

Mapping the actual and original distribution of the ecosystems and the chorological types for conservation planning in Colombia

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ABSTRACT

A key requirement for systematic conservation planning is the availability of good quality and comparable data about the biodiversity. However, for many highly diverse countries, this information is not available. Here we present the methodology and the results of the three-part construction of a conservation planning database in Colombia: (1) the actual distribution of the ecosystems; (2) their original-potential distribution, which is important to calculate fixed targets for conservation; and (3) the chorological types, which are groups of spatial related ecosystems that account for biodiversity process that operate at larger scales. The procedure consists of integrating the results of the interpretation of satellite images, and the construction of ecological diagrams and biogeographical regions. The limits of the original-potential ecosystems in the transformed landscapes can either still be seen on the images or are reconstructed on the base of the information from the ecological diagrams. The chorological types are constructed by clustering of ecosystems on the base of the shared boundary length. The implementation for Colombia resulted in maps of 337 ecosystems and 63 chorological types. This database was successfully used for the identification of the priorities for conservation.

Keywords

Actual ecosystems, chorological types, conservation planning, ecological diagrams, ecosystem mapping, original-potential ecosystems.

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INTRODUCTION

Colombia is a country with a very high biodiversity but less than half of the ecosystems are currently protected in the national park system (Fandiño-Lozano & van Wyngaarden, 2003). There is an urgent need to complete the system of conservation areas through a process of systematic conservation planning. One of the key requirements for such an exercise is the availability of good quality and comparable data for the whole territory analysed (Margules & Pressey, 2000). But in Colombia, as in many other countries in the tropics, knowledge about biodiversity is limited. For Colombia it is estimated that, at the most, 10% of all species have been described (Hernández-Camacho pers.com.). Some studies in the Amazon illustrate this problem. For the description of the vegetation of a relatively small area, several years of work in different herbaria of the whole world was needed by a team of taxonomists. At the end only between 40% and 70% of the specimens could be identified at species level (Duivenvoorden & Lips, 1995; Duque *et al.*, 2001). The rest were species that were never described before, sterile specimens

or whose morphological variation made their identification impossible.

The description of existing ecosystems and biotic communities for Colombia is also problematic in various ways. They cover only small parts of the country, and are often not comparable because of the taxonomic incompleteness or discrepancies between taxonomists. These limitations became clear to us when trying to include some biological data in our ecosystem map. We ended up with a vegetation table in which the clusters coincided more with the different authors than with the variation in ecosystems. In this sense, Colombia is not unique. Biotic information has proven to be insufficient for conservation planning even in far more studied regions (e.g. Pressey *et al.*, 2000; Cowling & Heijnis, 2001). Therefore, a major challenge for conservation scientists is to find alternative methods that, in a reasonable time, generate information that is comparable for the whole territory and that is valid as a base for systematic conservation planning.

In the last decade, several techniques, definitions and names have been proposed for this. Land classes (Pressey & Logan, 1995), ecoregions (Dinerstein *et al.*, 1995), vegetation types (Jennings,

2000), land systems (Pressey & Taffs, 2001) and broad habitat units (Cowling & Heijnis, 2001) are some examples. They form a range of more physically determined units to ones with some biological content. In general they are constructed on the base of widely available physical land attributes such as climate, topography, geology or soils, and sometimes combined with some biological, biogeographical data, or both. It is generally assumed, although not always proven, that the used physical attributes have a relationship with the biotic elements and that the variation in the latter can be directly inferred by the variation in the former.

Although the efforts mentioned contribute to the principle aim of providing comparable data for conservation planning, some aspects need further elaboration:

The confirmation that the physical variables used to define the land types, are effective as surrogate for species (Lombard *et al.*, 2003). As suggested by Ferrier (2002), integrating biological and environmental data, and using relatively data-rich regions as test beds can help in this respect.

The minimum target — the area of an ecosystem that has to be conserved to secure the survival of its species — is normally expressed as a percentage of area of the actual ecosystems. However, this means that it is limited to the present extension of the remnants and that it varies in time because of the ongoing transformation of nature. Expressing the minimum target as a fraction of the original extent of the ecosystem avoids this (Fandiño-Lozano, 1996; Jennings, 2000; Pressey *et al.*, 2003).

Given that not all species can satisfy their requirements within a single ecosystem, a higher level conservation unit comprising various ecosystems is needed to support those biological processes that operate at larger scales (Fandiño-Lozano, 1996; Pressey *et al.*, 2003).

In this paper we present the procedure and results of the construction of the conservation planning database for Colombia. First we describe the mapping of the actual ecosystems on the base of some biological and biogeographical characteristics and those physical attributes of the land that have a proven relationship with biotic elements. Then we present the map of the original distribution of the ecosystems. To account for the need to also consider the relations between individual units, the mapping of chorological types is also shown. Chorological types are defined here as groups of ecosystems that are more spatially related between them than with others.

This database was already used for the systematic conservation planning undertaken for Colombia as a whole (Fandiño-Lozano & van Wyngaarden, 2003). Its broad usefulness was demonstrated in other applications such as the description and explanation of the transformation of ecosystems (van Wyngaarden & Fandiño-Lozano submitted) and the zoning of national parks for management based on a condition and vulnerability analyses (Fandiño-Lozano, 1996; van Wyngaarden & Fandiño-Lozano, 2002).

MATERIALS AND METHODS

Study area

Colombia is a relatively large (1.14 million km²) country located in the Neotropics with a growing population of

about 45 million. The dominant physiographic phenomenon is the Andes mountain range that crosses the country from north to south and reaches an altitude of more than 5000 m. The climate varies from almost desert conditions in the north-east (200 mm/year) to extremely wet conditions along the coast of the Pacific Ocean (18,000 mm/year). Soil fertility varies from relatively fertile in the recent alluvial plains and regions with recent volcanic ash deposits to extremely poor in the highly leached soils of the Guyana shield. This large variety of physical conditions is associated with an extremely rich biota.

