flooded vegetation		
CES408.569	Western Amazon alluvial plains swamp forest	Pe
CES408.571	Amazon mixed-water flooded forest and riparian vegetation	Pe, Bo
CES408.560	Upper Amazon treed savannas on wet soils	Pe, Bo
CES408.552	Upper Amazon alluvial plains marsh	Pe, Bo
Co01 Amazon	South Amazon savanna complex	Pe, Bo
Co07 Beni	Beni mixed-water riparian vegetation and forests complex	Bo
WETLANDS OF THE BENI (BOLIVIA)		
12. Beni seasonally saturated vegetation		
CES406.225	Western Beni seasonally flooded thorn forest of the alkaline flatlands	
CES406.241	Cerrado and Beni saturated “Cerradão” of the non-alkaline flatlands	
CES406.245	Beni seasonally flooded palm grove and savanna of the alkaline flatlands	
CES406.246	Cerrado hydrophytic savannah with termite mounds	
CES406.248	Beni and Chiquitania open hydrophytic savanna	
Co01 Beni	Complex of non-alkaline savannas of the Beni transitional to the Cerrado	
Co02 Beni	Complex of non-alkaline savannas of the Beni	
Co06 Beni	Cerrado complex of the northern Beni	
13. Beni seasonally flooded vegetation		
CES406.226	Beni gallery forest	
CES406.249	Beni seasonally flooded herbaceous mesotrophic savanna	
CES406.250	Chiquitania and Beni seasonally flooded herbaceous oligotrophic savanna	
Co03 Beni	Beni white-water floodplain savanna complex	
14. Beni permanently flooded vegetation		
CES406.251	Beni wet savanna	
CES406.253	Chiquitania and Beni aquatic and palustrine neotropical vegetation	
Co04 Beni	Beni swamp complex	

Bo = Bolivia; Pe = Peru

1.3 METHODOLOGY FOR THE MAPPING OF ECOLOGICAL SYSTEMS

The study area was divided into three regions. Each partner was responsible for one of these regions. CDC-UNALM was in charge of the Peruvian Yungas, IIAP for the Peruvian Amazon and G. Navarro and W. Ferreira, consultants residing in Cochabamba, were in charge of the Bolivian Yungas and the lowlands, including the Amazon and Beni savannahs. The previous sections have explained the classification of ecological systems applied in this study. Several meetings were held with the three mapping teams to guarantee that the concept of each class identified according to this classification was interpreted in the same way, since the same classes could occur in different regions.

Given the extension of the study area, we decided to use, whenever possible, existing information developed at the regional or ecoregional level, described in the previous section. Although the maps were used as starting point, they were all improved and thoroughly modified in some cases, to adjust to the classification requirements and spatial resolution of this project. The ecological systems map for the Beni savannahs in Bolivia was developed from scratch and os the first to cover the region in detail.

1.3.1 Common aspects

In addition to the applied classification, other aspect shared by the maps of the three regions in their genesis is the fact that all of them were based on the visual interpretation of the coverage from individual and mosaic Landsat TM and ETM+ satellite images. The mosaics and/or indivdual scenes were georeferenced to UTM coordinates, zone 18, 19 and 20 depending on their location, datum and spheroid WGS 84.

Other common methodological elements are: field data for validation, cartographic standards adopted for projection and minimum mapping unit, and the treatment of anthropogenic areas and areas with secondary vegetation.

The methodology used for field sampling for the development of the map and evaluation of the final product was agreed upon with the participation of the three teams. Parameters and ranges for sample taking were defined for this purpose, and consigned in the form (see Appendix 2). These samples should be used to describe the sample point as a representative place for a homogenous environment of a radius of at least one hectare. Quantitative analysis were not contemplated and thus, no plot shape or size was established to carry out inventories. However, the three teams took data by using some variable plot shape and area, depending on the vegetation type, and structure and homogeneity characteristics. Part of the field sampling procedure was based on linking the relationship between an ecological system class and the sample at the moment in which the sample was being analyzed in the field. However, not always this procedure was followed. In some cases, we needed taxonomic identification of botanic collection to distinguish to which system the sample pertained.

As part of the methodology for field sampling , the sampling design was carried out through the SPOT (Spatial Optimization Tool) program, which suggests areas with the highest representation of systems to be sampled based on diverse criteria, such as: ease of access, communication ways, anthropogenic activities, sensitive areas, ecological systems area.

The area under study was subdivided into several sampling areas under the responsibility of different teams. The SPOT results were used to identify ecological systems to be sampled for each zone, as well as the number of samples to be taken (Fig. 3).

As seen on the graphic example (Fig. 3), the number of points selected is high and they can be frequently located in areas with difficult access. Thus, this tool and the results it generated finally served as reference for the planning of field trips, detailed in the following sections where the methods applied by each team are described.

The minimum mapping unit was established in 25 hectares, since the spatial working scale was set at 1:250.000, this size is applied both for natural ecological systems and anthropic coverage. In relation to the representation of areas with human intervention, it was agreed that when vegetation coverage is predominantly natural, even in presence of small inclusions of altered vegetation or small farms, if intervention areas do not reach 25 hectares, they will be included in the natural vegetation polygon. On the contrary, in areas where the matrix represents mainly human uses, alternating with natural vegetation spots (<25 hectares), the polygon corresponds to anthropic coverage. The interpretation for Bolivia and the Andean region of Peru is based on images from late 1990s, while data about change of soil use in the Peruvian Amazon date back to 2003 to 2005. Only some of the most inaccessible areas of the Peruvian Amazon are represented by images from 1980s.

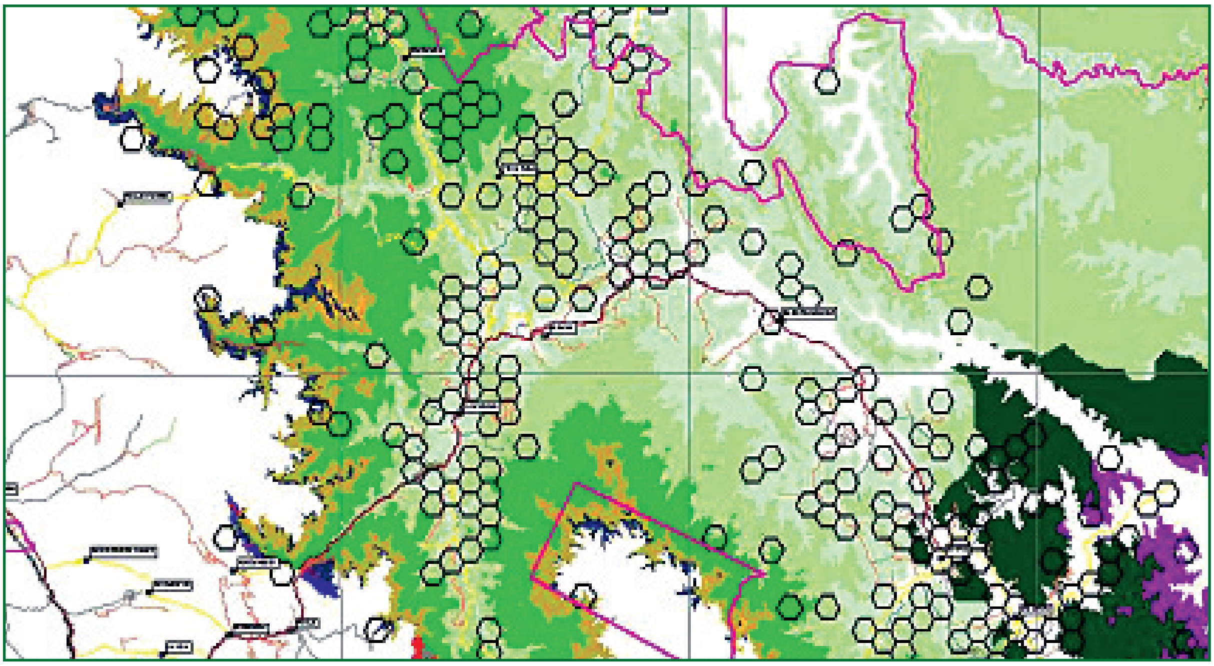


Figure 3. Example of SPOT result.

Within the context of the whole study area, the Peruvian Andean region map was developed with different method than others. This is a map that starts from cartographic modeling, where four types of input layers or thematic maps were overlapped. To a certain extent, maps of other regions also use this approximation in a deductive manner to identify the distribution of classes to be mapped and facilitate their delimination. Yet, in the case in question, the result of this model is the origin to the polygons, and not manual digitalization of each one, except for very few cases. In like manner, the class of anthropic coverage in this map was mapped separately and is the result of digital classification, as opposed to visual interpretation that has been used in the other mapping regions.

1.3.2 METHODOLOGICAL DESCRIPTION BY MAPPING REGION

1.3.2.1 Map of Ecological Systems of the Peruvian Yungas

Cartographic modeling of terrestrial ecological systems of the Peruvian Yungas

• Flow diagram

The procedure used to prepare the map of terrestrial ecological systems included the sequence indicated in the following figure.

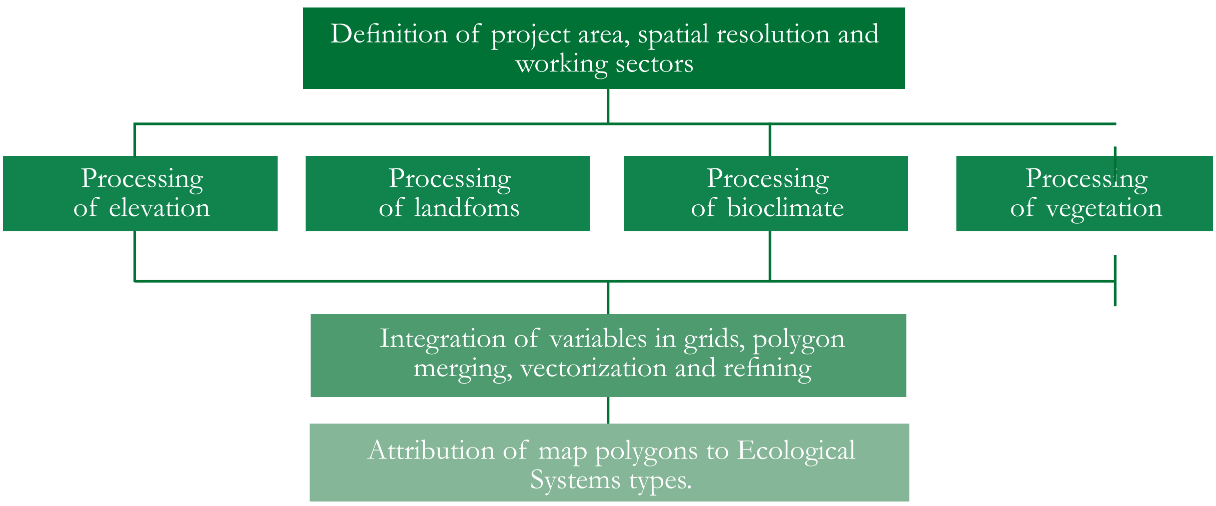


Figure 4. General flowchart of the process.

The separate sections presented below include the description of steps that are part of the sequence.

• Definition of project area, spatial resolution and working sectors

The Peruvian Yungas area is approximately located between these coordinates: 68º 49' 37" and 78º 41' 33" West Longitude and 3º 46' 37" and 14º 30' 38" South Latitude. Considering UTM coordinates (Universal Transverse Mercator projection, central meridian 75° W, ellipsoid WGS84), extreme points are located between abscissa values (X): 88,466 and 1,167,926 mE, and between ordinate values (Y): 8,369,685 and 9,544,815 mN. The area comprised between these limits (gross area) is of 1,268,505.83 km^2, the net area being 150,491.01 km^2.

The digital map was first developed in raster format and then vectorial format. The spatial database used consists of square cells measuring 90 m on the side, a dimension corresponding to the grid of the digital elevation model (Digital Elevation Model or DEM), coming from the Shuttle Radar Topography Mission (SRTM http://www.srtm.usgs.gov) spatial program.

Even though the resolution the spatial information was integrated to is of 90 meters, the source maps where thematic information used comes from have diverse resolutions:

1. elevation: 90 m (SRTM 90m)
2. geoforms: 90 m (SRTM 90m)
3. bioclimate: 30 seconds (approximately 910 meters near the equatorial line) (WORLDCLIM)
4. vegetation: 28.5 m (CDC-TM Landsat7)

In view of the extensive territory of Yungas, the size of the raster file for 90-meter cells is big and its handling becomes inefficient. This is why the area was divided into three geographic sectors or working areas, identified with letters A, B and C as shown in the next graphic (Fig. 5).

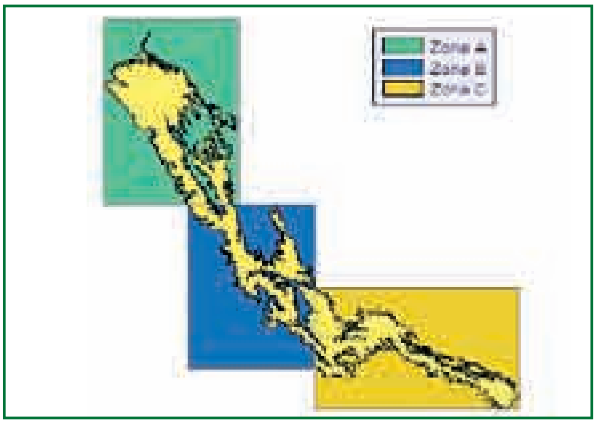


Figure 5. Subdivision of the study area in the Peruvian Yungas.

• Processing of the ELEVATION variable.

The cellular map of elevations (DEM90) was reclassified in elevation ranges as indicated in the next table:

Limit values (m.a.s.l.)		
Assigned code	**From (inclusive)**	**To (before)**
1	0	800
2	800	1,300
3	1,300	2,000
4	2,000	2,900
5	2,900	3,600
6	3,600	10,000

Table 2. Elevation ranges

Elevation was taken into consideration when defining the limit of the project area in the original map, its inferior level being 800 m.a.s.l. height, and its superior one 3600 m.a.s.l. In the last case, the project area border was adjusted upwards following the tree line but it was cut below 3600 meters when projected to the west as a narrow strip through inter-Andean valleys.

• Processing of the LANDFORMS variable

This variable was developed from the cellular map of elevations (DEM90), following an iterative process for the definition of predominant landforms.

Macroforms were defined in successive steps shown in Figure 6.

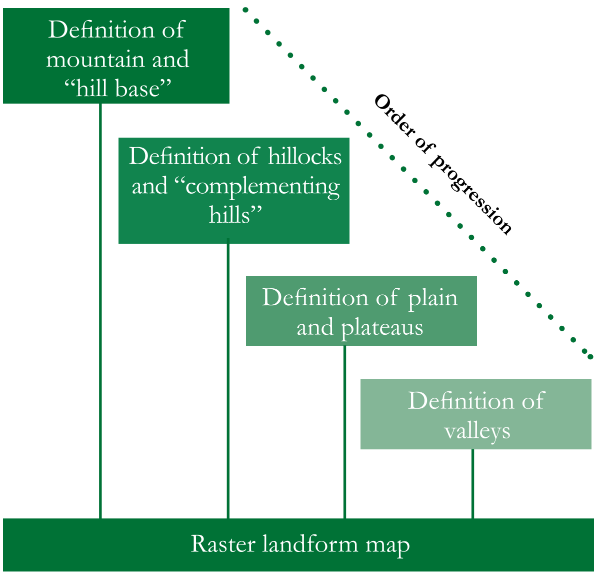


Figure 6. Processing of the geoforms variable.

The definition of macroforms was carried out by using three different cell sizes (resolutions): 900 meters for mountains and structural (base) hills; 180 meters for low hills and rolling plains, as well as valleys; and 90 meters for plains and plateaus.

Identification of cells pertaining to each category is carried out determining the altitudinal variation. By definition, mountains constitute volumes of great dimension and thus, their identification in the land relief must necessarily comprise big horizontal spaces, otherwise, only very abrupt changes (those occurring in a reduced horizontal distance as cliffs and very steep hillsides) would allow to differentiate them from hills. Rolling plains and hills are macroforms rising between 25 and 300 meters above basal land, with weak (2-8%) to moderate (8-16%) slopes for the first ones, and from pronounced (16-30%) to steep (30-50%) for the latter. As in the case of mountains, their identification as land rebounds can be done only if the evaluation comprises enough horizontal distance, in order to determine unevenness values even if the slope is low; otherwise, only steep hills would be classified as hills. Macroforms which definition requires less horizontal space to be defined are plains, theoretically areas lacking unevenness or presenting very reduced variation ranges.

Thus, areas with relative elevation greater than 233 meters in horizontal spaces of 4500 meters (5x5 900 m or 2025 ha evaluation windows) have been differentiated as mountains; the remaining areas were temporarily classified as "less conspicuous hills or landforms". Sectors with a temporary classification were analyzed in a 180-meter resolution, using a horizontal referential space of 540 meters (3x3 window, 180 m or 29.16 ha cells), and areas with relative elevation greater than 180 meters were reclassified as hills and the remaining areas were-temporarily- classified as "less conspicuous rolling plains or landforms". Temporarily classified sectors were analyzed in a 90-meter resolution, using 450-meter inspection windows (5x5 90 m cells), reclassifying as plains those with a relief lower than 20 m, with the remaining areas classified as rolling plains. With respect to the valleys landform, it was necessary to record the Yungas hydrography in a 180 m resolution raster image, exclusively located at an altitude between 800 and 3100 meters. Then, using the digital elevation map of 180 m cells and an inspection window measuring 900 m on the side, cells with a 50 – 300 meters unevenness range were selected, and these sectors were used to filter the adjusted hydrography. This filtered hydrography map was intersected with the mountain and base-hill map, and the hydrography that did not coincide with the Mountain class was discarded, as well as any other class that was not hydrography. Selected sectors were classified as valleys.

Since the loss of resolution tends to "flatten" prominence (the elevation taking on the resulting cell is the mean value of original cells), limit values among landforms have gone through some adjustment in correspondence, which was defined by visually verifying rebound values with the digital elevation model in different cell sizes.

• Processing of the BIOCLIMATE variable

This variable was processed from macro-grids of global climate data developed by the University of California in Berkeley, WORLDCLIM Project (http://biogeo.berkley.edu/worldclim/worldclim.htm), with 30 seconds resolution. Some global climatic data parameters were used to derive bioclimatic classes according to the system developed by Salvador Rivas-Martinez, Bioclimatic Classification of Earth (http://www.ucm.es/info/cif/book/bioc/global_bioclimatics_2.htm) (Table 3).

Bioclimate	Io	Iod2
Tropical pluvial	≥ 3.6	> 2.5
Tropical pluviseasonal-humid	6.0-12.0	≤ 2.5
Tropical pluvi-seasonal sub-humid	3.6-6.0	≤ 2.5
Tropical xeric	1.0-3.6	-
Tropical desertic	0.1-1.0	-

Table 3: Ombrothermal indexes according to Rivas-Martínez.

