Risk assessment of Colombian continental ecosystems: An application of the Red List of Ecosystems methodology (v. 2.0).

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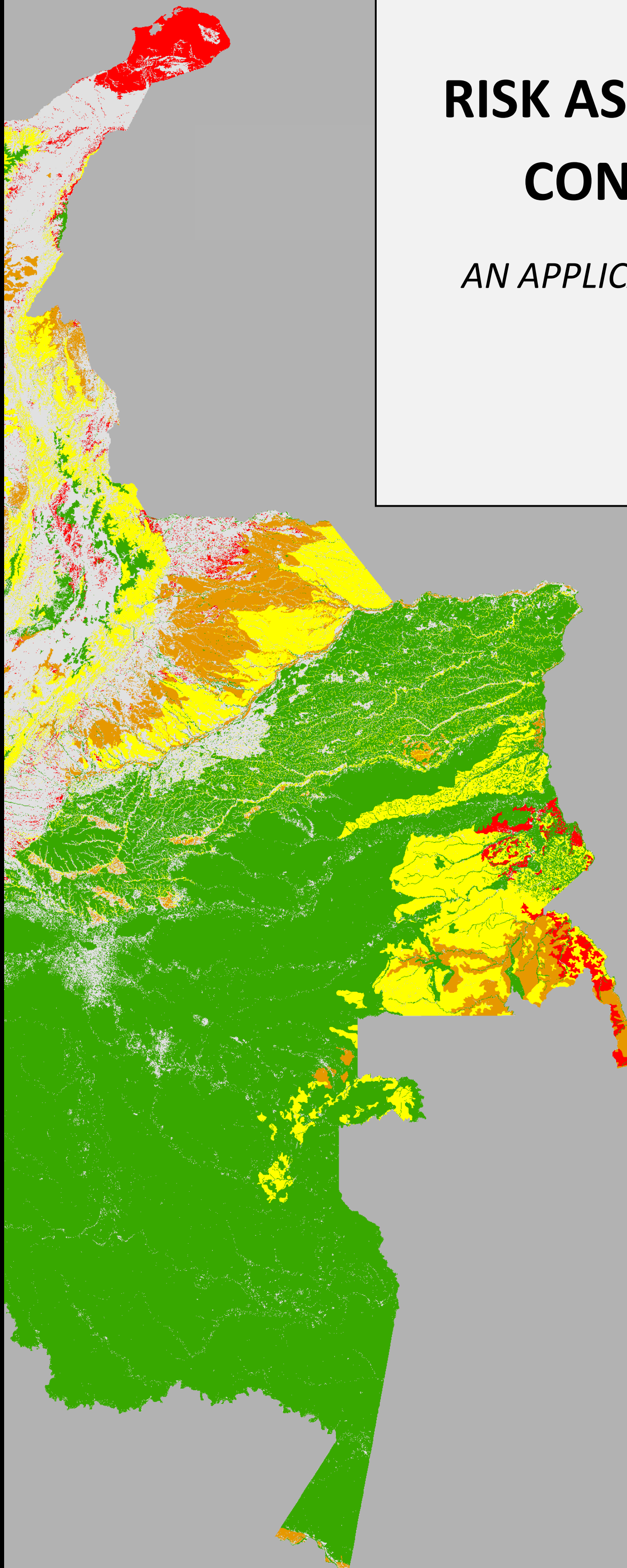
RISK ASSESSMENT OF COLOMBIAN CONTINENTAL ECOSYSTEMS

AN APPLICATION OF THE RED LIST OF ECOSYSTEMS METHODOLOGY

(v. 2.0) - 2017



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Abstract

Biodiversity, a fundamental component of ecosystems and ecosystem services needed to support life and human requirements, is increasingly threatened by human activities and climate change. In response to this scenario, there is a growing concern about finding adequate unified criteria to evaluate the transformation of ecosystems and ecosystem services associated with these, which can guide ecosystem management. An important initiative to this end has been the development by UICN of the Red List of Ecosystems framework. The purpose of this work was the applications of the Red List of Ecosystems IUCN of Colombia to understand the risk level ecosystems are facing.

This study identified the existence of 22 (27%) with the highest risk category (CR), out of the 81 ecosystems mapped. Additionally, 14 ecosystems (17%) were classified as Endangered (EN), which means that nearly half of Colombia's ecosystems have conditions that threaten their integrity, and therefore also their current and foreseen ability to provide services to society. The most important factors determining the threat level were in most cases the reduction of the original area of ecosystems, because of the historic and recent expansion of the agricultural frontier, with many of these ecosystems remaining in reduced mosaics in rural landscapes, and often with low levels of conservation. Future threats arising from climate change would have a greater effect in the Andean and Caribbean regions for the loss in water availability and the effect on biotic processes analyzed.

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1. INTRODUCTION

The expansion of the agricultural frontier and changes in land use are the main causes of global biodiversity loss (Norris 2008), as well as greenhouse gas emissions (Josep et al. 2007). During the last 50 years, the terrestrial and aquatic ecosystems of the world have been intervened and progressively modified by humanity in order to satisfy the growing world population's demands; it is even foreseen that the levels of demand that had existed for the 20^{th} century will double by 2050 (Tilman et al. 2002). Because of these transformations and their impact on associated ecosystem services, it is expected that by 2005 60% of the world's ecosystem services were degraded or used unsustainably (MEA 2005).

Biodiversity is a fundamental component of ecosystems and ecosystem services necessary to support life and human requirements. In the future, considering current levels of consumption and the impacts of climate change, and the increase in population and the expansion of the global economy, ecosystem degradation and loss of biodiversity could intensify.

In response to this scenario, a major concern is the need for adequate and unified criteria to assess the transformation of ecosystems and ecosystem services associated to them. The definition and proposal of AICHI Targets, is one of the initiatives that emerged within the 2010 Biodiversity Convention of COP 10 to this end. These look is to ensure the conservation of biodiversity as a support to the functioning of ecosystems and the provision of essential ecosystem services for human well-being, necessary to achieve the millennium's development goals. Out of AICHI's 20 Targets, the fifth explicitly refers to Habitat loss and degradation as the main driver of change of terrestrial and aquatic systems. Particular mention is made of the conversion of natural systems, including forests and savannas, to agricultural lands and pastures, processes that have led to a considerable reduction in natural systems' area and often in species' richness (Leadley et al. 2014).

According to the broad definition of biodiversity (Noss 1990), its conservation requires addressing not only the biotic component, but also the processes determined by the interactions between species (for example dispersal, pollination, predation, herbivory) and the physical environment and habitat factors. Because biodiversity manifests itself at multiple levels (species, populations, ecosystems), it is essential for the assessment and planning of biodiversity conservation to include information on the different levels. Only with such a multi-scalar approach will it be possible to comprehensively understand and manage current and potential threats, and assess the impacts on ecological systems and biodiversity in general.

The traditional emphasis on species-level information, led initially to initiatives such as IUCN's Red List of Species, begun in 1964 (IUCN 2012). This tool has been very successful and has become a benchmark and comparative parameter of the assessment of the status of biodiversity worldwide. However, the Millennium Ecosystem Assessment and the AICHI Targets made evident the need to generate complementary inputs that allow reporting on more general levels of the status and risks of biodiversity loss, such as ecosystems, that support decision-making and management of ecosystems.

IUCN´s interest to contribute to the conservation of biodiversity, has been developing since 2004 a tool for the systematic assessment of ecosystems, that takes explicitly into account the ecological processes and interactions between species (Rodríguez et al. 2007). In 2014 the IUCN Council adopted as a global standard, a series of Categories and Criteria that constitute the basis of the Red List of Ecosystems (RLE) (Keith et al. 2013).

The RLE is a tool of interest for the conservation and management of natural resources, but above all, it is a risk assessment tool. The analysis units are the ecosystems, whose limits approximate the spatial distribution of ecological entities. The RLE is an important input for the assessment processes of ecosystems in their prioritization for conservation, and for the evaluation of ecosystem services. The RLE identifies the threats and early warnings, to support the prioritization and fulfillment of conservation objectives, as well as the identification of restoration and monitoring priorities in response to land use and climate changes. It also contributes to areas such as environmental education to promote collective awareness of biodiversity and ecosystem services, and land use planning and environmental legislation. It will be of much use to the monitoring of the Aichi Targets, especially number 5, but also to numbers 11, 12, 12, 14, 15 and 16 (IUCN 2014).

The RLE protocol is in its first implementation stages, and it will need to be applied in several contexts and scales to better visualize its potential and limitations. In this first RLE application in Colombia, it offers an important opportunity to identify early warnings of unsustainable land uses, and to support conservation processes by identifying priority areas for both conservation and restoration. Likewise, the RLE can help the process of identifying No-go Zones and the development of policies on them, to promote conservation of areas for species' richness and threatened habitats, and for safeguarding ecosystem services they have (CBD 2014).

In order to strengthen the conservation efforts, it is necessary to develop administrative and legislative instruments that guarantee the protection of those ecosystems in high threat categories. It is necessary to have an instrument that guides the conservation actions for threatened ecosystems and that facilitates compliance with the control functions. As the already existing “legally threatened species act” in resolution 584 of the year 2002

(COLOMBIA 2002a), it is important to provide the necessary information to create similar resolutions for ecosystems, where Threatened Ecosystems such as those classified as endangered (EN) and critically endangered (CR), have a legal protection in the national territory.

As established in the 1991 Political Charter in Article 79, it is the State's duty to conserve areas of special ecological importance. In addition, Article 80 declares that the State is in charge of the management of natural resources to guarantee their conservation, preventing and controlling environmental deterioration factors (COLOMBIA 1991). In this sense, ecosystems in high threat categories (CR or EN), should be considered areas of special biological and ecological importance and prioritized in conservation and restoration plans.

On the other hand, the National Policy for the Comprehensive Management of Biodiversity and its Ecosystem Services - PNGIBSE (for its acronym in Spanish) (COLOMBIA 2012) highlights the importance of actions that have been carried out historically for the conservation of biodiversity (protected areas, biological corridors, among others), because of their contribution to the maintenance of the provision of ecosystem services, on which the development of human activities depends. The conservation of ecosystems with high threat assessments would help protecting ecosystem services provision offered by them.

Ecosystem assessments in Colombia must be considered in land use plans, which establish the determining provisions for rural land use and the development of urbanistic actions (COLOMBIA 2007). Areas that include endangered (EN) and critical (CR) threat categories ecosystems should be included in the “ecological structure plans”, highlighting their importance for conservation and restoration. This would help extending the legal protection of these ecosystems in Decree 3600 (COLOMBIA 2007), following the terms of Article 35 of Law 388 (COLOMBIA 1997), that establish these areas constituting protective grounds. Also if these areas do not represent any socio-economic importance, they should be integrated into areas of special ecosystemic importance, together with areas such as Páramos, water springs, wetlands, and flora and fauna reserves, already protected under the aforementioned decree.

In terms of environmental licensing for infrastructure projects, high threat category ecosystems should be legally included as special ecological importance and sensitive ecosystems, to require special prior concepts from the Ministry of Environment (COLOMBIA 2014).

For Colombia, the mapping of the current ecosystems has already been addressed in prior national studies (Etter 1998, IDEAM et al. 2007), regional studies (Rodríguez et al. 2004; Romero et al. 2009), as in several local studies. Some of these already contain information on the uses and coverage of transformed ecosystems. In addition, some studies have identified the transformation processes of ecosystems such as deforestation (Armenteras et al. 2003;

Etter et al. 2006a; Etter et al. 2006b; González et al. 2011) or the replacement of savanna ecosystems (Etter et al. 2011b). The current deforestation rates are around 150,000 ha/year (González et al. 2011), while the transformation rate of tropical savannas reaches 100,000 ha/year (Etter et al. 2011b). Other studies have analyzed the causes and historical patterns of ecosystem transformation, which allow us to measure human impact at longer time scales (Etter et al. 2008; Palacio 2001). Etter et al. (2011a) developed a more comprehensive analysis on the human footprint in Colombian ecosystems by integrating several of the previous sources.

However, there are still important gaps in the knowledge on the impact of human activities that need be included in land planning processes. In particular, it is necessary to have a reference of the "potential" (or original) ecosystems, as well as a series of multi-temporal maps that show the transformation process of ecosystems, to have a more dynamic vision of ecosystem transformation processes to better assess the effects of human activities. The RLE offers an important input to this end.

The aim of this work was to implement IUCN's framework of the Red List of Ecosystems (Keith et al. 2013), with the purpose of analyzing and assessing the threats and vulnerabilities of Colombian ecosystems. The research included several steps, beginning with the generation of a uniform national information base of the potential ecosystems, the production of multi-temporal maps of historical and future transformation scenarios, and the explanatory factors of the transformation processes, necessary to apply the Red List protocol. The second part provides the application of the RLE protocol to identify the threat levels of the country's ecosystems, and the most important threat factors for each case. Finally, examples of application possibilities are provided, and a discussion on the scope and limitations of the study is done.

2. METHODOLOGY

2.1. General characteristics of Colombia

Colombia (1.1 million km^2) is located on the equator between 10°N and 2°S, and consists of six large biogeographical regions: Andean (278,000 km^2), Inter-Andean (44,000 km^2), Caribbean (115,400 km^2), Pacific (74,600 km^2), Amazon (455,000 km^2), and Orinoco (169,200 km^2) (Figure 1). These regions show great variations in altitude (0 - 5800 m) and topography, in average annual precipitation (300 - 10,000 mm) and number of dry months, and in geological substrate and soils conditions. The foregoing determines that an outstanding feature of Colombian geography is its high environmental variability in relation to its geographical size.

Colombian ecosystems range from tropical deserts and savannas, to wet tropical forests and tropical mountains covered with snow, with different intermediate states. The high diversity of ecosystems and orographic complexity has produced high levels of endemism and species' richness, which makes Colombia one of the megadiverse countries (Hernández et al. 1992, Myers et al. 2000). The Northern Andes, for example, is a region with one of the highest concentrations of birds with restricted geographic distribution in the world, and therefore very susceptible to the loss and extinction of biodiversity due to deforestation and the transformation of ecosystems (Orme et al. 2005; Pimm et al. 2006).

During the last millennia, Colombia has suffered several historical transformation periods in human landscape, including the pre-Columbian and colonial periods, which have led to a cumulative human footprint that extends over a large part of its territory, especially the Andean and Caribbean regions (Etter et al. 2008).

The total population today exceeds 48 million, a tenfold increase from 1900. Since the 1970's, Colombia has become an increasingly urbanized and industrialized country, with 75% of the population living in urban areas, and more than 100 cities with a population of more than 50,000 people. With this transition, the rural population is stabilizing and the average growth rate of the national population fell below 2% at the end of 1990 DANE (2008). The population, both historically and at present, has concentrated in the Andean and Caribbean regions that have a rural population density of approximately 33 people per km^2, while the Pacific, Orinoco and Amazon regions have much lower densities, between 5 and 10 people per km^2. Nevertheless, the agricultural frontier continues to expand into forests and savannas, with an annual deforestation rate of over 200,000 hectares (IDEAM, 2015). Poor governance in border areas and an illegal economy still facilitates the expansion of the agricultural frontier

fueled by of illicit crops in remote jungle areas (Coca -*Erythroxylum coca*- in the lowlands, and opium -*Papaver somniferum*-, in the highlands), which also causes social and political instability.

The Colombian economy is mainly based on mining (oil, coal and nickel), export crops (coffee, flowers) and some industrial exports. Characteristically, the area devoted to livestock, often of low productivity, is more than 85% of the agricultural area (Etter et al. 2008).

Approximately 35% of the terrestrial ecosystems has been replaced by anthropogenic ecosystems (Etter et al. 2006a). One of the main consequences is the impact on biodiversity. For example, estimates from IUCN's Red Lists show that Colombia, with 214, has the highest number of endangered amphibian species, many of which are endemic (http://www.iucnredlist.org/initiatives/amphibians).

However, according to the spatial analysis of the human footprint, the impact on ecosystems is variable in terms of intensity and extension (Etter et al. 2011a). This study indicates that even important parts of the conservation areas have considerable human impact levels.

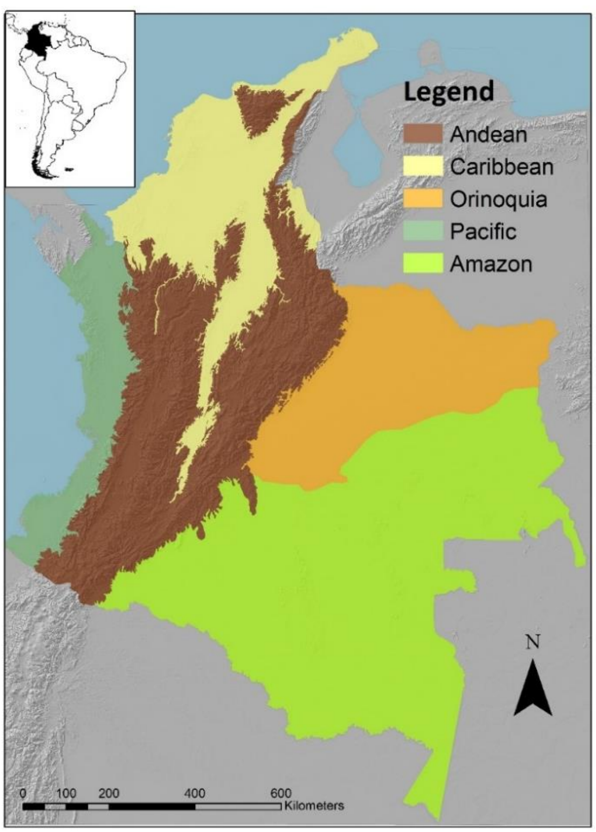

Figure 1. Map of Colombia showing the natural regions.

2.2. Data used

The drafting of the Red List of Ecosystems requires a series of minimum inputs that include the following (Keith et al. 2011):

- Basic ecological reference information consisting of a spatial representation of the potential reference ecosystems of the study area.
- A multi-temporal sequence of historical maps (of the last 50 years) that represent the original ecosystems' replacement and transformation status, because of the expansion and intensification of land use.
- A projection of the future transformation scenario of the original ecosystems (50 years).
- Spatialized information on physical processes of accumulated historical degradation (50 years) (for example precipitation, soils, and waters).
- Spatialized information on the disruption of accumulated historical biotic processes (50 years) (for example dispersal, pollination, migration).

Table 1 shows the inputs and sources used in this particular case.

Table 1. Inputs used for the development of the work.

Item	**Resolution/Scale**	**Source**
Weather	1km	WorldClim, IDEAM (2017)
Soils	1:100.000	IGAC (2014)
Ecosystems	250m, 1:100.000	Etter (1998), Etter et al. (2008), IDEAM (2007)
Coverages	30m, 90m	Satellite images (Landsat, SPOT, QBird, IKONOS, BING)
Altitude, Topography	90m, 30m	SRTM, ASTER
Species' Distribution	n.a.	GBIF, SIB, IAvH (2015)

For the analysis, all the spatial information was transformed to a uniform raster format, with a resolution of 250m (6.25 Ha).

2.3. Map of Potential Ecosystems

One of the crucial inputs to be able to develop the RLE methodology proposed by IUCN is the elaboration of a model of the possible distribution of ecosystems if human intervention

and transformation had not occurred. The current climate conditions and substrates were considered.

The first step in the development of an ecosystem map is the design and application of a classification system model, since this determines the reference units. This implies facing what all classification models of nature's systems face: representation limitations resulting from the need to generate exclusionary categories based on a reality that manifests itself mostly in terms of continuous patterns based on transitional gradualities of some kind.

However, when we speak of units with geographical expression, the classification and delimitation of "ecosystems" necessarily starts from the concept of the definition of an ecological system as a multi-scalar system, in the sense that the concept can be applied at different levels of detail and extension that meet the definition of "system formed by the interaction between biotic and abiotic components". Therefore, their representation depends on the spatial scale (and temporal, if such is the case), as with any cartographic representation.

Although there is no ideal scale to represent ecosystems, it determines the patterns and processes about which it can inform us. Because spatial patterns vary with the scale, the classification system must be based on nested patterns. Each delimited unit is characterized by presenting a mosaic with its own heterogeneity pattern that can be described in the form of *associations* (regular predictable patterns as topo-sequences or altitudinal gradients) or *consociations* (in the sense of edaphologists) of units of minor ecological values contained in them. Therefore any spatial representation, to a lesser or greater extent, corresponds to units that are "spatial and functional mosaics", rarely completely homogeneous or "pure" units.

The factors that determine the ecological patterns at different scales vary. In general, climate tends to dominate broader patterns because it is a more general characteristic (Walter 1979). Then follow patterns of geoforms and associated attributes such as soils and their responses in terms of vegetation. The main inputs available and used for the elaboration of ecosystem maps are climate, topography, soils, hydrology and vegetation.

Classification System

Generally, the classification of ecological units is based on the Biome definition: “the world's major communities, classified according to the predominant vegetation and characterized by adaptations of organisms to that particular environment" (Campbell 1996).

The classification was based on the conceptual proposal by Walter (1979), who developed a system that groups the Earth's biomes into: i) the Geo-Biosphere: the set of Terrestrial Ecosystems; and ii) the Hydro-Biosphere: the set of aquatic ecosystems.

Subdivisions of the Geo-Biosphere:

Units corresponding to large and uniform environments of the biosphere in terms of climate and/or landform, encompassing sets of ecosystems. Among these, it recognizes four general categories:

ZONOBIOMES: Units delimited by the Climatic Zones (9 worldwide) that determine ZONAL VEGETATION types.

ZONOECOTONES: climatic transition areas (tension zones) between ZONOBIOMES.

OROBIOMES: correspond to pronounced mountainous environments within the Zonobiomes, which produce orographic units that can be subdivided into altitudinal bands determined by changes in temperature and precipitation.

PEDOBIOMES: INTRAZONAL conditions within the ZONOBIOMES. In this case, the resulting vegetation and ecosystems are strongly related to the local substrate conditions (rock, water and soil) than to climatic conditions: PEDOBIOMES (PSAMMOBIOMES-soils in washed sands and PEINOBIOMES-extremely oligotrophic) and LITOBIOMES-limitations due to the presence of superficial rock.

In these cases, the condition of the zonal vegetation (e.g. dense forests) changes to shrubbier or herbaceous (Pastures or Savannas) conditions and mesophilic leaves tend to change to leaves with different degrees of sclerophilia: SAVANNA PEDOBIOMES, SHRUBBY PEDOBIOMES, and FOREST PEDOBIOMES.

Subdivisions of the Hydro-Biosphere:

Units that correspond to large and uniform environments of the biosphere in terms of coverage and temporality of water dynamics, encompassing sets of ecosystems. Three general categories were recognized:

HYDROBIOMES: Aquatic ecosystems with a permanent, static or running water mirror.

HELOBIOMES: Ecosystems determined primarily by the activity of freshwater flood pulses, as it occurs in alluvial plains with significant changes in water levels. They vary a lot depending on the Zonobiome's precipitation characteristics.

HALOBIOMES: Ecosystems determined primarily by the activity of salty or brackish water flood pulses, as it occurs in coastal plains. They vary depending on the level of salt accumulation, depending on the Zonobiome's precipitation characteristics.

Construction of the map of potential ecosystems

This used the implicit approach in the conception and methodology of the Landscape Ecology of European origin (Zonneveld 1979). Representation was made based on the material expression of the visible ecological processes in the landform and vegetation cover, because these patterns show the greatest part of the species' and ecological processes' distribution. The map building followed the sequential process shown in Figure 2.

The climate was used in an indicative manner, but not to define limits, given that climatic transitions are very gradual, which makes it difficult to establish abrupt ecological limits. Climate's ecological effect is modulated by its interaction with the characteristics of landforms and soils.

Therefore, the spatial boundaries between ecological units are generally determined by macro-physiognomic attributes of ecosystems such as landforms and the physiognomy of the vegetation cover, among others. All these attributes are proxies that inform/express ecosystems' dimensions.

Once the ecosystems were identified and delimited, a series of descriptors were used that make up the database of the model and include, for climate, descriptors such as PPT/ETP, annual PPT, annual average T°, slope, altitude and dominant soils.

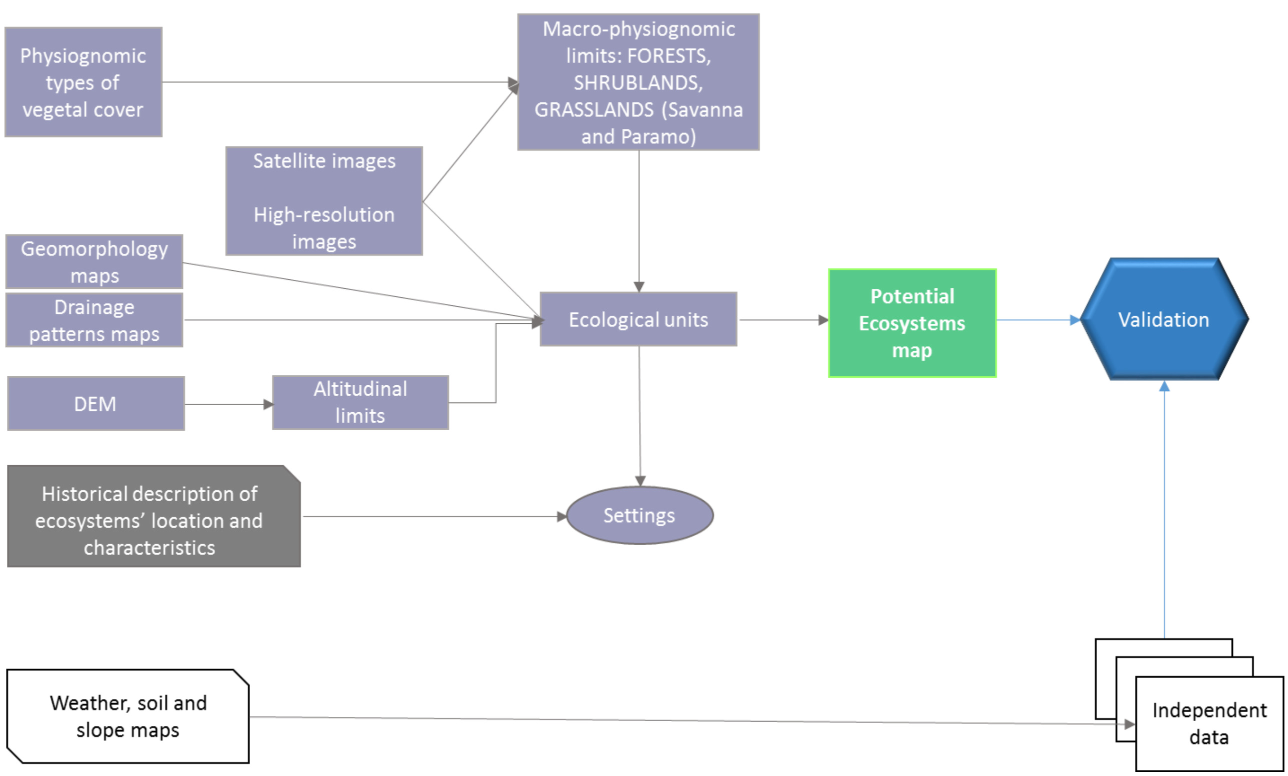

Figure 2. Diagram of inputs and processes to build a map of potential ecosystems.