Mapping the actual ecosystems

The mapping of the actual distribution of ecosystems has a long history and there are standardized procedures available for this (e.g. Zonneveld, 1979, 1988). This approach was our starting point, but because of the large size of the country and the problems already mentioned, it was not feasible to neither collect field data nor to use comparable secondary data. Therefore, we modified that routine into a procedure that consisted of four steps:

Delineation of preliminary units

The preliminary units were extracted from satellite images by visual interpretation, using physiography and vegetation structure as criteria. We started this process more than 10 years ago with a variety of images and updated the preliminary units using recent Landsat ETM + images as available at the Global Land Cover Facility (GLCF, 2003). From each image, a pseudo natural colour composite was produced from the bands 3, 4 and 5. It was displayed on screen at a scale of 1 : 100,000 to 1 : 200,000 and the limits of the preliminary units were captured through screen digitizing. A total of 59 Landsat ETM scenes are necessary to cover the whole territory of Colombia. But because in several cases, no cloud-free images were available over the required period, several images of the same area were requiring a cloud-free picture. A total of more than 100 images were processed and interpreted.

For regions with clear differences in physiography and vegetation structure, the interpretation was straightforward and the preliminary units could be identified easily. Remains of extant ecosystems in the transformed areas could normally be identified on the base of the structure of the vegetation: forest versus pastures or cropland, and field pattern. Extreme climatic conditions, in terms of a long dry season, could also be recognized with ease on the base of the deciduousness of the vegetation cover. The physiography was classified directly at the level of landform (Verstappen & Zuidam, 1991). The associated geology and soil data were extracted from secondary sources (e.g. IGAC, 1985; Botero, 1999). The vegetation structure was classified at formation level (UNESCO, 1973) but, within these categories, there might be variation in floristic composition (Gils & van Wyngaarden, 1994). That variation was explored on the base of the variation in forming factors.

Construction of the ecological diagrams

Given that not every physical and historical factor influences the position of the communities in the landscape, we determined which forming factors have explanatory value in Colombia. A number of studies containing a quantitative analysis of the vegetation–environment relations through direct gradient analysis (Jongman *et al.*, 1987) are available for some parts of the country (Duijvenvoorden & Lips, 1995; Fandiño-Lozano, 1996; Duque *et al.*, 2001; van Wyngaarden & Fandiño-Lozano, 2002). Based on the results of these studies, we could conclude that the physiography and related soil conditions, length of the dry period, altitude and old events of isolation–connectivity of the biota, explain to a large extent the distribution of the well-studied communities. These data were then used to construct ecological diagrams for the different regions of the country. These are two- or three-dimensional graphs, where the axes represent the explanatory forming factors and the community types are plotted in the feature space (Zonneveld, 1960; Fandiño-Lozano, 1996).

Some of these forming factors, physiography in particular, show abrupt limits in the landscape and, for that reason, were used already in the definition of the preliminary units during the image interpretation. Others, such as altitude and length of the dry period, change gradually. Their effect on the vegetation is sometimes visible on the images, but is not always characterized by sharp limits. Neither is it easy to see what is the influence of past connectivity–isolation on speciation. Those cases were solved in the following way.

Subdivision of the preliminary units

Before introducing the relevant limits into the preliminary units, the maps of altitude and climate had to be produced. The map with altitude was obtained by linear interpolation of the contour lines of the national topographic map (IGAC, 1995). The map of the length of dry period was produced in two steps. First, the length of the dry season was calculated for about 1400 climatic stations using a water balance model based on the agro-ecological zones (FAO, 1981) and Land Evaluation Computer System principles (Wood & Dent, 1983). The map of the length of the dry season was then produced through spatial interpolation of the point data by means of anisotropic kriging (ITC, 2001). Both maps were divided into classes according to the values of the ecological diagram that indicated changes between ecosystems. The class boundaries of the two maps were overlaid on the satellite images and, when the boundaries coincided more or less with variations in the image, the preliminary units were corrected through re-interpretation. If they were not visible, the preliminary units were subdivided through a process of spatial modelling or conditional map overlaying in a geographic information system (GIS).

Construction of a biogeographical model and its use

The historical forming factor of isolation–connection has to do with the process of speciation. Without species data, it is difficult

to describe those effects. However, its role was evident in the results of the direct gradient analyses available. Different communities were identified under identical physical conditions and that can only be explained by historical factors. For example, different forest communities were found at opposing flanks of the cordillera under identical geomorphologic, soil and climate conditions. The effect of differences in micro (meso) climate because of exposition or insulation is thought to be insignificant in this area which is so close to the equator. Thus a biogeographical model was developed in order to predict the influence of tectonic processes, vast rivers and flood plains, and extreme climatic conditions on speciation (Fandiño-Lozano & Wyngaarden, unpublished data). In order to test the model, the expected differences were compared with the available data about the distribution of some endemic species (Hernández-Camacho & Cooper, 1976; Hilty & Brown, 1986; Alberico *et al.*, 2000; Hernández-Camacho & Rodríguez-Mahecha, 2002). This revision of literature allowed us to corroborate the biogeographical model. It was then used to subdivide again the preliminary units.

Mapping the original–potential ecosystems

Fifty years ago, Tuxen (1956) introduced the concept of the potential natural vegetation to describe what could be the natural vegetation of nowadays highly transformed landscapes. He defined it as the final stage of a spontaneous development of the vegetation under the present site conditions. A different concept is that of the original vegetation. That is the vegetation as it was before the human impact (see also the discussion in Mueller-Dombois & Ellenberg, 1974). We merged the two terms into original–potential ecosystems because for a large part of Colombia, it is still possible to observe the limits as they were before human influence but for some highly transformed parts of the country, a reconstruction had to be made in the sense of Tuxen (1956). The present authors already published original–potential ecosystem maps for some parts of the country (Fandiño-Lozano, 1996; van Wyngaarden & Fandiño-Lozano, 2002).