The ombrothermal index (Io) was obtained by using this formula:

$$Io = PT / (TT/100) \times 12$$

Where:

PT total annual rainfall (sum of 12 monthly PP, in mm)
TT total annual temperature (sum of each month's average temperatures, in degree tenths

The ombrothermal index of the driest period (Iod2) was calculated by using this formula:

$$Iod2 = PTd2 / (TTd2/100) \times 12$$

Where:

PTd2 total rainfall for the driest bimester (sum of total monthly rainfall for the driest two months of the year).
TTd2 total temperature for the driest bimester (sum of verage temperatures for the same driest two-month period).

The sequence used for the definition of this variable, starting from the bioclimatic grid, is:

1. Converting the macro-grids digital map to the UTM cartographic projection, centered at Central Meridian 75W (zone 18 S) and sectorizing it.
2. Recording the bioclimatic map in raster image with 450 m resolution and generalize in three iterations through modal filters (inspecting the image with a moving 3x3 window and assigning the class that most repeats itself to the central cell) to eliminate isolated cells to soften angular forms.
3. Vectorizing the 450-meter resolution digital map.
4. Recording the map in a 90-meter resolution image, generalizing to soften the limits in the final resolution.
5. Subdividing the 90-meter cells image in the three sections: A, B and C.

• Processing of the VEGETATION variable.
This variable comes from the land cover and land use digital map of 12 thematic categories, developed by CDC–UNALM using Landsat images.

Working with the ArcView program and the Image Analyst extension to visualize raster images, using a group of 23 Landsat-TM images with different dates, the map was simplified down to three vegetation classes: forest, shrubland and grassland. To do so, the ecological condition indicated by the Ecological Map of Peru at a 1:1 000 000 scale and the hydrography of the area were taken into consideration. These maps represented an important backup for the process. In the upper edge of the Yungas, the satellite images showed cloud coverage, which obstructed the visualization of real vegetation areas limits and attenuated zones. In this case, we had to deduce the extension and form of cartographic units by analogy with those of the ecological map and hydrographic features. The work scale was 1:100.000, since the printing scale was 1:250 000. The minimum dimension of polygons to work with was defined as 0,5 cm, which means polygons with a minimum land size of 500 meters, representing approximately 25 hectares in area.

• Integration of variables in grids, polygon merging, vectorization and refining
A procedure by which each cell acquires a four-digit code describing the combination of variables was used to combine the four environmental variables, (Fig. 7).

As mentioned before, the processing of spatial information was carried out using three raster files, corresponding to zones A, B and C. Once the grid codes in the raster files cells were recorded, the three files were joined as one. The resulting file was converted to a vectorial format, eliminating borders between same code pixels to constitute irregular polygonal forms representing the base of the map of terrestrial ecological systems, The polygon codes generated were assigned to an ecological system based on each system's concept and its diagnostic elements. Thus, for example, a 3642 combination corresponds to a system characterized by an elevation range of 1300 to 2000 m, occurring in a valley with tropical xeric climate which vegetation structure is considered a shrubland or scrub. Different combinations can pertain to the same ecological system, depending on its ecological range.

Polygons defined this way were subjected to a filtering process, after which isolated elements with a non-linear shape with less than 40 hectares were merged with adjacent polygons sharing the broader border. At a scale of 1:250 000, a 40 ha polygon is slightly bigger than 2,5 millimeters, the resolution required for the map.

Expansion of area under study and validation of the Peruvian Yungas modeled map
It was agreed to extend the project's study area of the Peruvian Yungas to the bottom of the valleys surrounded by the ecoregion.

The following criteria were considered to identify the areas to be added to the ecological systems map:

- The Peruvian Yungas ecoregion must not have isolated valley bottoms in the ecoregion.
- The bottom of the valleys must include main rivers such as: Huallaga, Perené, Ene, Tambo and Urubamba rivers.
- The overlapping area between the ecological systems developed by CDC–UNALM and the map developed by the Instituto de Investigaciones de la Amazonia Peruana (IIAP) must be as uniform as possible.

The effect of this addition to the original map is represented in Figure 8.

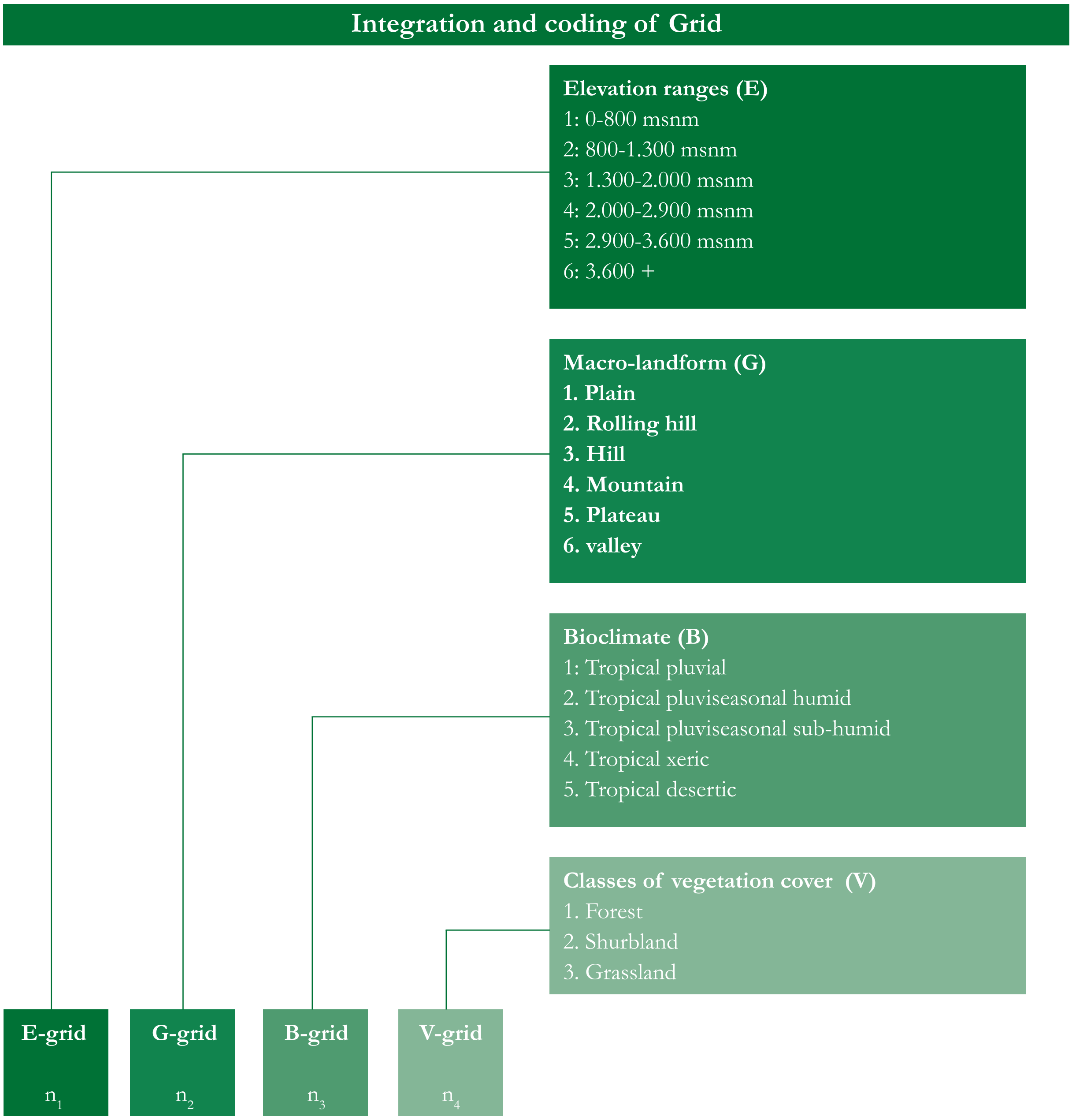


Figure 7. Integration of variables.

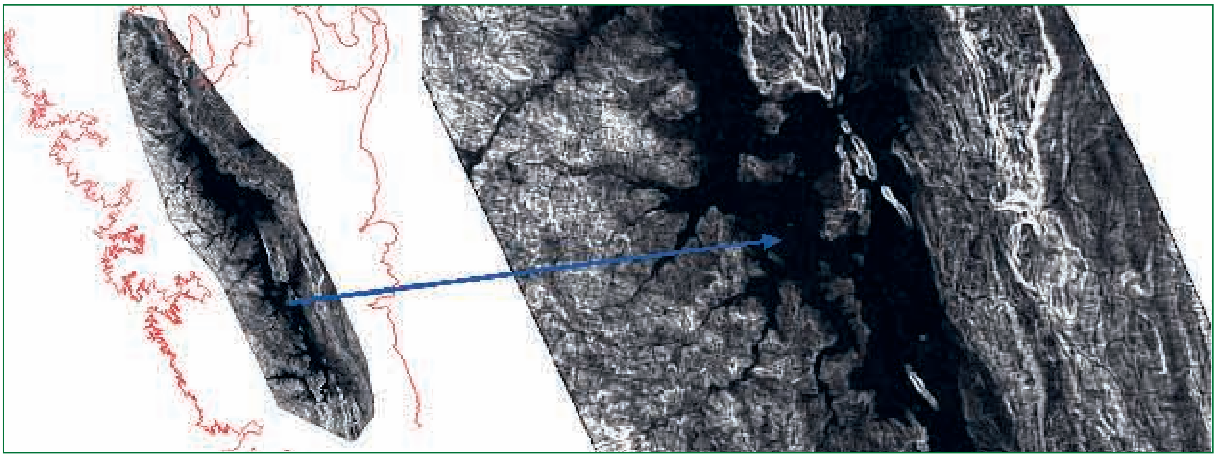


Figure 9. Resulting image of the algebraic subtraction of Maximums and Minimums.

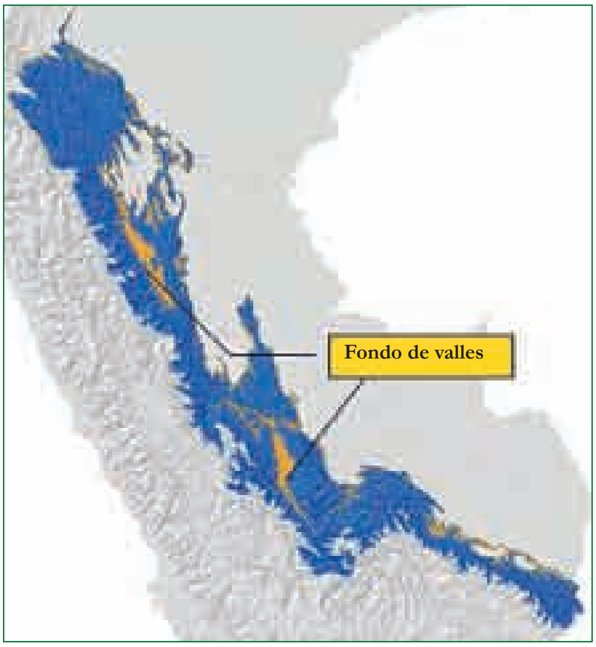


Figure 8. Areas added to the original Peruvian Yungas map.

Landsat imagery of the added areas went through an unsupervised classification with 150 classes and 20 interactions, to determine the diverse components of the landscape, such as: hydrography, forest vegetation, anthropogenic activities with no forest coverage, natural sliding, clouds, shadows, sandbanks, dry forest, other type of vegetation. It is important to mention that these valley bottoms are among the areas with the most transformations due to agricultural use and human presence. Being extensive, rather flat valleys, at a lower altitude, warm and mostly humid, potential vegetation is mainly that of Amazonian forests. In addition, the above mentioned rivers ramble forming meanders, reason why flood plains are also important. This is why the flood plain was modeled by using the results of the algebraic subtraction of the maximum and minimums in the 90-meter DEM (Fig. 9). Those places where differences between maximum and minimum elevations are lowest pertain to terrains with a relative eveness on the surface and are classified as flood plains.

• Pre-field stage: Identification of points to be sampled

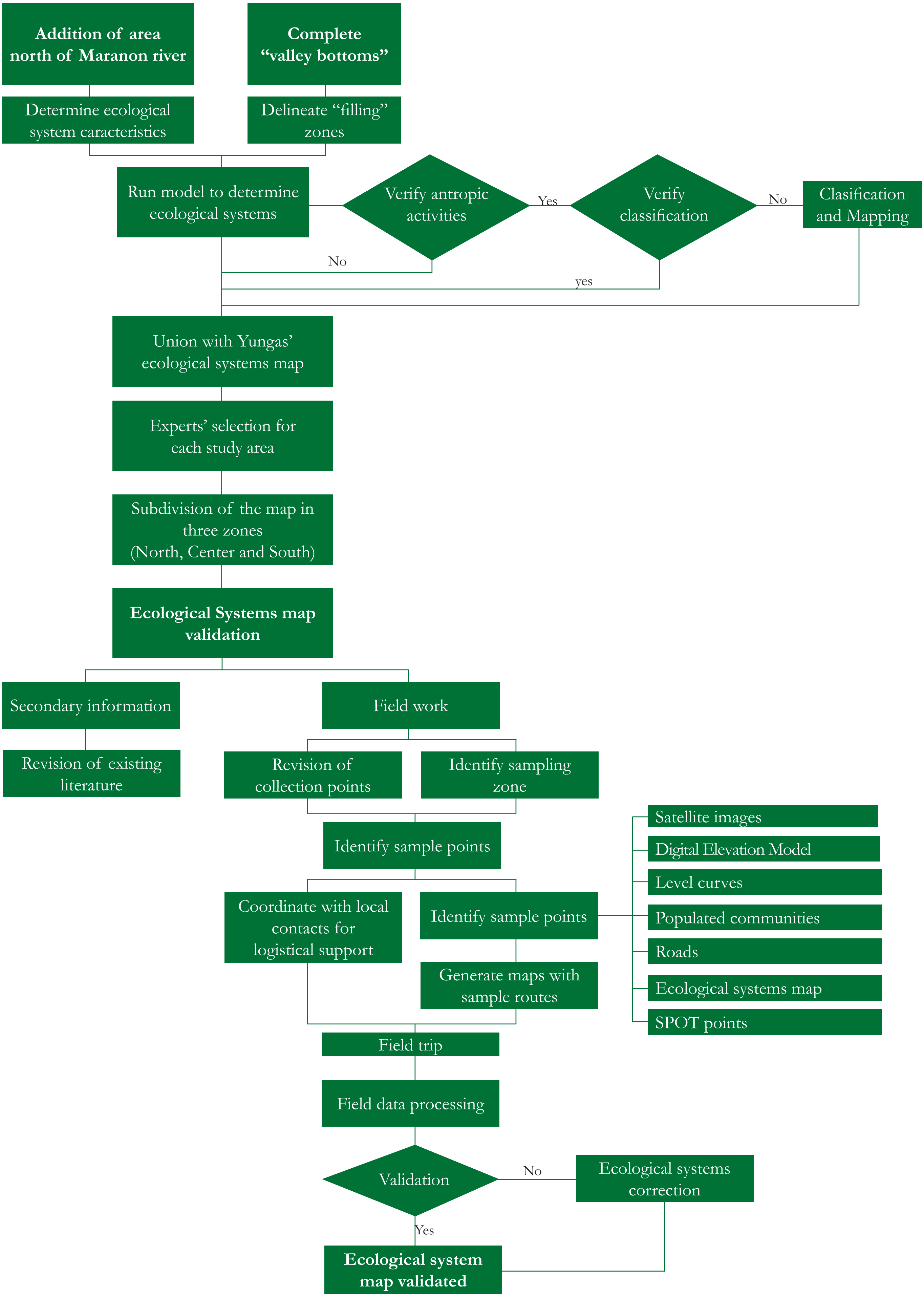
The preliminary location of field sampling points was carried out through the SPOT (Spatial Portfolio Optimization Tool) program. In practice, it was possible to study a fraction of said points during the 12 field trips organized, since sampling was concentrated on accessible systems due to the broken geography and the density of the vegetation. The study area was divided into three zones: North (consisting of Bagua, Chachapoyas and Tarapoto areas), Center (Tingo Maria–Alto Huallaga, Panao, La Merced–Oxapampa–Satipo) and South (San Francisco, Abancay–Andahuaylas, Quillabamba, Pilcopata, Sandia). This division was made based on the logistics (transportation, time of arrival to the area, field work duration, contacts with local field botanists, and others). Once the areas to be sampled and ecological systems within them had been located, the points to be sampled were identified.

Satellite images, the digital elevation model , topo maps, populated centers info, roads, ecological systems map, and SPOT results were used to locate the points to be sampled (Fig. 11).

The criteria used for the location of said points were:

- Forest presence
- When possible, along access roads
- Points located at different altitudinal levels
- Points within and/or near SPOT hexagons
- The point to be sampled does not demand more than two hours of travel from a road wide enough to allow vehicle transit

Figure 10. Flowchart for the validation of the terrestrial ecological systems map.



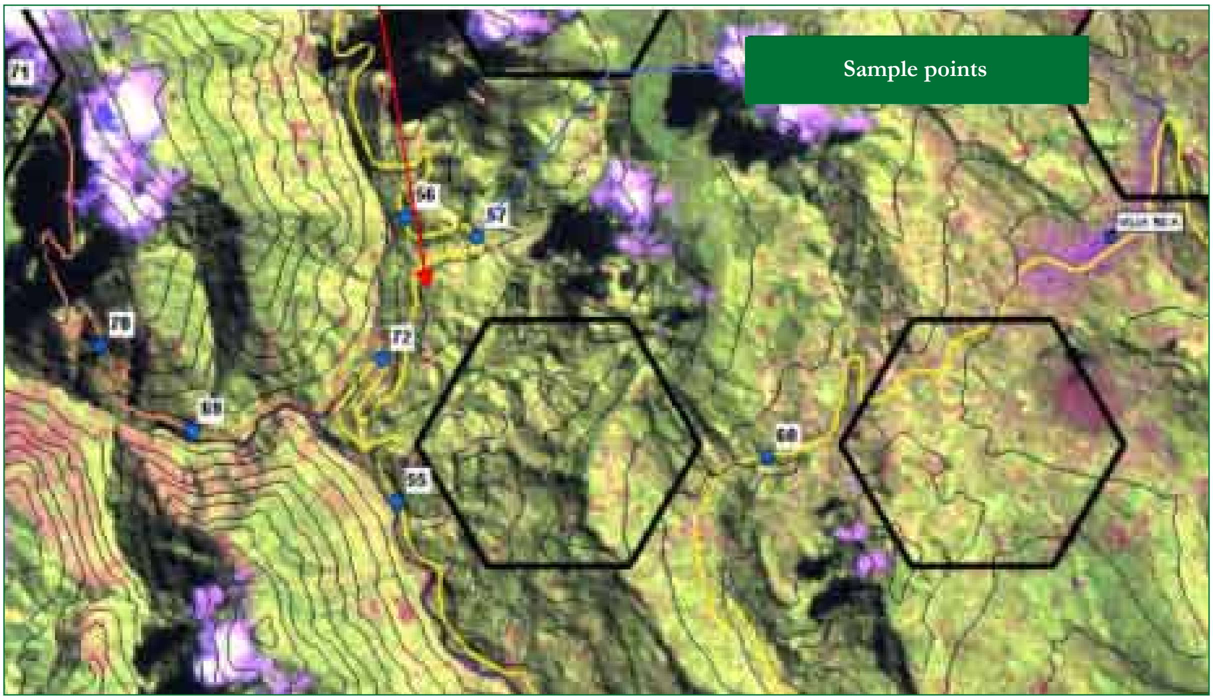


Figure 11. Location of sample points.