Validation of the map of potential ecosystems

An important aspect of a model that represents some aspect of reality, is the level of confidence of its representation. A way to measure its validity is to analyze the possibility of reproducing it based on independent data not used for its construction. In this case, a validation was carried out using independent climate, topographic, natural and geomorphological variables data (Figure 3).

A "decision tree" type model was implemented, which is a classification technique used for the prediction of finite numerical values, called "classification trees" (Frank *et al.* 1998). One of these models is C5.0, an algorithm developed by Quinlan (1993), used to build decision trees from training data, where the objective is to predict the response of Y using independent variables X_1, X_2, ... X_p, through a binary tree that extracts informative patterns from the data (Kuhn and Johnson 2013). The procedure can be summarized as follows:

Given training variables (vectors), $x_i \in R^n$, i = 1, ..., l, and a label vector $y \in R^l$, a decision tree generates space partitions recursively in such a way that equal labels are grouped.

Let the data in node *m* be represented by Q. For each candidate division $\theta = (j, t_m)$e and consisting of a characteristic *j* and the threshold *t* $_m$, divide the data into subsets $Q_{left}(\theta)$ and $Q_{right}(\theta)$.

$$Q_{left}(\theta) = (x, y) | x_j <= t_m$$
$$Q_{right}(\theta) = Q \setminus Q_{left}(\theta)$$

The impurity in *m* is calculated using a function of impurity$H()$, whose choice depends on the task that is being solved (classification or regression).

$$G(Q, \theta) = \frac{n_{left}}{N_m} H(Q_{left}(\theta)) + \frac{n_{right}}{N_m} H(Q_{right}(\theta))$$

Select the parameters that minimize impurity.

$$\theta^* = \operatorname{argmin}_\theta G(Q, \theta)$$

Then it is repeated for subsets $Q_{left}(\theta^*)$ and $Q_{right}(\theta^*)$ until reaching the maximum admissible depth of the tree according to, $N_m < \min_{samples}$, or $N_m = 1$.

The software C5.0 (Quinlan 1993) was used to model the distribution of ecosystems from our "theoretical model" the map of potential ecosystems, based on explanatory biophysical variables (climatic, topographical, pedological and geopedological) (Annex 1).

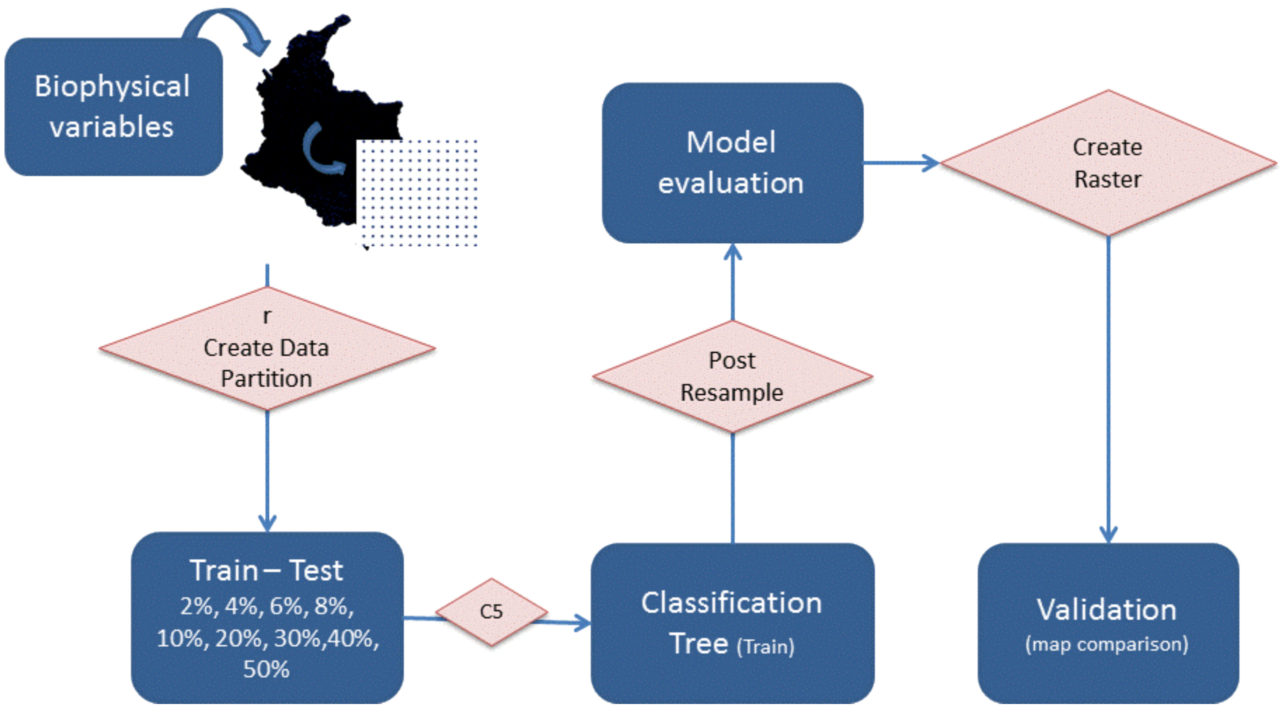

Figure 3. Validation process of the map of original ecosystems

2.4. Multi-temporal maps of Ecosystem transformation

Another essential component that the Red List requires, as an input for the assessment of the changes in geographical extent and spatial patterns *criteria A and B* (Keith et al. 2013), is a series of multi-temporal maps that identify the status of past transformation and, if possible, some future scenarios as well:

- The past 50 years (for our case 1965-2015), **A1**
- The next 50 years (2015-2065), **A2a**
- Any 50-year period between past and future (for example 1990-2040), **A2b**
- Since 1750, **A3**

Multi-temporal maps 1970-2014

The transformation of ecosystems, its response, and the possibility of tracing it, depends on the context, since the transformation processes and its detection have particular characteristics which can vary considerably in the case of contracting ecosystems (forest) or herbaceous ones (savannas or Paramo). To consider this aspect, the elaboration of cartographic products for the transformation of ecosystems initially took into account a grouping of physiognomic-ecological macro-units from the map of potential reference ecosystems mentioned above (Figure 4):

i) forests
ii) savannas/deserts
iii) Páramos

A homogeneous series of multi-temporal maps was built, that shows the progress of the conversion of natural ecosystems during the past 45 years. The transformation of each of the macro-units for four periods was mapped and analyzed: 1970, 1990, 2000 and 2014.

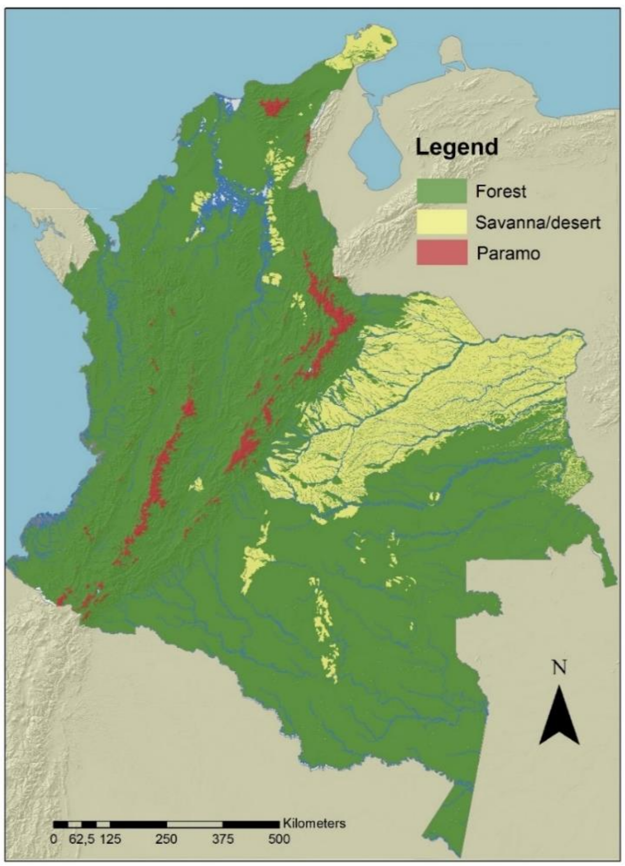

Figure 4. Map of the macro physiognomy units based on the map of potential ecosystems, used to build the ecosystem transformation maps, and develop the models of future scenarios of ecosystem transformation.

For forest ecosystems, IDEAM forest maps (2014) were used as first inputs (González et al. 2011). These maps had to be adjusted and completed in the areas categorized as "without information", using additional data available in GoogleEarth and other satellite image sources (Landsat, MODIS, CBERS or high resolution such as IKONOS and QuickBird).

For the year 1970, we used the map from Etter et al. (2008), making adjustments with the available Landsat 2 and 3 images from 1972-1977, taken from the USGS (http://glovis.usgs.gov/).

For savanna ecosystems, the data from Etter et al. (2011b), and more recent satellite images (Landsat, MODIS, CBERS or high resolution such as IKONOS and QuickBird) were used. For the Paramo ecosystems, new transformation maps were built from visual interpretation of satellite images (Landsat, MODIS, CBERS or high resolution such as IKONOS and QuickBird) based on the delimitation of the Páramos of the map of potential ecosystems.

Subsequently, the ecosystems transformation maps of Forests and Shrublands, Savannas and Páramos were integrated to build four transformation layers: *Transformation_1970*, *Transformation_1990*, *Transformation_2000 and Transformation_2014*.

Future scenarios

To build the future transformation scenarios, we used an adaptation of the protocol developed in González et al. (2011), applying the Dinamica-EGO software (Soares Filho et al. 2013) to simulate future scenarios. Given that ecosystem transformation processes are very different in forest ecosystems, savannas or Páramos, we built a sub-model for each of the three major types land cover types (Figure 4) to simulate the projection of the changes separately, and also using the natural regions (Figure 1) as an input.

A scenario was built for the year 2040 (scenario+25), using the historic trends and corresponding to a BAU (Business As Usual) model. In the future, other secnarios could be built (for example a development or conservationist scenario), as was done in Etter and Arévalo (2014), or generate models for more distant scenarios such as 2065 (scenario+50).

Qualification of the transformation level

According to the RLE protocol regarding the information required for *criterion A,* ecosystems transformation is often considered in terms of binary excluding statuses (transformed/non-transformed, intervened/not intervened). However, this simplification is not very informative if one wants to analyze the processes that determine explicit threats and their magnitudes, for which knowledge on the accumulated impact of land uses that are operating is required.

Besides ecosystem transformation in the sense of the replacement or disappearance of an ecosystem as used in *criterion A* of the RLE, other available approaches such as the spatial human footprint by Etter et al. (2011a), qualifies the human transformation in terms of the intensity of land uses, the temporal length of intervention, and the ecosystem's biophysical vulnerability to human intervention. This a convenient approach to approximate a measure of habitat quality loss, useful to assess the sub-criterion B1*aii* "measure of environmental quality appropriate for the characteristic biota of an ecosystem".

Additionally, to inform criterion B1*aiii*, a fragmentation index as the "percentage natural habitat in a 100 ha moving window, calculated with the transformation map of 2014.

Characterization of Threats

Another input for the Red List of Ecosystems to inform the risk assessment, is the identification and qualification of the threats operating in each ecosystem. To this end we grouped threat processes in three categories (Table 2).

Table 2. List of constituent threat processes to Colombian ecosystems.

Category	Process
Land use	Agricultural frontier expansion
	Agricultural intensification
	Soil erosion from mechanization
	Soil degradation by compaction (grazing, mechanization)
	Soil erosion due to livestock in sloping areas
	Extensive homogenization from exotic grasses expansion
	Wood extraction (commercial)
	Exotic species forest crops
	Connectivity disruption by extensive land cover fragmentation
Hydrology	Degradation and desiccation of peatlands
	Glacier cover loss due to warming
	Desiccation of wetlands
	Canalization of channels
	Clogging of channels due to erosion of adjacent plains
	Hydrological flow interruption
	Decreased infiltration rates with effect in hydrology
	Drainage of savannas
Fire	Increased fires and fire risk
	Fire suppression

These processes were used to characterize each of the ecosystems where there is indication and empirical evidence that are operating (Annex 2).

On the other hand, processes and activities with some degree of threat to ecosystems and biodiversity were chosen, which had spatial information. Development projects for the energy, hydrocarbons, infrastructure and mining sectors were included. Also, information related to land use conflicts (underuse and overuse) and data on the national density of illicit crops (ha/km2). Other threat factors included information on the risk level of fire, soil degradation and mass removals.

These aspects were assessed in terms of their severity of occurrence based on the proportion area affected, according to four levels the following levels (Table 3).

Table 3. Severity categories for assessment of threatening processes.

Severity of threatening processes		Proportion (total area of threatening process/total ecosystem area)
	Low	0.1 - 0.4
	Moderate	0.4 - 0.7
	High	0.7 - 0.9
	Very High	0.9 - 1.0

2.5. Climatic variability and changes in the distribution of species

Changes in physical and biotic processes complement ecosystem disruptions from In loss in area and changes in the spatial patterns of the ecosystems in the RLE framework. These correspond to changes in components or processes that relate to risks of environmental degradation in physical variables (related to climate, soils, water availability), or in biotic variables (key processes such as pollination seed dispersal, migrations, predation) that are contemplated in *Criteria C* and *D* (Keith et al 2013).

Changes in future rainwater availability

Criterion C seeks to analyze and assess changes in physical (abiotic) variables of the environment, important in the functioning of ecosystems. These include, for example, water availability due to precipitation, changes in soil characteristics (effective depth, fertility, water accumulation capacity, ...), or the hydrological regime (flood pulses).

For the assessment of criterion C for environmental degradation, we applied the sub-criterion C2 which assesses the degradation prediction of an abiotic variable in the time

horizon of the 50 years with respect to a historical reference date (Keith et al., 2013). In this case we assessed the change in rainwater availability, understood as the future change in the average monthly and annual precipitation, compared to the historical variability pattern measured as the standard deviation. Table 4 presents the inputs used.

Table 4. Data sources used for the assessment of Criterion C2.

	Number of seasons	Analysis period	Source
Historical precipitation series	1369	1970 - 2016	IDEAM et al. 2015
Precipitation series scenario CC	963	2017 - 2067	IDEAM et al. 2015
Map of Regions of Colombia	-	-	Etter et al. 2015
Map of Colombia's Potential Ecosystems	-	-	Etter et al. 2015

The historical precipitation series and the future CC scenario were treated and selected according to the WMO quality criteria (WMO, 2011). For the construction of the fields of average rainfall (26) and historical standard deviation (13), an interpolation with a regionalized approach was carried out using the best of 3 different methods (IDW, linear Kriging and radial base function) according to the SLOO cross validation (Soenario, Plieger and Sluiter, 2010) (Figure 5).

Two indexes were built from these fields. The *relative severity index* (SR_i) as proposed by Keith et al. (2013), and the *severity index with variability* (SV_i) that describes the number of times in which the historical variability (standard deviation) is exceeded by the observed changes in precipitation into the future (Figure 5).

Six severity classes were generated from these indexes. The severity classes with annual, monthly and total variability, and the annual, monthly and total relative severity classes (CSVa, CSV_b, CSV_c, CSR_a, CSR_b and CSR_c respectively) (Table 5).

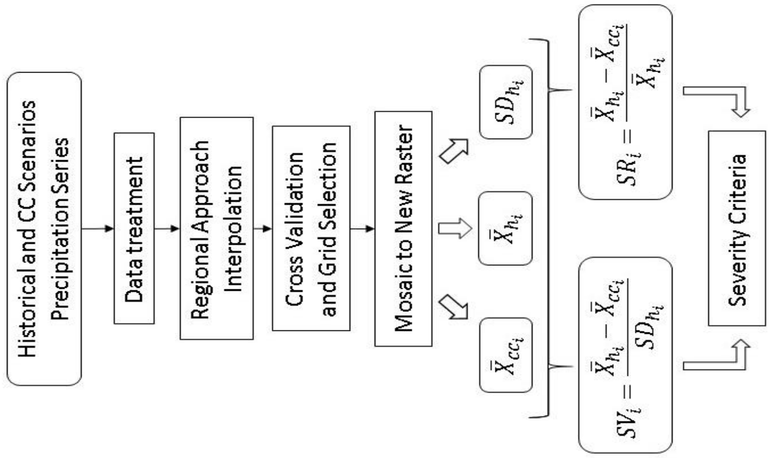

Figure 5. Methodological flow chart for obtaining the severity criteria (C2).

Table 5. Severity classes for the assessment of Criterion C2.

Severity Classes	Methods								
CSV_a	1. Reclassify	SV_a	< -3.5	-3.5 – -2.5	-2.5 – -1.96	-1.96 – 1.96	1.96 – 2.5	2.5 – 3.5	> 3.5
		CSV_a	-3	-2	-1	0	1	2	3
CSV_b	2. Reclassify	SV_i	< -0.3	-0.3 – 0.3	> 0.3				
		SV_i	-1	0	1				
	3. Map Algebra	$SV_m = \sum_{i=1}^{12} CSV_i$							
	4. Reclassify	SV_m	< -6	-5	-4	-3 – 3	4	5	> 6
		CSV_b	-3	-2	-1	0	1	2	3
CSV_c	1. Map Algebra	$SV_t = CSV_a + CSV_b$							
	2. Reclassify	SR_t	< -5	-4	-3 – -2	-1 – 1	2 - 3	4	> 5
		CSR_c	-3	-2	-1	0	1	2	3
CSR_a	1. Reclassify	SR_a	< -0.8	-0.8 – -0.5	-0.5 – -0.3	-0.3 – 0.3	0.3 – 0.5	0.5 – 0.8	> 0.8
		CSR_a	-3	-2	-1	0	1	2	3

<table>
<tr><th>Severity Classes</th><th colspan="2">Methods</th></tr>
<tr><td rowspan="3">CSR_b</td><td>1. Reclassify</td><td>
<table>
<tr><th>SR_i</th><th>< -0.3</th><th>-0.3 – 0.3</th><th>> 0.3</th></tr>
<tr><td>SR_i</td><td>-1</td><td>0</td><td>1</td></tr>
</table>
</td></tr>
<tr><td>2. Map Algebra</td><td>$$SR_m = \sum_{i=1}^{12} CSR_i$$</td></tr>
<tr><td>3. Reclassify</td><td>
<table>
<tr><th>SR_m</th><th>< -6</th><th>-5</th><th>-4</th><th>-3 – 3</th><th>4</th><th>5</th><th>> 6</th></tr>
<tr><td>CSR_b</td><td>-3</td><td>-2</td><td>-1</td><td>0</td><td>1</td><td>2</td><td>3</td></tr>
</table>
</td></tr>
<tr><td rowspan="2">CSR_c</td><td>1. Map Algebra</td><td>$$SR_t = CSR_a + CSR_b$$</td></tr>
<tr><td>2. Reclassify</td><td>
<table>
<tr><th>SR_t</th><th>< -5</th><th>-4</th><th>-3 – -2</th><th>-1 – 1</th><th>2 - 3</th><th>4</th><th>> 5</th></tr>
<tr><td>CSR_c</td><td>-3</td><td>-2</td><td>-1</td><td>0</td><td>1</td><td>2</td><td>3</td></tr>
</table>
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</table>

Changes in the historic and future presence of dispersal and pollination processes[1]

As an approach to analyze and assess changes in the environment's biotic variables that are important in the functioning of ecosystems, the mutualistic processes of seed dispersal and pollination were addressed. These processes of plant-animal interaction play a fundamental role in the maintenance of ecosystem integrity, by conditioning other processes such as the establishment of seeds, the recruitment of plants and ecosystems regeneration (Fontúrbel et al. 2015). These processes are especially important in tropical forest ecosystems were over 80% of plants rely on these mutualistic processes, and are therefore fundamental to the stability of most Colombian ecosystems.

Criterion D was analyzed for all three sub-criteria (D1, D2, D3) based on the construction of historical and future (with CC) distribution models, and the ecosystem transformation layers (sec *2.4.1*).

The methodology used to build the presence maps of the dispersal and pollination processes, assume that the co-occurrence or the overlap in the distributions of a plant-animal species pairs can be used as a proxy of an interaction, and therefore of the occurrence of the biotic process in question (Morales-Castilla et al. 2015).

[1] *Developed with the participation of:* Mauricio Vejarano (CI), Camila Pacheco (PUJ), Juliana Cortés (PUJ) and Laura Eraso (PUJ).

Based on this, plant-animal species pairs were selected that could inform on dispersal and pollination processes well supported by literature data, and on which there were sufficient distribution data to produce spatial models.

For the purpose of representativeness, animal species belonging to several groups of vertebrates (Birds, Primates and Chiroptera) and a group of invertebrates (insects) were included. In the case of plants, the selection process was carried out considering the representation of different successional stages in the ecosystems: pioneer, intermediate and late stages.

We also took into account where possible, additional information on the effectiveness of the relationships in the processes which included: i) for dispersal, the evidence or germination percentage of dispersed seeds (Samuels and Levey 2005); ii) for pollination, the volume of the pollen load of the pollinating agent was taken into account, beyond the simple visit to the plant (King, Ballantyne and Willmer 2013).

After the selection process, 67 seed dispersal pairs and 63 effective pollination relations were obtained (Annex 3), which included 73 plant species representing families such as Moraceae, Arecaceae, Melastomataceae, Urticaceae, Asteraceae, Rubiaceae; and 49 animal species divided into birds (Capitonidae, Cotingidae, Cracidae, Emberizidae, Parulidae, among others), primates (Atelidae), chiroptera (Phyllostomidae) and insects (Apidae, Calliphoridae and Nymphalidae).

Once the pair of species for each biotic relationship were chosen, the georeferenced records of the occurrences of each species were collected from the Colombian national database SIB and Global Biodiversity Information Facility (GBIF) database. For the construction of the distribution models, Maxent ver. 3.3.3k which is a software that uses the maximum entropy algorithm to build spatial distribution models, was used (Phillips, Anderson and Schapire 2006).

The modeling results were subjected to a review by experts and an adjustment was made when confronting them with the bibliographic information that could be gathered on the distribution and habitat of each species in Colombia. Finally, a map was built for each functional pair, as a consequence of the convergence of both distributions, both for the present and for the 2050 scenario, and the areas of gain, loss and without changes of the pollination or dispersal relation were analyzed (Criterion D2) (Figure 6).

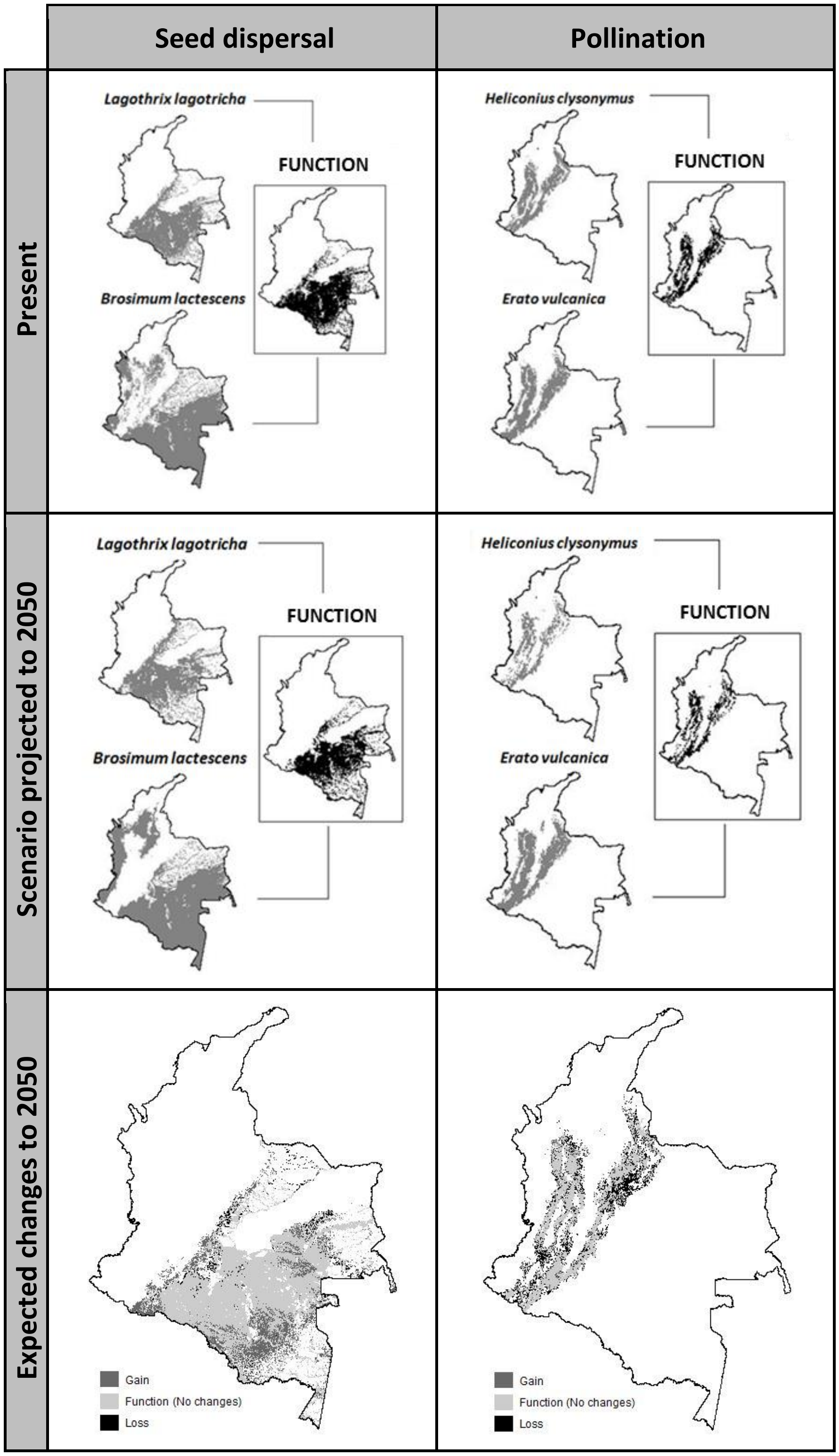

Figure 6. Example of loss of ecological functions (2014-2050) due to changes in the distribution of functionally connected species: a) *Lagothrix lagotricha -Brosimum lactescens* (dispersal); b) *Heliconius clysonymus - Erato vulcanica* (Pollination).