The procedure to follow in the construction of the original–potential ecosystem maps depended on the level of transformation of the landscape. In untransformed landscapes, the limits of the original ecosystems are the same as those of the actual ecosystems. In little transformed areas, the limits could normally be traced easily on the base of the scars on the landscape and the final delimitation could follow a procedure that is similar to the mapping of the actual ecosystems. In moderately to strongly transformed landscapes, the procedure depends on whether the limits between the ecosystems are still recognizable or not. If they are, the limits are drawn in the same way as above; if not, the values of the forming factors at which the ecosystem occur in the ecological diagram and the bio-geographical position of the units were used to trace the limits through spatial modelling. In some completely transformed landscapes, where no relicts are left at all, this resulted in the prediction of lost community types. It will never be known exactly what the detailed content was. At the most, a rough prediction can be made on the basis of minor

natural elements in the landscape such as hedgerows, research on seed banks and palynological data.

Mapping the chorological types

Zonneveld (1979, 1995) described chorological patterns as one of the dimensions of the landscape that was derived, as an indirect result, from the delineation of topological units or ecosystems. Fandiño-Lozano (1996) made the concept of chorological types operational in the sense that they became units containing a group of spatially related ecosystems. The way to express that spatial relatedness is to look at the proportion of the boundary that is shared. Once the original-potential distribution of the ecosystems is known, it becomes possible to calculate, for each ecosystem, the boundary length shared with each other. Because of the very large variation in the size of the ecosystems, absolute values of boundary length may distort the relationships. Therefore, it was expressed as a percentage of the total boundary length per ecosystem. The differentiation of the chorological types is then done by cluster analysis using TWINSpan (Hill, 1979) or gradient analysis with CANOCO (Braak & Smilauer, 1998) on the base of the values of the shared boundary length.

All image processing, digitizing and spatial modelling was done in the Integrated Land and Water Information System (ILWIS) geographical information system (ITC, 2003).

RESULTS

About 150 different preliminary units were identified. However, in some parts of the country, these preliminary units consisted of

large tracts of forest with a similar physiography and suspected differences in physical and biotic conditions. Here the differences in ecosystems related to the large range of altitudinal or climatic conditions were not always reflected in delineable image characteristics.

The next step was thus to identify which forming factors are relevant for Colombia and what are the critical values at which the communities change. Figure 1 depicts an example of a direct gradient analysis for the Iguaque area situated in the eastern Cordillera of the Andes (Fandiño-Lozano, 1996). That analysis started with 30 environmental variables but only six contributed significantly to the explanation of the variation in the biotic communities. They belong to either a group dealing with soil conditions (geomorphologic positions, slope form, rockiness and soil depth), or climatic conditions (altitude-temperature and length of the dry season).

For the Nevados area, the soil conditions were important also to explain the differences within the Paramo ecosystems; but the altitude — temperature — and length of the dry season were the main differentiating factors for the forest types located on the slopes of the Central, Cordillera (van Wyngaarden & Fandiño-Lozano, 2002). Based on these two examples and other data from literature (e.g. Rieger, 1976; Cleef, 1981; Lozano-C, 1986; Rangel-Ch, 1991), we expressed the relation between the ecosystems and the explanatory physical variables in ecological diagrams for the transformed regions (Fig. 2).

But the ecological diagrams do not include yet the effect of differences in biogeographical history of places with similar physical conditions. Colombia has a varied and relatively recent geological history (Ingeominas, 1988). One of the main events was the rise of the Andes mountain ranges over the last few million years (Robertson, unpublished data). That, combined with

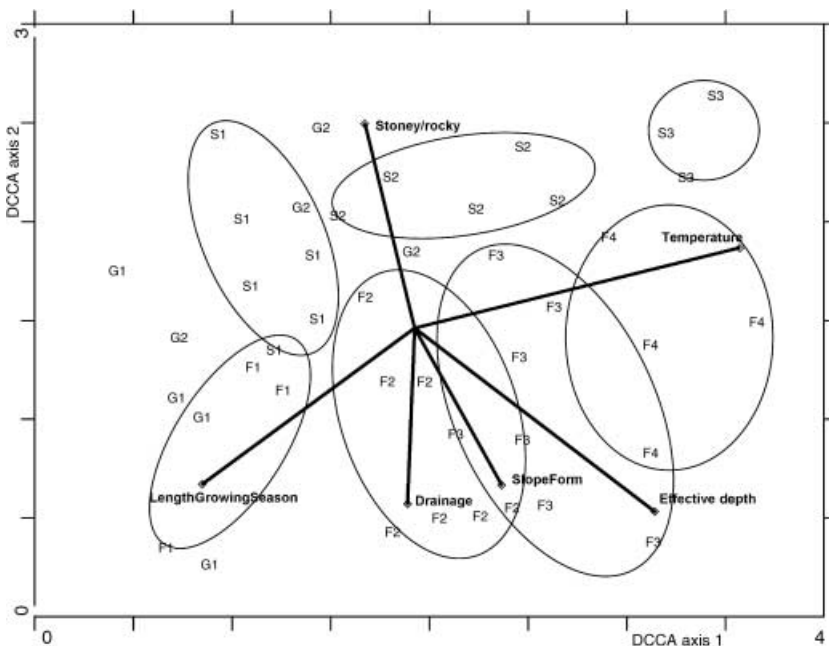


Figure 1 Ordination diagram showing the vegetation-environment relationship for the Iguaque area (modified from Fandiño-Lozano, 1996). Biplot of the sample plots (codes) and the environmental variables (arrows). The sample plots are coded by their vegetation communities: G1-2 high Andean grasslands, S1-3 Andean shrublands and F1-4 Andean forests.