• Field Sampling

The field work consisted of trips to previously established sites (Fig. 11) using specific routes to take samples based on the project field form, with the idea of identifying ecological systems in situ and thus validate the ecological systems map developed by CDC–UNALM. Field teams consisted of CDC staff and renowned botanists from UNALM and the Universidad San Antonio Abad del Cusco to assist in the botanic identification in situ and the collection of botanic specimens.

• Post-field Stage: validation of the map and its modifications

A database with all indicative species named in the ecological systems descriptions, as well as their altitudinal ranges was created for the analysis.

Once the points sampled were processed, they were intercepted with the ecological systems map. The resulting data base is shown in Table 4.

Name	Name of the point
X-Form	UTM East coordinates obtained from the field form
Y–Form	UTM North coordinates obtained from the field form
UTM Zone	UTM Zone
Altitude	Altitude of the sampled point obtained by the GPS
SE-Map	Ecological system obtained from the map generated by CDC-UNALM
SE-Form	Ecological system identified in the field

Table 4. Sampling points attributes table.

The analysis of results consisted of verifying if ecological systems determined in the field corresponded to variables (indicative species, altitudinal range) used to determine said systems, in addition to their correspondence with the systems in the existing map to verify if there was correspondence between validation samples and the map.

Comparisons of samples taken during the first field trips resulted in low success percentages with the map to be validated. In face of this situation, the field samples database was subject to revision on behalf of researchers that were most familiar with the classification, which, along with a revision of other studies inventories and additional information led to corrections in some samples in reference to their ecological system classification. Additional points were then reserved to carry out the final map assessment with independent reference samples.

Points available for map validation and correction were compared to the map and, in the case of lack of coincidence, the polygon of intersection was assigned to the system identified in the field sample. This type of changes involves the analysis of other spatial information layers to determine the area to be modified, especially Landsat images and the DEM. Personal communication with field botanists and any other type of information that could confirm the natural characteristics of geographical areas in question were other resources used.

The revision of the original modeled map allowed establishing that the extension of the sub-humid ombrotype for the bioclimate variable was overestimated, especially in the Apurimac and Urubamba river valleys and the adjacent area of the Vilcabamba Mountain Range. This is why climatic indexes were derived again to generate a new layer for the bioclimate variable. It was used in a new cartographic modeling replacing only the bioclimate layer and limited to the geographic area of the valley in question, as captured in Figure 12. Once the new grid codes were obtained, combinations were reassigned and a new map for this area was generated.

The edition of this map was carried out to improve some limits that had no sufficient apexes, thus having the appearance of big squares with little detail. Tools of the ArcView 3.2 program were used to soften the limits of ecological systems, which allowed to model limits according to the relief of areas represented through the 90-meter DEM. The hydrography of the area was also taken into consideration.

Finally, the ecological systems and anthropic coverage maps were united. As a result of this merge, some ecological systems polygons were divided, and when this is the case towards borders, it can result in polygons < 25 hectares. Considering that filter application to discard these minor polygons can cause changes in their classification, it was decided to eliminate only polygons < 2 hectares.

The description of the methodology applied by CDC-UNALM for the identification of areas with anthropic activity is available through the links to the project on the NatureServe web site.

Figure 12. Area that was re-modeled in the map of the Peruvian Yungas.

1.3.2.2. Map of Ecological Systems of the Peruvian Amazon

Mosaic of Images and Spatial Information

• Acquisition of images

The satellite images mosaic was generated with 42 Landsat 5 and 7 scenes (TM and ETM+ sensors respectively), originally obtained within the BIODAMAZ Project framework (Peru-Finland agreement) in late 2004. Diverse images were updated during the execution of the present project, prioritizing areas with a strong anthropic pressure and subsequently subject to accelerated land use change. Scenes used are shown in Table 5.

• Image Pre-processing

The ERDAS Imagine 8.4 software in a Microsoft windows XP platform was used for the digital processing of images.

Radiometric correction techniques were used to apply algorithms that allowed the modification of pixels lacking information (salt and pepper) on some scenes, as well as to correct pixel lines missing in other (images missing more than four lines were rejected).

Images gathered from INPE-FUNCATE were received in GeoTIFF format, so appropriate procedures were

Path/Row	Acquisition date	Satellite	Sensor	Source
002-068	20050709	Landsat 5	TM	ND
002-069	19861025	Landsat 5	TM	Internet-TRFIC
003-067	19920618	Landsat 5	TM	Internet-GLCF
003-068	20050801	Landsat 5	TM	ND
003-069	19860712	Landsat 5	TM	Internet- TRFIC
004-062	19970510	Landsat 5	TM	Internet-GLCF
004-063	20031209	Landsat 7	ETM+	INRENA
004-066	19860703	Landsat 5	TM	Internet- TRFIC
004-067	19891007	Landsat 5	TM	Internet- TRFIC
004-068	19900916	Landsat 5	TM	Internet-GLCF
004-069	19930807	Landsat 5	TM	Internet-GLCF
005-062	20030122	Landsat 7	ETM+	INPE-FUNCATE
005-063	20030122	Landsat 7	ETM+	INRENA
005-066	19930830	Landsat 5	TM	Internet-GLCF
005-067	19940630	Landsat 5	TM	Internet-GLCF
005-068	19860726	Landsat 5	TM	Internet- TRFIC
005-069	19860726	Landsat 5	TM	Internet- TRFIC
006-061	19871101	Landsat 5	TM	Internet- TRFIC
006-062	20010312	Landsat 7	ETM+	Internet-GLCF
006-063	20050619	Landsat 5	TM	INPE-FUNCATE
006-064	19930805	Landsat 5	TM	Internet-GLCF
006-065	19930805	Landsat 5	TM	Internet-GLCF
006-066	20040803	Landsat 5	TM	INPE-FUNCATE
006-067	20040803	Landsat 5	TM	INPE-FUNCATE
006-068	19930805	Landsat 5	TM	Internet-GLCF
007-060	19860825	Landsat 5	TM	Internet-GLCF
007-061	19910401	Landsat 5	TM	Internet-GLCF
007-062	19990821	Landsat 7	ETM+	Internet-GLCF
007-063	19990821	Landsat 7	ETM+	Internet-GLCF
007-064	20010826	Landsat 7	ETM+	Internet-GLCF
007-065	19890825	Landsat 5	TM	Internet- TRFIC
007-066	20040131	Landsat 5	TM	INPE-FUNCATE
007-067	19970908	Landsat 5	TM	Internet-GLCF
008-060	19891222	Landsat 5	TM	Internet- TRFIC
008-061	19891222	Landsat 5	TM	Internet- TRFIC
008-062	19960811	Landsat 5	TM	Internet-GLCF
008-063	19841216	Landsat 5	TM	Internet- TRFIC
008-064	20041207	Landsat 5	TM	INPE-FUNCATE
008-065	20031018	Landsat 5	TM	INPE-FUNCATE
009-062	19990819	Landsat 7	ETM+	Internet-GLCF
009-062	20030721	Landsat 5	TM	INPE
009-063	19990819	Landsat 7	ETM+	Internet-GLCF
009-063	20030721	Landsat 5	TM	INPE
009-064	20030721	Landsat 5	TM	INPE

Table 5. Landsat images used in the mosaic of the Peruvian Amazon.

applied to convert them to ERDAS Imagine format. Transformation procedures facilitated by the software were used to convert the Affine geometric model of these same images to the MapInfo model.

Out of 42 scenes used, some of the ones obtained by the IIAP had no georeferentiation, and were subject to a polynomial geometric correction process with the Nearest Neighbor resampling method. Parameters for the projection used are detailed on Table 6.

Cartographic Projection:	Universal Mercator Transverse
UTM Zone:	18 South
False East:	500 000.000000
False North:	10 000 000.000000
Origin Latitude:	0.000000
Central Meridian Longitude:	-75.000000
Central Meridian Scale Factor:	0.999600
Plain Coordinates:	x, y ordered pair
Plain Distances Units:	meters
Horizontal Datum:	WGS1984
Ellipsoid:	WGS1984
Greater semiaxis:	6378137.000000
Reason for Crushing:	1/298.257224

Table 6. Parameters of the projection of satellite images and thematic layers used on the map of ecological systems.

Ground control points were obtained from the 1:100000 National Planimetric Map for some scenes, while others were georeferenced with the Image-Image technique.

Images in zones 17S and 19S were reprojected to the 18 South zone to provide spatial continuity to the scenes when generating the mosaic.

Georeferenced images with a 30 x 30 m resolution were grouped by scenes in a combination of 5, 4, 3 (RGB) bands, allowing to observe vegetation in light green shades and intervened areas in yellow and fuchsia shades, while water bodies with high levels of sedimentary material content are perceived in shades of blue and water with a high inclusion of humic compounds in black. Other shades characterize diverse specific components of the landscape.

• **Mosaic generation**

Considerations in Table 7 were taken into account to generate the mosaic.

Image addition:	Compute Active Area
Matching Options:	Overlap Areas
Histogram type:	Band by Band
Overlapping function	
Intersection type:	No Cutline Exists
Function selection:	Overlay

Table 7. Qualitative considerations for the generation of a satellite images mosaic.

The following empiric methods were tested when adding images:

1. Assembly of scenes considering the path/row correlative starting with the lowest (002/068) and finishing with the greatest (009/064).
2. Assembly of scenes considering the acquisition date, adding most recent scenes first and then the oldest.

The best results were obtained with the second method. The resulting mosaic is shown on Figure 13.

• **Georeferencing Quality**

No formal testing was carried out to determine the georeferentiation precision, however, overlapping of field sampling points (rapid type for the ecological systems map validation) taken throughout the rivers (some time at the river talweg and others near the shore) with a GPS Garmin V navigator showed more than 90% match with expected positions, representing a very significant empirically estimated precision.

Preparation of the Ecological Systems Map

This map was generated from the thematic coverage (Table 8) of physiography (FISIO) covering specific sectors of the Peruvian Amazon (Aguaytia river basin, Madre de Dios region, Iquitos-Nauta road, Nanay river basin, San Martín region, Abanico de Pastaza) and geomorphology (GEOMO) covering the Peruvian Amazon lowlands. The geomorphology (FISIOGEOM) map was derived from the FISIO coverage for those specific areas by adapting the physiographic terminology to geomorphology. These maps were overlapped on the images mosaic, and starting from the FISIOGEOM coverage, the existing GEOMO coverage was rectified or ratified, and results of the transformation of physiographic elements into geomorphologic elements were verified. Subsequently, GEOMO and geology (GEOLO) coverage were merged through a spatial union operation to provide

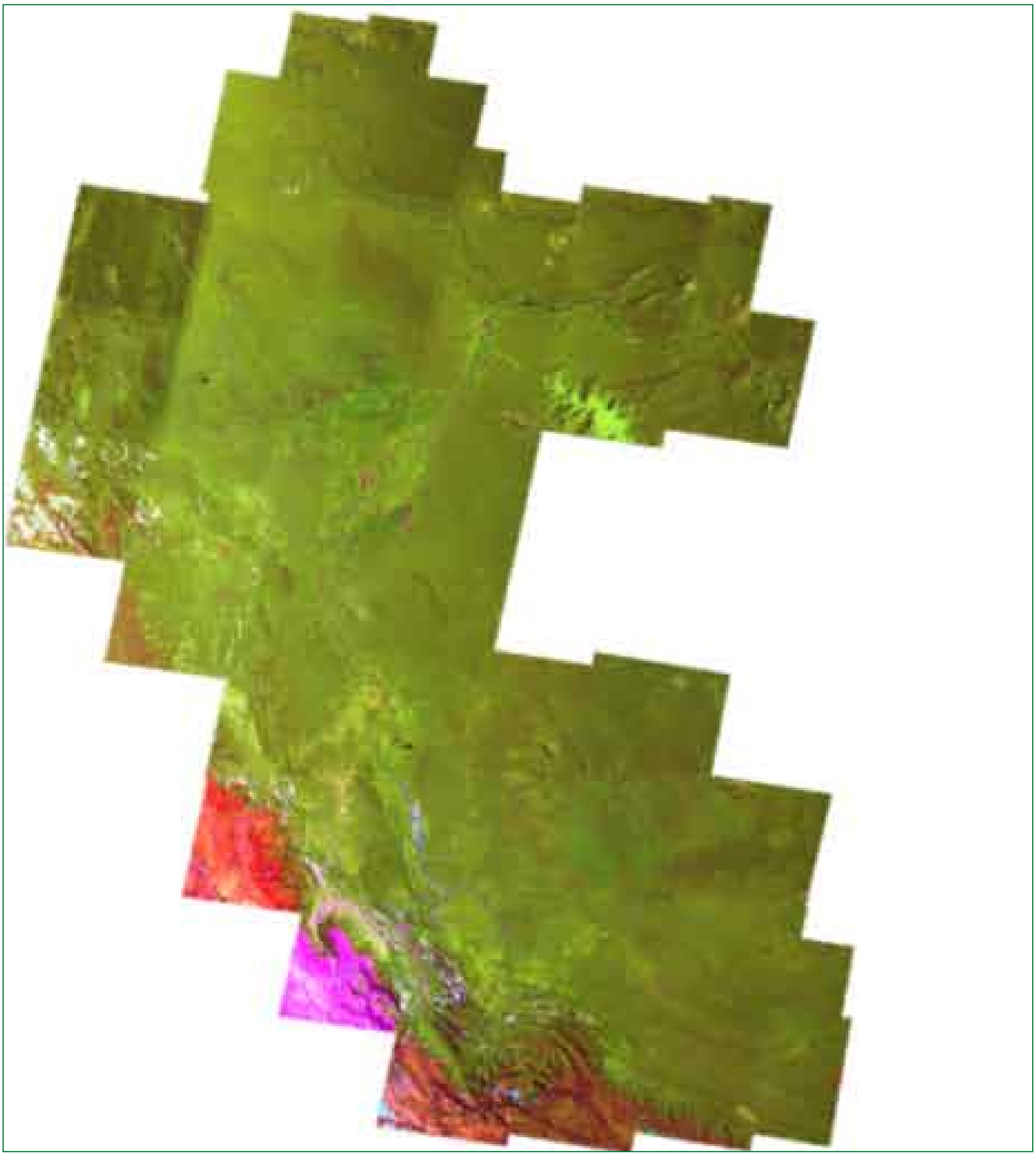


Figure 13. Mosaic of Landsat images for the Peruvian Amazon.

geomorphologic elements with specific geological characteristics (Capas Rojas, Pebas formation, etc.). Vegetation characteristics were incorporated to GEOM_GEOL through a spatial union operation with the Peruvian Amazon vegetation cover (VEGETA). Bioclimate (BIOCLIMATE), ecological regions (REGION) and ecological sub-regions (SUB_REGION) information was also added.

The hydrographic network was digitalized (1 : 60 000 scale) by visual interpretation, considering as polygon format rivers (RIOPOL) all those with a width ≥ 120 meters and those lagoons and swamps with a water mirror area ≥ 25 hectares. The remaining water bodies were recognized as line format rivers (RIOLIN). Next, all elements in GEOM_GEOL included in the area covered by RIOPOL elements were excluded through a spatial deleting action and RIOPOL and GEOL_GEOM coverage were united to incorporate the hydrographic element to the latter, obtaining the SISECOL coverage, which constituted the preliminary map that served as base to plan field sampling and which field data were compared to for the necessary rectifications.

The basic metadata record of the above-mentioned spatial layers are detailed in Table 8. These layers are

Subject	Coverage	Type of element	Source	Working scale	Publishing scale
PHYSIOGRAPHY	Aguaytia river influence area	Polygon	CTAR Ucayali, IGN, IIAP Landsat 5 TM Images	1 : 100 000	1 : 250 000
	Madre de Dios Region	Polygon	CTAR Madre de Dios, IIAP, IGN, INADE, ONERN, INRENA	1 : 100 000	1 : 500 000
	Iquitos Nauta road area of influence	Polygon	IIAP, IGN, Landsat 5 TM Images	1 : 100 000	1 : 150 000
	Nanay river basin	Polygon	IIAP, IGN, Landsat 5 TM Images	1 : 100 000	1 : 250 000
	Abanico del Pastaza	Polygon	CDC-La Molina, IGN, IIAP, WWF, 5 and 7 (TM y ETM+) Landsat images	1 : 100 000	1 : 600 000
GEOMORPHOLOGY	Peruvian Amazon Lowlands	Polygon	IIAP, ONERN, 5 and 7 (TM and ETM+) Landsat images	1 : 250 000	1 : 1 750 000
GEOLOGY	Peruvian Amazon Lowlands	Polygon	IIAP, ONERN, 5 and 7 (TM and ETM+) Landsat images	1 : 250 000	1 : 1 500 000
VEGETATION	Peruvian Amazon Lowlands	Polygon	IIAP, ONERN, 5 and 7 (TM and ETM+) Landsat images	1 : 250 000	1 : 1 000 000
BIOCLIMATE	Peruvian Amazon Lowlands	Polygon	IIAP		1 : 1 000 000
REGION	Peruvian Amazon Lowlands	Polygon	5 and 7 (TM and ETM+) Landsat Images	1 : 250 000	
SUB-REGION	Peruvian Amazon Lowlands	Polygon	5 and 7 (TM and ETM+) Landsat Images	1 : 250 000	
HYDROGRAPHY	Peruvian Amazon Lowlands	Polygon	5 and 7 (TM and ETM+) Landsat Images	1 : 250 000	
		Line	5 and 7 (TM and ETM+) Landsat Images	1 : 250 000	

Table 8. Basic metadata of ancillary thematic layers.

projected with the system summarized in Table 6. The cartographic model scheme to develop the preliminary map of ecological systems can be found on Figure 14.

Field Sampling

- **Pre-field Laboratory Stage.** Field forms. Field Sampling Planning. Existing data collection. Materials.

Activities during the pre-field stage were:

- Preparation of a base line for ecological systems interpretation: Geomorphology and hydrography physical variables, bioclimate and vegetation variables as well as anthropogenic deforestation variables were considered.
- Gathering and analysis of existing documentation, composed by:
  -Collection of texts and maps on geomorphology, hydrography and climate of work sectors.
  -Selection and evaluation of existing inventories (or plots) sampled in the past, based on collections, floristic inventories and floristic analysis.
  -Preparation of an Excel data base to characterize 236 existing or "already sampled" plots (Figure 15).

- Visual analysis of the mosaic of satellite images in digital format with a 1:250000 scale, taking into consideration:
  - Date of the image to facilitate system confrontation in the geographical context.
  - Image sharpness to distinguish particular systems.
  - Apparent texture or roughness, composition or detailed spatial arrangement and internal variability of existing image reflectances.