2.6. Application of the RLE Assessment System

The different criteria were applied as described below.

Assessment of Criterion A

Sub-criteria A1, A2b and A3 were analyzed.

For *criterion A1,* corresponding to the past 50 years, the interval of the *Transformation_1970* and *Transformation_2014* maps was used.

For *criterion A2b,* corresponding to the 50 years between the past 1990 and the future, the *Transformation_1990* and *Transformation_2040* maps (BAU scenario) were used.

For *criterion A3,* corresponding to the historical transformation, the map of potential ecosystems without transformation and the *Transformation_2014* maps were used.

Assessment of Criterion B

Sub-criteria B1 was assessed in the assessment of criterion B, for which the minimum enveloping polygons of all occurrences were built, and sub-criterion B2, for which the extension of occurrence was calculated (number of 10x10 km cells occupied by all occurrences). For both sub-criteria, a measure of the disruption of the biotic processes/interactions reported by the Human Space Footprint index was used (Etter et al. 2011a).

Assessment of Criterion C

Only sub-criterion C2 was analyzed, which assesses the changes in rainwater availability during the next 50 years according to the expected climate change trends.

In order to calculate the area of each severity class in the ecosystems, for each of the 6 classes (Table 5), the *tabulated Area* tool of the *Spatial Analysis* package present in ArcGIS 10.3 (ESRI, 2014) was used. Subsequently, the percentages of area occupied by each severity category in each of the ecosystems were calculated (Table 6). The risk category used the severity class with the largest area within the ecosystem and the extension classes proposed by the IUCN (Keith et al., 2013).

Table 6. Risk categories of ecosystems collapse for Criterion C2.

Severity \ Extension (%)	1	2	3
≥ 80	CR	EN	VU
≥ 50	EN	VU	LC
≥ 30	VU	LC	LC

Assessment of criterion D

For *criterion D1*, which assesses the changes in biotic processes of the past 50 years, the Transformation_1970 and Transformation_2014 maps were used. The the severity was calculated based on the loss in area of the biotic processes between 1970 and 2014 for each ecosystem.

For *criterion D2*, which assesses the change in biotic processes corresponding to a 50-year period between the present and the future, the map of current ecosystems was used, and the results of the modeling of biotic relationships in the present and in the climate change scenario projected to 2050.

The ranges of relative severity were established as follows: a loss in the number of biotic processes greater than 50% between present and future was assigned the CR category (> 80); a loss of between 30 and 50% was assigned the EN category (> 50%); a loss between 15 and 30% was assigned the VU category (> 30%) (Table 7).

Because the spatial information was in raster format, ecosystems presented cells with different loss values across their ranges. The final severity category for each ecosystem was assigned according to the category with the highest area percentage within the ecosystem.

The extension class used the percentage area occupied by the assigned severity class (Table 7). For example if it represented more than 80% of the total ecosystem area and the percentage of biotic interactions lost was greater than 50%, it was assigned the CR category.

Table 7. Risk categories of ecosystems collapse for Criterion D2.

Severity (%) / Extension (%)	≥ 80 *(> 50% processes lost)*	≥ 50 *(30-50% processes lost)*	≥ 30 *(15-30% processes lost)*
≥ 80	CR	EN	VU
≥ 50	IN	VU	LC
≥ 30	VU	LC	LC

For *criterion D3*, which assesses the historical change in processes, the map of potential ecosystems without transformation and the Transformation_2014 map were used. The procedure was the same as for sub-criterion D1.

3. RESULTS

3.1. Potential ecosystems: Classification and cartography

General Aspects of Ecosystem Diversity

The ecological characterization that we present for the country identifies a total of 81 types of ecological units or hierarchically organized ecosystems (Figure 7, Annex 4). Out of these, 54 correspond to forest ecosystems, 6 to shrub ecosystems, 16 to ecosystems with herbaceous stratum dominion such as savannas and Páramos, and 5 to wetland ecosystems with herbaceous vegetation and open waters (Table 8).

Table 8. General physiognomic types and their potential extension in the country.

Type	Extension (Ha)	%
Forests	94,146,930	82.5
Shrublands	1,543,390	2.2
Savannas	14,128,937	12.6
Páramos	2,291,240	2.7

The Zonobiome of Humid Tropical Forests (ZBHT) groups the largest number of ecosystems with a total of 69 ecosystems, and occupies 100.5 million hectares equivalent to 87.7% of the country. Out of these, 45.9 million hectares (46%) correspond to zonal forests, 26.5 million hectares to Orobiomes (mountain forests, shrublands and Páramos), 14.1 million hectares correspond to the Helobiomes (alluvial and swamp forests), and 19.9 million hectares to Pedobiomes (savannas and edaphic shrublands).

General description of the Biomes

A. Zonobiome of Humid Tropical Forests (ZBHT)

Includes all the biomes of altitudes lower than 500 m, which present a surplus precipitation and some degree of seasonality from 1 to 3 months without generating marked water deficits. Annual average precipitation is greater than 1800-2000 mm, and may reach more than 8000 mm as in the Pacific or in some areas of the Andes foothills.

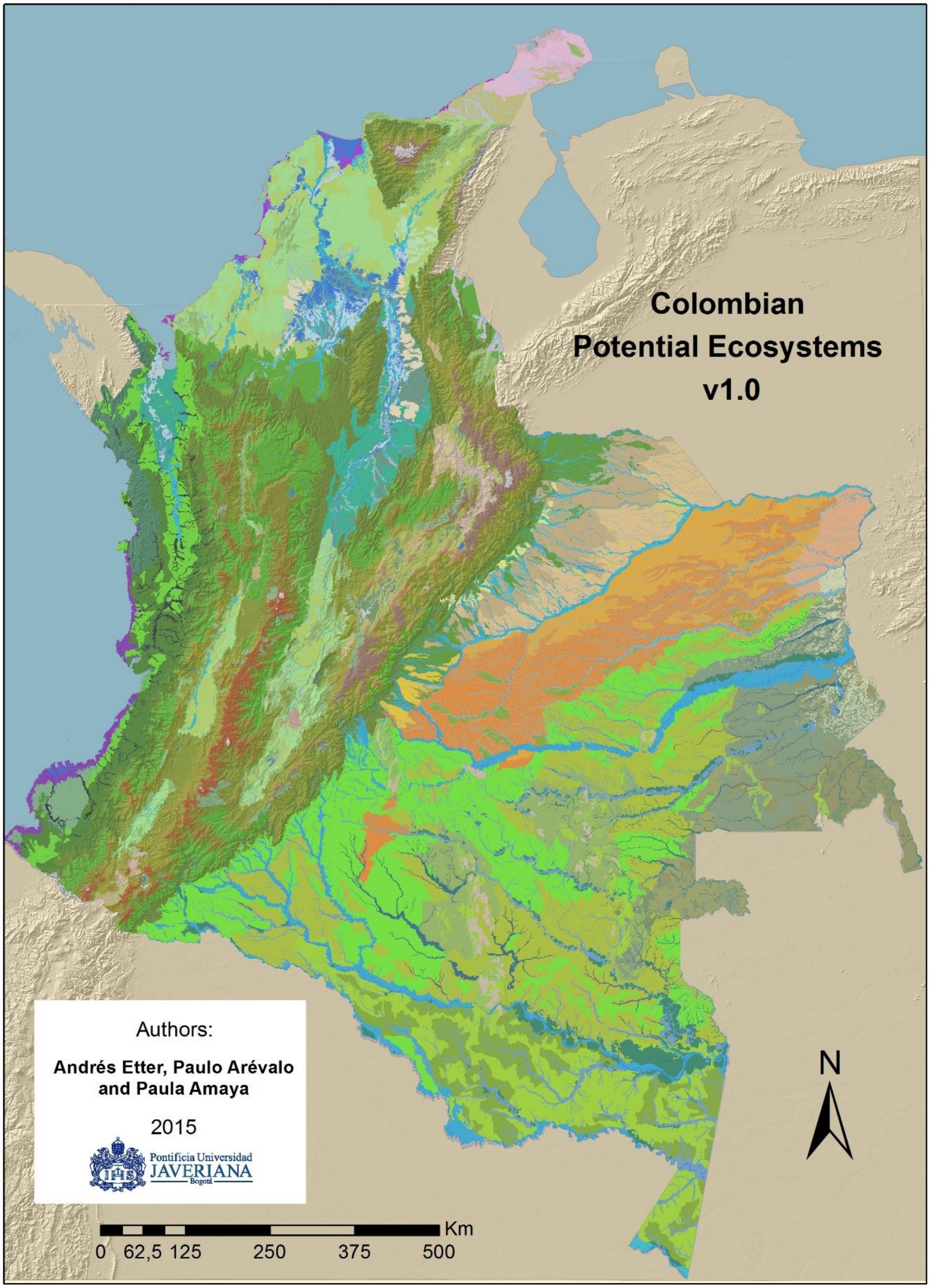

Figure 7. General Map of Potential Colombian Ecosystems.

Physically, the vegetation corresponds to dense forests (20 to 35m height). They generally have multiple strata, with high diversity and low levels of dominance. They are for the most part mesophyllous forests. Soils tend to be acid due to the leaching effect of high precipitation.

B. Zonobiome of Tropical Dry Forests (ZBBST)

Includes the biomes of altitudes lower than 500 m, which have a strong seasonality in precipitation between 3 and 5 months per year, and an average annual rainfall of less than 1500 mm.

C. Zonobiome of Subtropical Desert (ZDT)

Includes all the biomes of altitudes below 500 m, which have a high deficit in precipitation between 6 and 12 months a year. Average annual rainfall is less than 500 mm, representing arid conditions.

D. Orobiomes

Correspond to biomes determined by the temperature deviations from the zonal norm of the ZBHT resulting from the orographic factor. Altitudes range from 500 m up to 5400 m. Most correspond to HT conditions where a positive water balance predominates, but affected by the reduction in the average and the maximum and minimum temperatures, which in cases of high mountains can imply the existence of frost (Paramo ecosystems).

i. Andean Orobiomes

The Andes orobiomes are characterized by a wide diversity and heterogeneity resulting from large variations in altitudinal amplitude, and the varied topography caused by the diversity in geological substrates (igneous, sedimentary and metamorphic; presence of volcanic ash and substrates of glacial origin) and tectonism. In some cases, the orographic characteristics of large valleys and plains generate variable ecosystems with locally dry climates, or hydromorphic intra-zonal soils.

ii. Amazonian Orobiomes

Amazon orobiomes are characterized by the presence of residual topographies of the Guyana shield, with enough orographic and pedological conditions to determine changes in the expression of ZBHT zonal ecosystems. They are mainly related to the presence of the Guiana Shield in the north-east and center of the region.

E. Pedobiomes:

They refer to biomes whose vegetation cover and productivity characteristics deviate from the zonal standard due to limiting conditions of the edaphic factor. They are mostly located at altitudes below 500 m, although occasionally they can exceed these altitudes, as in the Andean region, but the edaphic factor remains the main limiting factor.

Characteristically, transitions between the zonal ecosystems of the ZBHT and the pedobiomes are abrupt. Among the pedobiomes themselves, transitions may be gradual but are generally given at shorter distances, because of contrasts in the toposequences.

i. Forest, shrub or herbaceous pedobiomes

They correspond to situations where the soil and/or drainage conditions are sufficiently dominant to determine a deviation of the zonal condition of the mesophylic forests, towards sclerophylous conditions. These arise from limitations in the availability of nutrients, either due to oligotrophy resulting from the parent rock or the conditions of extreme soil washing, as occurs in the regions with granitic outcrops in Guainía and Vaupés (tropical Oxisols or Spodosols according to the USDA classification (1999)).

Depending on the level of oligotrophy, these types of ecosystems conform to low forests, shrublands or even grasslands.

When oligotrophy conditions are combined with an increase in seasonality of rainfall, ecosystems change to grass savannas with different levels of tree components, in which fire and herbivory constitute important processes of their dynamics, as is the case in the Llanos Orientales and the north of the Colombian Amazon (Meta and Guaviare).

F. Helobiomes:

These ecosystems deviate from the zonal norm due to excess water in at least one representative period. Characteristics and dynamics of these ecosystems are determined primarily by the activity of fwater flooding pulses, as is the case in alluvial plains with significant changes in water levels, or by the permanent presence of a water mirror. They present important contrasts with the zonal ecosystems with which they co-occur. Their characteristics and contrasts can vary greatly depending on the precipitation characteristics of the Zonobiome (ZBHT, ZBST, ZDT) in which they are immersed.

Halobiomes:

Ecosystems determined primarily by the activity of salty or brackish water flood pulses, as it occurs in coastal plains. They vary depending on the level of salt accumulation, depending on the Zonobiome's precipitation characteristics.

Hydrobiomes:

Aquatic ecosystems with a permanent, static or running freshwater.

Description of Ecosystems

The description of the ecosystems includes 10 fields:

- Code
- Biome
- Physiognomy
- Landscape
- Characteristic Native Biota
- Physical Environment (Substrate, Altitude, Slope, Average temperature, Annual average precipitation)
- Region / Department
- Potential Ecosystem Area
- Remnant proportion in 2014
- Bibliographic references

This information is recorded in the map's legend (Annex 5).

3.2. Ecosystem Transformation Processes

Multi-temporal evolution of the transformation and replacement process.

Figure 8 shows the transformation trends in the historical time series and the future projection for the biomes. The multi-temporal transformation sequences are shown as, "transformed" and "non-transformed" units in the maps of figure 9. The highest levels of ecosystem transformation are located in the center and northern part of the country, which correspond to the ecosystems of the Andean Orobiomes and the Zonobiome of BST.

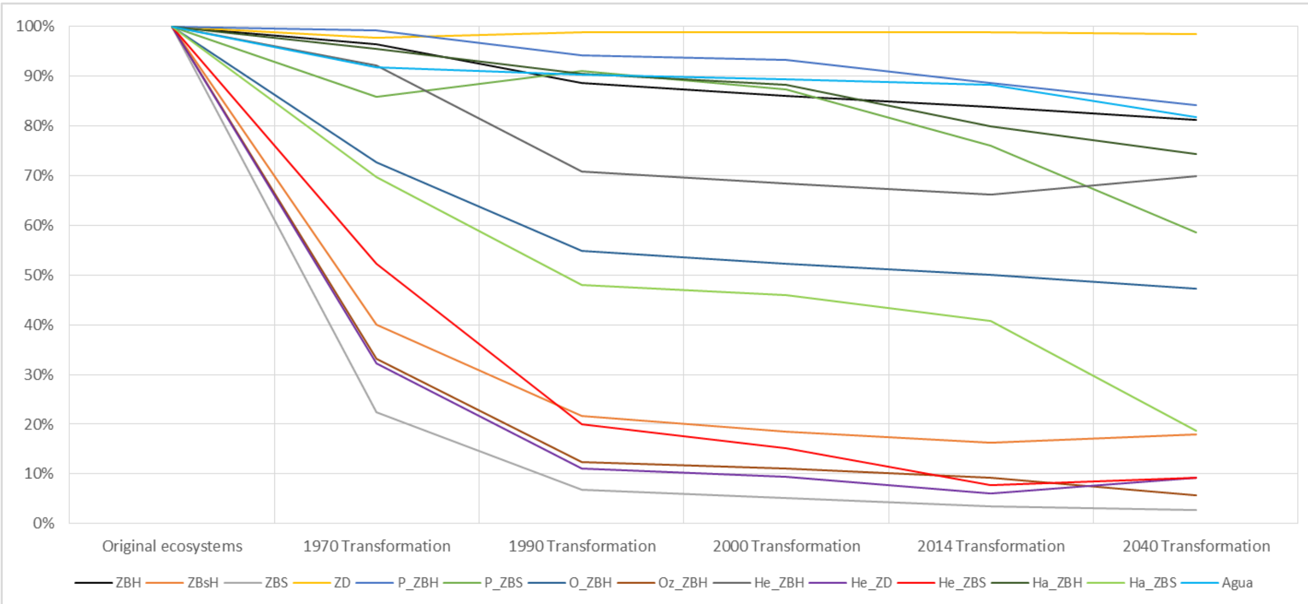

Figure 8. Biomes transformation trend in the period 1970 -2014 and the BAU projection by 2040 (see Annex 5 for biome codes).

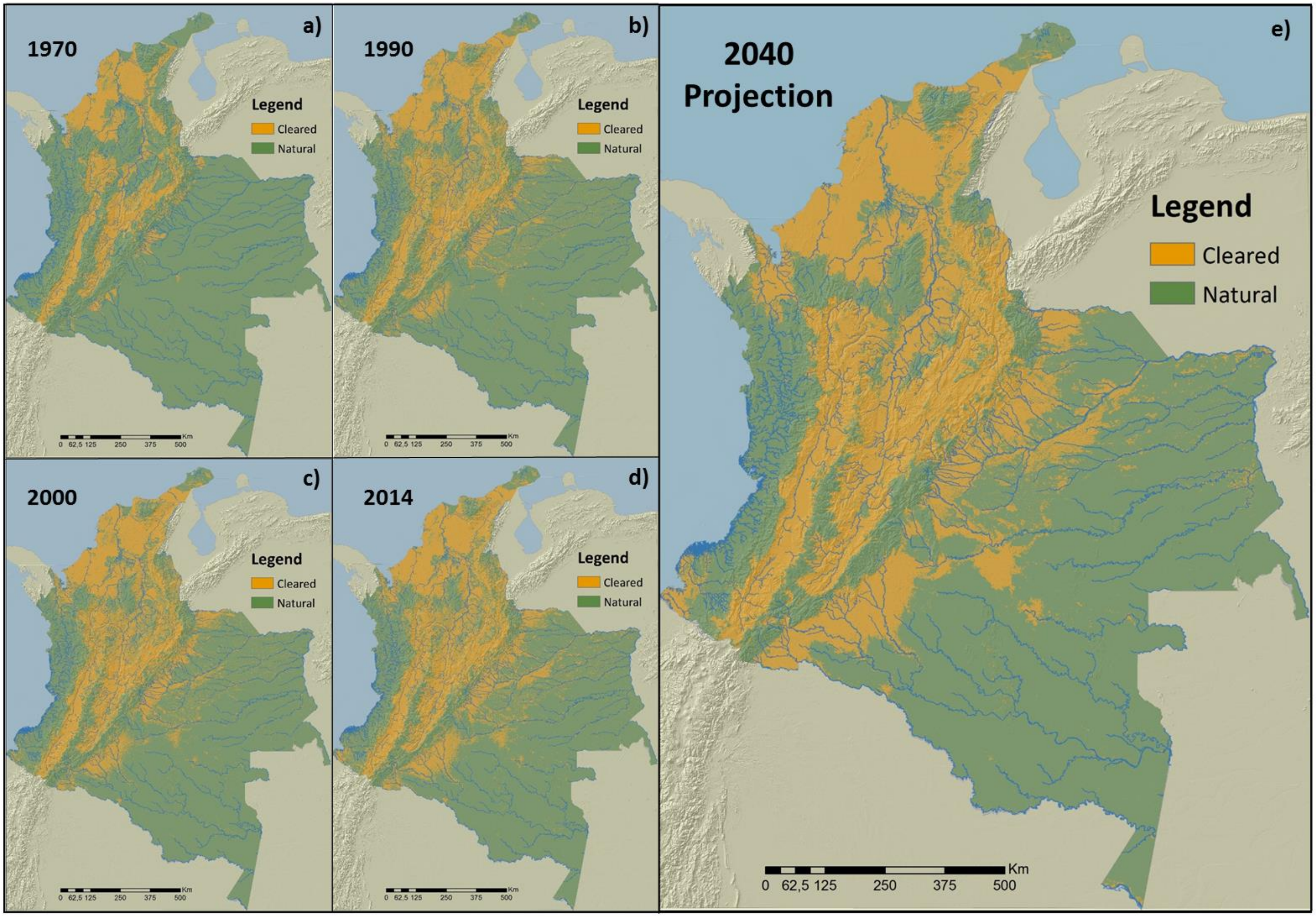

Figure 9. Ecosystems Transformation Map. a) 1970; b) 1990; c) 2000; d) 2014; e) BAU 2040 projection.

3.3. Forecasts of future degradation of physical and biotic components and processes[2]

Environmental degradation: changes in the availability of rainwater during the next 50 years (Criterion C2)

The effect of precipitation changes given by the analysis of the future scenario of precipitated water availability shows two important aspects: i) there are both significant increases and decreases; ii) the differences in the future scenarios in regards to the historical ones are not very big.

According to the analysis of future variation in the availability of precipitation water, it is observed that the behavior of the relative severity indexes and the variability present spatial patterns and values that are fairly coincident on an annual basis (Figure 10a and 10d). However, when the values of the monthly behaviors of consecutive months are analyzed, very different spatial patterns are observed, with larger relative severity indexes and spatially more extended, than for the variability indexes (Figure 10b and 10e). The above also happens when the annual and monthly indexes are aggregated (Figure 10c and 10f).

When combining the severity index with its extension of occurrence in the ecosystems, it can be seen that seven ecosystems are included in the CR or EN categories. Of these 7 ecosystems, only one is threatened by a decrease in water availability (B2d - Dense High Forests of the Zonobiome of Tropical Humid Forest), while the remaining six are threatened by an increase in it. Additionally, it is observed that the criterion of greatest risk for all of them is the one elative monthly severity (CSR_b) with the exception of the A3 ecosystem (very open low shrublands and desert areas of the Zonobiome of the Tropical Desert) where the annual (CSR_a) and total (CSR_c) relative severity criteria also intervene.

The area with the greatest expected changes is the Guajira peninsula, where almost all of the ecosystems are in critical danger (CR) or endangered (EN). Additionally, some ecosystems located in the northern part of the department of Norte de Santander and a large

[2] The biological data on the dispersal processes of Chiroptera were provided by Yaneth Muñoz and her Research Group on Evolution and Ecology of Neotropical Mammals, at the Institute of Natural Sciences, of the Colombian National University.

heterogeneous strip that vertically crosses the central region of the departments of Arauca and Casanare are endangered (EN).

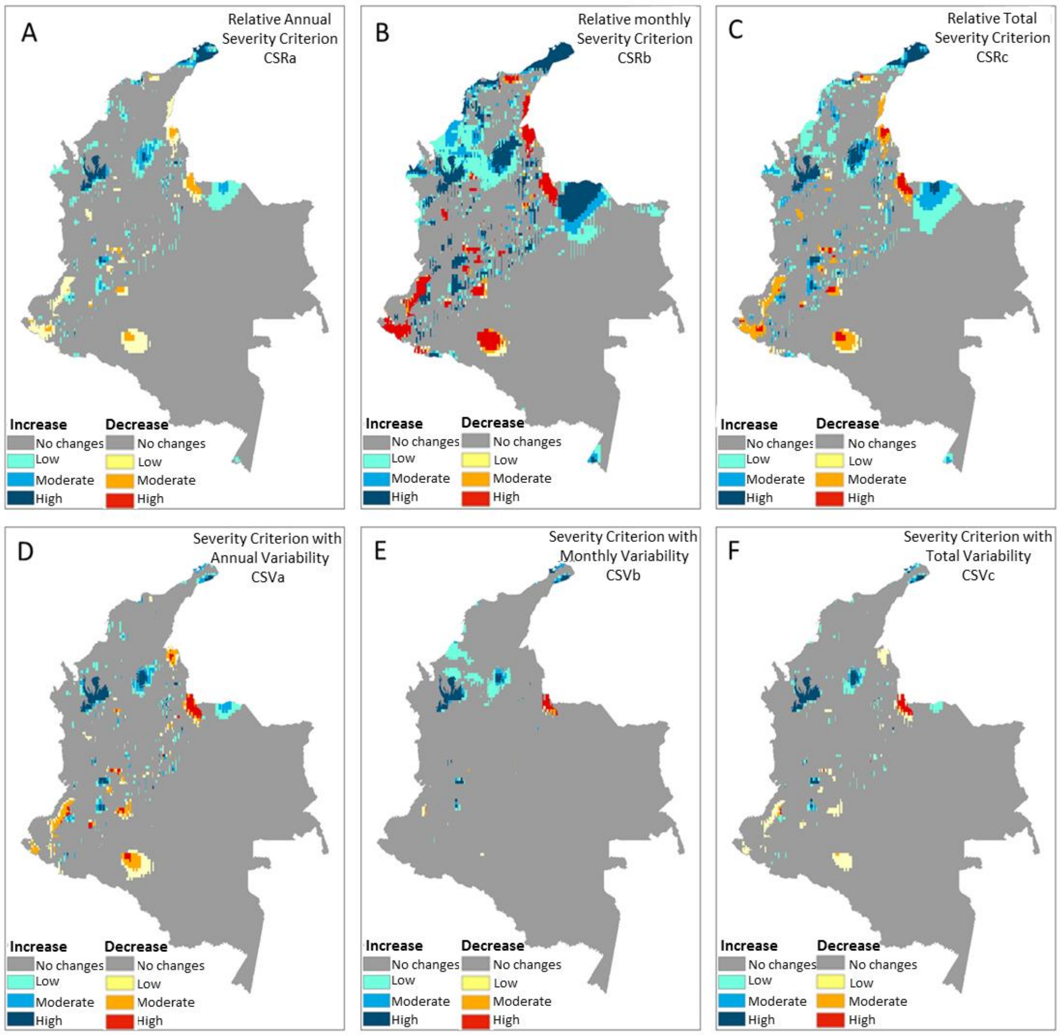

Figure 10 Severity criteria of changes in precipitation in the next 50 years (Criterion C2).