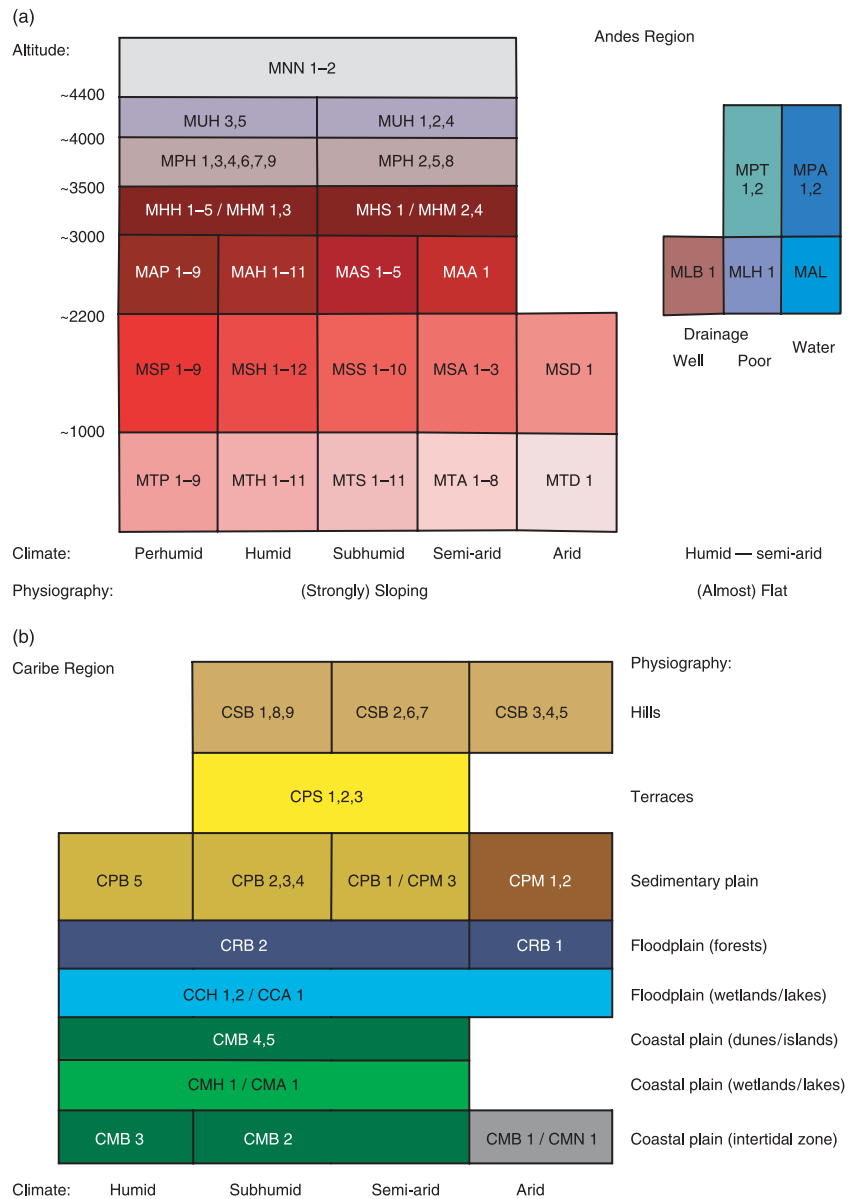


Figure 2 Ecological diagrams of the Andes (a) and Caribe (b).

the climatic variation during the Pleistocene and other variables, has given rise to many events of isolation of different parts of the country resulting in the generation of different (sub)species assemblages under nowadays similar environmental conditions (e.g. Prance, 1987; Eisenberg, 1989; Hernández-Camacho, 1992).

The preliminary units were finally subdivided along the boundaries of these biogeographical regions. For the Andes region, this resulted in a subdivision of the 28 preliminary units into 137 different ecosystems. For example the unit humid Andean forests (MAH) was divided into 11 different ecosystems because they were occurring on different cordilleras, on different flanks of the same cordillera, or separated by a zone with totally different climatic conditions. Each of these locations probably gives rise to

a different biological community under further identical physical conditions. At least partial evidence for this is provided by the distribution of various bird and plant species (Gentry, 1988; Hernández-Camacho & Rodríguez-Mahecha, 2002). In the Amazon region, an important criterion to define biogeographical zones was the presence of major river systems. There is evidence that they form a barrier for at least some mammal and plant species (Hernández-Camacho & Cooper, 1976; Salo *et al.*, 1986). So, most probably, different communities have developed in the north and south of these major rivers.

The application of the relevant set of physical and biogeographical variables to the preliminary units of the extant ecosystems resulted in the subdivision of some of the units and created in a total of 337 different ecosystems for the whole