- Typification of ecological regions and their corresponding subregions with the purpose of facilitating the systematization of the interpretative analysis. Advances included:

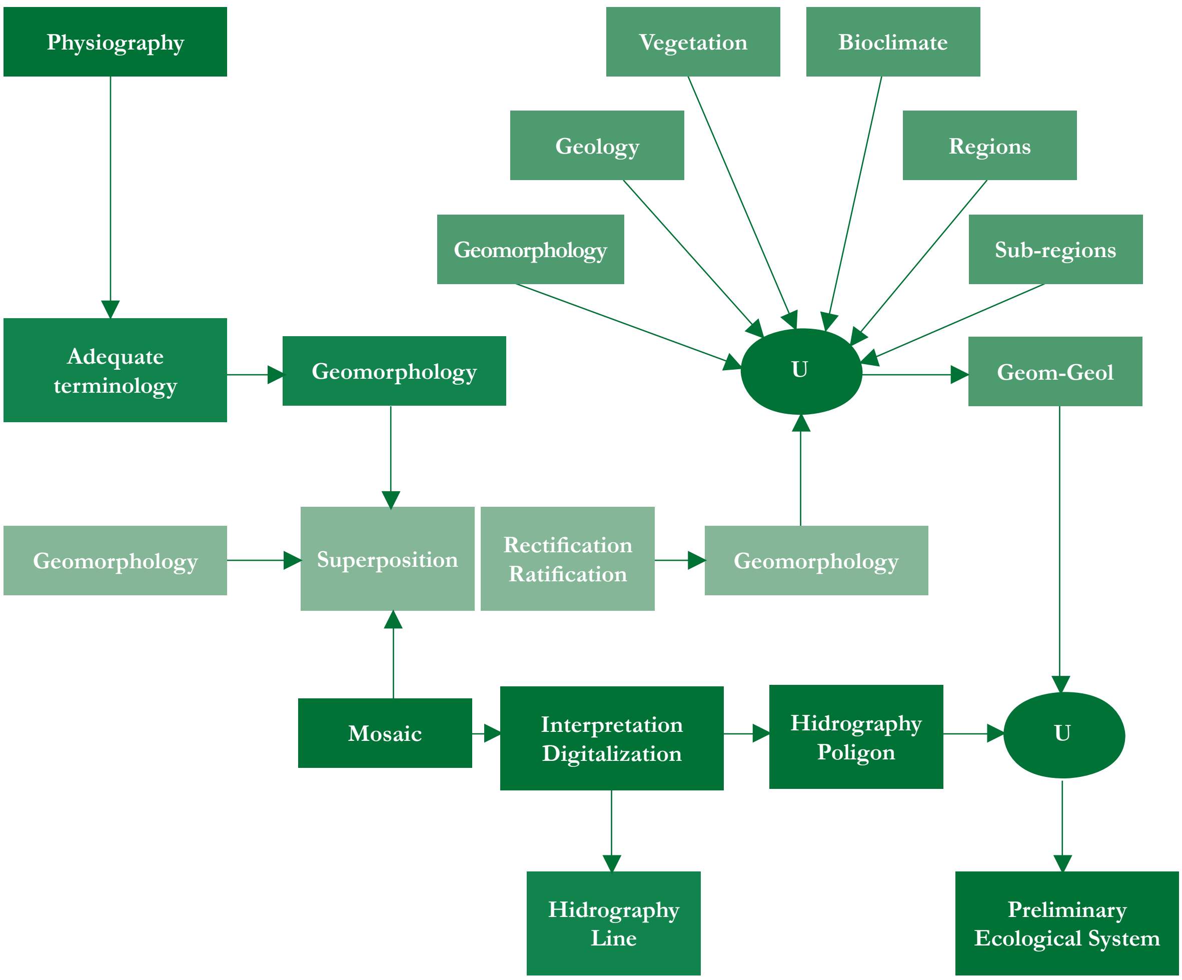


Figure 14. Cartographic Model to Determine Ecological Systems of the Peruvian Amazon.

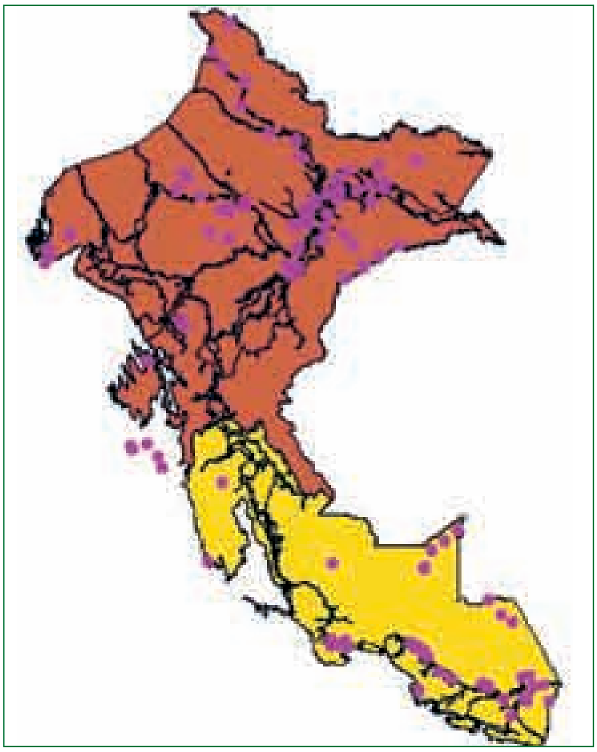


Figure 15. Distribution of existing plots with inventories until 2004 (n=236).

- The delimitation of territories or large landscapes of: Western Amazon, Southwestern Amazon and flooding areas, stratified in turn by corresponding subregions.
- Preliminary interpretation of ecological systems in the corresponding regions and subregions, based on the geomorphology and hydrography, as well as their interrelations to vegetation and bioclimate.
- Intersection of geographical points of inventories or plots collected with the mosaic of satellite images.

• Selection of sampling areas for the Project (Western Amazon and Southwestern Amazon) (Table 9), based on the following considerations:
 - Inclusion of sampling subregions and sectors for different systems.
 - Dismissal of sampling sectors that pose access difficulties due to logistic reasons and social conflicts.
 - Route selection for sampling: from a list of sites proposed to sample the majority of ecological systems, stratified by different subregions, it was necessary to dismiss some due to access difficulties or because the areas had already been covered by the existing inventories obtained (Table 9).

• Preparation of a field form based on criteria agreed by the project mapping teams and to be used to collect information of detailed and rapid samples.
• Selection of staff with conditions to carry out work in the Amazonian forests, which included:
 - General training to carry out the inventory sequence.
 - Criteria standardization for the use of field forms.
 - Standardization in the use of equipment for georeferentiation and orientation, measurement and calibration, and others.
 - First aid training.
 - Creation of work teams or brigades: Four working teams were composed by a professional botanist who worked as chief, a senior graduate student of the Biological Sciences School of Universidad Nacional de la Amazonia Peruana, in Iquitos, as an assistant; and a tree climber, as collection technician. The team was then completed by hiring two local residents with knowledge of the area's vegetation who worked as assistant guides. Additionally, the participation of other locals as trail blazers was also foreseen.

• Purchase and collection of materials and equipment for field work.
 - Data processing in the field: Laptop and miscellaneous accessories.
 - Navigation and georeferentiation: GARMIN GPS navigator, SUNNTO compasses, clinometers, and other.
 - Visualization and photographic records: BUSHNELL binoculars, digital cameras.
 - Field forms and notebooks for rapid and detailed sampling.
 - Specimen collection: telescopic pruning scissors, manual scissors, various tools, alcohol, and various accessories.
 - Printed satellite images of selected sectors at 1:250000.
 - List of inventories already performed in the sector as well as of representative species, manuals, field guides, and texts for taxonomic determination.
 - Camping equipment.

• Field sampling methods. Plot size and shape, sample types.

Sampling of the Amazon lowlands were carried out by the IIAP's team in three campaigns or expeditions between May and November of 2006 during the "dry" season. The two initial expeditions included the northern sector of the Peruvian Amazon through the exclusive use of fluvial transportations logistics. The third one, in the southern sector, through a combined use of air, terrestrial and fluvial transportation. In the expeditions of the northern sector participated all of the four work teams or brigades and the route included the Amazon, Napo, Marañon, Tigre, Pastaza, Morona and Huallaga rivers. In the southern expedition, three brigades participated traveling though the Las Piedras

Route	Town of Reference	Regions	Proposed	Executed
1	Chambira (low Amazon)	Western Amazon	X	X
2	Yanashpa (low Amazon)	Western Amazon	X	X
3	Copal Urco (Napo, Curaray/ Santa Clotilde)	Western Amazon	X	-
4	Santa Clara de Nanay	Western Amazon	X	-
5	Santa Maria/ Napo	Western Amazon	X	-
6	Estación Quebrada Blanco/ Río Tahuayo	Western Amazon	X	-
7	Intuto/ Río Tigre	Western Amazon	X	X
8	Tierra Blanca/ Río Morona	Western Amazon	X	X
9	San Fernando (Boca Huitoyacu) Río Pastaza	Western Amazon	X	X
10	Santa Martha (close to Yurimaguas), Río Huallaga	Western Amazon	X	X
11	Contamana/ Río Ucayali	Western Amazon	X	X
12	Masisea/ Río Ucayali	Southwestern Amazon	X	X
13	Atalaya/ Río Tambos / Urubamba	Southwestern Amazon	X	X
14	Aguajal (Río Las Piedras), Río Madre de Dios	Southwestern Amazon	X	X
15	Iberia/Iñapari (Acre-Tahuamanu), Madre de Dios	Southwestern Amazon	X	X
? a	Río La Torre (Río Madre de Dios)	Southwestern Amazon	X	-
? b	Esperanza, Río Purus	Southwestern Amazon	X	-
? c	Curaray/Nashiño, Río Napo	Western Amazon	X	X

Table 9. Sampling areas proposed and implemented for the study of ecological systems in the Peruvian Amazon.

River, the Puerto Maldonado- Iñipari section and the Ucayali River.

Regarding the field sampling, fluvial or terrestrial transportation placed the teams by the riverbank or roadside at the nearest or more accessible point to selected systems or sample units. The river or road adjacent sites are generally deforested areas or consist of mosaic of agricultural and secondary vegetation ("Chacras and Purmas complex"), demanding a one or two hour walk (4-10 km) in order to access the sample site.

Plot sizes and distance between them were of two types:

- In the forests adjacent to the Napo and lower Amazon rivers (first expedition), plots were circles with a 10 meter radius (= 0,03 ha) with 100 meter distance between them and in groups of 4 and above, following the major longitude of the axis of the predefined polygon.
- In the forests inventoried during the second and third expeditions, plots were of a rectangular shape of 20 x 50 m (=0,1 ha), with a 2km distance between each lot.

Samples were of two types: detailed and quick. Quick samples were collected in all river expeditions during transportation between sampling sectors, and some were collected on foot in the Madre de Dios sector.

• The detailed samples included notes related to the aspect of the landscape within a 30 m field of vision with notes on:
- Georeferentiation in the UTM coordinate system
- Estimated degree of human intervention
- Type and state of relief and description of the soil and litter
- Generic description of the structure and list of the composition of the undergrowth, the different strata and the canopy
- Panoramic photographic records of the undergrowth, the strata and the canopy
- Measurement of the diameter and height of the shafts (poles), total height of the trees and photographic records
- Type of ground cover
- Phenologic occurrence of flowers, fruits, leafshed, etc.
- Collection of herbarium samples, both fertile and infertile specimens and photographic records.

• Quick samples, also known as complementary or verification samples, were collected especially for the riverbank systems, which had been clearly described before, and after a panoramic distinction between adjacent systems through the use of binoculars. The inventory or collection of samples took place in a spatial sector of 100 to 200m and at a speed of 10 to 12 km per hour downstream and at 7 to 8 km per hour upstream. The notes included:

- Georeferentiation of starting and ending points of the sample
- Description of the relief and visible states of flooding in the marsh system
- Estimated degree of human intervention
- Description of the community structure and composition list of conspicuous species
- Photographic records
- Random collections when vegetation forms appeared different to the ones already known or when exhibiting polymorphism.

The list of species corresponds to a preliminary or field determination. The collection and processing of specimens follows classical and conventional steps, from sample collection, transfer to camp, preservation, transfer to IIAP and drying.

Detailed information regarding each sampling point, including a list of species and photographs, has been stored in an Access Database available to users in the project links of Nature Serve's website.

• Post-field Stage. Validation of the preliminary map. Sample identification.

Post-field activities took place in the following order: (1) Preliminary map validation based on field experience and samples, and adjustments and corrections within geomorphologic and hydrographic contexts, with the appropriate adjustments regarding the vegetation component; and (2) Systematic taxonomic processing and treatment of collected specimens in order to select representative species, complemented by the references of existing inventoried plots.

• Validation of the preliminary map: With the use of reference samples, a verification phase of the preliminary map of ecological systems map was carried out. The procedure was as follows:

- The sample points were superimposed on the preliminary map. From the 1100 sample points, 56% were used to correct or verify the preliminary map and 44% were kept for the exclusive use in the accuracy assessment of the final map.
- Detailed check of the correspondence between the preliminary map systems and the information and characterization of field samples. This step was carried out through the visual interpretation of the mosaic of satellite images and individual scenes, in order to identify within the image the resulting pattern of the relationship between the geomorphology characters and the adaptation of the vegetation to the influences of the periodic seasonal flooding dynamics.
- Visual extrapolation for each class. Regional areas of the ecological systems are identified based upon the previous step and observing the different characteristics of reflectance, texture and spatial context in the image in association with points where ecological systems are known to exist based on field information.
- Readjustment of polygons in ecological systems. Carried out through manual digitization on the mosaic of satelite image over the area of each system. As a result of the process, some of the the polygons were divided and others that were contiguous were combined into one. Naturally, there were also changes in the denomination of some systems.
- Edition of the Ecological Systems Map: through the union of arches or vectors following quality control and precision analysis.

• Processing and systematic taxonomic treatment of the collected specimens.

One of the criteria for the classification of ecological systems is the composition of representative species from either one or a group of vegetation communities. The botanical collections were carried keeping this goal in mind, and were later transferred to the operations center at IIAP where the specimen processing included:

- Sample pressing and drying according to the conventional procedures.
- Taxonomic-systematic determination of the specimens. Based on the preliminary determination in the field, samples were compared to existing ones, already determined and available in the herbariums of AMAZ (National University of the Peruvian Amazon, Iquitos) and USM (Natural History Museum of the UNMSM, Lima) and botanical specialists were consulted for the definitive systematic determination.
- Selection of representative species. Once the polygons had been adjusted and with the goal of identifying representative species for each ecological system, floristic composition similarity indexes were estimated among the samples at the genus taxonomic level. The results obtained were as follows:
  - Occurrence of species and groups of species with distribution restricted to the ecological systems characterized by extreme ecological conditions in their substrates, such as sandy, saturated, or excessively eroded soils. Within these systems it is possible to distinguish different representative species.
  - Presence of species or group of species with a wide range of distribution in several ecological

systems where environmental conditions are not extreme. There is a manifestation of polymorphism in the structures. It is not possible to distinguish representative species.
- As the analysis of similarity between ecological systems included abundance by species or groups of species, the maximum similarity between the systems is 0.3 (range 0-1), which indicates the existence of significant differences among them.

- Allocation of ecological systems. As a result of the comparison between inventories, vegetation communities were identified and the definitive ecological system is assigned to each sample point.

• Database of field samples with appendix of botanical collections by sample point.

In total, 1100 validation samples were collected in the field among both detailed sampling plots and quick sample points throughout the field phase between May and November 2006 (Tables 10 and 11). From a total 335 detailed sampling points and 745 quick points, 484 were reserved for the accuracy assessment of the final map and the remaining 56% were used for verification during the production of the ecological systems map of the Peruvian Amazon (Table 11), complementing the reference data of 236 points of inventories done until 2004 (Figure 15).

Exp.	Regions	Type / number of plots	Plot area / total area (ha)	% sampled
I	Western Amazon: Napo and Low Amazon River	Circles, 10m radius /223	0,031 = 7,005	62,82
II	Western Amazon: Tigre, Maranon, Pastaza, Morona and Huallaga Rivers	Rectangles, 20 x 50 / 78*	0,1 = 7,8	21,97
III	Southwestern Amazon: Madre de Dios, Ururbamba and Ucayali	Rectangles, 20 x 50 / 54	0,1 = 5,4	15,21
	TOTAL PLOTS/ TOTAL AREA	**355 (Circles 223Rectangles 133)**	**20,205**	**100,00**

Table 10. Total number of detailed sample points in the Peruvian Amazon lowlands. May-October 2006.

Expedition	Type of sampling	No. of No. of Samples	% of total samples	Reserved	%	Analyzed	% of tota samples
I	Detailed*	223	20,27	104	9,45	119	10,82
	Quick**	251	22,81	88	8,0	163	14,82
II	Detailed*	78	7,07	24	2,18	54	4,91
	Quick**	389	35,36	109	9,91	280	25,45
III	Detailed*	54	4,91	54	4,91	0	0
	Quick**	105	9,54	105	9,55	0	0
	TOTAL	**1100**	**100,00**	**484**	**44,00**	**616**	**56,00**

* Total record of individuals, DAP, total heights, phenology and collection.
** The quick samples correspond to sampling sectors through quick visualization and recording of most abundant species, occasional collections.

Table 11. Total field samples and number of samples analyzed.

1.3.2.3. Ecological systems map of the Yungas, the Amazon and the Bolivian Beni Savannahs

Image Mosaic and Spatial Information

The georeference and interpretation base of ecological systems has been the GEOCOVER mosaics from the National Space Agency NASA, that are detailed as follows:

Mosaic ID S-19-05, S-19-10, S-19-15, S-19-20, S-20-05, S-20-10, S-20-15, S-20-20, S-21-15; FileFormat Musid; Platform Landsat; Sensor ETM; Bands 7, 4, 2; Pixel size 14.25 m x 14.25 m; Projection UTM 19, 20, 21; Datum WGS84; Spheroid WGS84; Units Meters; Latest Component Acquisition Date 20010919; Earliest Component Acquisition Date 19990815.

The mosaics were georeferenced to UTM coordinates zones 19 and 20, datum and WGS 84 spheroid, the only available bands in the geocover mosaics are 7, 4, 2 from the ETM+ captor fused with the panchromatic band so that a better spatial resolution can be obtained.

The mosaics were combined in false colour (4, 7, 2 RGB), to highlight dense, leafy vegetation in red. The secondary information was superimposed for each UTM zone, including the georeferenced information collected in the field.

Even though a systematic control of the georeference of NASA's geocover mosaics was not carried out, the concordance of georeference control points collected in the field using a garmin GPS navigator over the mosaics, showed a higher precision than expected at that work scale.

In addition to the image mosaics previously described, secondary digital information was compiled, which was used in specific locations and conditions due to the fact that it comes from different scales and sources, (Table 12).

• Cartographic Model

The following flow chart (Fig.16), shows in a schematic and summarized way the elaboration process of the ecological systems map of the Beni, Amazon and Yungas regions of Bolivia.

Preparation of the Ecological Systems Map

• Pre-field Stage

The following are the methodological activities of this phase:

• Analysis of existing literature, particularly regarding the geology, edaphology, bioclimate and vegetation of the zone to be covered.