Historical (D1, D3) and future (D2) loss and degradation of biotic processes

The changes observed for the analyzed seed dispersal and pollination processes (mainly forest ecosystems) show different spatial patterns. The loss of these interaction functions responds to changes or shifts in the distribution ranges of animal and plant species due to climate change, and consequently, changes in the potential area of the seed dispersal or pollination relationship.

For future changes due to CC (D2), the areas with high loss/degradation rates are mostly located in the Andes, and the north of the Amazon and south of the Orinoquia (Figure 11, Table 9). According to this analysis for 2050 an approximate area of 20 million hectares with very high and high severity and about 40 million hectares with moderate to low severity.

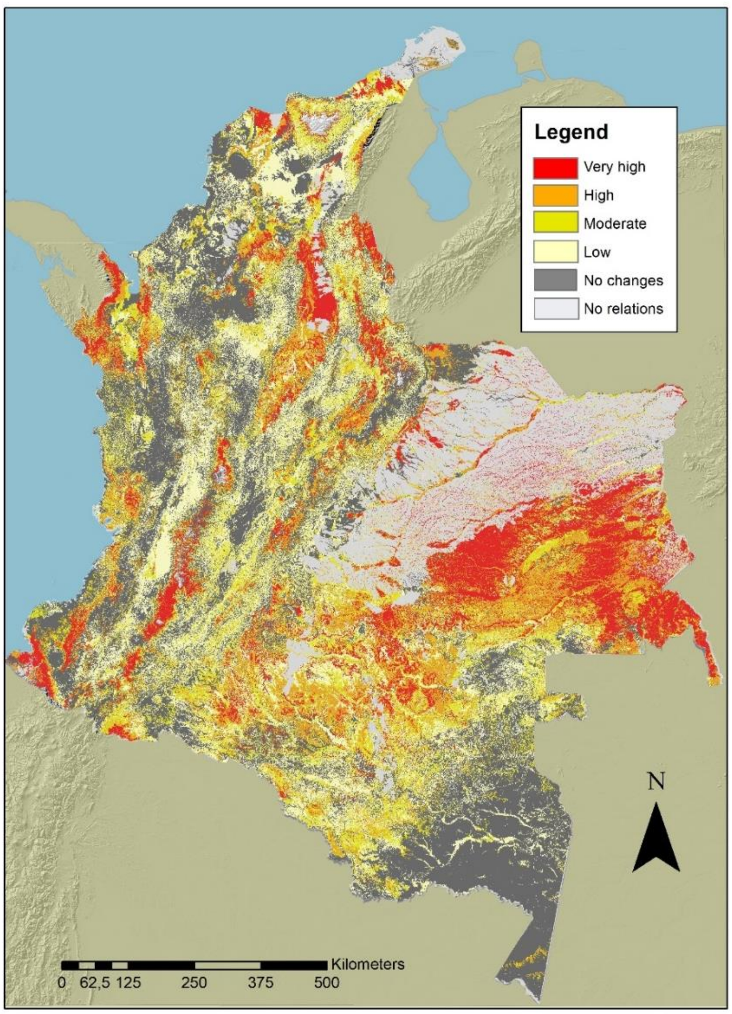

Figure 11 Severity of the loss of ecological function of dispersal and pollination in the next 50 years based on 130 plant-animal functional pairs.

Table 9 Severity level of loss of biotic processes in the different regions in Colombia and its percentage with respect to the total loss.

	Low	Moderate	High	Very High
Andean	69%	16%	8%	6%
Caribbean	65%	12%	11%	11%
Orinoquia	37%	16%	20%	27%
Pacific	52%	17%	16%	14%
Amazon	48%	17%	17%	18%

With respect to the impacts of the historical transformation of ecosystems and their impact on the selected seed dispersal and pollination processes (D1 and D3), the analysis show important effects for the Andean and Caribbean regions' ecosystems (Figure 12 and 13). In general, the transformation processes that have occurred over the last 50 years in Colombia have meant a 35% reduction in the area of occurrence of biotic processes and interactions (Table 10).

Since the human transformation process has been predominant in the Andean and Caribbean regions, and the analysis privileged forest ecosystems, the ecosystem risk level for this concept is higher for those forest ecosystems that are dominant in these areas (Table 10).

In the case of seed dispersal, approximately 22% of the plant-animal effective interaction area had been lost by 1970 in weighted terms per area/# relations, and by 2014 a loss of 41% had already ocurred (Table 10). The progressive advance of the degradation of these biotic processes is observed in the time series of Figures 12, especially in the Caribbean, Andes and Orinoquia regions, having the representation of the potential ecosystems as a reference.

The change trends in pollination processes that result from the transformation scenarios, indicate a 13% reduction in the area of interactions by 1970, and a total 28% decrease by 2014 (Table 10). Figure 13 shows that a greater relative degradation occurs in areas where there is a lower number of relationships, in the Caribbean, Andes and Orinoquia regions.

Table 10. Changes in the last 50 years in the areas of occurrence of the analyzed biotic processes.

Biotic process	Area of relationships in potential ecosystems (Ha)	Area lost by 1970 (%)	Area lost by 1990 (%)	Area lost by 2000 (%)	Area lost by 2014 (%)
Seed dispersal	1,281,318,781	21.9	35.4	38.2	40.8
Pollination	1,291,267,231	12.8	23.4	26.1	28.4
Total	2,572,586,012	17.3	29.4	32.1	34.6

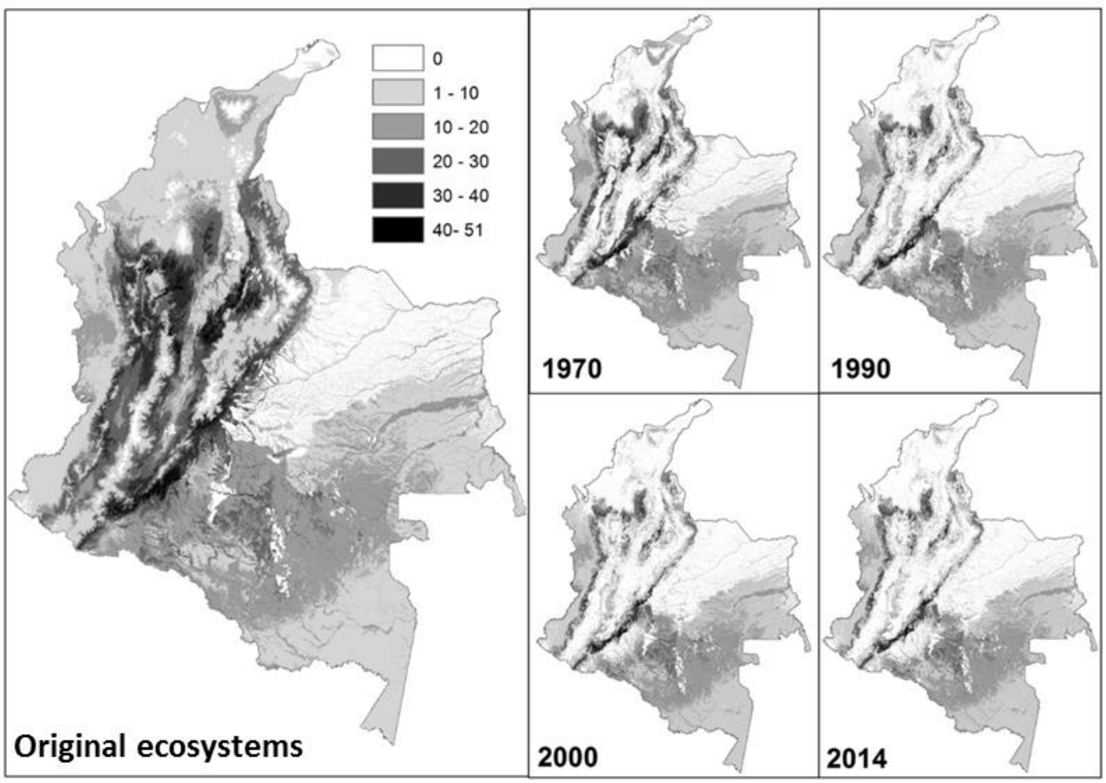

Figure 12. Total number of seed dispersal process relations lost, and for each time period.

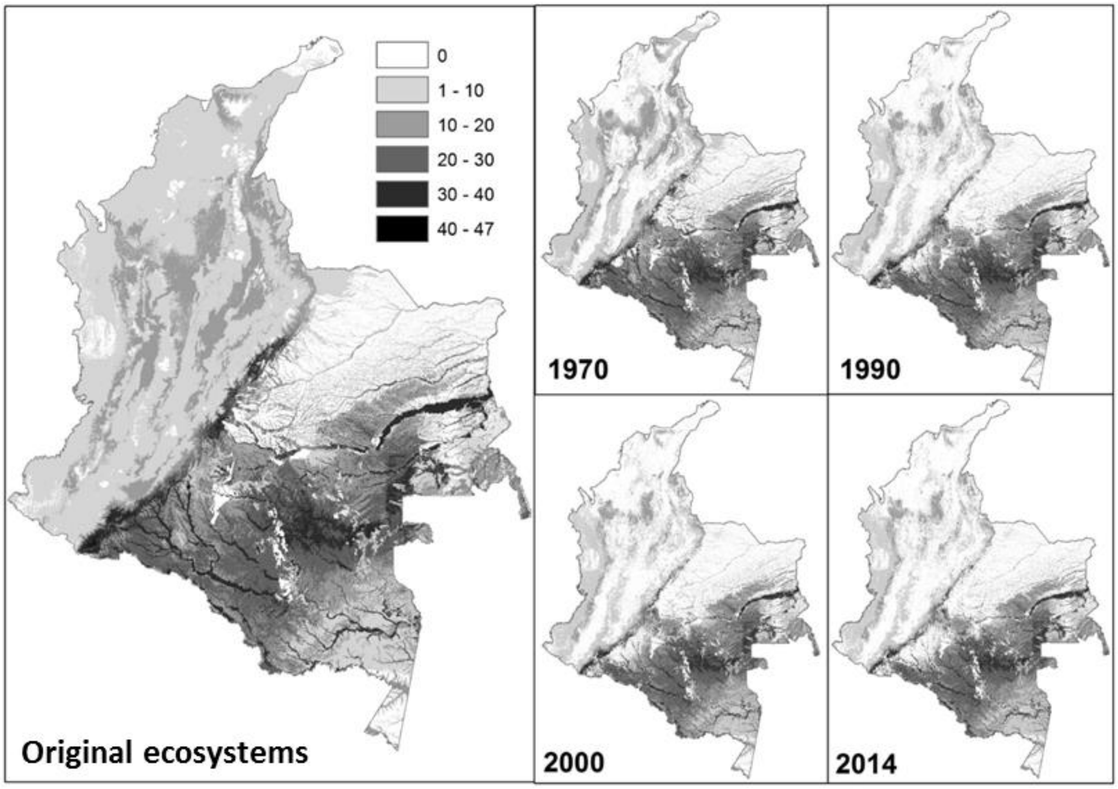

Figure 13. Total number of pollination process relations lost, and for each time period.

3.4. RLE Assessment

The general risk assessment of the country's ecosystems in this second version indicates that almost half (36) of ecosystem types show high-risk levels (CR and EN): 22 ecosystems, equivalent to 27%, were categorized as critical status (CR), and 14 ecosystems (17%) in an endangered status (EN) (Table 11). This means that about half of the country's ecosystems show conditions that put their permanence and the services they provide to society at risk (Figure 27). Meanwhile, 12 ecosystems (15%) are in vulnerable status (VU), while 33 ecosystems (41%) were listed as low concern (LC).

The dominant criterion that defined CR category was criterion A, in particular criteria A1 and A3. In two cases, criterion C2 also determined the CR status, while criteria D1 and D3 also contributed to this categorization for at least 14 ecosystems.

Table 11. Final collapse risk assessment of Colombian Ecosystems.

ECOSYSTEM CODE	A1	A2b	A3	B1ai	B1aii	B1aiii	B2ai	B2aii	B2aiii	C2	D1	D2	D3	FinalEv
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ZBH-B1b	CR	LC	CR	LC	LC	LC	LC	LC	LC	LC	CR	LC	VU	CR
ZBH-B1c	CR	EN	CR	LC	LC	VU	LC	LC	LC	LC	CR	VU	CR	CR
ZBH-B1d	EN	LC	EN	LC	LC	EN	LC	LC	VU	LC	VU	EN	VU	EN
ZBH-B2a1	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC
ZBH-B2a2	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC
ZBH-B2b	EN	LC	EN	LC	LC	VU	LC	LC	LC	LC	VU	LC	LC	EN
ZBH-B2c	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC
ZBH-B2d	VU	LC	LC	LC	LC	LC	LC	LC	LC	EN	LC	EN	LC	EN
ZBH-B3a1	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC
ZBH-B3a2	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC
ZBH-B3b	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC
ZBH-B4a	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC
ZBH-B4b	LC	LC	LC	LC	LC	VU	LC	LC	LC	LC	LC	CR	LC	CR
ZBH-B4c	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	EN	LC	EN
ZBH-B4d	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC
ZBH-B5	EN	LC	VU	LC	LC	LC	LC	LC	LC	LC	VU	EN	LC	EN
ZBH-B6	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC
ZBH-B7	LC	LC	LC	LC	LC	VU	LC	LC	LC	LC	LC	LC	LC	VU
ZBsH-B8	EN	VU	CR	LC	LC	LC	LC	LC	LC	LC	VU	LC	VU	CR
ZBsH-B9	EN	LC	CR	LC	LC	EN	LC	LC	LC	LC	LC	LC	VU	CR
ZBS-B10	CR	EN	CR	LC	LC	LC	LC	LC	LC	LC	CR	LC	CR	CR
ZBS-B11	CR	CR	CR	LC	LC	LC	LC	LC	LC	LC	CR	LC	CR	CR
ZBS-B12	EN	VU	CR	LC	LC	LC	LC	LC	LC	LC	VU	LC	CR	CR
ZBS-B13	CR	LC	CR	LC	LC	EN	LC	LC	LC	EN	CR	LC	CR	CR
ZD-A1	LC	LC	LC	LC	LC	EN	LC	LC	LC	CR	LC	LC	LC	CR
ZD-A2	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC
ZD-A3	LC	LC	LC	LC	LC	LC	LC	LC	LC	CR	LC	LC	LC	CR
P_ZBH-B14	LC	LC	LC	LC	LC	VU	LC	LC	LC	LC	LC	LC	LC	VU
P_ZBH-B15	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	VU	LC	VU
P_ZBH-S1	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC
P_ZBH-A4	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC
P_ZBH-S2	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC
P_ZBH-S3	EN	LC	VU	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	EN
P_ZBH-S4	EN	LC	CR	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	CR
P_ZBH-S5	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC
P_ZBH-S6	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC
P_ZBH-S7	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC
P_ZBH-S8	LC	LC	LC	LC	EN	LC	LC	LC	LC	LC	LC	LC	LC	EN
P_ZBH-S9	LC	LC	LC	LC	LC	LC	LC	LC	LC	EN	LC	LC	LC	EN
P_ZBH-S10	LC	LC	LC	LC	LC	VU	LC	LC	LC	LC	LC	LC	LC	VU

(Cont.)

ECOSYSTEM CODE	A1	A2b	A3	B1ai	B1aii	B1aiii	B2ai	B2aii	B2aiii	C2	D1	D2	D3	FinalEv
P_ZBS-S11	LC	VU	LC	LC	LC	VU	LC	LC	LC	LC	LC	LC	LC	VU
P_ZBS-S12	LC	VU	LC	LC	LC	EN	LC	LC	LC	LC	LC	LC	LC	EN
O_ZBH-B16	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC
O_ZBH-B17	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC
O_ZBH-B18	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC
O_ZBH-B19a	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC
O_ZBH-B19b	VU	LC	VU	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	VU
O_ZBH-B20a	LC	LC	VU	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	VU
O_ZBH-B20b	VU	LC	VU	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	VU
O_ZBH-B21a	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC
O_ZBH-B21b	VU	LC	VU	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	VU
O_ZBH-B21c	EN	VU	CR	LC	LC	LC	LC	LC	LC	LC	VU	LC	VU	CR
O_ZBH-B21d	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC
O_ZBH-B22	CR	LC	CR	LC	LC	VU	LC	LC	LC	LC	CR	LC	CR	CR
O_ZBH-S13	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC
O_ZBH-S14	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC
O_ZBH-S15	LC	VU	LC	LC	LC	EN	LC	LC	LC	LC	LC	LC	LC	EN
O_ZBH-N	LC	LC	LC	LC	LC	LC	LC	LC	VU	LC	LC	LC	LC	VU
Oz_ZBH-B23	EN	EN	CR	LC	LC	LC	LC	LC	LC	LC	CR	LC	CR	CR
Oz_ZBH-A5	EN	CR	CR	LC	LC	LC	LC	LC	LC	LC	VU	LC	CR	CR
Oz_ZBH-A6	CR	EN	CR	LC	LC	EN	LC	LC	VU	LC	CR	LC	CR	CR
Oz_ZBH-S16	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC
O_ZBH-P1	CR	LC	CR	LC	LC	LC	LC	LC	LC	LC	CR	LC	CR	CR
He_ZBH-B24	EN	LC	EN	LC	LC	LC	LC	LC	LC	LC	VU	LC	VU	EN
He_ZBH-B25	VU	EN	VU	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	EN
He_ZBH-B26	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC
He_ZBH-B27	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC
He_ZBH-B28	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC
He_ZBH-B29	VU	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	VU
He_ZBH-B30	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC
He_ZBH-B31	VU	LC	VU	LC	LC	LC	LC	LC	LC	LC	VU	VU	LC	VU
He_ZBH-B32	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC
He_ZBH-P2	EN	EN	EN	LC	LC	LC	LC	LC	LC	LC	VU	LC	VU	EN
He_ZD-B33	CR	LC	CR	LC	LC	LC	LC	LC	LC	EN	CR	LC	CR	CR
He_ZBS-B34	CR	LC	CR	LC	LC	LC	LC	LC	LC	LC	CR	LC	CR	CR
He_ZBS-P3	CR	EN	CR	LC	LC	LC	LC	LC	LC	LC	CR	VU	CR	CR
He_ZBS-P4	CR	EN	CR	LC	LC	EN	LC	LC	VU	LC	CR	LC	CR	CR
Ha_ZBH-B35	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC
Ha_ZBS-B36	VU	EN	VU	LC	LC	LC	LC	LC	LC	VU	LC	LC	LC	EN
Agua	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC

Assessment of Criterion A

Criterion A (reduction in geographic extension and distribution) was analyzed through sub-criteria A1 (Figure 14), A2b (Figure 15) and A3 (Figure 16).

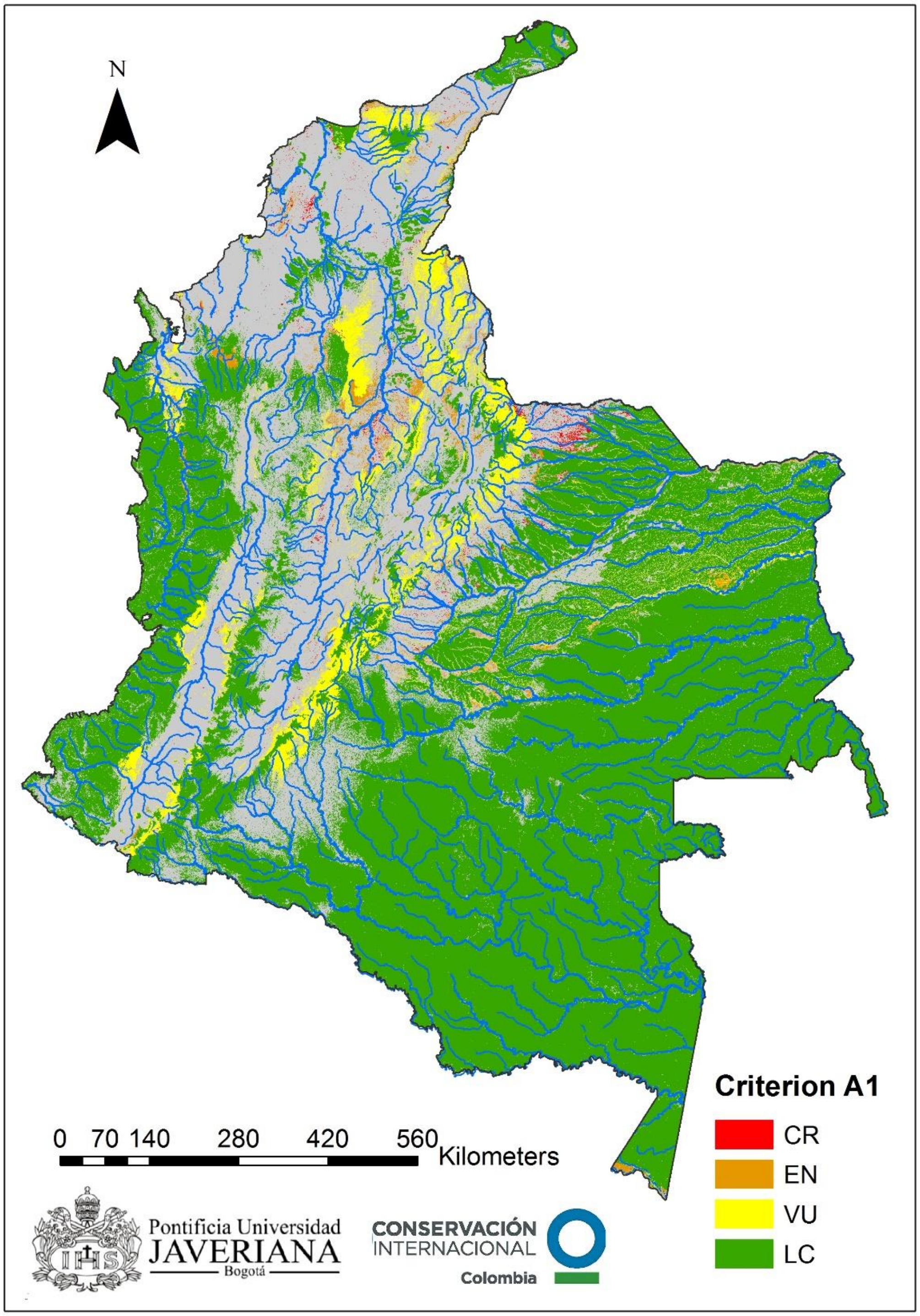

Figure 14. Risk assessment with sub-criterion ***A1***: Present (during the past 50 years).

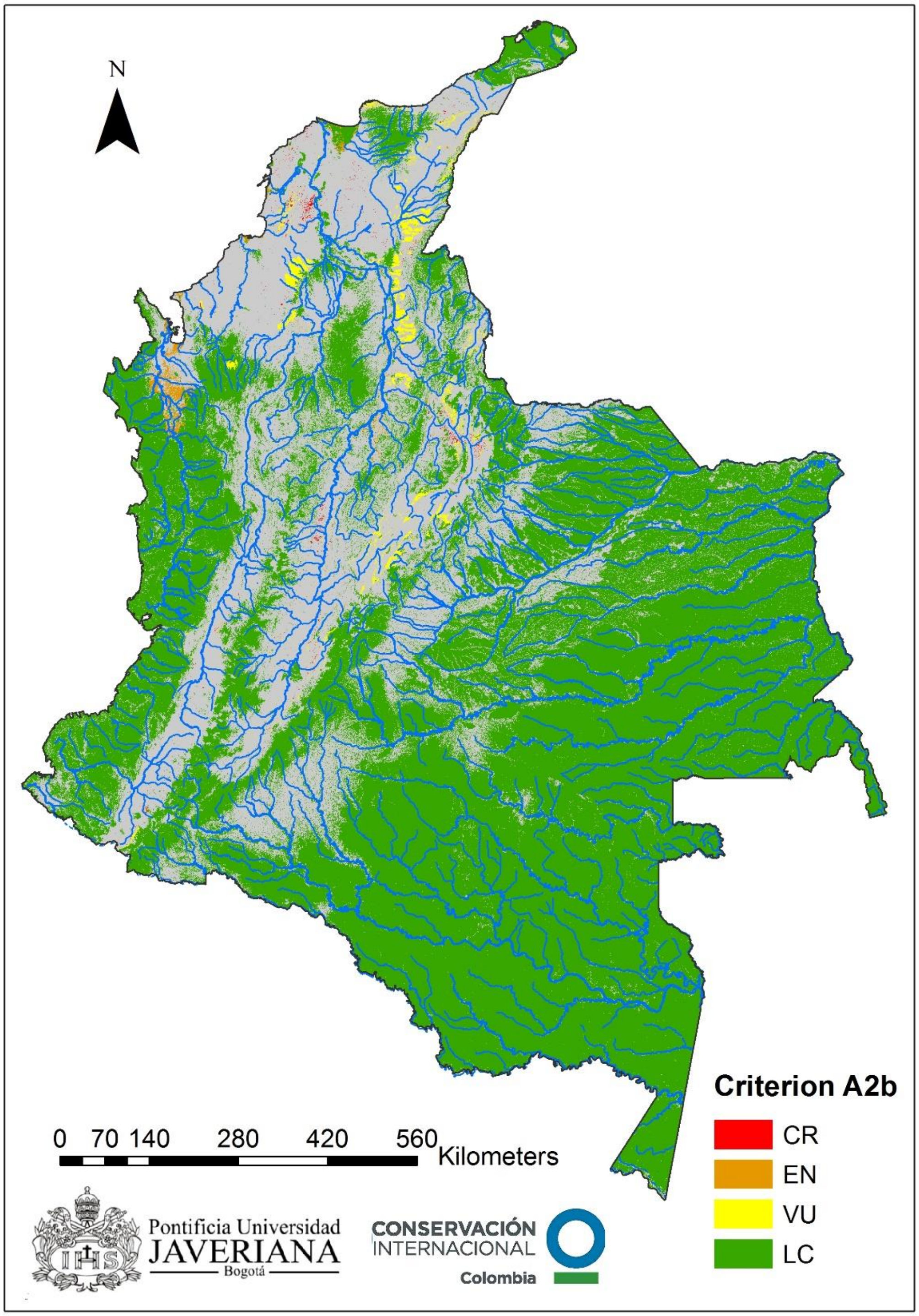

Figure 15 Risk assessment with sub-criterion ***A2b***: Future (in a 50-year period including the present and the future: 1990-2040).