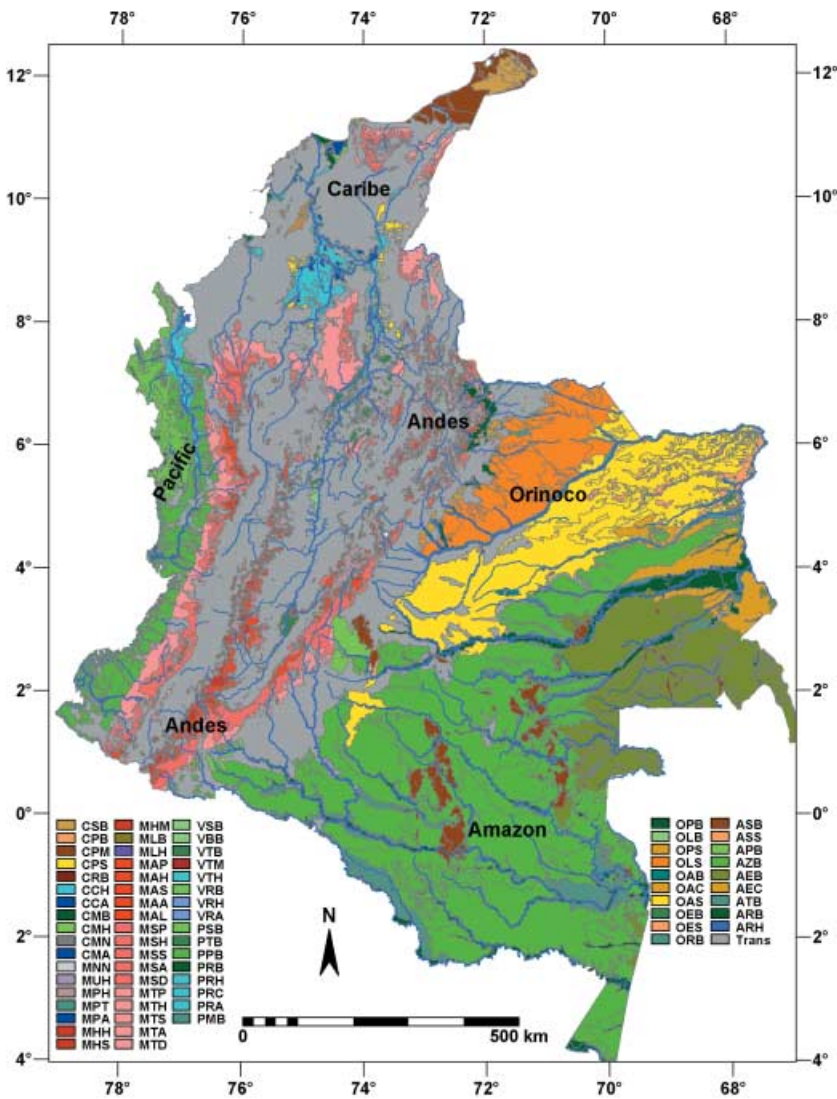


Figure 3 Map of the actual ecosystems of Colombia (for the description of the units see Appendix 1).

country. The distribution of the actual ecosystems is presented in Fig. 3.¹ Because of the small scale of the map presented here, not all the individual ecosystems can be displayed; only the 74 groups of ecosystems with similar biophysical characteristics and the special category of transformed areas (in grey). The description of these groups of ecosystems in terms of physiography, vegetation structure, length of the dry season and altitudinal range can be found in Appendix 1.

The construction of the map of the original-potential ecosystems followed different paths for the different parts of the country. For a large part of the Orinoco, Amazon and Pacific regions,

the boundaries of the original ecosystems are the same as the actual ecosystems or can still be seen in the transformed parts. In contrast, most of the Andes and Caribe regions have been transformed to such an extent that little information can be obtained from the present distribution of the remnants. Here the original-potential ecosystems had to be constructed for many parts, using the information about important boundaries from the ecological diagram and the spatial distribution of the forming factors. Figure 4 shows the result of this exercise.

The cluster or gradient analysis of the shared boundary length between the ecosystems, as extracted from the original-potential ecosystem map, produces groups of spatially related ecosystems. The result of the gradient analysis for the Amazon is presented in Fig. 5. Most of the ecosystems form clear clusters which were identified as chorological types. But some ecosystems show an intermediate position between the clusters. In most cases these are floodplains of the major rivers. This is logic as they often form the boundary between groups of ecosystems and thus share

¹The resolution at which the satellite images were interpreted was between 1 : 100,000 and 1 : 200,000. The resulting map will be printed at the scale of 1 : 2,000,000 as part of a publication on conservation priorities for Colombia (Fandiño-Lozano & Wyngaarden 2003, in press). Readers who are interested in that publication are requested to contact the authors.