• Study and compilation of topographic and geographic charts.

• Study and compilation of the floristic inventories and collections performed in the zone.

• Preparation of forms for the registration of field data.

Theme	Source	Scale/Resolution	Format	Extension
Vegetation zones of Bolivia	Navarro & Ferreira, 2004	1:7.000.000	Polygons	SHP
Bioclimate	SENAMHI		Points	SHP
Biogeography	Rivas-Martinez et el 2002	1:10.000.000	Raster	TIF
Geology	IGM 2000	1:1.000.000	Raster	TIF
Base map	IGM 2000	1:1.000.000	Raster	TIF
Topography	IGM	1:250.000	Vector	DGN
Road links	VMMA 2000	1:1.000.000	Vector	SHP
Hydrographic network	VMMA 2000	1:1.000.000	Vector	SHP
Population centers	VMMA 2000	1:1.000.000	Points	SHP
Political-administrative limits	VMMA 2000	1:1.000.000	Polygons	SHP
Digital elevation model	NASA 2003	90 m andes		
		14,5 m llanos	Raster	RRD
Water conductivity	Navarro & Ferreira 2006		Points	SHP
Soils	Soil Laboratory Univ. San Simón		Points	SHP

Table 12. Auxilliary spatial thematic layers.

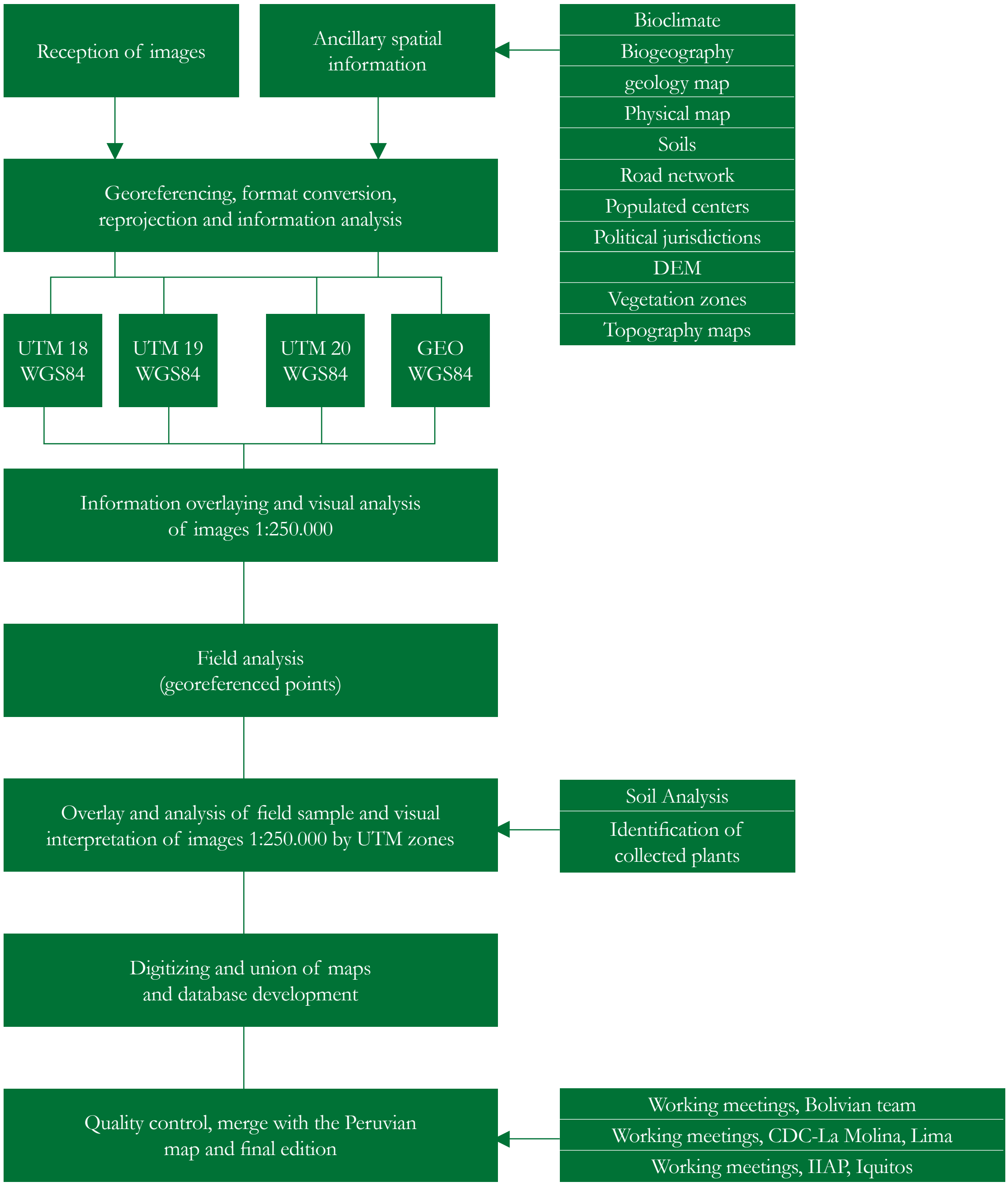


Figure 16. Schematic methodological process for the preparation of the ecological systems map of the Beni, Amazon and Yungas regions of Bolivia

• Preparation of the base for spatial information and overlay with image mosaics.

• Visual study of satellite images in digital and printed format using a 1:250000 scale, false colour on high quality photographic paper. Preliminary identification of problematic sampling zones based on previous experience and the presence of unknown characteristics inherent to the image. Fundamentally:
  -Reflectance (false color): problematic image tones not associated with certainty to a particular system.
  -Texture: grain size, apparent texture or roughness and composition or detailed spatial arrangement and internal variability of existing image reflectances.
  - Geographic context: repetitive characteristic patterns at a regional scale, linked to each image zone.

• For all of those areas with characteristics in the image not clearly associated to an ecological system, sampling sites were determined and verified in the field in order to obtain information that allows their subsequent allocation to the different systems.

• Finally, the selected sites based on listed criteria and resulting from the SPOT program, were optimized and reduced according to the accessibility of the zone and time availability in the field.

• Preparation of field materials: GPS GARMIN navigator, Tommsen altimeter calibrated at first order sites, compasses, eclimeters, field forms (both quick and detailed), Bird's beak pruner, conductivemeter, pruning shears, machetes, printed images using a 1:250000 scale, topographic maps, geologic maps, list of meteorological stations with bioclimate indexes, list of key plants and inventories performed at the zone, texts and guides for field identification of plants, camping and herbarium materials.

• Field sampling methods

The collection of field samples for the Bolivian project was performed throughout several field campaigns during the dry seasons 2005 and 2006. Each campaign included, besides the basic work team, botanists from the Bolivian National Herbarium, occasionally, an ornithologist from the Universidad Mayor de San Simon's Biodiversity and Genetics Centre, both institutions in Cochabamba, plus local expert guides. Field campaigns were carried out using land and river transportation as well as day hikes through the more accessible zones. Besides the samples collected under this project in the previously mentioned years, the authors also used samples collected in prior projects.

The Bolivian work team primarily relied on the following techniques and methods:

• Selection of inventory points for the main vegetation types covered in each itinerary. Either a detailed inventory or a quick one was carried out depending on the number of points previously collected and the degree of certainty in the identification of the vegetation and the ecological system.

• In the detailed inventories, all the field forms were completed and data was collected in geobotanical transects along bands of variable length, generally between 20 m and 200 m, depending on the type of vegetation and its structure characteristics, homogeneity and repetitiveness. The width of these bands varied between 2 m for herbaceous formations and approximately 6-8 m for treed and bushy formations. Additional data was collected apart from the data required in the field forms:

  -Collection of important plant samples from the sampled formation that were not accurately identified on the field. The lists of samples collected for each sampling point and for each field outing are available in databases.
  -Soil samples in representative and homogeneous points of each fundamental ecological system. In all cases, only the sub-superficial horizon was sampled, approximately from 20 cm to 40 cm deep, considering it was the least affected by the organic matter of each type of vegetation.
  -Measure of the electric conductivity in streams, puddles and other water bodies present at the inventory or nearby sites.

• In the quick inventories, in the majority of cases performed from the vehicle, only the ecological system and some other relevant environment data were registered. Some quick inventories correspond only to a precise soil sample taken in known ecological systems or to water conductivity measurements taken while crossing rivers or streams.

• The complete information for each sample point remains in the Access database developed for this project.

• Post-field Stage: Validation of the preliminary map, sample identification

The steps taken back in the herbarium to allocate field samples and for the digitation of the ecological systems polygons on top of the image, are summarized as follows:

- Taxonomic identification and processing of selected botanical samples. Identification took place in the Bolivian herbariums of Cochabamba (BOLV) and La Paz (LPB) with the support of specialists from the Missouri Botanical Garden (MO) in the case of difficult specimens.

- Analysis of soil samples taken from the field. The analyzed variables are:
  -Interchangeable bases (Ca, Mg, K, Na)
  -Elements with diagnosis value: Fe, Al, S
  -Capacity for cationic exchange
  -% of saturation of the change complex
  -pH and electric conductivity
  -Texture

- Ecological-floristic regional comparison of the lists of plants noted in each inventory and of the existent edaphic and bioclimatic conditions in each site. The descriptors analysed in this comparison are:
  -Presence of species and restricted species groups or of preferential distribution in certain ecological systems or environments.
  -Presence of conditioned edaphic and bio-climate differentials for inventories or groups of inventories.

- Allocation of ecological systems. As a result of the comparison between inventories, vegetative communities present were identified and the final ecological system for each inventory point is assigned back at the herbarium.

- The field sampling points were superimposed on the satellite images to observe the different characteristics of reflectance, texture and spatial context associated to each point where specific ecological systems are known to exist based on field information.

- Visual image interpretation. Performed through the visual extrapolation on the images of regional areas of ecological systems from the local areas known in the field. This extrapolation was carried out by directly comparing from the images the perceptual characteristics of reflectance (false colour), texture, spatial context and secondary information, i.e. spatial thematic layers.

- Poligonization of ecological systems. As a result of the prior methodological steps, the manual drawing and polygonization upon the images of areas covered by each system in each zone is carried out.

- Digitalization, union of segments, quality control and accuracy analysis. Digitalization is performed through the vectorization of visually interpreted segments, these vectors are converted into polygons, values are assigned and they are connected over the mosaics until completing each UTM zone. They are then projected to geographic coordinates and joined to form one map to be revised by the technical team on a screen by random sectors or sectors previously identified with some kind of anomaly or peculiarity. For the accuracy analysis of the map, 25% of the points sampled in the field were reserved.

1.3.3 ASSESSMENT OF MAP ACCURACY

Thematic maps, derived from the use of remote sensors, especially maps of vegetation and land use, are generally used in different types of environmental evaluations, conservation planning, analysis for policy development, or as input for different types of models. Very often this is the use given by researchers that are not associated to the original map authors. For this reason, it is increasingly relevant to provide users with an estimate of the accuracy of the published map, in addition to all of the possible information about the metadata and its development. This type of information is needed by the users to decide if a map is appropriate for their purposes (Powell et al. 2004)

Knowing the degree of accuracy of the map is also important and useful for the authors of the map, because the process allows the identification of sources of errors, or the weaknesses of the methodology or the applied classification (Powell *et al*. 2004).

In this case the objective is to evaluate the thematic accuracy of the map. On account of the several geographic re-projections that have been made to accommodate such a large study area and different mapping teams, as well as the use that could be given to this product, it is possible to allow a certain low level of positional error and this is considered in the sample design for the production of the reference samples.

This type of evaluation embodies some challenges. In the first place, the challenge posed by the very nature of the subject represented in the map, which consists of vegetation patterns in response to certain physical environments. This subject involves the delimitation of discrete units in an environment that is actually a continuum (Gopal & Woodcock 1994), an objective that becomes even more difficult when considering that the satellite images used as the basis for interpretation, apart from their spatial resolution, include mixed pixels, whether in border or edge situations, ecotones or transition zones between one type of coverage and another.

Due to this ecological classification reality, methods to apply diffuse logic to the precision evaluations have been developed (Gopal& Woodcock 1994), where diffuse similarity rates are created, based upon the allocation of a quantitative measure of ecological similarity between each pair of classes , so that classes with a certain similarity level are considered as correct matches.

However, the most conventional analysis is conducted using an error matrix whose results are based on a binary logic: the reference sample matches the map or it does not.

There is abundant literature on the methodology and the statistical calculations needed to determine the sample size and the different options and types of analysis and reporting of results to carry out a statistically robust evaluation (Congalton 1991, Congalton & Green1999, Foody 2002, Wulder *et al.* 2006) What is not abundant, however, is specific literature on the implementation of this type of evaluation: the type of reference samples that can be used, the conditions under which the different types can be applied, the interpretation of reference samples and the interpretation of the results obtained from the application of different statistical calculations.

The methodological steps and the different decisions adopted to evaluate the ecological systems maps resulting from this project, as well as the results of the assessment, are described in detail in the report dedicated to this specific issue that will be available in project link in NatureServe website. It can be reported in advance that a more statistically robust evaluation will be performed on the map of the Peruvian Amazon, whereas in the Peruvian Yungas and the Bolivian map, the accuracy analysis will be applied only to those classes with sufficient field samples available.

In the case of the Peruvian Amazon, we have used photographic samples taken along over flight routes, in addition to the field samples selected from areas where over flights could not be performed (Figures 17 and 18). These georeferenced, high resolution photographic samples are interpreted as reference samples, assigned to an ecological system and then are compared to the map.

Figure 17. Example of aerial photographic sample.

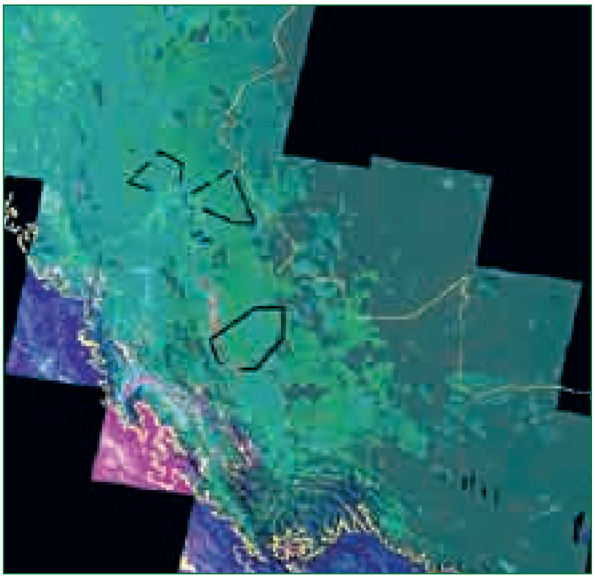


Figure 18. Over flight routes for photographic sampling of the Peruvian Amazon.

Confluence of rivers Maranon and Samiria, Loreto, Peru. Walter H. Wust

2. Results

2.1. SPATIAL STATISTICS AND DISTRIBUTION OF ECOLOGICAL SYSTEMS IN THE STUDY AREA

The initial definition of the boundaries of the study area in its southern edge was based, as for the whole study area, on the limits of the ecoregions included in the project according to their outlining in the year 2004 (Ecoregions WWF website). According to this definition, the area under study covers 1.249.281,7 km^2 and it is based on this area that final statistics and results are presented in this section to maintain consistency among project components. However, it is important to highlight that as a result of the production of the ecological systems map, the total mapped area is slightly larger. We consider that its southern limit represents with a greater accuracy, thanks to the field verification, the limits between the Madeira Tapajos ecoregion (Central-South Amazon biogeographic province, part of the project) and the ecoregion of the Bolivian Chiquitano forests (biogeographic province of the Cerrado, beyond the scope of the project). The published ecological systems map is available at the project's link on the NatureServe website (http://www.natureserve.org/andesamazon), and represents the total mapped area, with the limits differences illustrated in Figure 19.

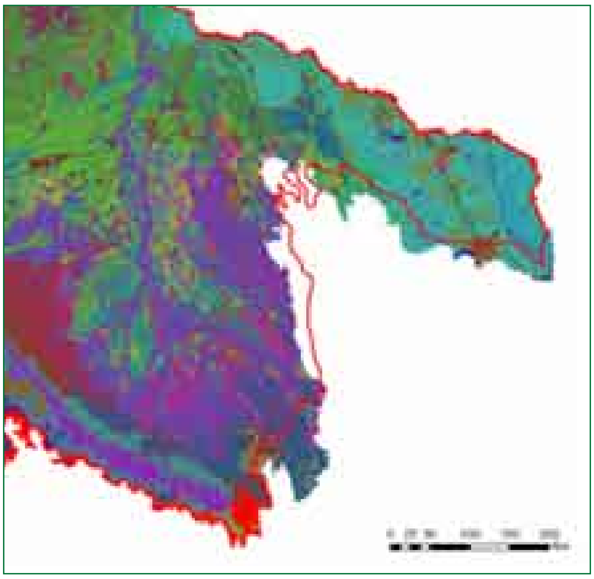


Figure 19. Southern boundary of the study area, highlighting the difference between the actual distribution of the ecological systems as mapped in the project and the pre-established boundary according to the WWF ecoregions map.

The following table shows the extension of each of the regions by country:

Country	% of national territory	Region	Area (km^2)
Peru	62	Yungas	127,112
		Amazon	667,600
Bolivia	42	Yungas	51,237
		Amazon	214,041
		Beni	189,292

Table 13. Regional area by country in the study area.

The total number of ecological systems identified within the study area is 84. However, only 81 have been individually mapped. The rest are captured in some of the 10 complexes that have also been mapped and are part of the map's legend (Table 1).

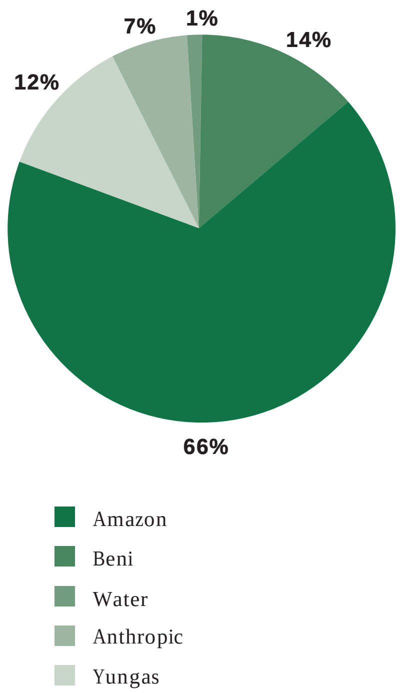


Figure 20. Proportional extent of major regions within the study area.

The following distribution is obtained after calculating the proportion of the study area occupied by each of the three large ecological regions (Amazon, Andes and Beni) using for the calculation the areas covered by their own systems (Fig. 20).

Despite the fact that the Yungas region represents only 12% of the study area, 37 ecological systems have been mapped. Whereas in the Amazon region, with 66% of the area, 32 system types had been mapped. In the Beni there are 13 ecological systems represented besides the presence of Amazonian systems of mainly the group of the flooding and riparian systems. An extensive part of the Beni area could only be mapped as complexes, because under certain conditions they form mosaics in which it is not possible to discern individual systems at this spatial scale. The distribution of the ecological systems mapped by country and region is represented in Figure 21.