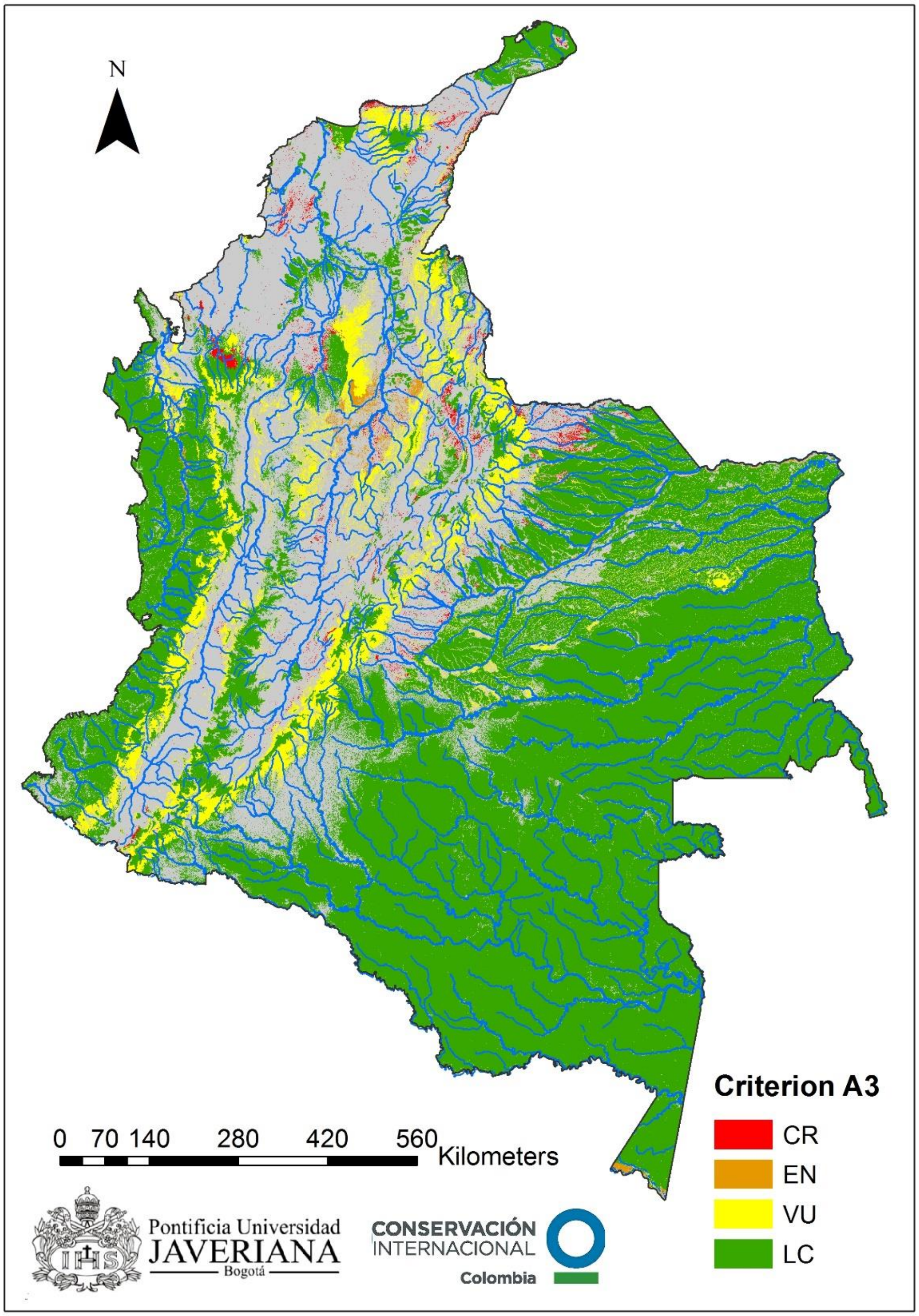

Figure 16 Risk assessment with sub-criterion ***A3***: Historical (since 1750).

Assessment of Criterion B

Criterion B (reduction in geographical distribution) was analyzed through sub-criteria B1ai (Figure 17), B1aii (Figure 18), B1aiii (Figure 19), B2ai (Figure 20), B2aii (Figure 21) and B2aiii (Figure 22). Among these, the one that contributed the highest risk ratings was B1aiii, which was assessed through changes in the minimum surrounding polygon and the change in fragmentation as an informing factor on the disruption of biotic processes such as species mobility. Most of the ecosystems with a greater risk for this concept are located in the Caribbean (3 EN) and Andean (2 EN) regions.

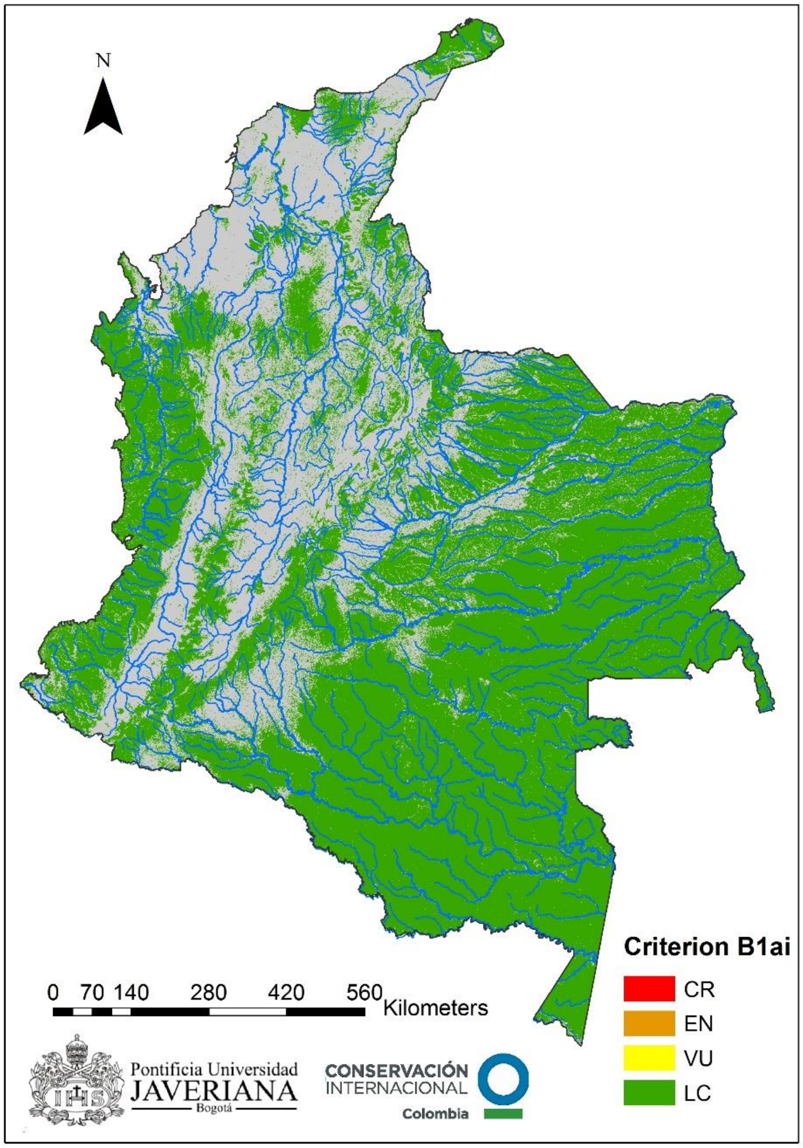

Figure 17 Risk assessment with sub-criterion ***B1ai***: changes in the extension of occurrence (minimum surrounding polygon of all occurrences) and a measure of the appropriate spatial extent for the ecosystem.

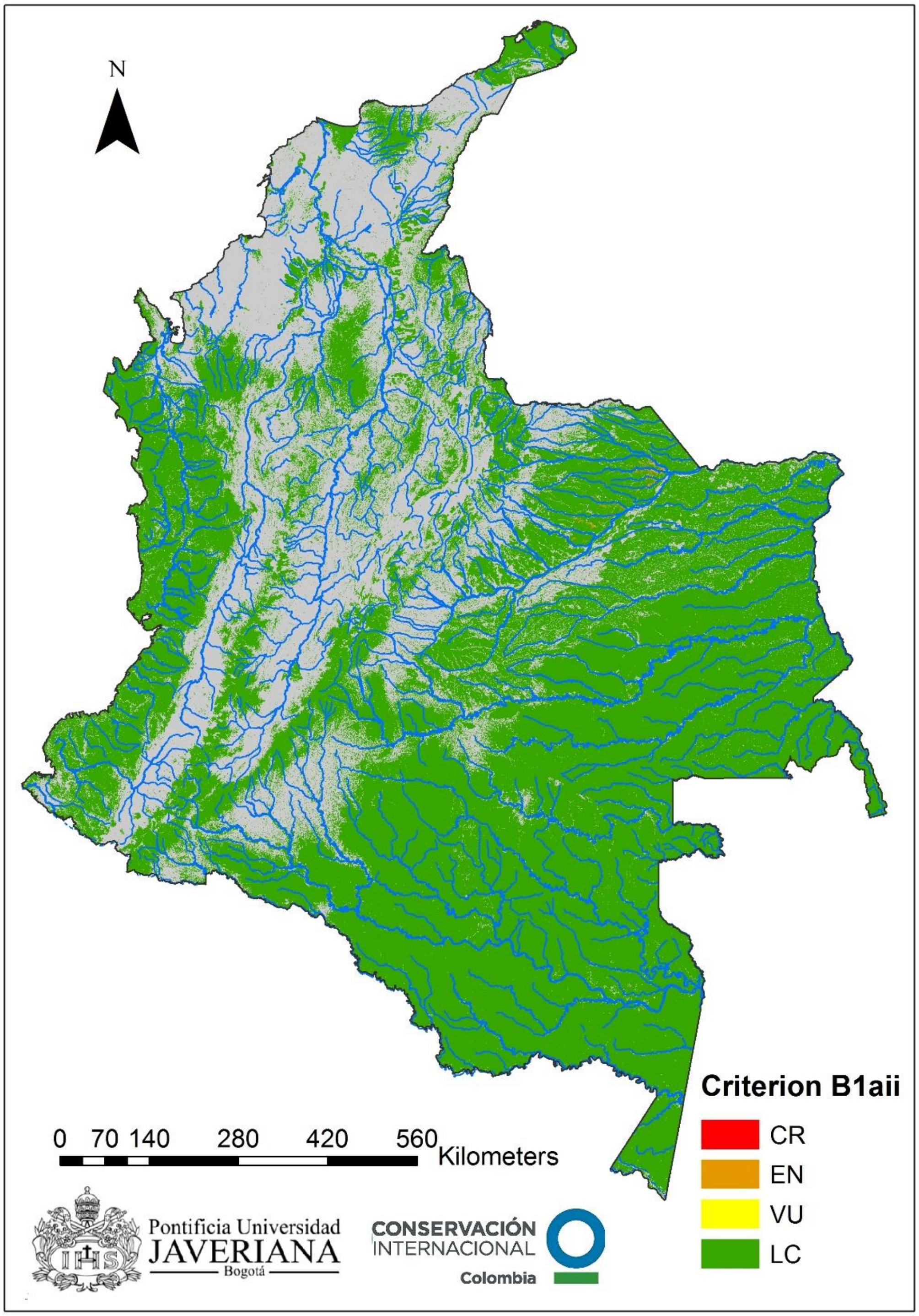

Figure 18 Risk assessment with sub criterion ***B1aii***: changes in the extension of occurrence (minimum surrounding polygon of all occurrences) and a measure of the environmental quality appropriate for the ecosystem's biota through spatial footprint (Etter et al. 2011a).

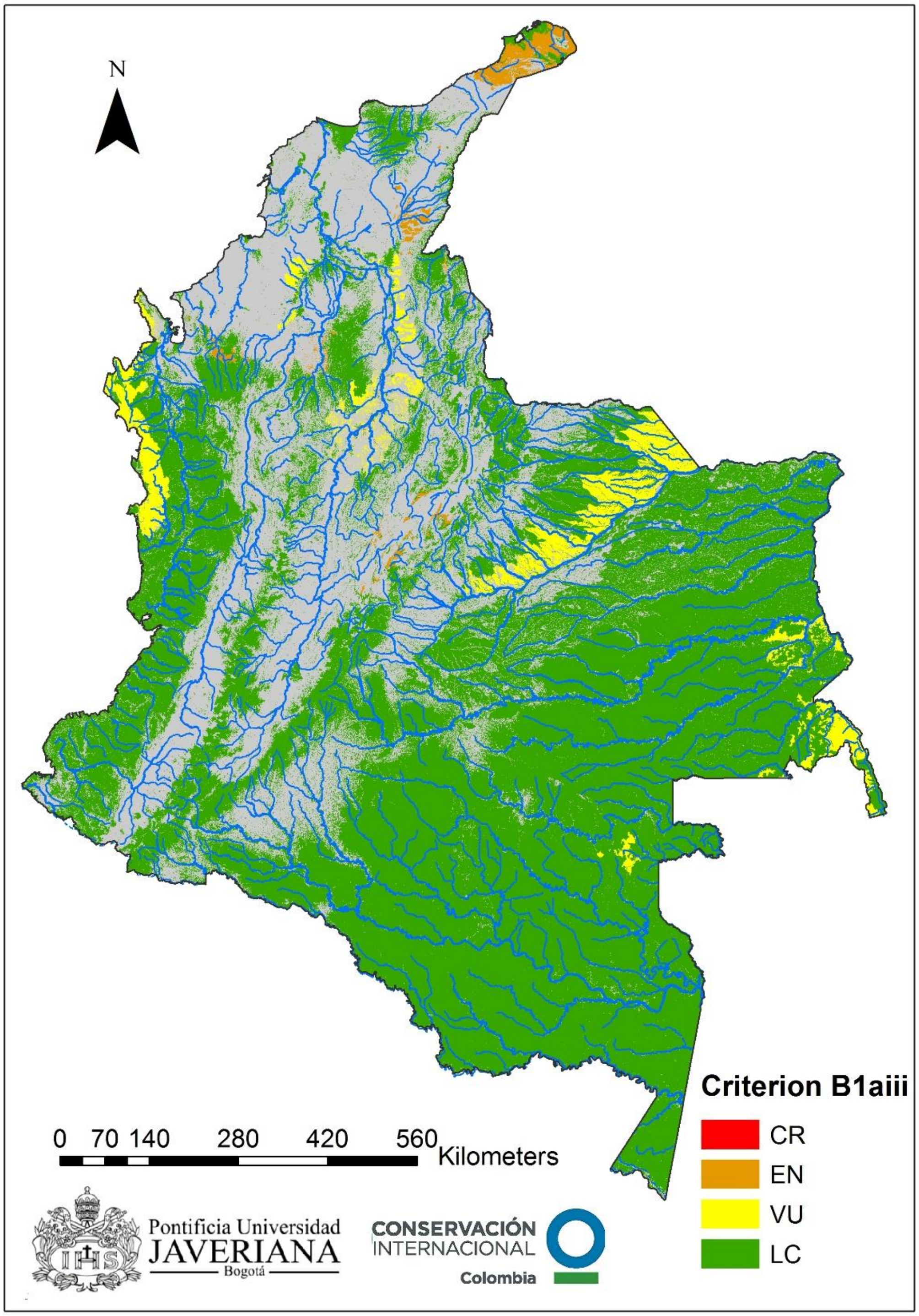

Figure 19 Risk assessment with sub criterion ***B1aiii***: changes in the extension of occurrence (minimum surrounding polygon of all occurrences) and a measure of the disruption of biotic processes (ecosystem's fragmentation level).

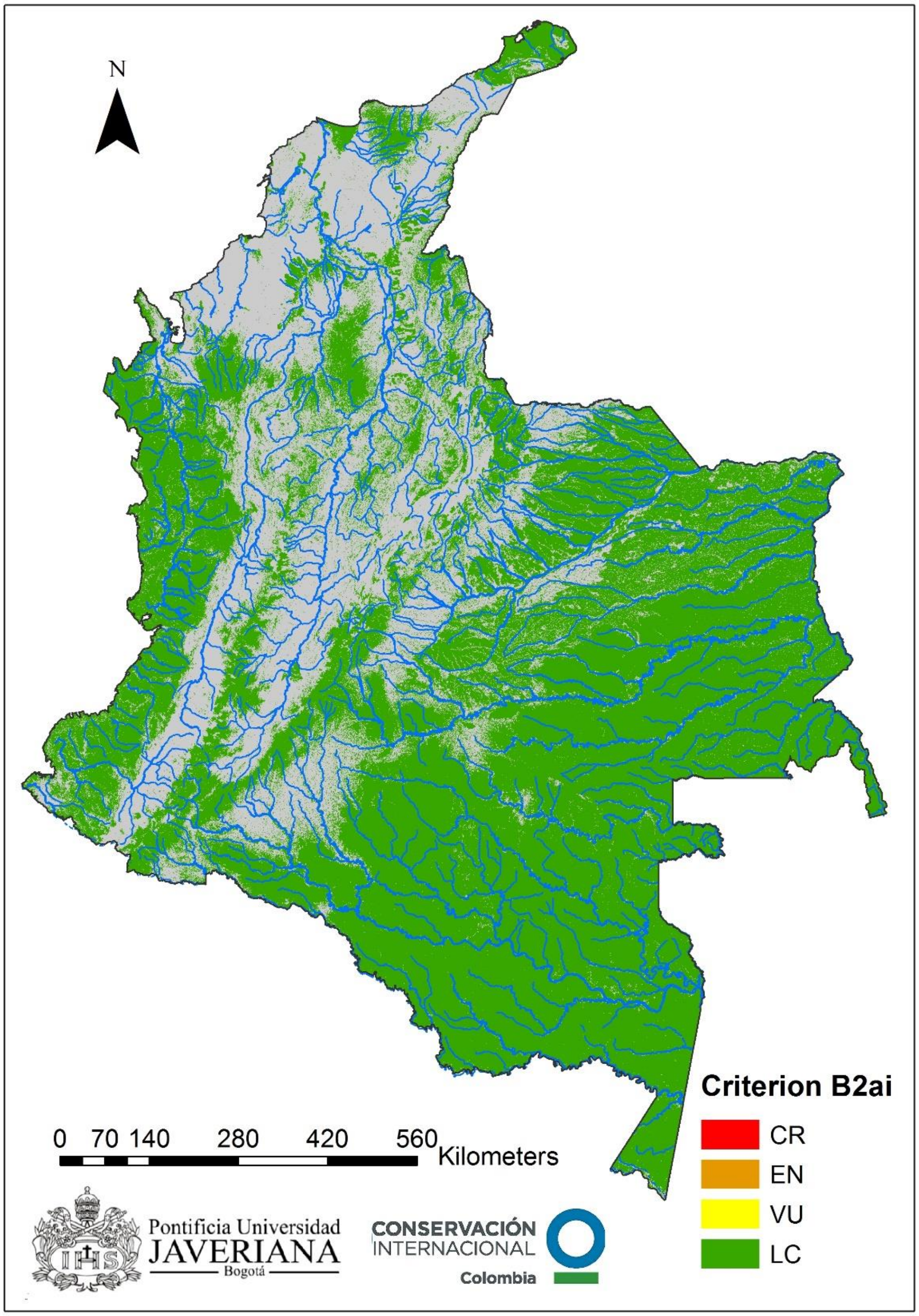

Figure 20 Risk assessment with sub-criterion ***B2ai***: changes in the extension of occurrence (number of 10x10 km cells that occupy all the occurrences) and a measure of the appropriate spatial extent for the ecosystem.

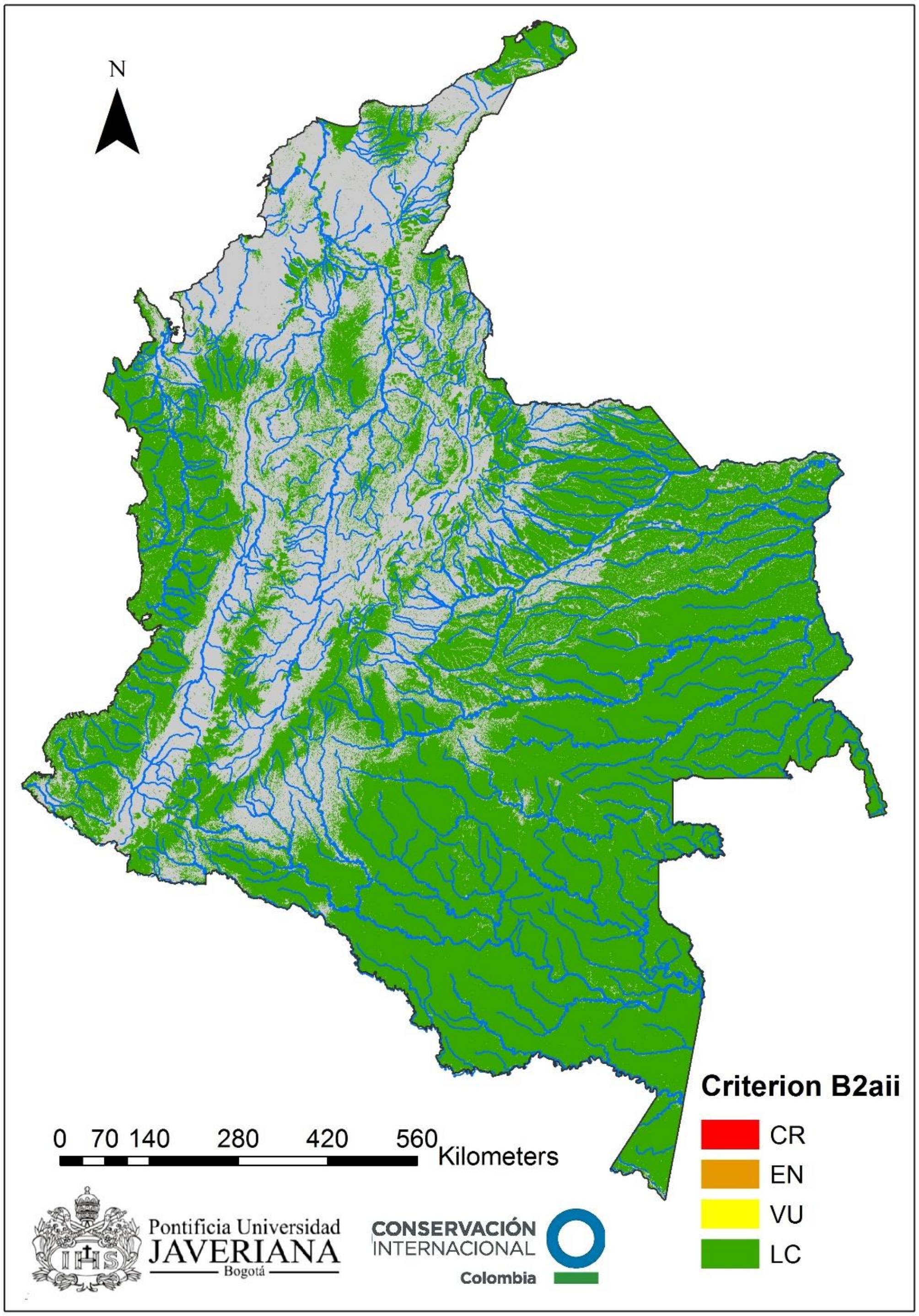

Figure 21 Risk assessment with sub-criterion ***B2aii*** (changes in the extension of occurrence (number of 10x10 km cells that occupy all occurrences) and a measure of the environmental quality appropriate for the ecosystem's biota through spatial footprint (Etter et al. 2011a).

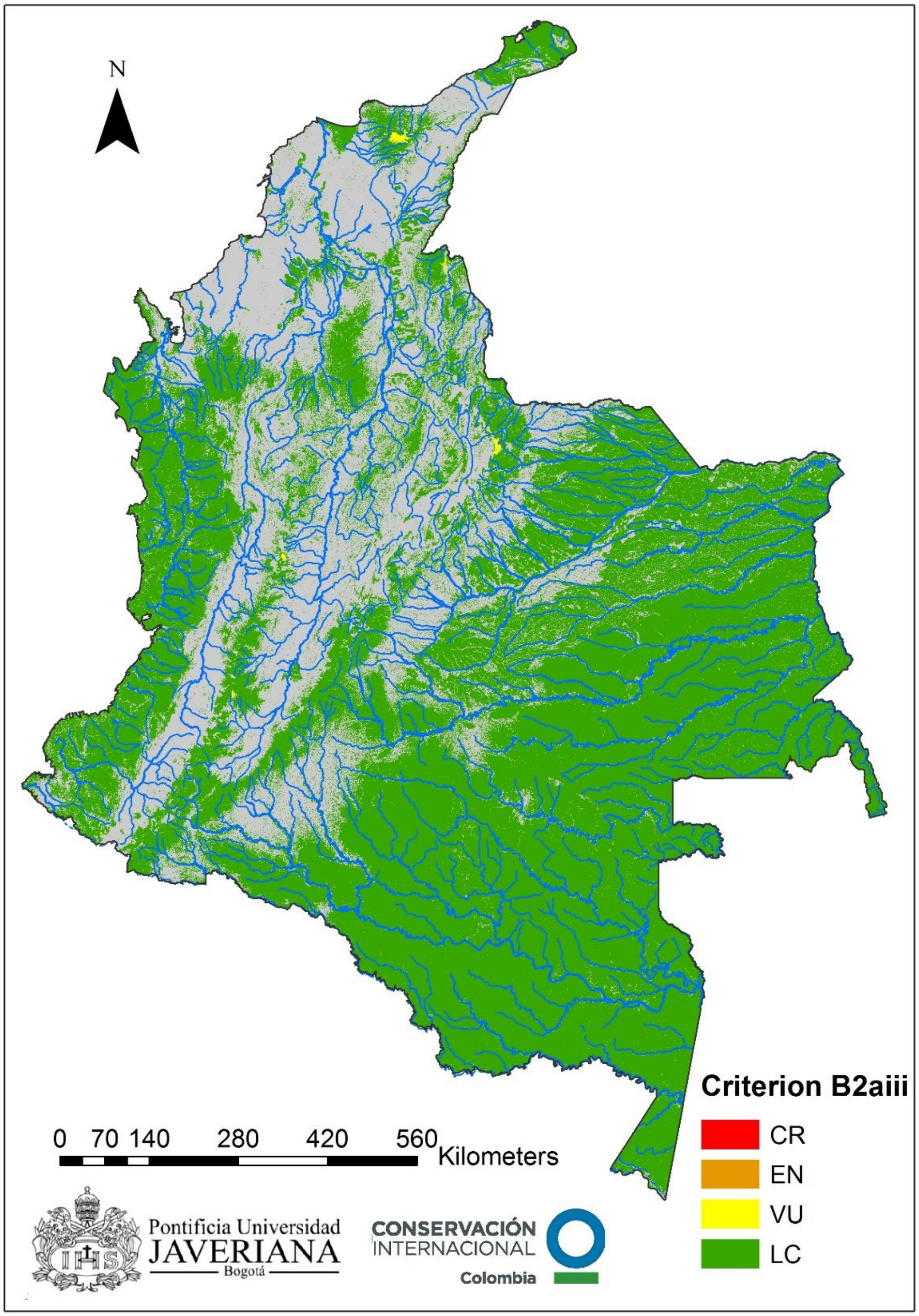

Figure 22 Assessment map of criterion ***B2aiii***: changes in the extension of occurrence (number of 10x10 km cells that occupy all the occurrences) and a measure of the disruption of biotic processes (ecosystem's fragmentation level).