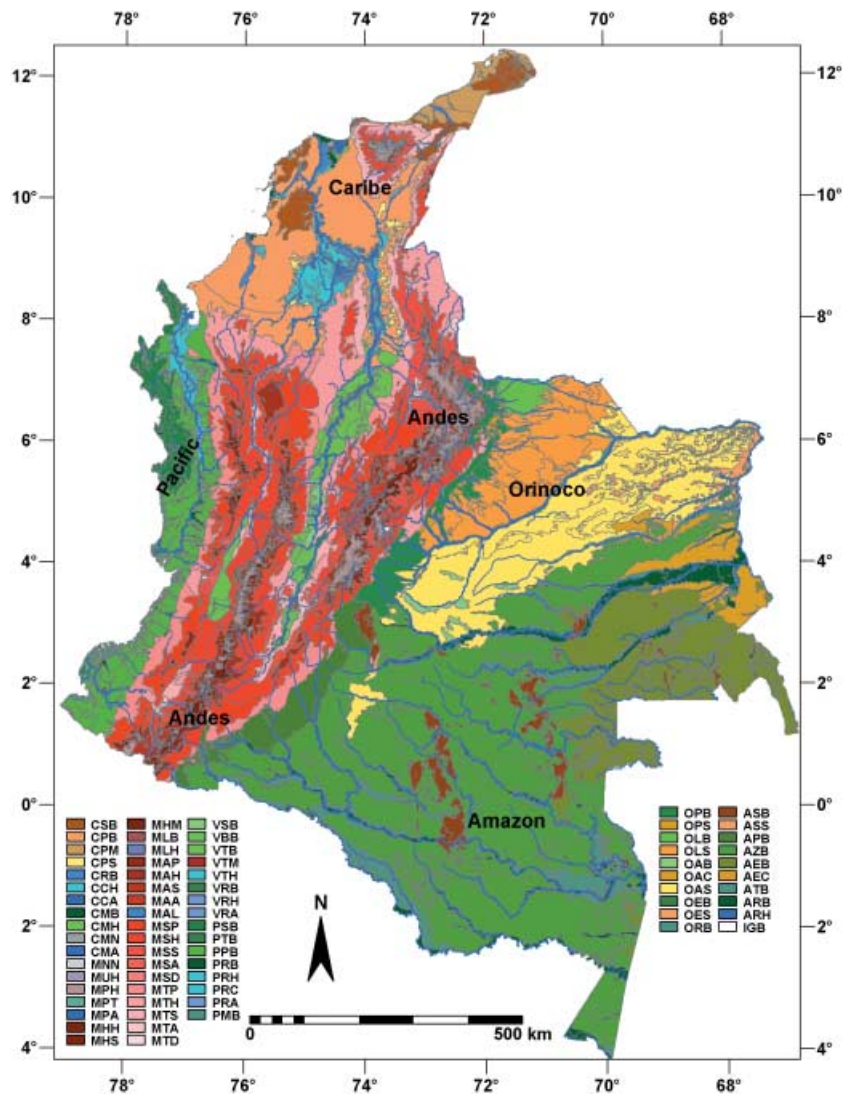


Figure 4 Map of the original-potential ecosystems of Colombia (for the description of the units see Appendix 1).

a large part of their boundary with both groups. In that case, they were assigned to both chorological types. In total, 60 chorological types were identified for the continental part of Colombia and three more for the islands.

Based on the final grouping of the ecosystems into chorological types, the map of original-potential ecosystems was reclassified into the map of chorological types (Fig. 6).

DISCUSSION

The database presented here is comparable for the whole country and is of good quality. Although we do not know exactly which species occur in each ecosystem, the 337 ecosystems of Colombia exist and are different from each other either because of their vegetation cover, their biologically relevant physical characteristics or their position in the biogeographical model. This is a far higher number of units as in earlier contributions such as Instituto Alexander von Humboldt: 64 general ecosystems

(IAVH, 1998), Instituto de Hidrologia, Meteorologia y Estudios Ambientales: 24 land cover types (IDEAM, 1998). Our map of actual ecosystems can be considered up-to-date as it is actualized with satellite images from the years 2000–2003. This is also in contrast to the mentioned earlier maps which are based on images from the period 1988–1996.

Of equal reliability is our map of original-potential ecosystems. In three of the five regions we could observe most of the boundaries directly, and although the transformation process continues here, the information about the original location of the ecosystems will never be lost now. Because of the high degree of transformation, the original limits have been lost for a large part in the other two regions — Andes and Caribe. But the ecological diagrams give the possibility to know what was there or what can be there when we want to recuperate the natural cover. However, the contents and limits of these predicted original-potential ecosystems in highly transformed landscapes should be verified.

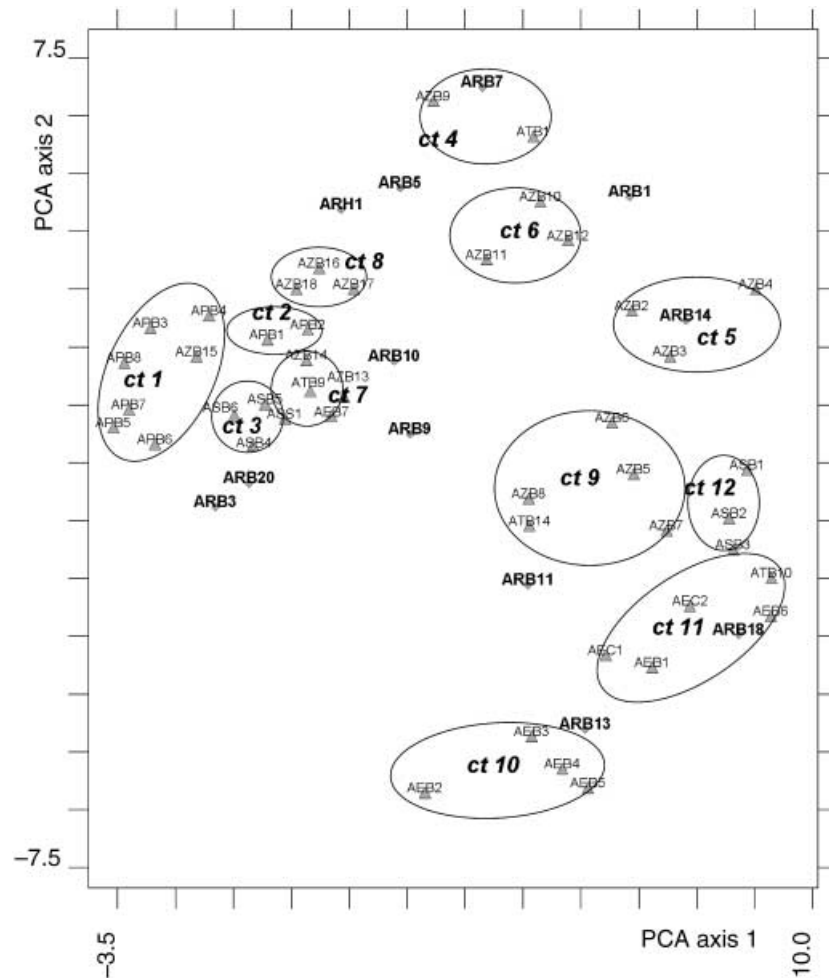


Figure 5 Ordination diagram based on a PCA of the shared boundary length between the ecosystems of the Amazon area. The coded triangles represent the non-riverine ecosystems. The coded squares are the riverine ecosystems and the codes in italic represent the chorological types.

Although the quality of the maps can be trusted, it may occur that within our ecosystems there is some variation: they may include others. When these inclusions are homogeneously distributed, this is not a problem in conservation planning because they will be included in a selection process (Pressey & Logan, 1998). If, on the contrary, those inclusions are not homogeneously distributed, they would have given rise to the differentiation of ecosystems. Also, the construction of the presented ecosystem maps here must be seen as the first step of a process of continuous refinement. As biological information becomes available in time, the description of the units should be completed with the biologic components. But that presupposes a huge coordinated and cooperative effort by a large group of taxonomists and ecologists.