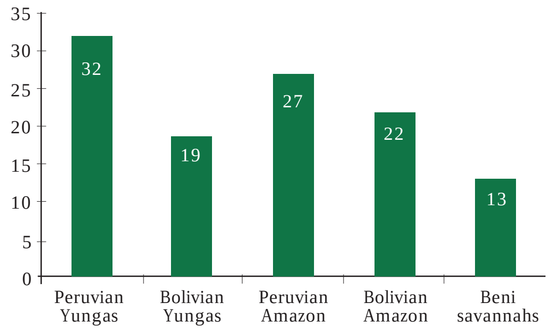


Figure 21. Number of mapped ecological systems by region.

Andean Ecological Systems

Out of the 37 Andean ecological systems in the study area, three are exclusive to Bolivia and 17 are exclusive to Peru. However of the latter only three (CES409.079, CES409.061 and CES409.049) represent systems that are actually constrained to Peru because the rest are distributed also in Ecuador. Additionally, among the 16 systems of the Yungas shared by Peru and Bolivia, some could possibly be subdivided into variants or even different ecological systems from north and south Yungas with differential species. However this is an aspect to be confirmed by a proper phytogeographic study. In the case of sub-humid and xeric forests and scrublands, expert opinions have supported the separation between the northern Yungas systems and the southern Yungas systems due to the presence of sufficient differential species with floral affinity to the Amotape-Huancabamba region and the Cerrado-Chiquitania province, respectively (Table 1). It is worth noting that in total these sub-humid and xeric ecological systems represent 12.5% of the Andean area of the project.

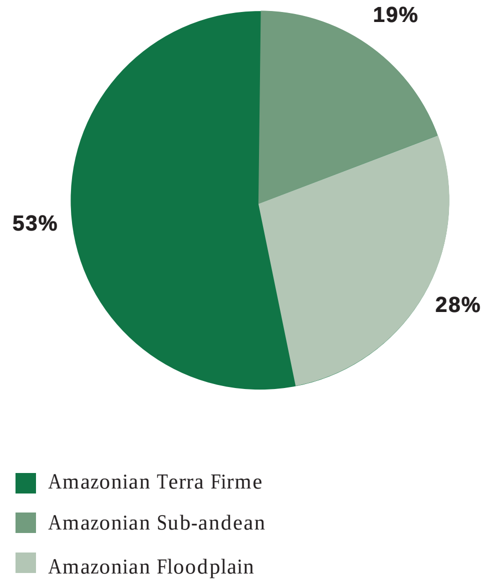


Figure 22. Proportion of three major groups of Amazonian ecological systems in Peru and Bolivia.

Sistemas Ecológicos Amazónicos

Of the 32 Amazonian systems, 17 correspond to flooding (Table 1) and/or poorly drained systems and represent 27,7% of the total Amazonian lowlands region in the study area (Fig. 22). Only the *Mauritia* palm swamp system covers almost 25% of the flooding area. Among the Amazonian systems three belong to the sub-Andean belt characterized by structural mountains and hills that cover 19% of the area in a range that goes from approximately 500 to 1000 m elevation, where flora with Amazonian affinity is predominant, although the presence of Andean elements is also observed. Below this range, 12 upland or terra firme ecological systems occupy the remaining 53% of the Amazonian region in the study area.

In the case of the Amazonian systems, seven are exclusive to Bolivia and 10 occur only in Peru, whereas 15 ecological systems are shared between the two countries. In reality, the systems exclusive to one country within the project study area are actually also found in Ecuador, Colombia or Brazil. Possible exceptions regarding Peru would include the CES408.562 and CES408.569 systems, commonly known as varillales and renacales, and the CES408.546, a type of semi deciduous forest that grows on hilly terrains and is constrained to the north. Among the Amazonian systems exclusive to Bolivia, four belong to systems located in the center-south of the Amazon region, probably with distribution on the Brazilian side and three are transitional systems from the Amazon region to Cerrado-Chiquitania, probably found only in Bolivia.

Ecological Systems of the Beni

As mentioned previously, in the region of the Beni's savanna, 13 ecological systems natural to this region have been mapped, aside from eight complexes made up of these same systems plus Amazonian riparian systems which are combined in different ways according to micro-topographic and edaphic conditions. Out of these 13 ecological systems, three occur in the Cerrado or Pantanal regions of Brazil and 10 in Bolivia.

Anthropic Areas

The areas with anthropic activity identified by satellite images from the years 1999 to 2005 represent 6.8% of the total study area. The Andean region of the project area is the most affected, with percentages of 11 and 14% of transformation in Peru and Bolivia respectively. Whereas in the Amazonian lowlands the percentage lies between 4 and 6%.

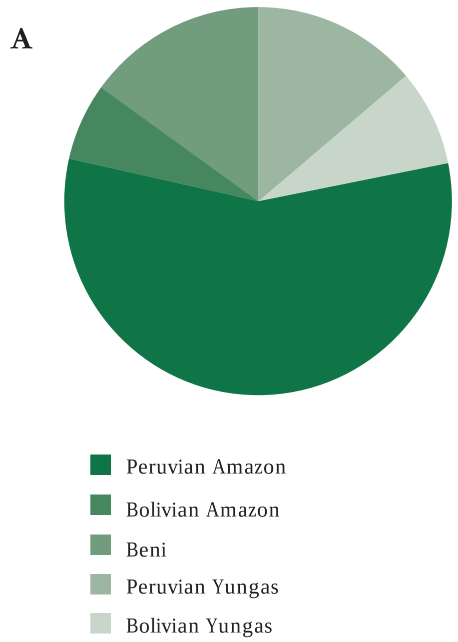
2.2.RESULTS OF FIELD SAMPLING

Throughout the duration of the project and using the previously described methodology, the three teams collected 1,938 sample points distributed by region according to the representation in Figure 23a. In addition to these samples, the teams used existing samples taken in the field by the same groups or by other researchers for the validation of the maps. Once all the available samples are added, the total amounts to 2,962 and the proportions by region change as indicated in Figure 23b and Table 14.

Region	Project Samples	Previous Samples
Peruvian Yungas	269	25
Bolivian Yungas	155	493
Peruvian Amazon	1100	236
Bolivian Amazon	124	235
Beni	290	35
Total	1.938	1.024

Table 14. Number of samples by region and source.

During fieldwork, the teams sampled 61 out of the 81 ecological systems that have been mapped. However, the majority of the 20 systems not sampled in this occasion had been previously sampled. In addition, anthropic zones were also sampled as well as some of the complexes that are part of the map's legend. A percentage of the samples was reserved in all cases to be used as independent samples in the final map evaluation. All the samples collected as part of the project are available in Access



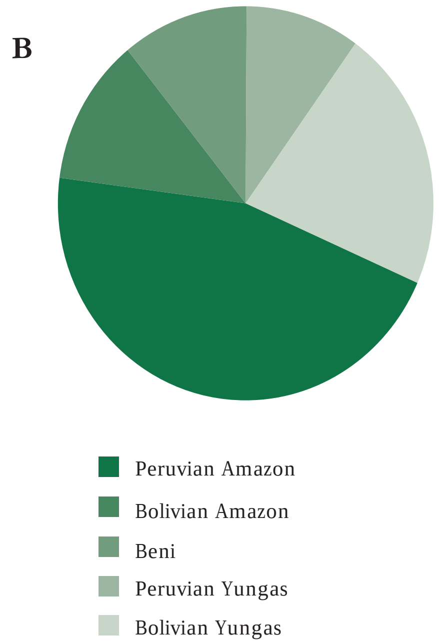


Figure 23. Proportion of validation samples by region. a) Taken in the field by the three ecological systems mapping teams. b) Total field samples available: project + existing.

databases. Also, as mentioned in the Methods section, there are two types of samples: detailed and quick (see Appendix 2). Only the detailed samples include short inventories of dominant or characteristics species. All the samples include photographic archives.

The following maps illustrate the sample distribution along the different regions in both countries (Fig. 24, 25 and 26).

2.2.1 Results of Botanical Collections

The field data gathering process involved botanical collections. In the project, we considered that due to the cost and effort of field trips, these should also be used to make botanical collections, particularly of representative plants of the sampled system whose identification was not certain in the field. The results obtained thus far of the taxonomic processing and identification of these collections, demonstrate that it was a good decision.

Botanical collections of the project in the Peruvian Yungas

Some interesting results were obtained from the botanical collections performed during the field trips to the Peruvian Yungas. Some were within the *Cedrela* genus of the Meliaceae tree family. Several individuals were collected and have been used for the description of a new species, *Cedrela "nebulosae"*, which is found in the Oxapampa valley. The new species is in the process of being described.

At the Utcubamba valley, individuals of what seems to be a new *Cedrela* species were also collected and have been provisionally called "*kualapensis*" until its description is formalized and published. Also within the *Cedrela* genus, the species *Cedrela saltensis* was recorded in the Quillabamba valley which represents a new record for Peru.

Botanical collections of the project in the Peruvian Amazon

In total, 13,935 herbarium specimens were collected, which added to other genus or species records amount to 21,114 taxa registered during fieldwork. Of the specimens collected, approximately 75% were classified. This information was used to describe the ecological systems. Similarly, 18,383 photographs were taken from the landscape as well as the vegetation at the sample sites. (Table 15).

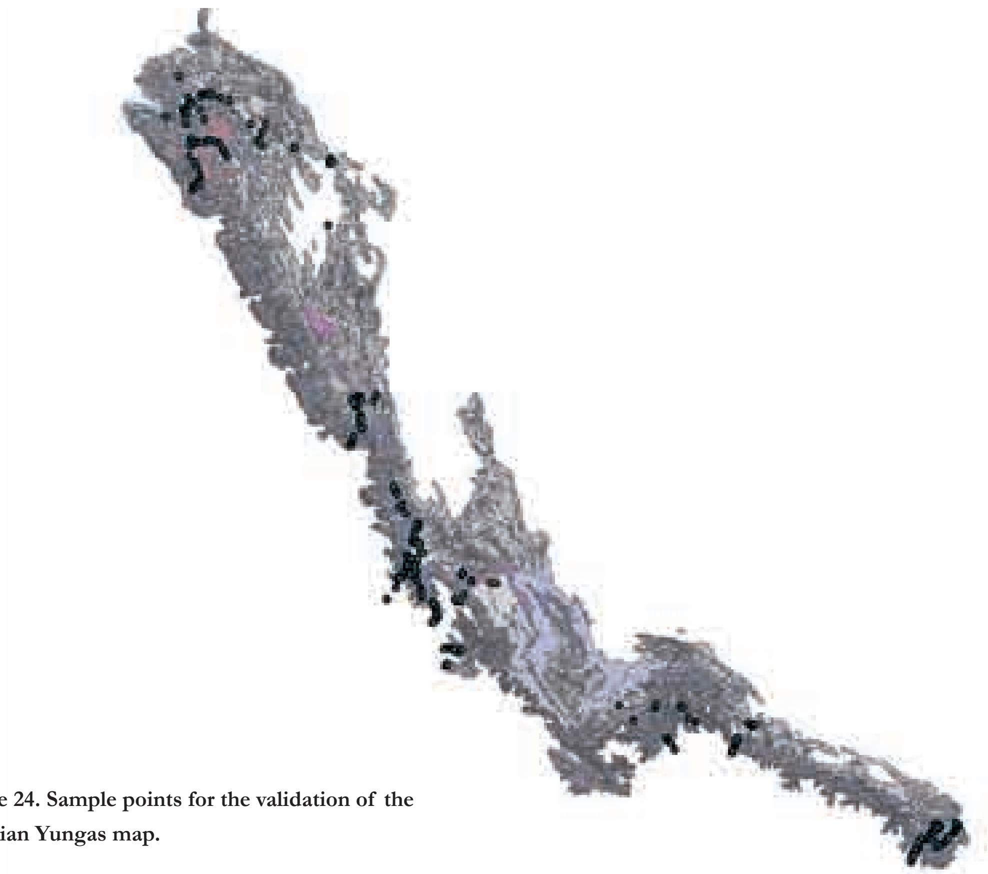


Figure 24. Sample points for the validation of the Peruvian Yungas map.

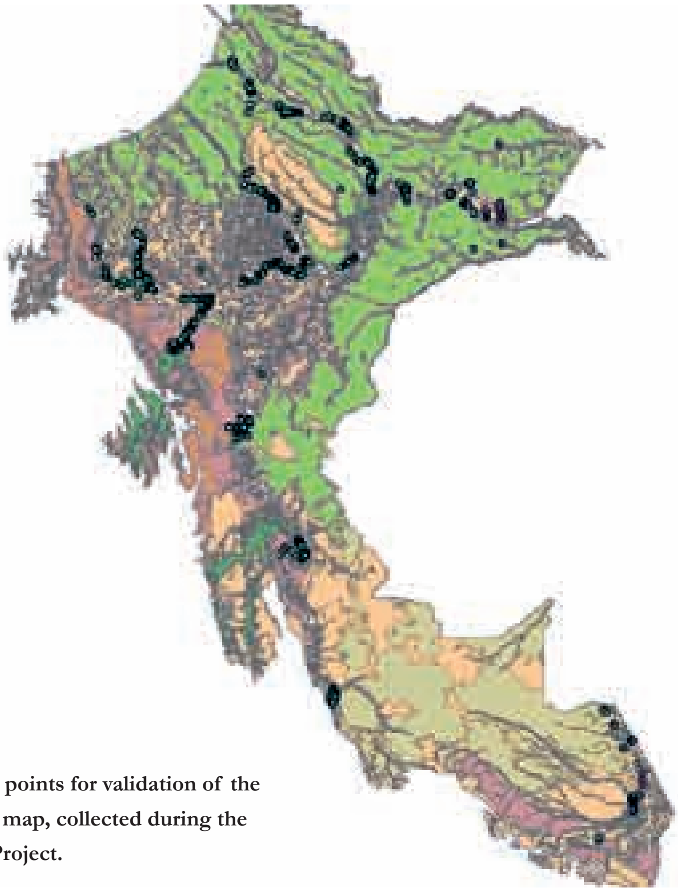


Figure 25. Sample points for validation of the Peruvian Amazon map, collected during the execution of the Project.

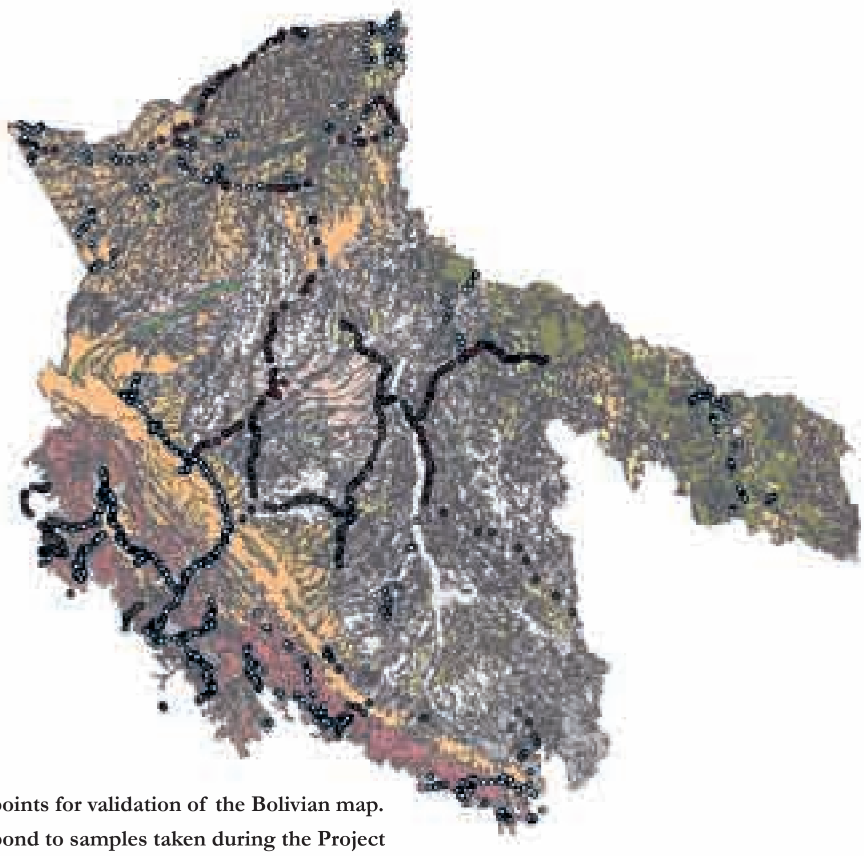


Figure 26. Sample points for validation of the Bolivian map. Dark points correspond to samples taken during the Project and light points to previous samples.

Expedition	Type of sampling	Number of plots	Total Area (ha)	Number herbarium collections	Total registered taxa	Number photographic records
I	Detailed	223	7,005	3.917	6.029	2.443
	Quick	251	--	415	1.646	532
II	Detailed	78	7,8	3.429	8.038	8.238
	Quick	389	--	526	2.194	3.282
III	Detailed	54	5,4	5.528	2.708	3.513
	Quick	105	--	120	499	375
TOTAL	Detailed	355	20,205	12.874	16.775	14.194
	Quick	745	0	1.061	4.339	4.189

Table 15. Sampling points, number of herbarium collections and photographic records.

Botanical collections of the project in Bolivia

In the field campaigns between 2005 and 2006, 756 botanical collections were made, and placed in the National Herbarium of Bolivia in La Paz and in the Herbarium of Universidad de Cochabamba under the collection numbers of botanists, Nelly De La Barra, Margoth Altahuachi and Saul Altamirano.

As shown in Figure 27, collections were carried out in 43 different ecological systems, 14 in the Beni region, 11 in the Amazon and 18 in the Yungas.