Assessment of Criterion C

Criterion C was analyzed for sub-criterion C2 (Figure 23), analyzing the changes in the availability of precipitated water due to the effect of climate change. The ecosystems categorized with CR and EN risk are in localized areas of arid and very seasonal ecosystems of the Caribbean and the Orinoquia regions.

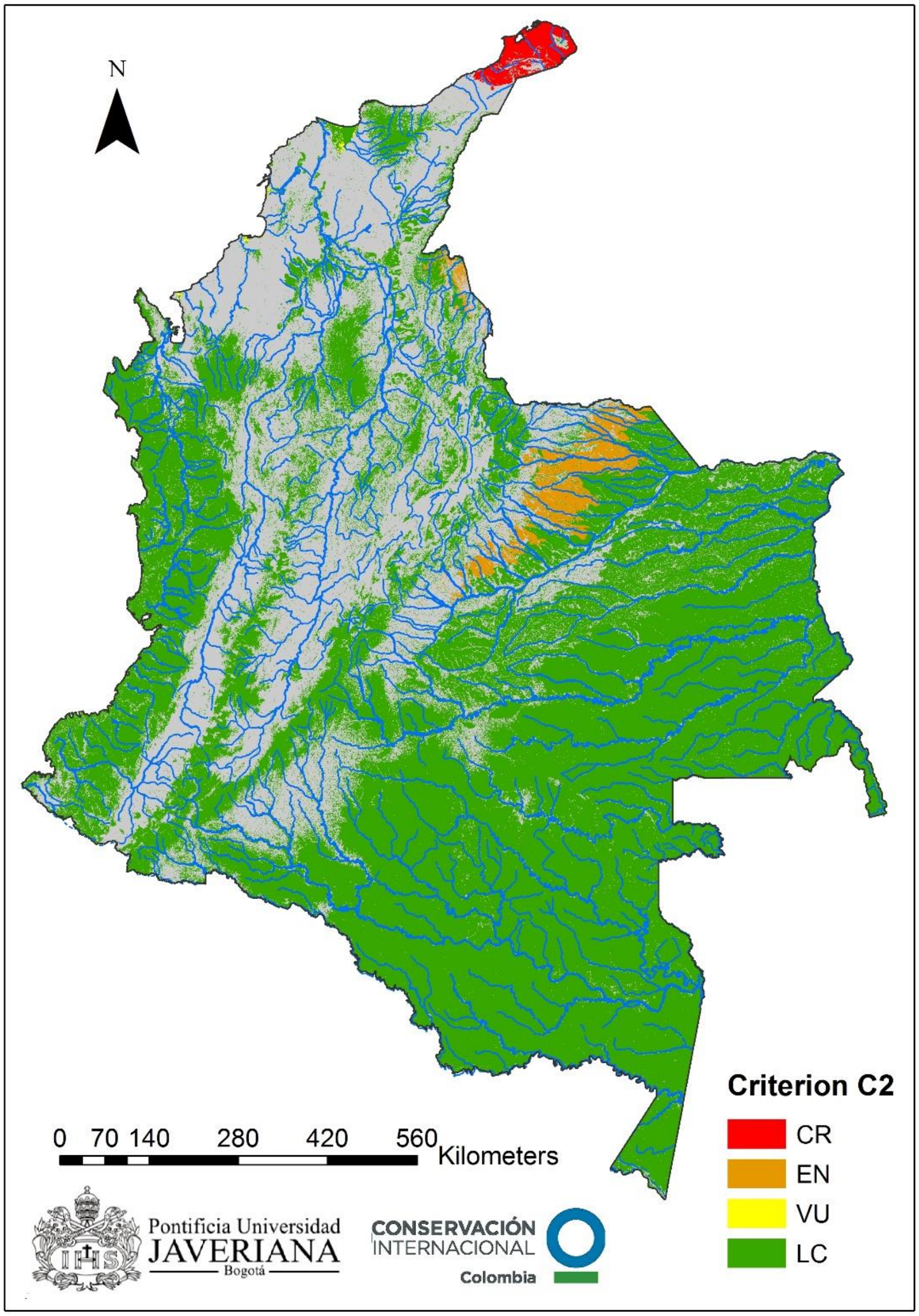

Figure 23 Assessment map of criterion ***C2***: Environmental degradation due to loss of Water Availability during the next 50 years.

Assessment of Criterion D

Criterion D was analyzed for the three sub-criteria D1 (Figure 24), D2 (Figure 25) and D3 (Figure 26), quantifying the risk posed by changes in displacement and loss of seed dispersal and pollination processes, due to transformation of ecosystems and to the effects of climate change. Generally, the risk level associated with sub-criteria D1 and D3 reinforce the results of criteria A because both take into account changes in the extent of the ecosystems. They are mostly located in the Caribbean and Andean regions. Regarding criterion D2 that assesses the changes due to spatial displacement of the processes in a scenario of climate change, the most affected ecosystems are in the eastern Amazon, in the area of the Guiana Shield.

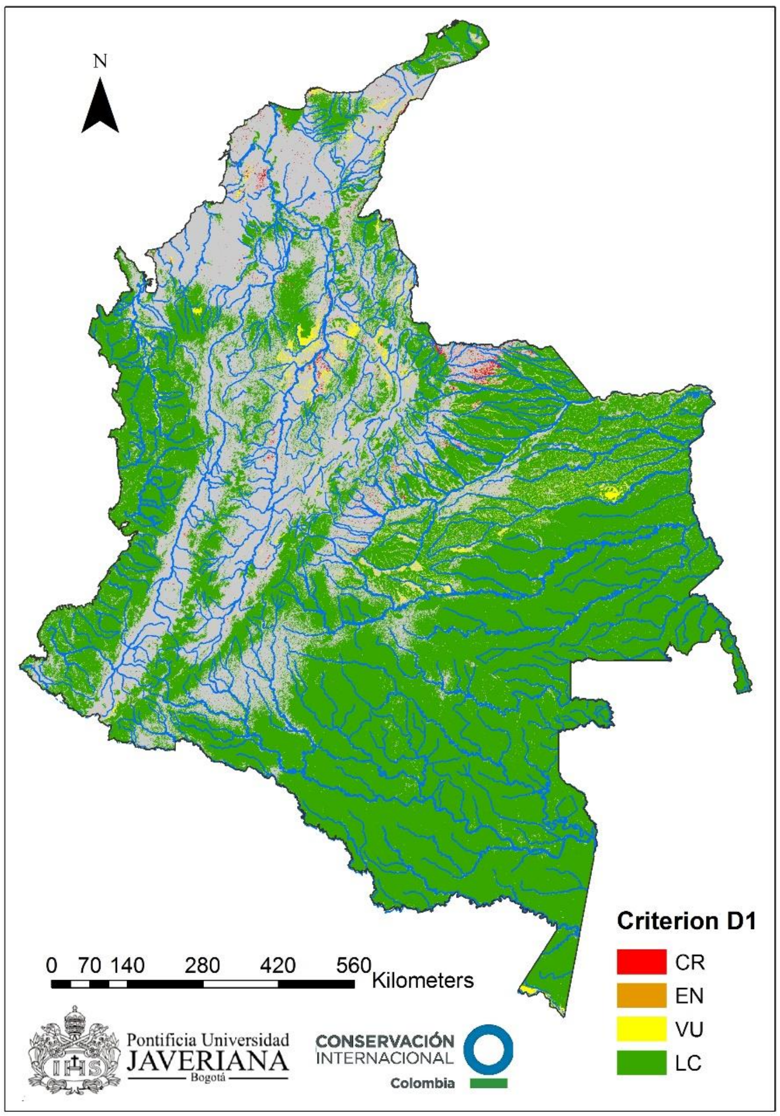

Figure 24 Assessment map of criterion ***D1***: Disruption of biotic processes due to loss of dispersal and pollination processes of the past 50 years (1970-2014).

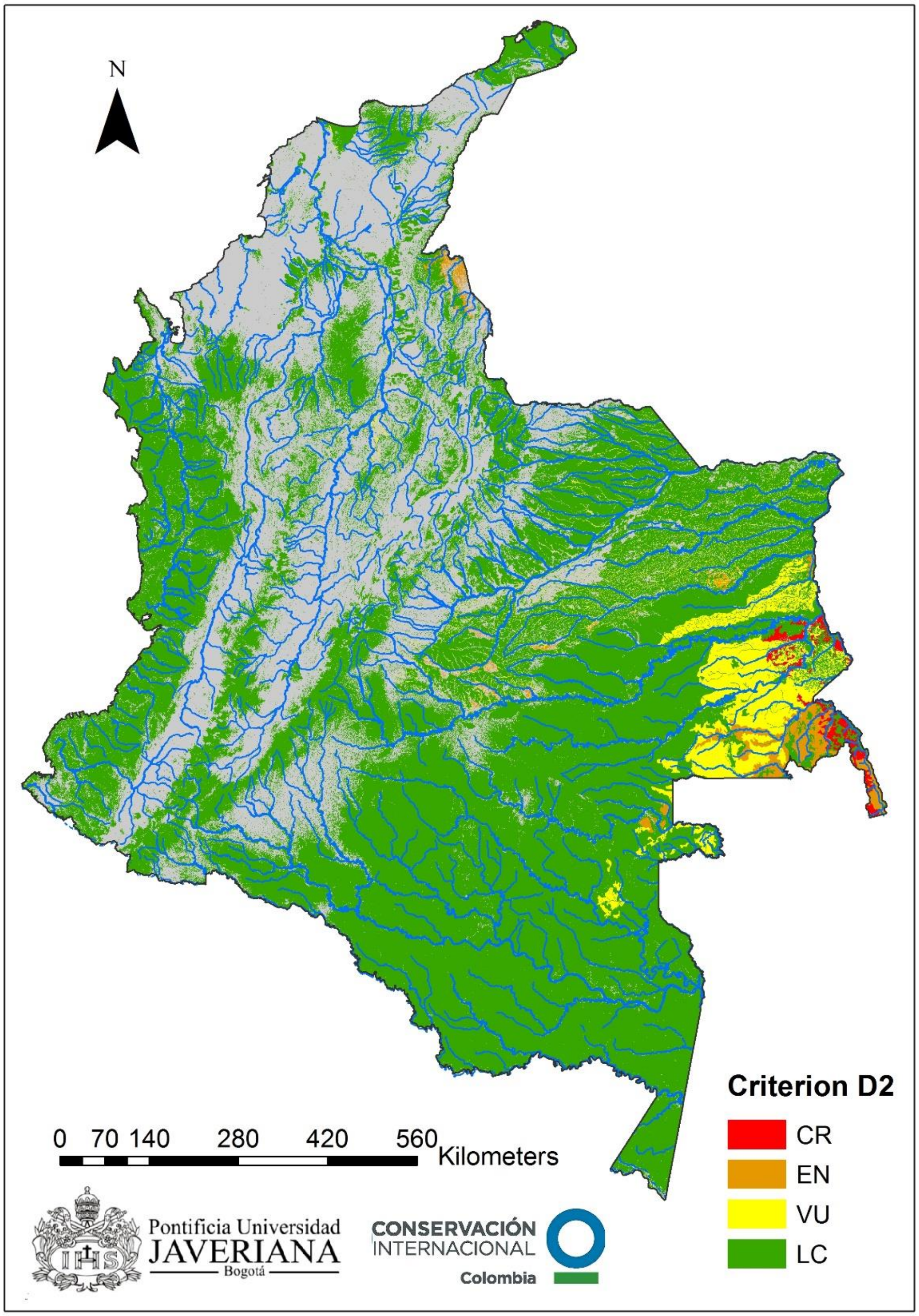

Figure 25 Assessment map of criterion ***D2***: Disruption of biotic processes due to loss of dispersal and pollination processes during the next 50 years (2014-2050).

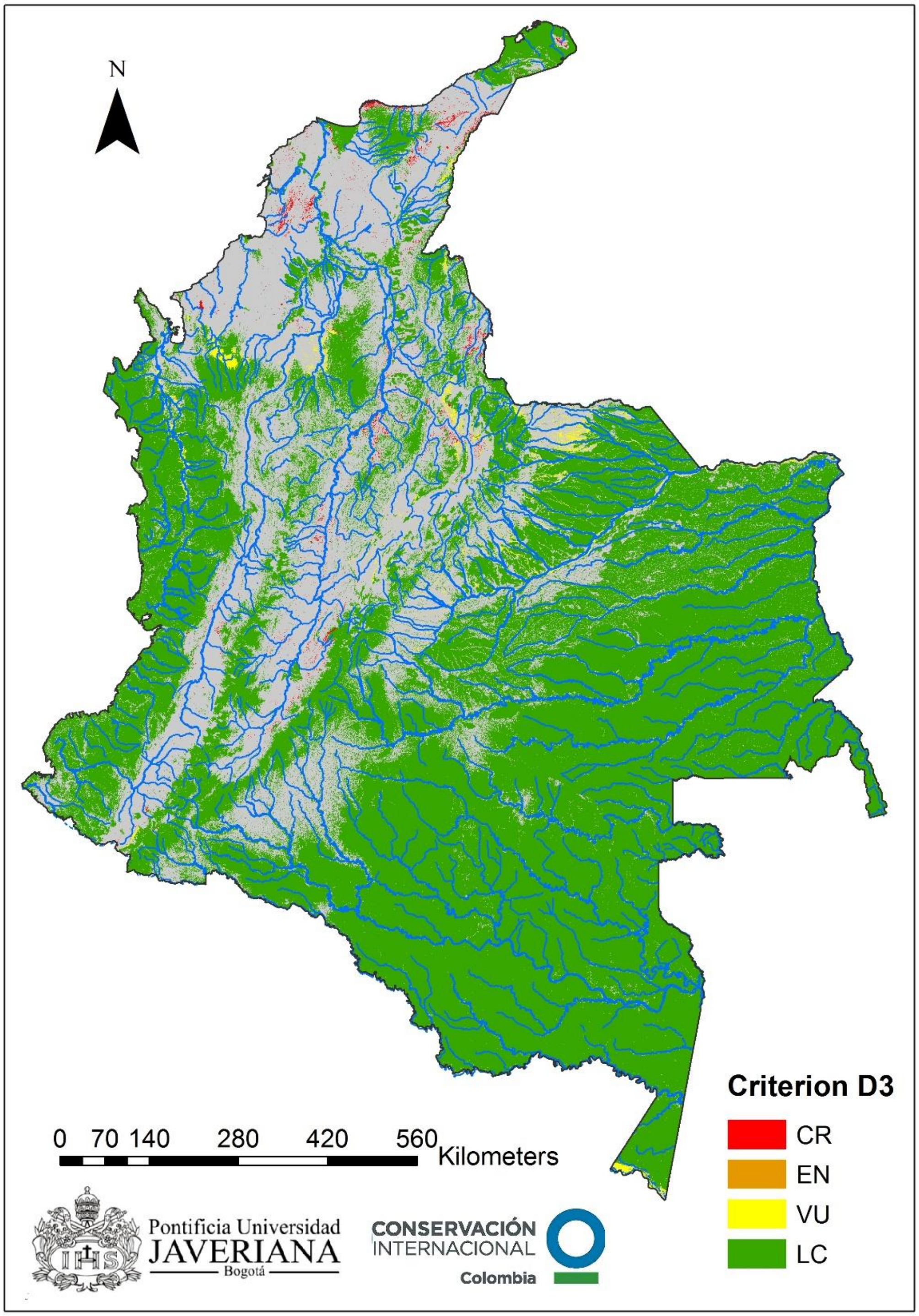

Figure 26 Assessment map of criterion ***D3***: Historical disruption (since 1750) of biotic processes due to loss of dispersal and pollination processes.

Final General Assessment

The final assessment shows a distribution of critical ecosystems in all regions of the country, but mainly in the Caribbean and the Andes regions (Figure 27, Table 12). Almost all the ecosystems in these two regions are at least classified in the VU category.

The total remaining area of the CR ecosystems is 1,906,773 hectares, which represents only 13% of their potential area (15,038,810 ha). Most of the ecosystems in the CR status owe their condition to their physical disappearance from the replacement by anthropogenic land covers, meaning the reduction in the geographical extension - and distribution; this is reinforced by the loss of ecological processes (seed dispersal and pollination) due to the same transformation process (Table 12).

The risk level in Guajira, the Plains piedmont and Guainía, where three ecosystems owe their CR condition to the threats of loss of abiotic (C) and biotic (D) processes, as a consequence of climate change ZD-A1, ZD-A1 and ZBH-B4b is striking.

Table 12. Ecosystems categorized as critical (CR).

Ecosystem	Code		Qualification criteria	% remaining
Tropical Desert Shrublands	***ZD-***	**A1**	C2	99%
	ZD-	**A3**	C2	99%
Dry Andean shrublands and forests	***O_ZBH-***	**A5**	A2b, A3, D2	7%
	O_ZBH-	**A6**	A1, A3, D1, D3	2%
Tropical dry forests	***ZBS-***	**B10**	A1, A3, D1, D3	1%
	ZBS-	**B11**	A1, A2b, A3, D1, D3	2%
	ZBS-	**B12**	A3, D3	9%
	ZBS-	**B13**	A1, A3, D1, D3	1%
Tropical rain forests	***ZBH-***	**B1b**	A1, A3, D1	15%
	ZBH-	**B1c**	A1, A3, D1, D3	7%
	ZBH-	**B4b**	D2	96%
Sub-humid Andean tropical forests	***O_ZBH-***	**B22**	A1, A3, D1, D3	0%
	O_ZBH-	**B21c**	A3	14%
Sub-humid high-Andean tropical forests	***ZBsH***	**B8**	A3	17%
	ZBsH	**B9**	A3	16%
Andean tropical dry low forests	***O_ZBH-***	**B23**	A3, D1, D3	7%
Floodplain forests wetlands	***He_ZBS-***	**B33**	A1, A3, D1, D3	9%
	He_ZD-	**B34**	A1, A3, D1, D3	6%
Mountain humid forest wetlands	***O_ZBH-***	**P1**	A1, A3, D1, D3	3%
Dry forest wetlands	***He_ZBS-***	**P3**	A1, A3, D1, D3	5%
	He_ZBS-	**P4**	A1, A3, D1, D3	5%
Tropical humid herb and shrub savannas	***P_ZBH-***	**S4**	A3	14%

Among the ecosystems in the CR status, one is almost in collapse: the Sub-humid mountain forests of the highlands (O_ZBH-B22), of which only a few hectares subsisting near Bogotá (van der Hammen 1998).

Threats to ecosystems

To understand the processes and impacts of transformation, the identification of specific threats is needed, as shown in Table 13. It can be seen that in general, soil degradation due to erosion, inadequate cattle grazing land uses, increase in fire risks, and the expansion of infrastructure projects constitute the major threats affecting all ecosystems that are in a CR status, although in different degrees.

Soil erosion by degradation is a process faced by nearly 100% of EN ecosystems, while inadequate land use threatens 90% of these ecosystems. Likewise, soil degradation by erosion gives a degree of threat to 82% of the ecosystems in the VU status. This information allows identifying the important threats for each ecosystem, based on which the variables that can contribute to ecosystem collapse can be defined.

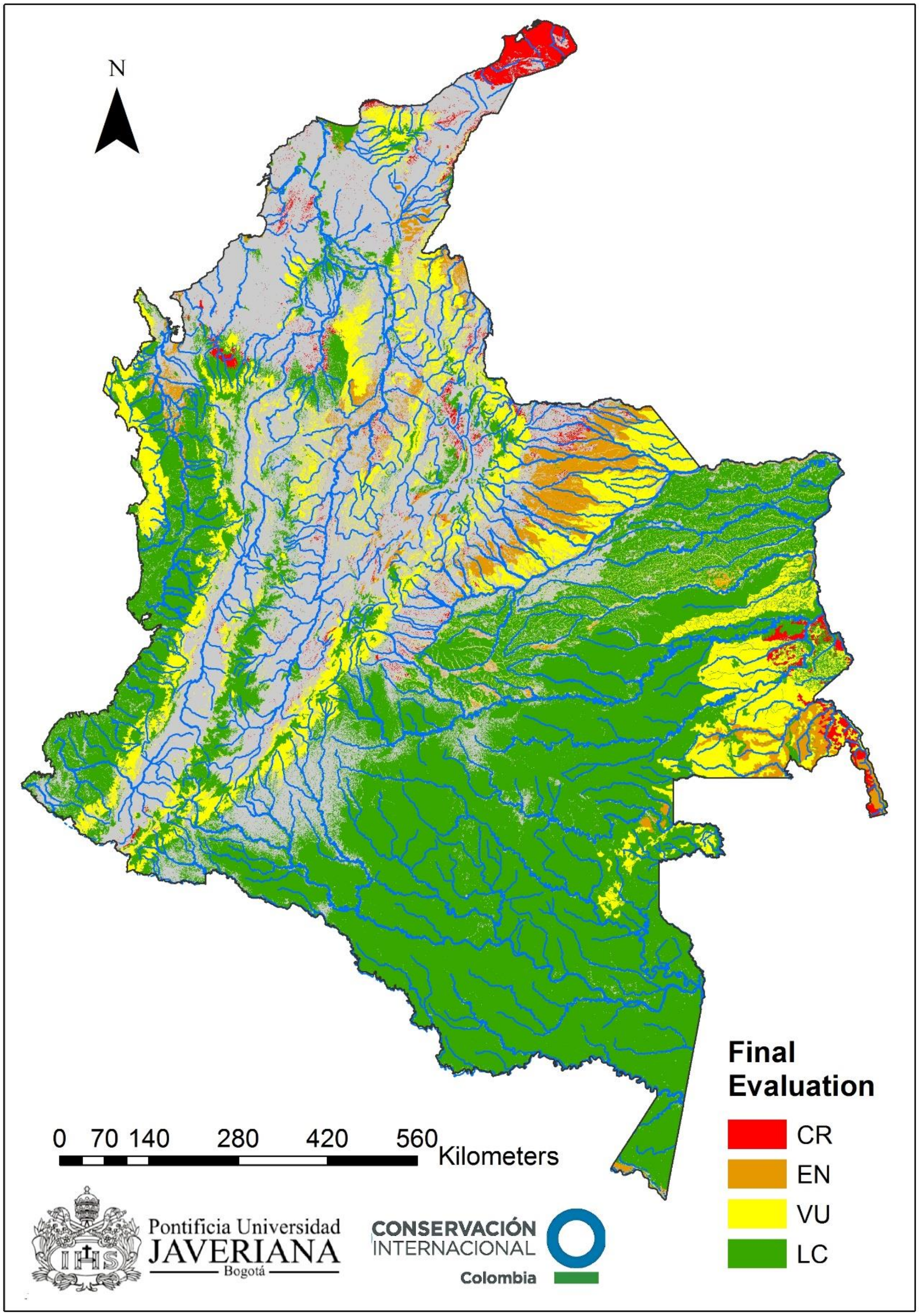

Figure 27. Final risk assessment of Colombian ecosystems.

Table 13. Threatening processes for each ecosystem in both, their potential extent, and their current remnant areas.

CODE	THREATENING PROCESSES																		FINAL EV
	Original areas									Remaining areas									
	ENERGY	HYDROCARBON	INFRA_ ESTRUCTURE	MINING	ILLICIT CROPS	LAND USE	FIRE RISK	MASS REMOVAL	SOIL DEGRADATION BY EROSION	ENERGY	HYDROCARBON	INFRA_ ESTRUCTURE	MINING	ILLICIT CROPS	LAND USE	FIRE RISK	MASS REMOVAL	SOIL DEGRADATION BY EROSION	
ZBH-B1a					Low	Low			Low										LC
ZBH-B1b		High	Moderate			Moderate	Low	Low	High		High	Low			Moderate	Low	Low	Moderate	CR
ZBH-B1c	Low	Very high	Very high	Low		High	Moderate	Low	High	Low	Very high	High	Low		Very high	Moderate	Low	Moderate	CR
ZBH-B1d		Very high	High		Low	Very high	Moderate	Moderate	Moderate		High	Low		Moderate	High	Low	Moderate	Low	EN
ZBH-B2a1		Low	Low		Low	Low	Low		Low					Low	Low			Low	LC
ZBH-B2a2																			LC
ZBH-B2b	Low	Very high	High	Low		Moderate	Low	Low	Moderate	Low	High	Low	Moderate		Moderate	Low	Low	Low	EN
ZBH-B2c			Low	Very high	Low	Moderate	Low	Moderate	Low				Very high	Low	Moderate		Moderate	Low	LC
ZBH-B2d		Very high	Moderate	Low	High	Moderate	Low	Moderate	Moderate		High	Low	Low	Moderate	Low	Low	Moderate	Low	EN
ZBH-B3a1					Low	Low			Low										LC
ZBH-B3a2																			LC
ZBH-B3b			Low	Very high	Low	Low	Low	Moderate	Low				Very high	Low	Low		Moderate	Low	LC
ZBH-B4a																			LC
ZBH-B4b						Low									Low				CR
ZBH-B4c									Low									Low	EN
ZBH-B4d																		Low	LC
ZBH-B5		Low	Low		Low	Low	Low		Moderate		Low	Low		Low	Low	Low		Low	EN
ZBH-B6									Low									Low	LC
ZBH-B7				Low		Low		Moderate	Low				Low		Low		Moderate		VU
ZBsH-B8	Low		Moderate	Very high	Low	Moderate	Moderate	Low	High			Low	Moderate	Moderate	Low	High	Low	Low	CR
ZBsH-B9	Low	Low	Moderate	Very high	Low	Moderate	Moderate	Low	High			Low	High	Moderate	Moderate	Moderate	Low	Moderate	CR
ZBS-B10	Low	High	Very high	Low		High	High	Low	Very high	Low	High	High	Low		High	High	Low	High	CR
ZBS-B11	Low	High	High	Low		High	High	Low	Very high	Low	High	Moderate	Low		High	High	Low	High	CR
ZBS-B12	Low	Moderate	Moderate	Low		High	High	Moderate	High		Moderate	Low	Low		High	High	Low	Moderate	CR
ZBS-B13		Low	High	Low		Low	Very high	Low	Very high		Low	Moderate	Low		Low	Very high	Moderate	Very high	CR
ZD-A1			Moderate				High	Low	Very high			Moderate				High	Low	Very high	CR
ZD-A2	Low	Very high	High			Very high	Moderate	Moderate	High		Very high	Moderate			Very high	Moderate	Moderate	Very high	LC
ZD-A3			Moderate				Moderate	Low	High			Moderate				Moderate	Low	Very high	CR
P_ZBH-B14									Low									Low	VU
P_ZBH-B15									Low									Low	VU
P_ZBH-S1						Low	Low								Low	Low			LC
P_ZBH-A4									Low									Moderate	LC
P_ZBH-S2						Low	Low								Low	Low		Low	LC
P_ZBH-S3		Very high	Very high			High	Moderate	Low	Very high		Very high	Moderate			High	Low	Low	High	EN
P_ZBH-S4		Low	High			High	Low	Low	High		High	Moderate			High	Moderate	Low	Moderate	CR

(cont.)