With regard to the concept of chorological types, it is based on the hypothesis that groups of spatially related ecosystems account for the different fluxes in the landscape. Some examples can be easily thought of: birds of prey that nest on rock outcrops and hunt in the surrounding lowland, large herbivores that need the floodplains for water and the uplands for food and seasonal bird migrations along altitudinal gradients. But it is necessary to

verify which of those fluxes are covered by this relatively simple and efficient clustering of ecosystems into chorological types, and especially which ones remain excluded. Perhaps these chorological types have to be clustered again on the basis of the same principles, building a hierarchy this way. This hierarchy, however, is fundamentally different from that in ecosystem classifications as present in many parts of the world. These classifications are normally based on the (topological) characteristics of the ecosystem (e.g. Klijn & Udo de Haes, 1994). This creates groups of ecosystems that have characteristics in common, but that are not always spatially related. The chorological types are the opposite: they are spatially related but can have very different characteristics.

The conservation database for Colombia, as described here, is a biodiversity surrogate. Given the short-term unsolvable lack of knowledge on the biodiversity, it is the only information available to make systematic and informed decisions about biological conservation now. The methods described here could contribute to generate it for other places in the world and, in that way, help make progress in biological conservation.

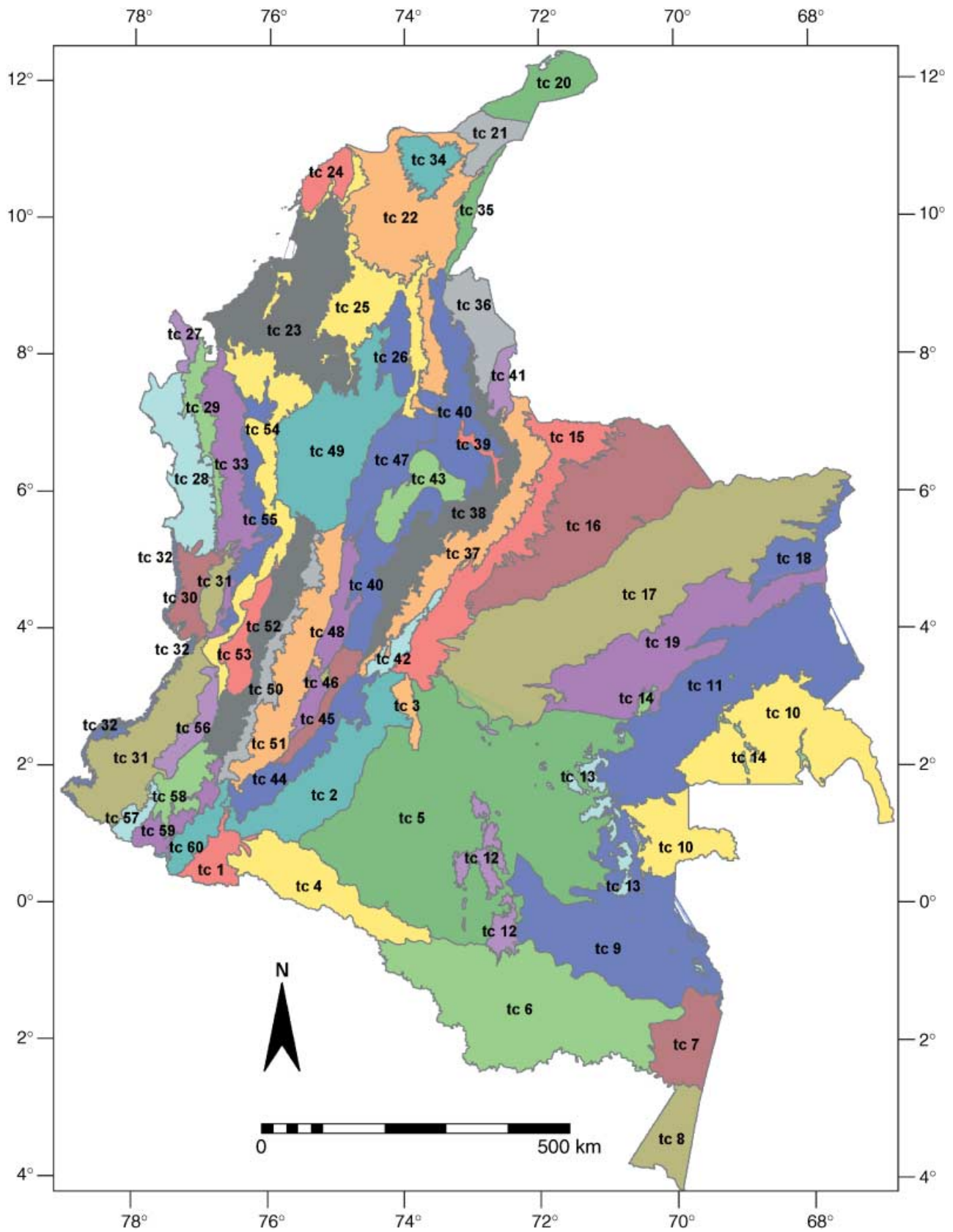


Figure 6 Map of the chorological types of Colombia.