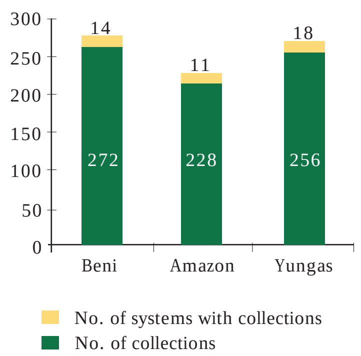


Figure 27 Comparison of number of collections made and number of ecological systems with botanical collection

Among the botanical collections in Bolivia, for different reasons it is important to highlight the following plants:

a) Endemic plants of the Bolivian Yungas:

- *Weinmannia cochabambensis*-(CUNONIACEAE), endemic of the Cochabamba Yungas
- *Oreopanax thaumasiophyllus*-(ARALIACEAE), endemic of the La Paz Yungas
- *Schefflera allocotantha*-(ARALIACEAE), endemic of the La Paz Yungas
- *Polylepis pacensis*-(ROSACEAE), endemic of the La Paz Yungas
- *Cleistocactus viridiflorus*-(CACTACEAE), endemic of the La Paz Yungas

b) New records for Bolivia, collected in the Yungas:

- *Weinmannia elliptica*-(CUNONIACEAE), new southern limit in the La Paz Yungas
- *Commicarpus crassifolius*-(NYCTAGINACEAE), plant never collected again in Bolivia since its description
- *Trichocereus cuzcoensis*-(CACTACEAE), new southern limit in the La Paz Yungas

c) New records for Bolivia or new collections of Amazonian plants very scarcely collected in the past:

- *Dialium divaricatum*-(LEGUMINOSAE), Abuná River
- *Lueheopsis althaeiflora*-(TILIACEAE), Manu River
- *Campsiandra chigo-montero*-(LEGUMINOSAE), Manu and Abuná Rivers Disjunctive occurrences regarding the known distribution area north of the Amazon in Colombia and Venezuela.
- *Couratari tenuicarpa*-(LECYTHIDACEAE), Manu, Negro, Bajo and Abuná Rivers
- *Macrolobium suaveolens*-(LEGUMINOSAE), Manu River
- *Swartzia simplex*-(LEGUMINOSAE), Abuná River
- *Psidium densicomum*-(MYRTACEAE), Abuná River
- *Salacia obovata*- Abuná, Manu and Negro Rivers
- *Licania niloi*-(CHRYSOBALANACEAE), Manu River
- *Dimorphandra pennigera*-(LEGUMINOSAE), new western limit regarding its distribution area in the Brazilian South-Central Amazon
- *Qualea parviflora*-(VOCHYSIACEAE), new western limit regarding its distribution area in the Brazilian South-Central Amazon

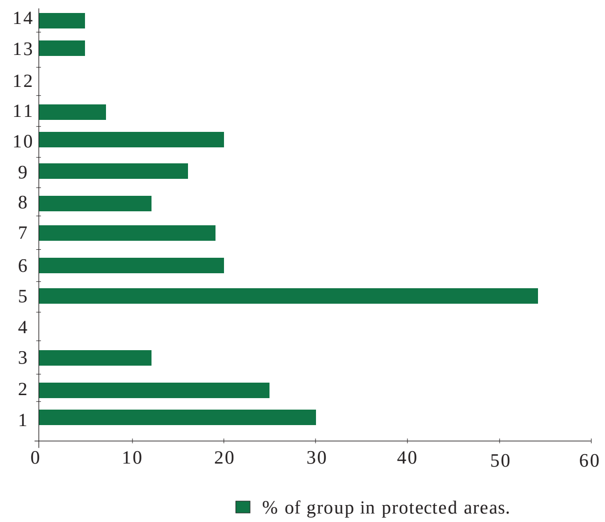


Figure 28. Proportion of the total area of each group occurring inside protected areas of the project study area.

d) Important collections in the Beni:

- *Caraipa llanorum*-(CLUSIACEAE) collected in abundance northwest of the Beni, assuming disjunctive occurrences regarding the know distribution area north of the Amazon in Colombia and Venezuela.
- *Swartzia acreana*-(LEGUMINOSAE) collected northwest of the Beni, in El Cerrado. Plant hardly collected for Bolivia in the past.

2.3. PROTECTION STATUS OF ECOLOGICAL SYSTEMS IN THE PROTECTED AREA SYSTEM OF THE STUDY AREA

The total of ecological systems and mapped complexes, was organized according to Table 1, in 14 ecological groups and the brief summary presented here respond to the results of the conservation gap analysis for these groups (Fig. 28). The groups are as follows:

1 Andean moist forests
2 Amazonian moist forests
3 Andean dry forests and xeric scrub
4 Chiquitano dry forests
5 Andean azonal vegetation
6 Amazonian azonal vegetation
7 Andean grassland and shrubland
8 Amazonian white water floodplain forests
9 Amazonian black water floodplain forests
10 Amazonian clear water floodplain forests
11 Amazonian black or white water flooded vegetation
12 Beni seasonally saturated vegetation
13 Beni seasonally flooded vegetation
14 Beni permanently flooded vegetation

As noted in Figure 28, there are two unprotected groups in the project area. One corresponds to the Beni's seasonally saturated vegetation and the other to the dry forests of the Bolivian Chiquitania. The second group has protection beyond the study area, where these forests are better represented. Nevertheless group 12, as well as groups 13 and 14 that together cover all the vegetation of the Beni's savannas, show very low protection levels. This is a preliminary result that should be taken into consideration since it deals with ecological systems and system complexes restricted only to this area.

Group number 3 of Andean dry forests, has 12 % of its total area under some degree of protection, which is quite low if we consider that the group itself only represents 12.5% of the Andean system's extension within the project area. Moreover, out of the eight ecological systems that compose this group, three are entirely lacking protection and another two include a minimal part of their distribution within any protected area.

Another two groups of systems also show low levels of protection, group number 8 of clear water floodplain forests with 12% and group number 11 of flooded vegetation (white waters, dark or mixed), with a 7% protection.

Other systems that are not included within the system of protected areas of the study area, are the Lithomorphic scrubland of the southern-central Amazonian highlands (CES408.554) and the palms dominated forest of the southern-central Amazon (CES408.518). Among the Andean systems, two of the systems within group number 5 do not have protection either, however, there is a possibility that this could be the result of the mapping difficulties imposed by this type of system due in part to its very restricted extensions. Finally, the *Polylepis* forests, highly threatened by fragmentation and so important to the diversity of the endemic birds they shelter, show a low level of protection in the area under study and in general along their distribution.

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Pongo de Maenique, Cusco. Walter H. Wust

Appendix 1
DIAGNOSTIC DESCRIPTION OF ECOLOGICAL SYSTEMS

Andean-Yungas Ecological Systems

MOIST FORESTS

CES409.920 **High-Andean Polylepis pluvial forest of the Yungas**

Low forests belonging to the hyper-humid pluvial high-Andean zone. Dominated by microphyllous species of Polylepis, which vary according to the geographic zone. Abundance of non-vascular epiphytes. These forests occur as discontinues patches in a matrix of humid Puna grasslands, located approximately between 3500 m and 4200 m elevation.

CES409.043 **Upper montane pluvial forest of the Yungas**

Evergreen forest 10 to 15 m high, typically with coriaceous, sclerophyllous, dark leaves. Abundant presence of epiphytes, vascular and non vascular. Constitutes the upper altitudinal belt of the continuous Yungas forests, developing in hyper-humid areas at an elevation between 2900 m and 3500 m.

CES409.045 **Upper montane pluvial Polylepis forest of the Yungas**
Evergreen forest with canopy from 12 to 15 m high dominated by different species of Polylepis according to the geographic zone, associated to various species of the CES409.043 system. Developing in humid to hyper-humid areas at an elevation between 3100 m and 3600 m.

CES409.044 **Upper montane pluviseasonal forest of the Yungas**
Evergreen seasonal forest with canopy height 10 to 15 m, dominated by species of coriaceous, sclerophyllous, dark leaves. Develops approximately between 2900 m and 3600 m elevation, in areas of the upper-montane humid Yungas belt with a dry season.

CES409.046 **Upper montane pluviseasonal Polylepis forest of the Yungas**
Low forest vegetation system, seasonal evergreen, dominated by species of Polylepis, that vary according to the geographical zone and are associated to species of the CES409.044 system. Belonging to areas with humid pluviseasonal bioclimate, having been substituted to a large extent by secondary grasslands due to human pressure. Potentially developing between approximately 3100 m and 3900 m.

CES409.105 **Northern Andes upper montane evergreen forest**
Evergreen forest with canopy height 10 to 15 m, typically with sclerophyll to sub-sclerophyll leaves. In montainous hillsides of the Northern Andes that reach northern Peru in the Tabaconas area. Pluvial humid to hyper-humid bioclimate, at an elevation between 2900 m and 3400 m.

CES409.050 **Montane pluvial forest of the Yungas**

Zonal system of the Yungas montane belt, between 1900 m and 2900 m elevation, with humid to hyper-humid pluvial bioclimate. These are evergreen, multi-stratified forests rich in epiphytes, with the canopy between 18 m and 25 m high. Characterized by diverse species of montane tropical conifers (Podocarpus, Prumnopitys) and the Weinmannia genus. In the Peruvian north a variant is distributed on sandy soils, where palms of the Ceroxylon genus are dominant.

CES409.110 **Northern Andes montane pluvial forest**

Forests with canopy from 15 to 25 m, evergreen and multi-stratified that grow on hillsides between 1900 m and 2900 m over diverse sustrates of the Northern Andes, may have an abundant presence of palms. Pluvial humid to hyper-humid bioclimate, additionally, according to the slope aspect may be covered daily by clouds.

CES409.913 **Montane pluvial forest of the Condor Mountain Range**

Ecological systems CES409.913 and CES409.903 are dense wooded systems, with canopy height from 15 to 20 m that occupy steep and highly dissected mountain slopes, over a variety of geologies that include metamorphic, sedimentary and volcanic rocks, and even calcareous rocks with kartsic modeling. Found at an altitude between 1400 and 2500 m. Predominance of Rubiaceae, Asteraceae, Mealastomataceae and Lauraceae.

CES409.903 **Lower montane pluvial forest of the Condor Mountain Range**

CES409.051 **Montane humid pluviseasonal forest of the Yungas**

Forests 15 to 25 m tall of the Yungas montane belt, growing in humid areas with a seasonal drop in rainfall that lasts 2-3 months a year. Occurs in mountain slopes from 1900 m to 2900 m elevation. The canopy is characterized by species of mountain tropical conifers (Podocarpus, Prumnopitys) and species of the Weinmannia genus, resistant to the seasonal precipitation deficit.

CES409.197 **Boliviano-Tucumano montane Podocarpus forest**

Forest characteristic of the transitional zone between the biogeographical provinces of the Yungas and Bolivian-Tucuman. Occurs in the humid pluviseasonal montane belt, at an elevation between 1900 and 2900 m in the northwestern part of Department of Santa Cruz (Bolivia). These are seasonal evergreen forests with a clear dominanace of montane conifers (Podocarpus parlatorei, Prumnopitys exigua).

CES409.054 **Lower montane humid pluviseasonal forest of the Yungas**

Seasonal evergreen, diverse and multi-stratified forest, usually characterized by the frequent and abundant presence of Neotropical walnut trees (Juglans neotropica, J. boliviana), distributed in an altitude from 1200 m to 2100 m, in areas with humid pluviseasonal bioclimate of the lower montane zone.

CES409.048 **Lower montane pluvial forest and palm grove of the Yungas**

Evergreen forests, often with abundant or dominant presence of Andean palms (Dictyocaryum lamarckianum), distributed in an altitude between 1200 m and 1900 m, in hyper-humid pluvial areas of the upper part of the lower montane belt. The aspects of the system least exposed to the fog, in low mountainous hillsides, present a lesser presence of palms and increased presence of Lauraceae species.

DRY FORESTS

CES409.921 **Montane subhumid pluviseasonal forest of the Yungas**
Ecological system with vegetation of semideciduous forests 20 to 25 m tall, multi-stratified and with abundant woody vines. Distributed at an elevation between 2100 m and 2900 m in mountainous slopes of the Yungan valleys with topographic effect of partial rain shadow and therefore with a long seasonal rain deficiency of 4-5 months per year.

CES409.075 **Montane interandean xeric forest and shrubland of the Yungas**
Low and drought deciduous forests and shrublands, with open canopy and frequent presence of thorny, mycrophyllous, and cacti species. Developed in inter-Andean valleys of the Yungas subject to a marked topographic rain shadow effect. Occupying areas with xeric dry to semiarid bioclimate, between 2100 m and 3100 m.

CES409.057 **Interandean xeric scrub of the Yungas**
System of very open xeromorphic scrub, offten mycrophyllic and resinous, with abundant agaves and cactus interspersed, in a mosaic with patches of perennial and annual grasslands. This vegetation is installed over degraded and eroded soils in areas of dry to semidry xeric bioclimate, substituting the Yungan inter-Andean xeric forests.

CES409.117 **Lower montane subhumid pluviseasonal forest of the northern Yungas**
Semi-deciduous forest with canopy 6 to 15 m tall, distributed in valleys of central and northern Peru, that experience a marked seasonal decrease in precipitation. Found below 1900 m elevation. This system shares several plant species with the semi-deciduous forests of the Tumbesian biogeographic region, on the western slope of northern Peru and southern Ecuador.

CES409.207 **Boliviano-Tucumano lower montane subhumid pluviseasonal forest**
Semi-deciduous forests with a dense canopy approximately 20 m high, developing at an altitude between 1000 m and 1900 m over mountainous hillsides in areas with sub-humid pluviseasonal bioclimate. In the area of the Project, limited to the extreme south of the Yungas of Santa Cruz, in Bolivia, at the contact area of the biogeographical provinces of Yungas and Bolivian-Tucuman.

CES409.079 **Lower montane xeric forest and shrubland of the northern Yungas**
Ecological system of low, drought deciduous, microphyllous and thorny forests, with frequent cacti and other succulent species. Occupies the bottom of inter-Andean valleys of the Yungas of the north of Peru (Marañon, Bagua) below an altitude of 1200-1400 m. Flora is rich in endemisms, particularly among the cacti family and is related to the xerophytic flora of northern Peru and southern Ecuador.

CES409.056 **Lower montane xeric forest of the southern Yungas**
and other succulent or species. Occupies the lowest part of inter-Andean valleys of the Bolivian Yungas, below 1000 -1200 m. In Peru, it is ound in the Mantaro and Apurimac valleys. The flora is rich in endemisms and is related to the Chiquitanía and the dry inter-Andean valleys of Bolivia-Tucuman floristic provinces.

AZONAL VEGETATION (RIPARIAN AND EDAPHIC)

CES409.063 **High-Andean and upper montane aquatic and palustrine vegetation of the Yungas**
Set of types of hydrophyllous vegetation, belonging to water bodies and their shores in the upper-montane and high-Andean zones of the Yungas. Formed by diverse associations that include marshes dominated by biotypes of helophytes and water bodies with communities of floating and rooted hydrophytes.

CES409.047 **Montane and upper montane riparian vegetation of the Yungas**
System constituted by forests of Alder (Alnus acuminata) and riparian meadows (Cortaderia spp.) that develop at an altitude between 1900 m and 3500 m, growing along the riverbanks and narrow adjacent alluvial plains in the montane and upper-montane elevation belts of the Yungas.

CES409.049 **Yungas ridge pluviseasonal forest**
Forests with seasonal evergreen to semi-deciduous canopies 6 to 12 m high, developed on ridges or abrupt topographical water divides of the lower-montane and montane zones with humid pluviseasonal bioclimate. They settle on rocky, excessively drained soils in situations affected by frequent fog.

CES409.067 **Montane lithomorphic vegetation of the Yungas**

System that includes the open or disperse vegetation that colonizes the rocky substrates of the Yungas. In general, the various associations that occur, have in their floristic composition a predominance of bromeliads, orchids, cacti, Piperaceae and Araceae species; as well as several non-vascular epilithic species.

HERBACEOUS/SHRUBBY VEGETATION

CES409.123 **Upper montane and montane paramo grassland**

Tussock grasses up to one meter heigh, with few forbs growing among them and without a shrubby stratum. Developing above 3000 m elevation, generally with pluvial or humid pluviseasonal climate. They are often the result of frequent fires in the shrubby paramo and the Andean forest. In Peru they are distributed exclusively in the north, where they represent the southern limit of their range.

CES409.124 **Upper montane paramo grassland and shrubland**
Tall and dense tussock grasses with disperse groups of shrubs, occasionally of considerable extension. Distributed at altitudes over 3000 m, on soft hillsides and open valleys with deep, moderately drained soils and humid to hyper-humid pluvial bioclimate. In Peru, they occur only at the extreme north, in the Tabaconas Namballe region

CES409.058 **High-Andean and upper montane pluvial grassland and shrubland of the Yungas**
Grassland system dominated by rhizomatous and caespitose biotypes, part of their extension is the result of the expansion of this system after the destruction of upper montane and high-Andean Polylepis pluvial forests. Given the prolonged intervention of humans in the Andes, they have become permanent natural vegetation types (disclimax).

CES409.059 **High-Andean and upper montane pluviseasonal grassland and shrubland of the Yungas**
Grassland system dominated by rhizomatous and caespitose biotypes, part of their extension is the result of the expansion of this system after the destruction of upper montane and high-Andean Polylepis pluviseasonal forests. Given the prolonged intervention of humans in the Andes, they have become permanent natural vegetation types (disclimax).

CES409.062 **Montane and lower montane savanna of the Yungas**
System formed by open wooded savannas, distributed below 2100 m in the Yungas of northern Bolivia and southern Peru. They occur in sub-humid or humid pluviseasonal areas and represent types of secondary vegetation originated by the effect of fires and cattle ranching on the original forests. Among plant species, the presence of species from the Cerrado and Chiquitania regions is noticeable.

Andean-Yungas ecological systems without photography

DRY FORESTS

CES409.053 **LLower montane subhumid pluviseasonal forest of the southern Yungas**
Semi-deciduous forests distributed below 2100 m in the inter-Andean Yungas valleys of Bolivia and southern Peru. Characterized by flora with frequent or abundant species common also in the forests of the Bolivian Chiquitania with phytogeographical affinity to the Cerrado province.

AZONAL VEGETATION (RIPARIAN AND EDAPHIC)

CES409.065 **Lower montane riparian vegetation of the Yungas**
Riparian system of the lower montane Yungas, distributed below 1900 m, along the riverbanks (rivers, streams, torrents and ravines). In general,under these circumstances, the successional riparian forest is dominated by Inga species. Below 1000 m, it is common to see floristic elements of the successional Amazonian white-water riparian vegetation.

CES409.912 **Upper montane lithomorphic shrubland of the Condor Mountain Range**
Evergreen and dense shrubland with canopy at 3-5 m, with abundant palms and herbaceous undergrowth, the wooded stratum coverage is of 30%. This physiognomy is typical of the upper-montane region. In this case, it takes place at a lower elevation, between 2300 m and 2700 m, due to the topography of steep slopes and mountain crests where landslides are common, associating it to rock outcrops and gravel.

CES409.914 **Pluvial forest on plateaus of the Condor Mountain Range**
This system represents montane forests growing between 1300 and 2200 m that occur in the slopes that form the spur of the sandstone plateaus of the Condor Mountain Range, with a humid to hyper-humid pluvial bioclimate. These are forests growing on acid substrates and well-drained soils. The structure is that of a dense forest with canopy at 10 to 20 m and loaded with moss and epiphytes.

CES409.039 **Shrublands and meadows on eastern Subandean plateaus**
System composed of sclerophyllous herbaceous vegetation dominated by terrestrial bromeliad and orchid clones that reach up to 1m in height, interspersed with low sclerophyll shrubs also intertwined with hemi-epiphytes. It is found along sandstone plateaus and summits or derivated sandy substrate at an altitud above 2000 m and with a humid to hyper-humid pluvial bioclimate.

CES409.195 **Boliviano-Tucumano low edaphoxerophilous forest**
Type of forest with seasonal evergreen canopy from 6 m to 12 m, characterized by the abundance of species with coriaceous or sclerophyllous leaves. Occurs on ridges or abrupt and cloudy topographical divides, on hyper-drained soils of the montane belt with humid pluviseasonal bioclimate. Restricted to the the Department of Santa Cruz (Bolivia).