CODE	THREATENING PROCESSES																		FINAL EV
	Original areas									Remaining areas									
	ENERGY	HYDROCARBON	INFRA_ ESTRUCTURE	MINING	ILLICIT CROPS	LAND USE	FIRE RISK	MASS REMOVAL	SOIL DEGRADATION BY EROSION	ENERGY	HYDROCARBON	INFRA_ ESTRUCTURE	MINING	ILLICIT CROPS	LAND USE	FIRE RISK	MASS REMOVAL	SOIL DEGRADATION BY EROSION	
P_ZBH-S5		Moderate	Low			Low	High		High		Low	Low			Low	High		Moderate	LC
P_ZBH-S6		Low	Low			Low	Moderate		High		Moderate	Low			Low	Moderate		High	LC
P_ZBH-S7			Low			Low	High		Moderate			Low			Low	High		Moderate	LC
P_ZBH-S8		Low	Low			Low	High				Moderate	Low			Low	High		Low	EN
P_ZBH-S9		High	Low			Low	Moderate		Moderate		High	Low			Low	Moderate		Moderate	EN
P_ZBH-S10		Moderate	Low			Low	High		Moderate		High	Low			Low	High		Low	VU
P_ZBS-S11	Low	Very high	Very high	Low		High	High	Low	Very high		Very high	Very high			High	High	Low	Very high	VU
P_ZBS-S12	Low	Very high	Very high	Very high		Very high	Very high	Low	High	Low	Very high	High	Very high		Very high	High	Low	Very high	EN
O_ZBH-B16					Low	Low	Moderate		Low					Low	Low	Moderate			LC
O_ZBH-B17							Moderate									Moderate			LC
O_ZBH-B18							High	Low								High	Low		LC
O_ZBH-B19a			Low	High	Low	Moderate	Low	Moderate	Low		Low	Low	Very high	Low	Low	Low	Moderate	Low	LC
O_ZBH-B19b	Low	Moderate	Low	Moderate	Low	Moderate	Low	Low	Moderate		Low	Low	Moderate	Low	Moderate	Low	Low	Low	VU
O_ZBH-B20a	Low	Low	Moderate	Low		Moderate	Low	Moderate	Moderate		Low	Low	Moderate	Low	Low	Low	Moderate	Low	VU
O_ZBH-B20b	Low	Low	High	Low	Low	Moderate	Low	Moderate	Moderate		Low	Low	Low	Low	Moderate	Low	Moderate	Low	VU
O_ZBH-B21a		Low	Moderate	Low		Moderate	Low	Moderate	Moderate		Low	Low	Low		Low	Low	Moderate	Low	LC
O_ZBH-B21b		Low	Moderate	Low		Moderate	Low	Moderate	Moderate		Low	Low	Low		Moderate	Low	Moderate	Low	VU
O_ZBH-B21c	Low	Low	Very high	Low		High	Moderate	Low	High	Low	Low	Moderate	Low		Moderate	Low	Low	Moderate	CR
O_ZBH-B21d		Low	Moderate	Low		Moderate	Low	Moderate	Low		Low	Low	Low		Moderate	Low	High	Low	LC
O_ZBH-B22	Low	Moderate	Very high	Low		High	Moderate	Low	Very high	Low	Low	Very high	Low		High	Moderate	Low	High	CR
O_ZBH-S13			Low	Low		Low	Low	Moderate	Low			Low	Low		Low	Low	Moderate		LC
O_ZBH-S14		Low	Low	Low		Low	Low	Moderate	Low		Low	Low			Low	Low	Moderate	Low	LC
O_ZBH-S15	Low	Low	Moderate	Low		Moderate	Low	Moderate	Low		Low	Low	Low		Moderate	Low	Low	Low	EN
O_ZBH-N							Low	Moderate								Low	Moderate	Low	VU
Oz_ZBH-B23	Moderate	Low	Very high	Low		Moderate	Moderate	Moderate	Very high	Low	Low	High	Low		High	Moderate	Moderate	High	CR
Oz_ZBH-A5	Low		Very high	Low		Moderate	Moderate	Moderate	Very high	Low		High	Low		High	Moderate	Moderate	High	CR
Oz_ZBH-A6	Low	Low	Very high	Low		Moderate	Moderate	Low	Moderate	Low	Low	High	Moderate		High	Moderate	Low	Very high	CR
Oz_ZBH-S16	Moderate		Very high			Moderate	High	Moderate	High	Moderate		Moderate			High	High	Moderate	Very high	LC
O_ZBH-P1	Low	Low	Very high	Low		Moderate	Moderate	Low	Very high			Low			Low	Low	Moderate	High	CR
He_ZBH-B24		Moderate	Moderate	Low		Moderate	Low		Moderate		Moderate	Low	Low		Moderate	Low		Low	EN
He_ZBH-B25			Low			Moderate	Low		Low						Moderate		Low	Low	EN
He_ZBH-B26		Low	Low		Low	Low	Low		Low		Low			Low	Low				LC
He_ZBH-B27			Low	Very high	Low	Moderate		Low	Low				Very high	Low	Moderate		Low	Low	LC
He_ZBH-B28					Low	Low			Low					Low	Low				LC
He_ZBH-B29		Low	Low			Moderate	Low		Low		Low				Moderate	Low		Low	VU
He_ZBH-B30									Low										LC
He_ZBH-B31		Low	Low			Low	Moderate		Low		Moderate	Low			Low	Moderate		Low	VU
He_ZBH-B32				Low	Moderate	Low		Low	Low				Low	Moderate	Low		Low	Low	LC
He_ZBH-P2						Low									Low				EN
He_ZD-B33		Low	High	Low		Low	Very high	Low	High		Moderate	Moderate	Low		Low	Very high	Low	High	CR
He_ZBS-B34	Low	High	High	Low		High	Moderate	Low	Very high	Low	Very high	Moderate	Moderate	Low	Low	Moderate	Low	Low	CR
He_ZBS-P3		Low	Low	Low		Moderate	Moderate		Moderate		High	Low	Moderate		Moderate	Moderate		Moderate	CR
He_ZBS-P4		Moderate	Low	Low		Moderate	Low		Moderate		Very high	Moderate	Low		Moderate	Low	Low	Moderate	CR
Ha_ZBH-B35				Low	Low	Low			Low				Low	Low	Low			Low	LC
Ha_ZBS-B36		Low	Low			Moderate	Moderate		Moderate		Low	Low			Low	Moderate		Moderate	EN
Agua		Low		Low	Low	Low	Low	Low	Low		Low	Low	Low		Low	Low	Low	Low	LC

4. Applications of the Red List Assessment

In this section, we show the use of the RLE risk assessment to evaluate the current conservation status of the remnant ecosystems in terms of their risk category, in relation to the NPAs, KBAs and World heritage sites; and the identification of areas of interest for future restoration activities of the most threatened ecosystems.

We also include an example of the implementation of the RLE in the early alert system in the online *Tremarctos-Colombia_3.0* platform, developed under the leadership of Conservation International Colombia (CI).

4.1. Representation of endangered System of Protected Areas and its representativeness from the Red List of Ecosystems

Protected areas are a major tool used by governments and the civil society to guarantee the conservation of humanity's natural and cultural heritage. In principle, these areas should be designed and coordinated in systems or networks favoring an orderly process of conservation planning (Morales, 2007). The Red List of Ecosystems provides an input to understand the conservation status of the most at risk ecosystems, assessing the degree of representativeness of threatened ecosystems within the protected areas, and/or the biological diversity that has some status of conservation and/or priority. We analyzed the remnant Colombian ecosystems categorized as threatened in: (**1**) the National Parks System, (**2**) the new proposed Areas and Expansions of National Parks, (**3**) Other public and private protected areas, of the National Registry of Protected Areas Platform, (**4**) the Indigenous Reserves and Afro Colombian Communities lands, (**5**) the Key Biodiversity Areas (KBA), and (**6**) the World Heritage Sites (WHS) (Table 14).

Table 14. Proportion area of remnant Colombian ecosystems by risk category within national Parks and other protected areas, the Indigenous Reserves and Lands of the Afro Colombian Communities, the KBAs and the WHS.

	National Natural Parks System (SPNN)	New Proposed Areas and Expansions of National Natural Parks (PNN)	Other public and private protected areas of (RUNAP)	Indigenous Reserves and Lands of the Afro Colombian Communities	Key Biodiversity Areas (KBA)	World Heritage Sites (WHS)
CR	0.04	0.02	0.03	0.57	0.03	0
EN	0.05	0.05	0.03	0.31	0.03	0,001
VU	0.14	0.04	0.05	0.40	0.05	0,001
LC	0.18	0.01	0.01	0.48	0.01	0,001

a. National Natural Parks System

The protected areas that correspond to the National Natural Park System (SPNN) are conformed by 59 National Parks representing 15’962.277 ha. In general, the ecosystems classified as CR and EN have a low level of protection in those areas (Figure 28). Only 4% of the total area of the ecosystems in CR status are being protected, compared to 32% of the total area of VU and LC (Table 14). Although the Andean and the Amazon regions have a good number of protected areas, there are still ecosystems that should be included in future delimitation of key conservation and protection areas in Orinoquia and Caribe. The dry forest of the Caribbean region and the valleys of the Cauca and Magdalena rivers, and the Tropical Humid Forest areas of the plains' piedmont, do not have any level of protection to allow for the preservation of ecological processes and the reduction of threatening processes.

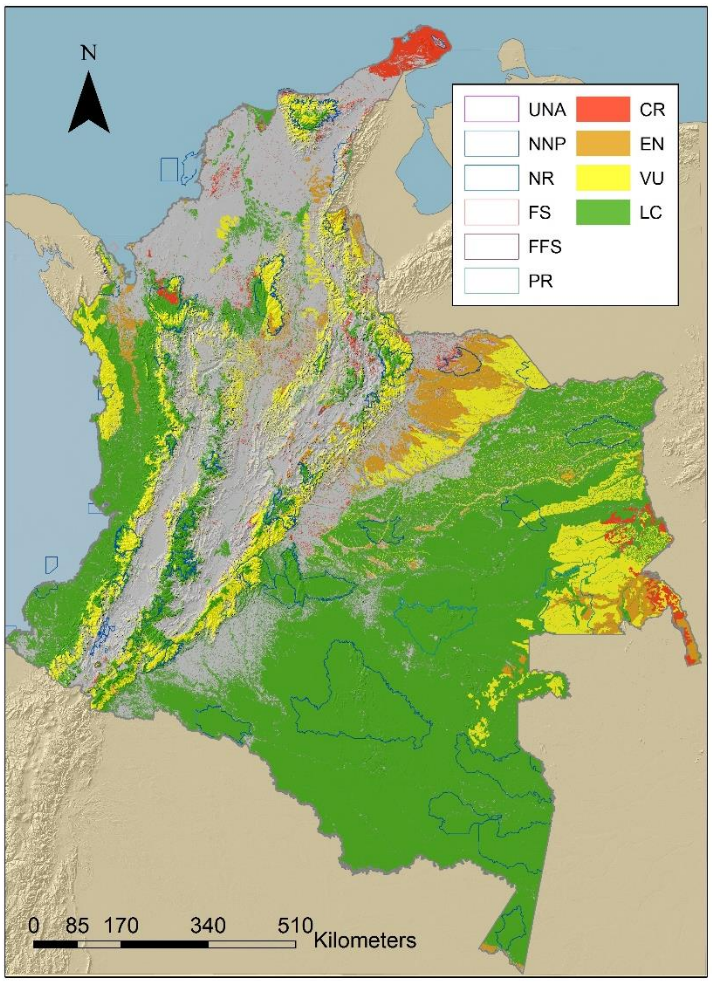

Figure 28. Location of National Natural Park System (SPNN) in relation to the RLE map. (UNA: Unic National Area, NNP: National Natural Park, NR: Natural Reserve, FS: Flora Sanctuary, FFS: Fauna & Flora Sanctuary, PR: Park Road). (*Source: PNN, s.f.*)

b. New Proposed Areas and Expansions of National Natural Parks (NNP)

If the situation of the new proposed declared areas is analyzed in regards to their contribution to the protection of the threatened ecosystems classified by the RLE's risk assessment, it is evident a contribution for 4 CR ecosystems, 4 EN ecosystems and 1 VU ecosystem that are no represented within the current National Natural Park System (Figure 29 and 30).

Of the 1,432,338 hectares covered by the new proposed Protected Areas, 51,168 hectares correspond to CR ecosystems, which help expand their protection level by an additional 2%. For EN ecosystems, the coverage would be expanded by 1,163,919 hectares, increasing their protection level by 5% (Table 14).

CR ecosystems such as the Medium Dense Humid Tropical Forest Orobiome (B21c), the High Dense Forests of the Tropical Humid Zonobiome (B1b) and the High and Medium Dense Forests of the Dry Tropical Heliobiomes (B34), have the largest increase in overage in the new proposed protected areas of the National Natural Parks System.

Areas such as Perijá Mountains, the savannas and wetlands of Arauca and San Lucas Mountain, would provide coverage in the CR and EN ecosystems that are currently not represented in National Parks.

c. Other areas of the Protected Areas National System of RUNAP

In addition to the Natural Parks and Reserves, the National Protected Areas System (RUNAP) includes 923 other protected areas of national, regional and local order, public and private that represent 12'768.273 hectares, made up of: (**1**) Protection/Production Forest Reserves (National and Regional), (**2**) Regional Natural Parks, (**3**) Integrated Management Districts, (**4**) Soil Conservation Districts, (**5**) Recreation Areas and (**6**) Nature Reserves of the Civil Society.

CR and EN ecosystems have a 3% representativeness (Table 14), distributed among the Regional Districts of Integrated Management, Regional Natural Parks and National Protective Forest Reserves (Figure 31). They also include a 5% area of VU ecosystems and 1% of LC ecosystems. Regional protected areas and private protected areas should focus on projects to restore areas of CR and EN ecosystems and to establish projects that favor biodiversity conservation and ecological processes maintenance.

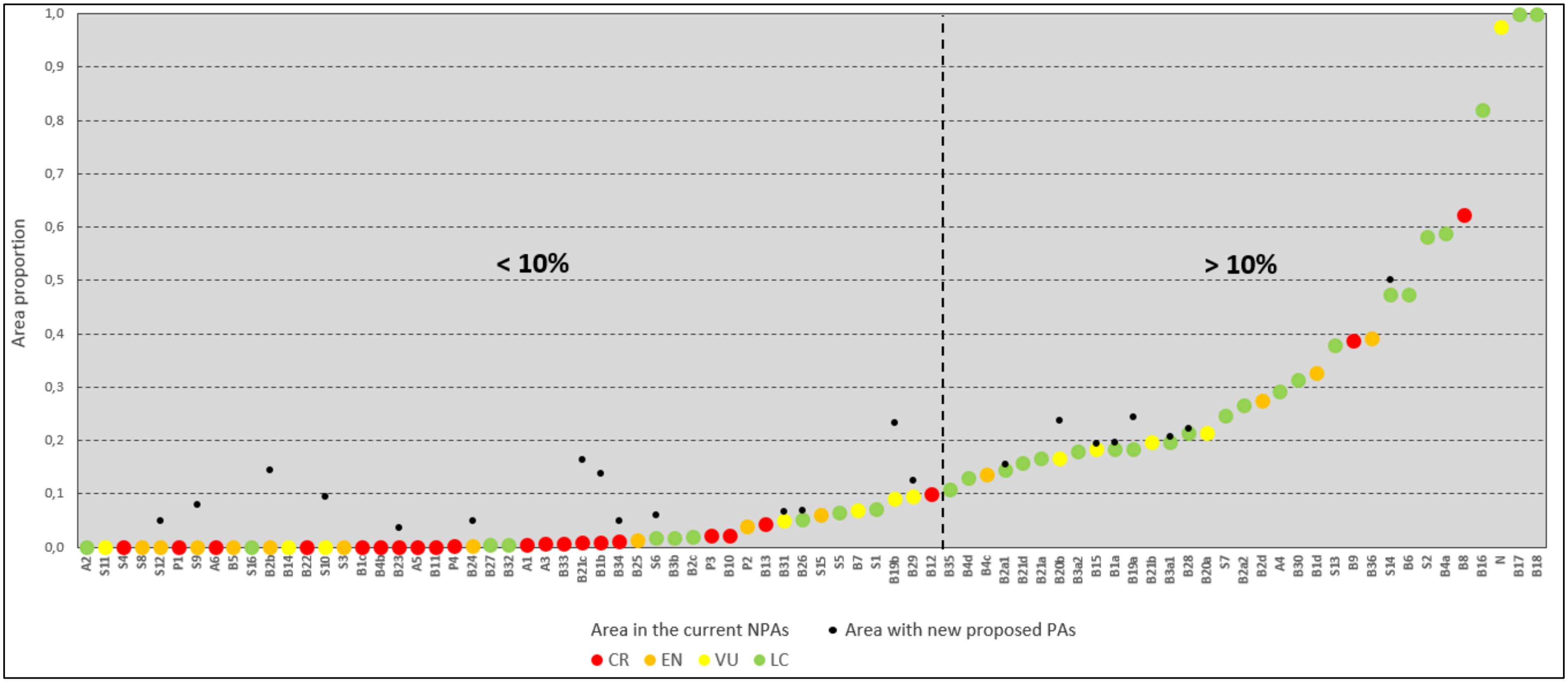

Figure 29. Increase in the protection of Colombian ecosystems based on the new proposed Protected Areas.

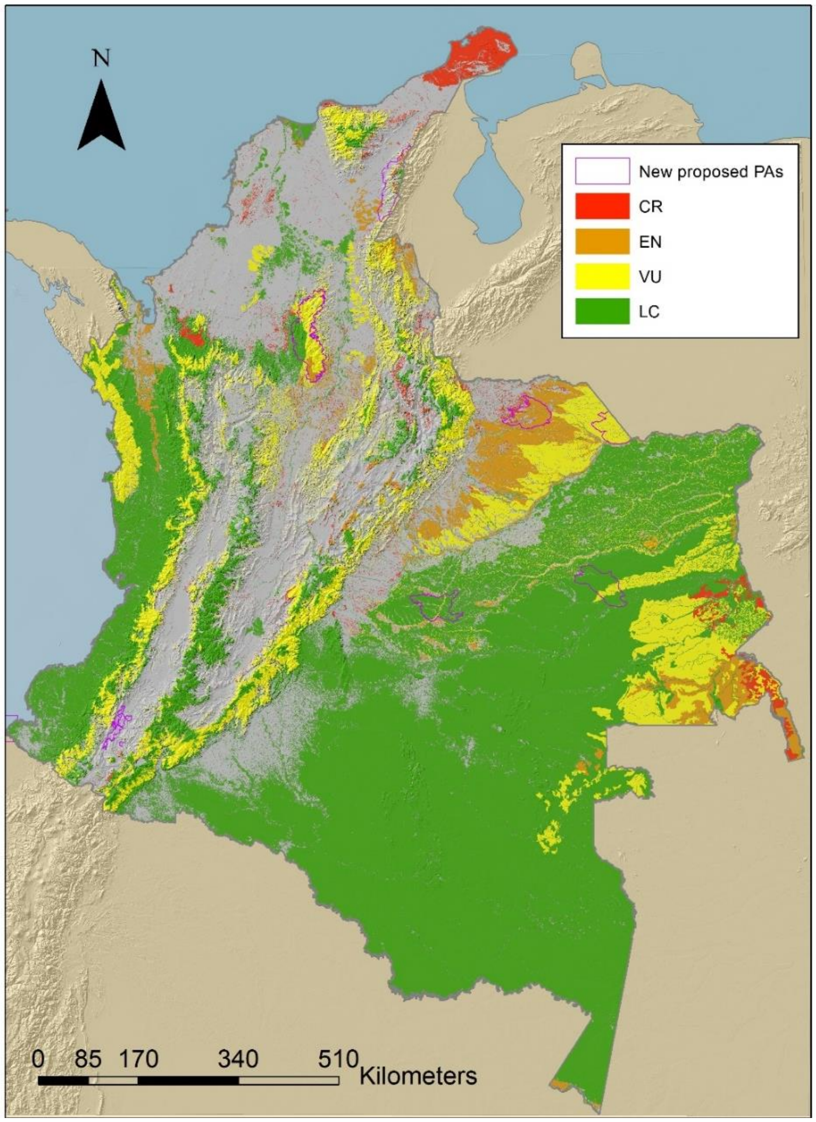

Figure 30. Relation of the new Areas and Expansions of PNN and the RLE assessment. *Source: SPNN, 2017.*

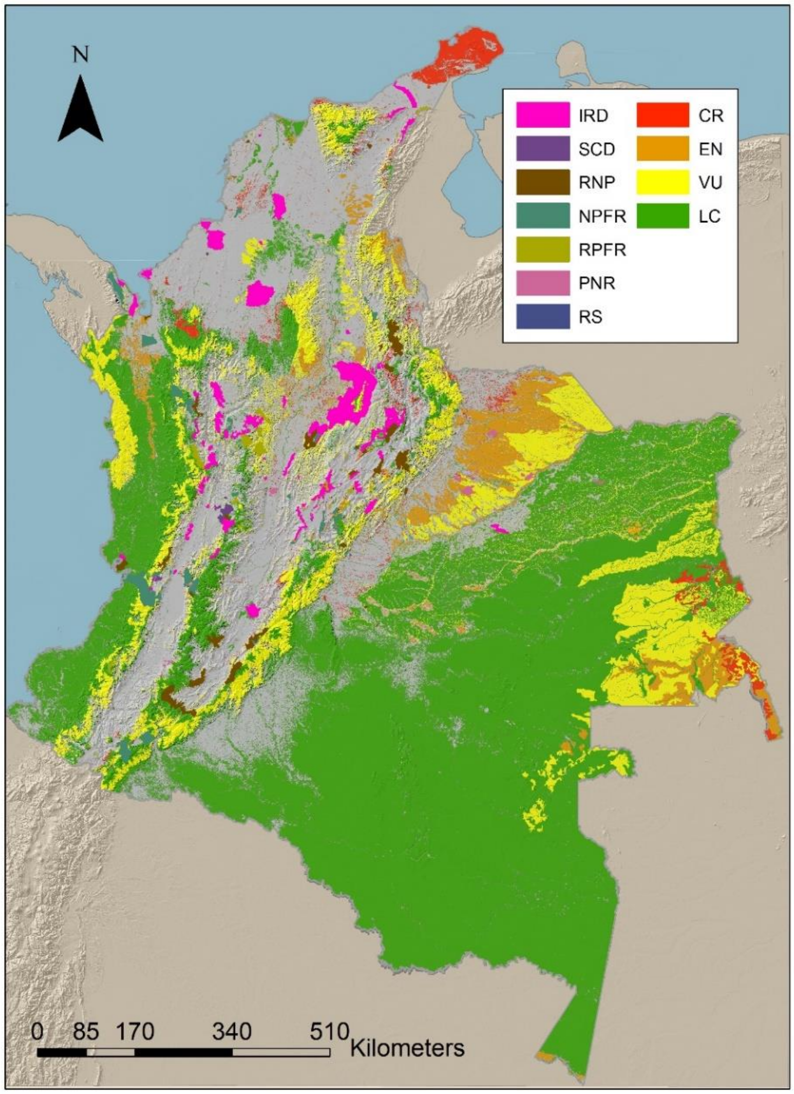

Figure 31. Relation between the RLE assessment and other protected areas of the Single National Registry of Protected Areas. (IMRD: Integrated Management Regional District, SCD: Soil Conservation District, PNR: Private National Reserves, RS: Recreation sites, RNP: Regional National Parks, NPFR: National Protected Forest Reserve, RPFR: Regional Protected Forest Reserve). (*Source: SPNN, 2017a*).

d. Indigenous Reserves and Afro Colombian Communities lands

The collective territories of ethnic groups (Indigenous Reserves and Lands of the Afro Colombian Communities Lands), are recognized as a natural conservation strategy that generates environmental representativeness, environmental protection and conservation, and management of natural resources. Indigenous peoples the Afro Colombian Communities

living in environmentally sensitive areas, are essential partners in environment management and in the understanding of ecology and conservation practices.

The indigenous reserves and lands belonging to Afro-descendant communities have a greater representativeness of the threatened ecosystems. These territories comprise 57% of ecosystems in CR category, large part of this category being located in the Guajira Peninsula. For the EN category, 31% of the area falls in these territories, while the figure is 15% for the VU category. The latter correspond to numerous indigenous reserves of the east of the Orinoquia region, and he north-east of the Amazon region (Figure 32).