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Appendix Legend of the ecosystem maps of Colombia: some characteristics of the major ecosystems

Region	Code for the groups of ecosystems	Number of ecosystems in group	Physiography	Vegetation cover	Dry months	Altitude
Caribe	CSB	9	Structural and denudational hills	Semi-deciduous and deciduous forests	3–12	0–500
	CPB	5	Sedimentary plains	Semi-deciduous and deciduous forests	0–9	0–200
	CPM	3	Sedimentary plains	Deciduous shrublands	6–12	0–200
	CPS	3	Sedimentary plains	Savanna grasslands and wooded grasslands	3–5	0–200
	CRB	2	Floodplains	Riparian forests	variable	0–100
	CCH	2	Floodplains	Wetlands	variable	0–100
	CCA	1	Floodplains	Lakes	variable	0–100
	CMB	5	Coastal plain	Mangrove forests	variable	0–100
	CMH	1	Coastal plain	Wetlands	variable	0–100
	CMA	1	Coastal plain	Lakes	variable	0–100
	CMN	1	Coastal plain	Saltflats	variable	0–100
Pacífico	PSB	5	Structural and denudational hills	Evergreen forests	0	100–1500
	PPB	9	Sedimentary plains	Evergreen forests	0	0–100
	PTB	1	Terrazas	Evergreen forests	0	0–100
	PRB	5	Floodplains	Riparian forests	0	0–100
	PRH	3	Floodplains	Wetlands	0	0–100
	PRC	1	Floodplains	Wetlands and lakes	0	0–100
	PRA	1	Floodplains	Lakes	0	0–100
	PMB	3	Coastal plain	Mangrove forests	0	0–100
Andes	MNN	2	Glaciers and glaciated peaks	Ice, snow and bare rock	variable	> 4400
	MUH	5	Glaciated landscapes	Open grasslands	0–6	3800–4500
	MPH	9	Glaciated landscapes	Tussock grasslands	0–6	3200–4100
	MPT	2	Glaciated landscapes	Wetlands	0–3	3700–4500
	MPA	2	Glaciated landscapes	Lakes	variable	> 3500
	MHH	5	Denudational slopes	Evergreen forests	0–3	3000–3600
	MHS	1	Denudational slopes	Evergreen forests	3–6	3000–3600
	MHM	6	Denudational slopes	Evergreen shrublands	0–6	2800–3700
	MLB	1	Sedimentary plains	Semi-deciduous forests	3–9	2400–2600
	MLH	1	Sedimentary plains	Wetlands	3–9	2400–2600
	MAP	9	Denudational slopes	Evergreen forests	0	2200–3000
	MAH	11	Denudational slopes	Evergreen forests	0–3	2200–3000
	MAS	5	Denudational slopes	Evergreen forests	3–6	2200–3000
	MAA	1	Denudational slopes	Deciduous forest	6–9	2200–3000
	MAL	2	Glaciated depressions and dams	Lakes	variable	2200–3000
	MSP	9	Denudational slopes	Evergreen forests	0	1000–2200
	MSH	13	Denudational slopes	Evergreen forests	0–3	1000–2200
	MSS	10	Denudational slopes	Semi-deciduous forests	3–6	1000–2200
	MSA	3	Denudational slopes	Deciduous forest	6–9	1000–2200
	MSD	1	Denudational slopes	Deciduous forests and shrublands	9–12	1000–2200
	MTP	9	Denudational slopes	Evergreen forests	0	< 1000
	MTH	11	Denudational slopes	Evergreen forests	0–3	< 1000
	MTS	11	Denudational slopes	Semi-deciduous forests	3–6	< 1000
MTA	8	Denudational slopes	Deciduous forest	6–9	< 1000	
MTD	1	Denudational slopes	Deciduous forests and shrublands	9–12	< 1000	
Inter-Andean valleys	VSB	1	Structural and denudational hills	Semi-deciduous forests	3–5	100–600
	VBB	2	Alluvial fans	Semi-deciduous forests	0–5	300–800
	VTB	9	Terrazas	Evergreen and deciduous forests	0–9	100–1100
	VTM	2	Terrazas	Deciduous shrublands	> 7	400–600
	VTH	2	Terrazas	Wetlands	variable	100–1000
	VRB	5	Floodplains	Riparian forests	variable	100–1000
	VRH	1	Floodplains	Wetlands	variable	100–1000
	VRA	2	Floodplains	Lakes	variable	100–1000

Appendix *Continued*

Region	Code for the groups of ecosystems	Number of ecosystems in group	Physiography	Vegetation cover	Dry months	Altitude
Orinoco	OPB	3	Piedemonte	Evergreen forests	2–4	100–700
	OPS	1	Piedemonte	Savanna grasslands and wooded grasslands	2–4	100–600
	OAB	1	Dissected sedimentary plain	Semi-deciduous forests	2–4	100–300
	OAC	2	Dissected sedimentary plain	Semi-deciduous forests and savanna grassland	2–4	100–300
	OAS	6	Dissected sedimentary plain	Savanna grasslands and wooded grasslands	2–4	100–400
	OLB	1	Sedimentary and eolic plains	Semi-deciduous forests	2–4	100–300
	OLS	5	Sedimentary and eolic plains	Savanna grasslands and wooded grasslands	2–4	100–200
	OEB	2	Denudational plains	Semi-deciduous forests	2–4	100–300
	OES	3	Denudational plains	Savanna grasslands and wooded grasslands	2–4	100–300
	ORB	4	Floodplains	Riparian forests	2–4	100–300
Amazon	ASB	12	Structural hills	Evergreen forests	0–1	100–2200
	ASS	1	Structural hills	Savanna grasslands and wooded grasslands	0–1	400–1000
	APB	8	Piedemonte	Evergreen forests	0–2	400–800
	AZB	18	Sedimentary plains	Evergreen forests	0–2	100–500
	ATB	14	Terrazas	Evergreen forests	0–1	100–200
	ARB	20	Floodplains	Riparian forests	0–1	100–200
	ARH	1	Floodplains	Wetlands	0–1	100–200
Islands	IGB	1	Island of Gorgona	Evergreen forests	0	0–200
	IMN	1	Island of Malpelo	Bare rock	0	0–200
	ISB	2	Islands of San Andres and Providencia	Semi-deciduous forests	3–5	0–200