Amazonian Ecological Systems

UPLAND FORESTS

CES408.565 **Western Amazon subandean evergreen forest**

These are Amazonian forests with few Yungas elements that are dense, tall and multi-stratified and constitute one of the most diverse and least known ecological systems in South America. They are distributed along the low sub-Andean ridges with humid to hyper-humid pluvial bioclimate, below 1300 m approximately. Species of Rubiaceae and Lauraceae are important components of the system, as well as Oenocarpus, Iriartea and Wettinia palm trees. It is distributed from southern Colombia to central and north Peru.

CES408.572 **Western Amazon piedmont forest**

Wooded communities settled on basal plains and gentle slopes characteristic of the alluvial glacis of the eastern Andes piedmont, with clayey to sandy soils and black-water runoff during the dry season and mixed-waters during the rainy season. The canopy reaches 20 m to 25 m and goes from continuous to open with scattered emergents.

CES408.543 **Southwestern Amazon subandean evergreen forest**
Dense, tall and multi-stratified Amazonian forests with some Yungas elements, highly diverse and poorly studied. They are distributed along the low sub-Andean ridges of central south Peru to northern Bolivia with pluvial humid to hyper-humid bioclimate, below 1000 m to 1300 m.

CES408.545 **Southwestern Amazon subandean evergreen seasonal forest**
Amazonian forests distributed below 1100 m and 1300 m, along the low sub-Andean ridges with humid pluviseasonal bioclimate from southern Peru to central north Bolivia.

CES408.570 **Southwestern Amazon piedmont forest**
Assemblage of several types of forests developed on the alluvial glacis of the eastern piedmont of the Andes, primarily on well-drained top soils but with poor drainage or high water table in the subsurface zone. The combination of upland species together with species from the white-water floodplains is characteristic.

CES408.523 **Western Amazon evergreen forest of the peneplain**
Is the system of greater extension in the study area and with the highest diversity of woody species, associated in some sectors to large palm trees. This is a multi-stratified forest with the canopy at 35 m with scattered emergents more than 40 m tall and diameters that are usually between 80 and 120 cm. They are upland forests developed over plains and low hills of sedimentary origin.

CES408.548 **Western Amazon isolated ridges forest**

System that develops on isolated mountains of the El Divisor Mountain Range, originated in the Tertiary, over soils that go from clayey at the hillsides to sandy at the tops and with good drainage due to the slope. The forest on the hillsides is taller and more diverse than on the summits, where it characterized by slender, short trunks. It is found between 150 m and 800 m, in the mountains southwest of Contamana towards the border between Peru and Brazil.

CES408.544 **Southwestern Amazon evergreen seasonal forest of the peneplain**

This is a multi-stratified forest with a canopy that reaches 30-35 m and emergents of up to 40 m. It develops on well-drained soils of the lateritic rolling peneplain of the southwestern Amazon, where it represents the extensive matrix of vegetation cover in areas with humid pluviseasonal bioclimate of southern Peru, northern Bolivia and western Brazil. In most of these forests is characteristic the frequent to abundant presence of the brazil nut tree (Bertholletia excelsa).

CES408.549 **Southwestern Amazon Bamboo forest**

This is a system of pure or mixed Guadua forests that develops over flat and dissected reliefs and on the low hills of the Tertiary and the Quaternary to the Andean piedmont at an altitude between 150 m and 1200 m. It covers extensive areas in the southwestern Amazon region of Peru, Bolivia and Brazil. The bamboo forest canopy reaches up to 20 m in height.

CES408.518 **Central-south Amazon palm dominated forest**

Amazonian forests with Bertholletia excelsa and abundant to dominant presence of the Attalea speciosa palm tree, characteristic of very seasonal areas of the Precambrian shield of northeastern Bolivia and western Brazil.

CES406.235 **Chiquitanian precambrian shield evergreen seasonal Amazonian forest**

Seasonal upland forest that constitutes in Bolivia the southernmost limit of the seasonal forests of Central-south Amazon, at the transition zone to the Chiquitanía. The floristic foundation is Amazonian, with some extensive Chiquitanian elements.

AZONAL VEGETATION (EDAPHIC)

CES408.546 **Western Amazon azonal semi-deciduous forest**

This is an azonal system with localized distribution and structure determined by the conditions of the relief and the humidity gradients of the slopes in the complex system of hills where it grows. The physiognomy of the vegetation is defined by a sequence of low and open woodlands and tall, dense forests corresponding to the summits and the streams, respectivelly. This hill complex can be found between the Nanay and Tigre – Pucacuro Rivers.

CES408.562 **Western Amazon white-sand sclerophyll vegetation**

System with disjunct distribution, determined by the edaphic conditions of the white-sand low-nutrient soils and the presence of a hardpan layer in the subsoil. The depth of this layer and the topography of the site influence the physiognomy of the communities that varies from woody forms 1-2 m in height, to woodlands 5-8 m tall, up to forests of 15 m known as varillales due to the slender tree diameters of ~20 cm.

CES408.554 **Central-south Amazon ridges lithomorphic scrub**

This vegetation is characteristic of the rocky outcrops of plateaus, ridges and domes or inselbergs above 300 m elevation. Structurally, these are xeromorphic scrubs with some very disperse bushes and small trees. Due to the preponderance of Vellozia species and other elements, it has floristic relationships with the saxicolous flora of the Guiana Shield.

CES408.557 **Central-south Amazon savanna transitional to the Cerrado**
Treed savannas with flora from the Cerrado province, developing over well drained soils along plateaus and ridges of the north of the Brazilian Shield, in areas with a landscape matrix of Amazonian forests. These are distributed along easternmost Bolivia and adjacent Brazil.

FLOODABLE FORESTS

CES408.532 **Western Amazon white-water floodplain forest**
This system is exposed to seasonal and relatively short sediment rich, white-water floods. It develops in the recent and sub-recent alluvial plains of white-water rivers of Western Amazon. These forests reach up to 30 m in height, and are characterized by an association of trees and palm trees of caespitose and thorny habits.

CES408.531 **Southwestern Amazon white-water floodplain forest**
These forests are seasonally flooded by flowing white-waters carrying important loads of sediment and develop in the recent to sub-recent alluvial plains of the Southwestern Amazon.

CES408.578 **Southwestern Amazon stagnant white-water flooded forest**
These are forests with irregular canopies that grow in the furthermost areas of the alluvial plains of white-water rivers. They flood superficially due to the more distal spills of the large flood tides of the river and also in part due to the rain. These waters accumulate in the depressions and remain stagnant for several months.

CES408.550 **Amazon white-water riparian successional vegetation complex**
Pioneer herbaceous communities followed by bushy and treed patches – also from pioneer species, which colonize the ecologically unstable banks of the white-water Amazonian rivers, in areas with unevolved soils, periodically re-deposited that are swept away during the large flood tides.

CES408.536 **Western Amazon black-water floodplain forest and riparian vegetation**
This is a system of forest and shrubland communities that develops in flat to slightly depressed relieves, over primarily white-sand soils, floodable by non-mineralized waters poor in sediment and rich in humic acids and tanic substances.

CES408.535 **Southwestern Amazon black-water floodplain forest and riparian vegetation**
These are Amazonian riparian forests that are flooded by flowing black-waters. They are distributed along the riverbanks and the recent alluvial plain of the Amazonian rivers of non-mineralized waters, poor in sediment and rich in humic acids.

CES408.538 **Western Amazon alluvial plains palm swamp**
This system covers very large extensions of almost pure Mauritia flexuosa palm communities with low abundance of tree species and in sectors associated to other palm trees. The height of the canopy is between 25 and 30 m. It occurs in slightly depressed, slow drainage plains flooded by runoff rainwater and black-water meandric rivers.

CES408.573 **Southern Amazon alluvial plains palm swamp**

Palm groves and forests with Mauritia flexuosa palm trees, flooded by waters without or with very low minerals content and without suspended sediment. They are distributed along the banks and shores of permanent water bodies, streams and depressions of the alluvial floodplains, which in the south of Peru and the Bolivian Amazon are of relatively limited extension.

CES408.526 **Southern Amazon stagnant black-water alluvial forest**

These are forests with irregular canopies, 20 m to 25 m in height, that grow in the furthermost areas of the alluvial plains of black-water rivers. They flood superficially due to the more distal spills of the large flood tides of the river, due to the rainwater and the overflow of streams. Characteristic on clayey soils with flatted mounds 0.5 to 1 m in height, i.e. "gilgai relief".

CES408.574 **Central-south Amazon black-water floodplain forest**
Flowing black-waters flood this vegetation. It is distributed along the mid and upper basins of the Madeira and Tapajoz rivers, in the center of Brazil and easternmost Bolivia.

CES408.576 **Southern Amazon upland depression forest**
Medium or short forests developed in flat and topographical depressed areas with poorly drained soils. The flora is partially shared with black-water systems. They are distributed along large extensions of the Bolivian-Brazil border. They also extend towards the west along the Madre de Dios and Beni rivers, reaching the Pampas del Heath in Peru.

CES408.567 **Central-southern Amazon clear-water stream forest**
This forest develops along the riverbeds and banks of oligotrophic clear-water streams of the Amazonian uplands in the northeast of Bolivia and the southwest of Brazil.

CES408.569 **Western Amazon alluvial plains swamp forest**
This system is composed by a group of semi-open woody communities, interspersed along marshy grasslands and palm swamps. It is part of the mosaic that occupies the extensive lateral depressions of the alluvial plains of the large rivers of the western Amazon, exposed to the black-water and mixed-water flows filtered during the flood season.

CES408.571 **Amazon mixed-water flooded forest and riparian vegetation**

Ecological system of the riverbanks and the recent alluvial plains of mixed-water Amazonian rivers, that floods seasonally with flowing waters chemically intermediate between black and white waters. The floristic composition contains elements both of white-water flooded forests and black-water flooded forests.

CES408.560 **Upper Amazon treed savannas on wet soils**

Savanna woodlands occurring on a relief of mounds, surrounded by clayey poorly drained soils including areas with marshes and grass savannas. This mosaic of savannas is surrounded by seasonal evergreen Amazonian forests. It is distributed in a small enclave along the Heath River in Peru and extensively along the Bolivian Amazon.

CES408.552 **Upper Amazon alluvial plains marsh**

Complex of swamps within a matrix of waterlogged meadows and marshes with large hydrophytic forbs, associated in occasions to disperse palm trees. Mainly distributed along recent alluvial plains and in depressions of the Amazonian savannas.

Amazonian ecological systems without photography

UPLAND FORESTS

CES408.566 **Central-south Amazon isolated ridges forest**

Semi-deciduous to evergreen seasonal forest distributed along the ridges and isolated plateaus in the north of the Brazilian Precambrian shield, on rocky and well-drained soils within areas of humid pluviseasonal bioclimate. Semi-open, 25 m high canopy. Occurs in easternmost Bolivia and adjacent areas of Brazil.

FLOODPLAIN FORESTS

CES409.061 **Subandean palm swamp of the Yungas**

This system is distributed along the meandric rivers that are found on a few flat upstream valleys or plateau-like landforms of the Peruvian Sub-Andean ridges below 1600 m and with a humid to hyper-humid pluvial bioclimate. Canopy dominated by Mauritia flexuosa palms of 30 m, followed by another stratum 10 m tall, with scattered Euterpe precatoria palms and grassy undergrowth.

CES408.528 **Southwestern Amazon clear-water stream forest**

Flooded forests of the riverbeds and banks of permanent and seasonal oligotrophic clear-water streams of the southwestern Amazon peneplain. The canopy reaches 20 m to 25 m with scattered emergents.

Ecological Systems of the Beni

DRY FORESTS

CES406.238 **Chiquitania and Beni semideciduous subhumid forest**

Semi-deciduous forests 20-25 m tall, with several strata of undergrowth and abundant lianas. They develop in well-drained soils of the Chiquitanía and the Beni, in areas with sub-humid pluviseasonal bioclimate. Distributed to the east of Bolivia, but floristically representing regional variations of similar forests from central Brazil.

CES406.240 **Chiquitania and Beni "cerradão"**

Low, semi-open and sclerophyllous forest system of the Cerrado that develops on well drained and poor red lateritic soils, of northern Beni. These are a series of forests that reach their optimal distribution along the Bolivian Chiquitania and the Bolivian border with Brazil.

SEASONALLY SATURATED VEGETATION

CES406.241 **Cerrado and Beni saturated "cerradão" of the non-alkaline flatlands**
Low forests and wooded savannas distributed along the semi-uplands of the central-north Beni, with non-alkaline seasonal poorly-drained or slightly saturated soils. The flora is mainly composed of wide elements of the Cerrado.

CES406.245 **Beni seasonally flooded palm grove and savanna of the alkaline flatlands**
Palm groves and semi-deciduous open forests with abundant palms (Copernicia alba) that develop in the semi-uplands with poorly-drained or slightly saturated alkaline soils of the eastern Beni. The flora shares numerous species with the Eastern Chaco.

CES406.246 **Cerrado hydrophytic savanna with termite mounds**

Wooded savanna growing on flooding plains with abundant termite mounds. Woody plants grow preferably on the hillocks, while grasses thrive in the interspersed depressions or swales that get seasonally saturated. It's a system with huge extensions in the Brazilian Pantanal and the Cerrado. In Bolivia, it is located to the northwest of the Beni and contains disjunct elements from the savannas north of the Amazon, such as Caraipa llanorum.

CES406.248 **Beni and Chiquitania open hydrophytic savanna**

Herbaceous savanna growing on poorly-drained and briefly flooded soils, distributed along the Beni semi-uplands. The floristic composition varies according to the abundance of bases in the soil and the level of seasonal flooding.

SEASONALLY FLOODED VEGETATION

CES406.226 **Beni gallery forest**

Low riparian forest that forms galleries along streams and small rivers of the secondary drainage network of the Beni in a matrix generally composed of flooding savannas.

CES406.249 **Beni seasonally flooded herbaceous mesotrophic savanna**

Open savanna grasslands without a woody component and dominated by large grasses of robust culms or tall sedges. Seasonally flooded 4 to 8 months a year by flowing white-waters from the overflow of the Beni river.

CES406.250 **Chiquitania and Beni seasonally flooded herbaceous oligotrophic savanna**
Dense herbaceous savanna of grasses and sedges, developed in very flat depressional areas over clayey soils poor in mineral nutrients that are seasonally flooded by oligotrophic waters. Distributed along the center-north of the Beni and the Chiquitanía.

SEMI-PERMANENTLY FLOODED VEGETATION

CES406.251 **Beni wet savanna**
Treed and shrubby savannahs seasonally flooded for long periods by white-waters, distributed extensively along the lowest topographical areas of the center and south of the Beni.

CES406.253 **Chiquitania and Beni aquatic and palustrine neotropical vegetation**
Complex of emergent, submergent and floating aquatic plant communities distributed in lagoons edges, riverbanks and fluvial pools of the Beni.

Beni ecological systems without photography

CES406.225 **Western Beni seasonally flooded thorn forest of the alkaline flatlands**
Low forests from 6 to 8 m in height with emergents up to 15 m tall, frequently composed of thorny species that develop in patches over the topographical semi-uplands on poorly drained alkaline, somewhat saline soils of the west of the Beni. The flora shares numerous species with the Eastern Chaco.

Appendix 2

Field forms

Zona de mapeo ☐ Yungas Bolivia ☐ Yungas Peru ☐ Beni
☐ Amazonia Oeste ☐ Amazonia Suroeste ☐ Amazonia Centro Sur

Grupo en Campo ☐ UNALM ☐ IIAP ☐ GN

Departamento

ID DEL PUNTO

localidad
fecha numero
responsable ID GPS

No. de fotos

Dato Horizontal
UTM Zone ☐ 17 ☐ 18 ☐ 19 ☐ 20
UTM East UTM North
Precision del punto GPS ☐ DOP______ ☐ EPE______
☐ buena ☐ media ☐ regular

Altitud (m)

Clasificacion Sistema Ecologico

Confianza en clasificacion
☐ alta ☐ media ☐ baja

Macrogeoforma
☐ planicie ☐ lomada ☐ colina ☐ montana
☐ valle ☐ meseta ☐ llanura de inundacion
☐ terraza ☐ abanico ☐ depresion ☐ ladera ☐ filo

Nivel intervencion del paisaje
☐ alto ☐ medio ☐ bajo ☐ nulo

Nivel intervencion en la muestr
☐ alto ☐ medio ☐ bajo ☐ nulo

Field form developed for quick samples

Zona de mapeo ☐ Yungas Bolivia ☐ Yungas Peru ☐ Beni
☐ Amazonia Oeste ☐ Amazonia Suroeste ☐ Amazonia Centro Sur

Grupo en Campo ☐ UNALM ☐ IIAP ☐ GN

Departamento ____________

ID DEL PUNTO

localidad			
fecha		numero	
responsable		ID GPS	

No. de fotos ____________

Dato Horizontal ____________

Latitude ____________ **Longitude** ____________

UTM Zone ☐ 17 ☐ 18 ☐ 19 ☐ 20

UTM East ____________ **UTM North** ____________

Precision del punto GPS ☐ DOP______ ☐ EPE______
☐ buena ☐ media ☐ regular

Altitud (m) ____________

Tamano de muestra ☐ <1 ha ☐ >1 ha

Clasificacion Sistema Ecologico
____

Confianza en clasificacion ☐ alta ☐ media ☐ baja

Especies caracteristicas	Estrato	Cobertura

% Cobertura: 5. 80 - 100% 4. 60 - 80% 3. 40 - 60% 2. 20 - 40% 1. 10 - 20% r. 5 - 10% +. < 5%

Confianza en identificacion
☐ alta (>60%) ☐ media (30-60%) ☐ baja (<30%)

Clase fisonomica
☐ bosque ☐ sabana arbolada ☐ arbustal
☐ arbustal enano ☐ herbacea ☐ palmar
☐ bambusal ☐ no vascular ☐ dispersa

Altura del dosel (m) ____________

Cobertura
☐ cerrada (>75%) ☐ semi-cerrada (50-75%)
☐ semi-abierta (25-50%) ☐ abierta (<25%)

Fenologia
☐ siempreverde ☐ siempreverde estacional
☐ semideciduo ☐ deciduo

Clase hidrologica
☐ tierra firme bien drenada ☐ ripario
☐ tierra firme regularmente drenada ☐ humedal temporal
☐ tierra firme mal drenada ☐ humedal permanente

Textura suelo
☐ fina ☐ media ☐ gruesa ☐ pedregoso

Profundidad suelo
☐ profundo (>50 cm) ☐ media (20-50 cm)
☐ superficial (<20 cm)

Pendiente ☐ <5% ☐ 5-15% ☐ 15-30%
☐ 30-50% ☐ 50 - 75% ☐ 75 -100% ☐ >100%

Orientacion ____________

Macrogeoforma
☐ planicie ☐ lomada ☐ colina ☐ montana
☐ valle ☐ meseta ☐ llanura de inundacion
☐ terraza ☐ abanico ☐ depresion ☐ ladera ☐ filo

Nivel intervencion del paisaje
☐ alto ☐ medio ☐ bajo ☐ nulo

Nivel intervencion en la muestr
☐ alto ☐ medio ☐ bajo ☐ nulo

Notas

Field form developed for detailed samples

Ecological Systems

of the Amazon Basin of Peru and Bolivia

Clasification and Mapping

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