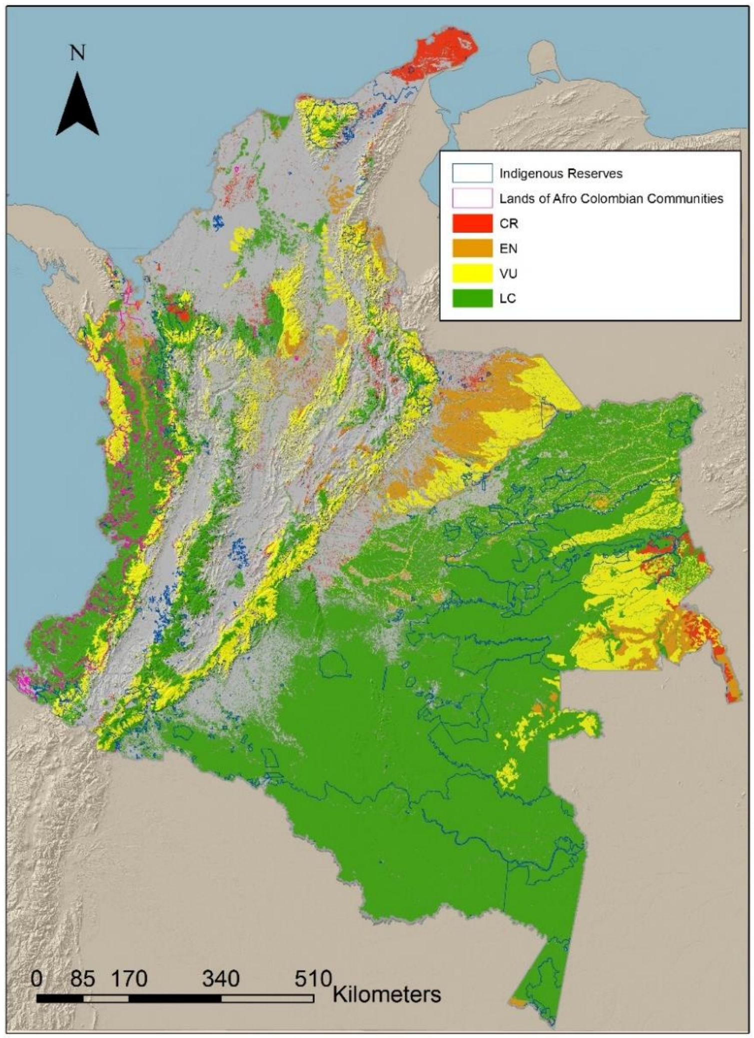

Figure 32. Representativeness of the threat categories within the Indigenous Reserves and Lands of the Afro Colombian Communities. *Source: IGAC, 2015.*

Projects and initiatives seeking to promote the sustainable resource management within territories declared as indigenous reserves and territories of Afro Colombian communities acquire relevance.

e. Key Biodiversity Areas (KBA) and World Heritage Sites (WHS)

The identification of Key Biodiversity Areas (KBA) of the IUCN is based on the location of important sites for the different taxonomic, ecological and thematic subsets of biodiversity. KBAs can be a first phase of selection by national jurisdictions to identify sites that contribute significantly to the global persistence of biodiversity in terrestrial and aquatic ecosystems (IUCN, 2016). The representation of ecosystems categorized as threatened within the KBA and WHS, allows determining the level of risk for key species and their habitat.

For Colombia, 149 KBA areas have been defined, of which 140 relate with ecosystems with certain degree of threat (11% in CR ecosystems, 3% in EN ecosystems and 14% in VU ecosystems). It is important to mention that most of these sites have a high level of human transformation.

These 140 areas (Annex 7) have little, partial or whole protection because they are part of the National Protected Areas Systems. Of the 140, only 51 areas are under fuill protection, in 4 in most of their area, in 7 only slightly, while in 48 protection is almost inexistent, and for 30 areas there is no information. For instance, the dry Enclave of the Dagua River, the dry forests of the Chicamocha River Valley of the Zonobiome of the tropical Dry Forest (CR) and the coastal wetlands complex of Guajira in the Zonobiome of Tropical Deserts (CR), have nothing of their distribution area protected, having most of their area transformed by human activities (Figure 33).

Of the 140 areas that have representation in threatened ecosystems, 91 areas have more than 20% transformed. The transformation not only happens in private areas, such as the Eco Park Los Besotes (98% of transformed area) and the Natural Reserve Laguna del Sauce (89% of transformed area), but also in National Natural Parks, for instance Macuira National Natural Park (67% of transformed area), Pisba National Natural Park (66% of transformed area) and the Ecodeltaic Fluvioestuarine Region of the Dique Channel (58% of transformed area).

The creation of new protected areas, the management of the national, regional and private areas is not favoring the protection of Colombian ecosystems. It is necessary to develop more efficient conservation projects in transformed areas and set down more stringent regulations in the NNPs that allow reducing and avoiding activities that endanger biodiversity and the functioning of CR and EN ecosystems.

In conclusion, the relation between the LRE and the KBA allows locating the areas where the biodiversity loss, due to transformation by anthropic activities, is endangering endemic and valuable species for Colombian ecosystems functioning. The representation of CR ecosystems in the KBAs, demonstrates the need to join efforts to recover areas of threatened ecosystems and restore areas that favor the fauna and flora establishment.

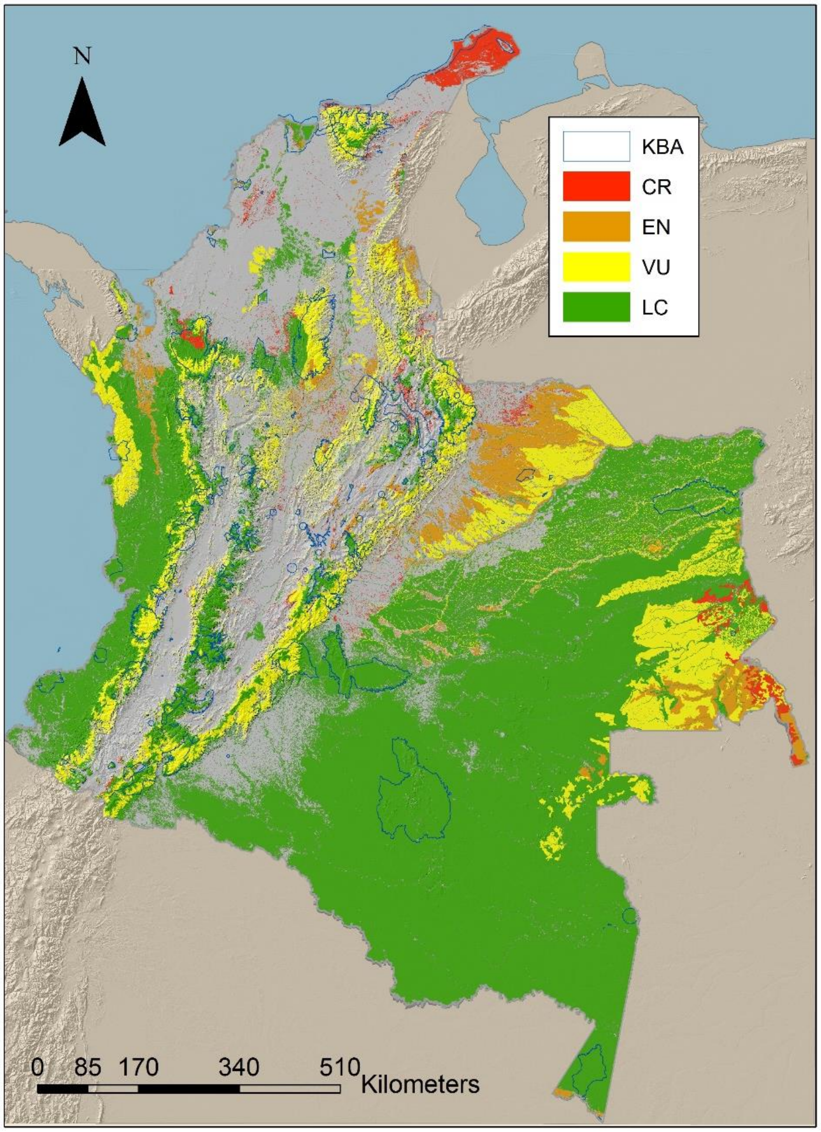

Figure 33. Representativeness of the threat categories within the Key Biodiversity Areas (KBA). *Source: BirdLife International, 2016.*

World Heritage Sites (WHS) locate globally important areas of a cultural and natural relevance to society. Colombia has 8 World Heritage sites, which include 2 natural areas and 6 cultural areas. The natural areas are Los Katíos Natural National Park and Malpelo Flora and Fauna Sanctuary. The cultural areas include the Cultural Heritage Coffee Landscapes, the Historic Center of Santa Cruz de Mompox, the Archaeological Natural Park of Tierradentro, El Puerto, Muralla and the group of monuments of the City of Cartagena, the Qhapaq Ñan route system of the Andes, and the San Agustin Archaeological Park. The representation of the threat categories within the Natural Areas of the World Heritage Sites is not significant. There

is only one natural area that has representation in terrestrial ecosystems. Within Los Katios PNN there are ecosystems with an EN, VU and LC status (Figure 34).

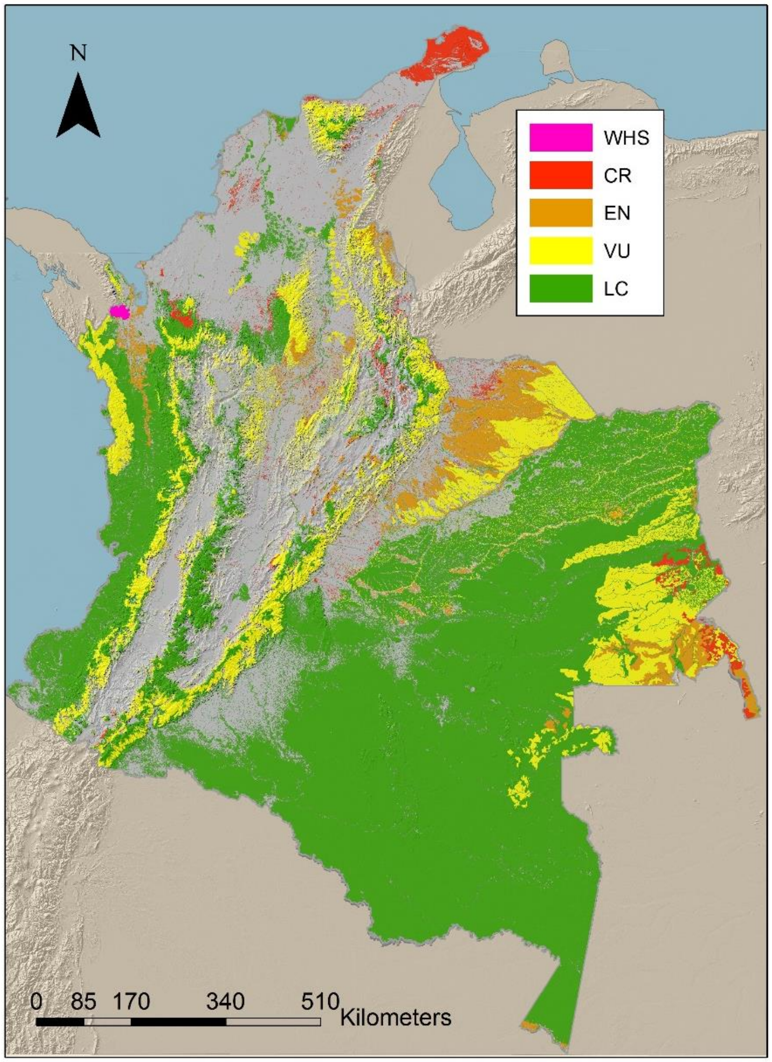

Figure 34. Relation of the threat categories within the Natural Sites of the Colombian WHS. *Source: UNESCO, 2006.*

4.2. Relationship between the Red List of Ecosystems (RLE) and the Red List of Species (RLI) [3]

The Red List framework can be applied to two complementary levels of biodiversity: species and ecosystems. From this outline, the question arises of how much each one coincides or complements itself in the assessment of biodiversity risk in a specific area.

To this end, IUCN's expert's maps of 2,638 vertebrates distributed in Colombia and the risk category assigned to each species were used. Afterwards, the presence of each species and each ecosystem on the map of threatened ecosystems of Colombia was identified. After this, the Red List Index (RLI) was calculated using the equation (Butchart et al., 2007):

$$RLI(e) = 1 - \frac{\sum_{S} W_{c(s)}}{W_{EX} N}$$

Where ***S*** is the set of species in the ecosystem ***e***, ***Wc***(***t, s***) is the weight assigned to the risk of extinction for species ***s***, ***Wex*** is the threat category ***EX***, and ***N*** is the total number of species. The weight for each category was: EX=5, CR=4, EN=3, VU=2, NT=1, LC=0. The RLI value varies between 0 (all species are extinct) and 1 (all species are in minor concern).

The weighted area index (**RLIw**) was also calculated according to the area occupied by each species in each ecosystem. This gives more weight to the species that occupy large areas of the ecosystem:

$$RLIw(e) = 1 - \frac{\sum_{S} W_{c(s)} \, {}^{A_{s(e)}}\!/_{A_e}}{W_{EX} \sum_{s} {}^{A_{s(e)}}\!/_{A_e}}$$

Where ***As***(***e***) is the area occupied by species ***s*** in the ecosystem, and ***Ae*** is the area of the ecosystem **e**. This equation reduces to the previous one in that all species occupy all the ecosystems where they occur.

The results of the analysis for all the RLIs show a positive general trend between the RLI and the RLE. Critically endangered ecosystems (CR) have low RLI values in the two analyzes, indicating high concentrations of threatened species (Figure 35). However, the RLE category ranking does not fully agree with the RLI. For example, the median of the RLI of threatened

[3] With Jorge Velásquez (Instituto Alexander von Humboldt).

ecosystems (EN) is greater than the median for vulnerable ecosystems (VU), and should be low (although the category has greater dispersion) to be consistent with the RLI.

For the case of the calculation with the weighting by area (Figure 36), although the critical ecosystems (CR) show the lowest RLI that indicates the highest concentration levels of threatened species, the following 3 categories show inverse results.

This analysis could be continued by crossing the RLI against specific sub-criteria of the RLE, or calculating the relationship for specific taxonomic groups.

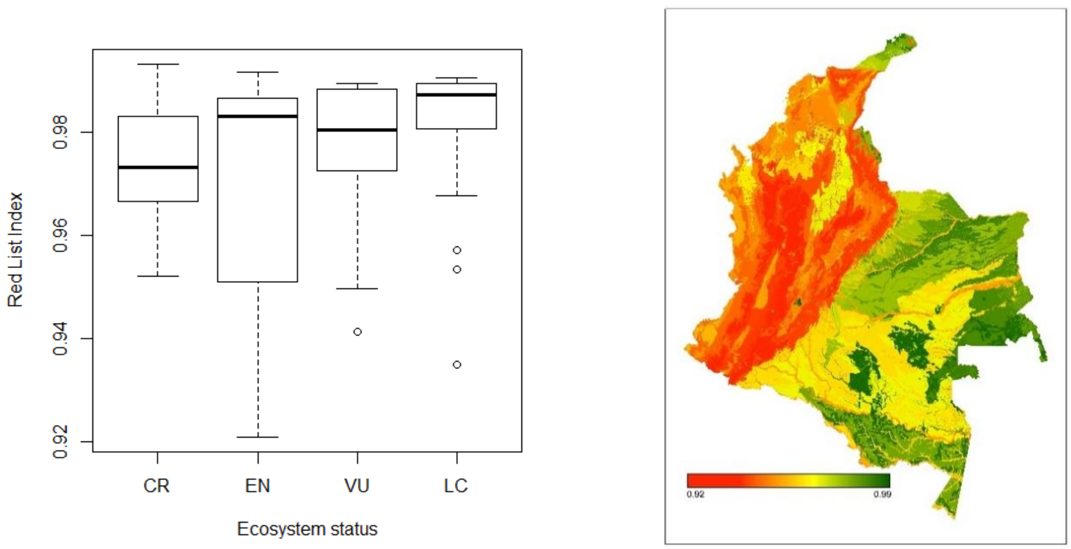

Figure 35. Relationship of the Red List Index with the categories of the Red List of Ecosystems.

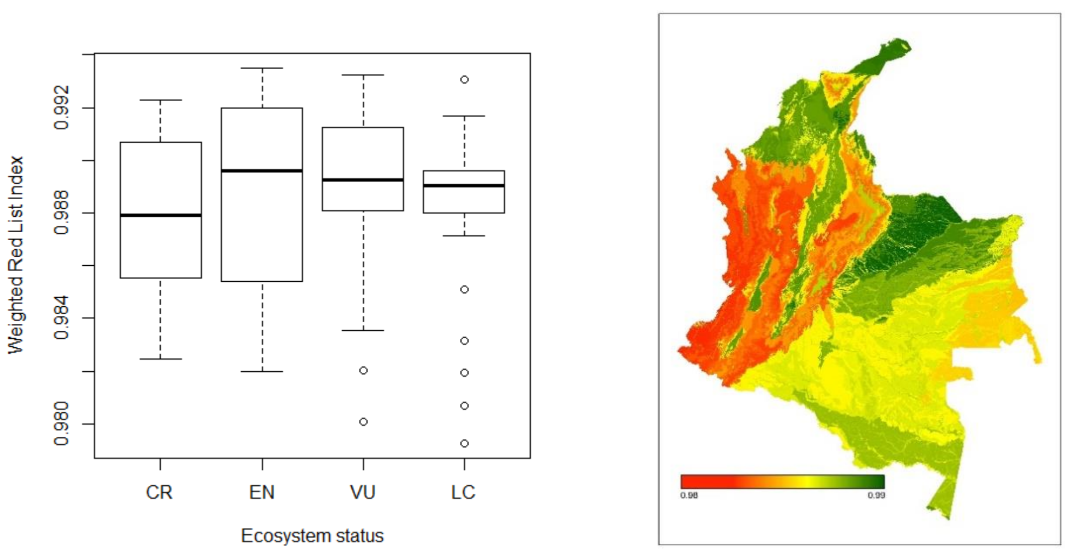

Figure 36. Relationship of *RLIw* with the categories of RLE.

4.3. Identification of Priorities for Restoration

The integration of the ecology of restoration to the conservation of ecosystems allows mitigating the damages to ecosystems and communities caused by anthropic activities. The restoration of ecosystems ideally requires knowing the reference of the area of the potential ecosystems lost in the transformation process. It also benefits knowing the representation of the remnant ecosystems and their collapse risk level.

For this, the assessment of the Red List of Ecosystems is a useful input. It allows identifying the ecosystems' current risk level, and the location of the areas where they have disappeared. For example, Figure 37 shows the transformed ecosystem areas categorized as CR and EN, which are an important criterion to focus restoration processes. The map shows that such areas which would be priority areas, are concentrated in the Caribbean region and the intra-zonal areas of the Andes.

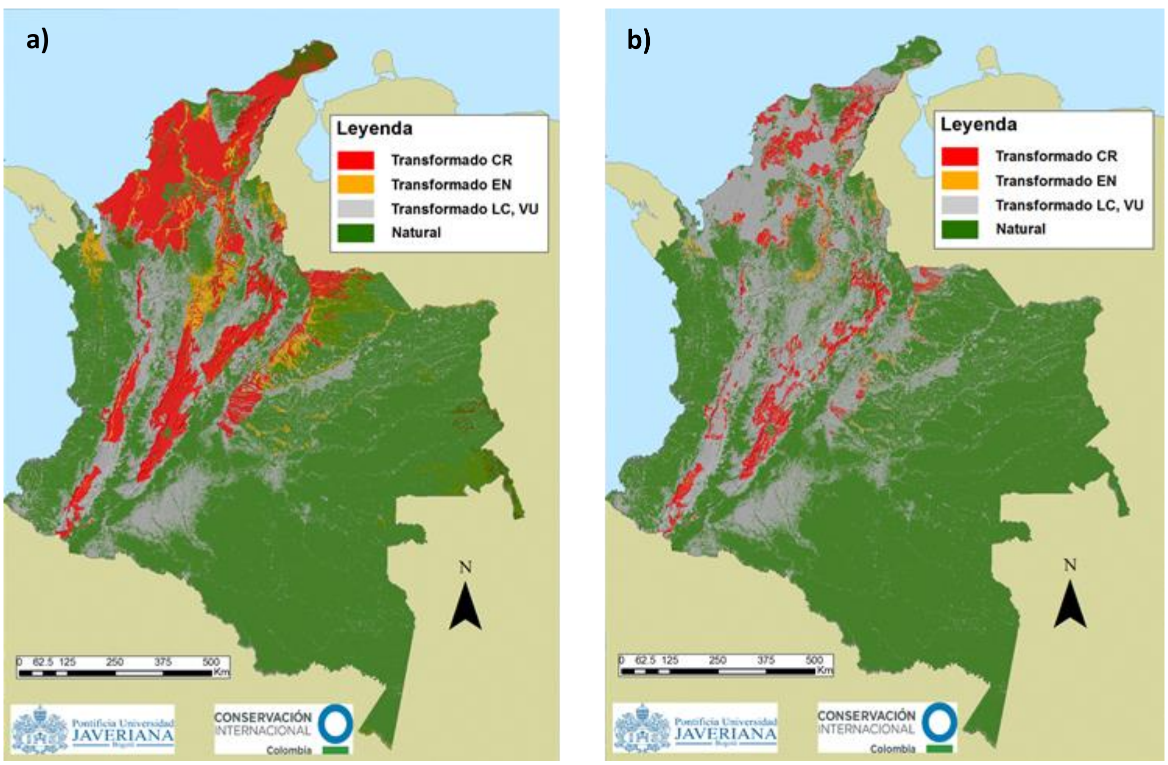

Figure 37. Identification of priority restoration areas in transformed areas of Colombia (a) total area available; b) area under unproductive livestock systems according to Zuluaga et al. (2017).

The total areas of CR and EN ecosystems that have disappeared account for more than 24 million hectares (Figure 37a, Table 15). An additional criterion to give focus to the areas to be

restored is productivity level of current uses. In this regard, Zuluaga et al. (2017) identified low productivity livestock systems, a major environmental and socioeconomic concern in the country. Using this data, permits an additional focus, and reduces the area of restoration interest to just over 6 million hectares, equivalent to 25% of the total CR and EN area. Selecting the areas that meet these requirements will allow critically endangered ecosystems such as high mountains and dry tropical forests to increase their distribution area.

Table 15. Transformed CR and EN ecosystems areas to be restored: A) total (See Figure 37a); B) corresponding to areas with low productivity land uses (See Figure 37b).

	A	B
CR	17,002,394	5,187,213
EN	7,940,213	857.231
Total	24,942,606	6,041,319

Analyzing these areas in terms of their jurisdiction in the 10 Regional Autonomous Corporations (CARS) which are in charge of such projects, with highest coverage, it is evident that the greatest demand are those that have the dry tropical forests of the Magdalena Valley and the Caribbean in their jurisdiction, such as CORTOLIMA, CAM, CORPAMAG, COPRPCESAR and CORPOGUAJIRA. The dry forest and shrubland areas of the Andean valleys of CORPOBOYACÁ and CAR also appear (Table 16).

Table 16. Restoration areas according to the CARs (Regional Environmental Corporations) jurisdictions.

CAR	TOTAL		IMPROD	
	CR	EN	CR	EN
CORTOLIMA	**1,042,356**	56	**527.169**	19
CAM	601.900	0	**457.925**	0
CORPAMAG	**1,416,250**	157.350	**443.031**	23.519
CORPOCESAR	**1,147,038**	283.450	**420.150**	36.275
CORPOGUAJI	**1,820,456**	24.531	**334.100**	4.219
CORPOBOYAC	527.625	142.863	**313.063**	13.225
CAR	831.756	104.575	**294.750**	11.294
CORANTIOQU	586.944	412.663	**264.125**	146.750
CAS	669.438	561.488	**254.006**	30.350
CORPORINOQ	**1,039,438**	**2,974,475**	**251.494**	135.456

4.4. Application of LRE in the *Tremarctos-Colombia_3.0* platform[4]

A major application field of assessments such as the RLE concerns the visualization of the impacts of infrastructure projects, agricultural expansion or resource extraction, to undertake development-planning processes. The limitations to decision making due to the lack of an easy and readily access to relevant information to evaluate development projects at the pre-feasibility level, led Conservation Internacional Colombia – CI, to develop during the past 10 years the *Tremarctos Colombia ©* platform. This platform constitutes an early alert system, to assist public and private decision makers to visualize and analyze the possible environmental, socioeconomic impacts. One important objective of the system is to safeguard important conservation targets, in particular, large areas still found outside of the National Protected Areas system.

The *Tremarctos Colombia ©* platform (Figure 38) already provides uniform and updated online maps and information about the NPAs including National Parks and Ethnic territories, as well as endangered species lists and maps (CR, EN and VU), endemic and migratory species , ecosystem services (habitat quality, scenic landscapes, water balance. The inclusion of the RLE is an important complement to the array of data already available in *Tremarctos Colombia-3.0 ©.*

Now the RLE can be accessed through the *Tremarctos Colombia ©* platform at www.tremarctoscolombia.org (Figure 39). There, the LRE allows performing online analyses of the impacts of specific development projects, or as a tool for planning of government institutions. Figure 39 shows the conventions and the procedures that allow the early alert system. The analysis is performed either introducing project data in Shapefile format, GPX, coordinate systems files or onscreen hand drawn features.

Figure 40 and 41, show examples of the use of the LRE to visualize and quantify the potential impacts of new road infrastructure developments, using a conventional 50m buffer zone at both sides of the roads. Figure 40 addresses the “4G road infrastructure Project Arauca-Tame-Yopal” project, showing the affected ecosystems include categories CR (269Ha), EN (446Ha), y VU (143Ha). Figure 41 in turn, shows the impacts of the “4G road infrastructure Project Cúcuta-Pamplona-Sogamoso” project, which would affect extents of ecosystems of categories CR (186Ha), EN (25Ha), y VU (465Ha).

[4] Elaborated by Ing. Tito Muto, Conservación Internacional - Colombia

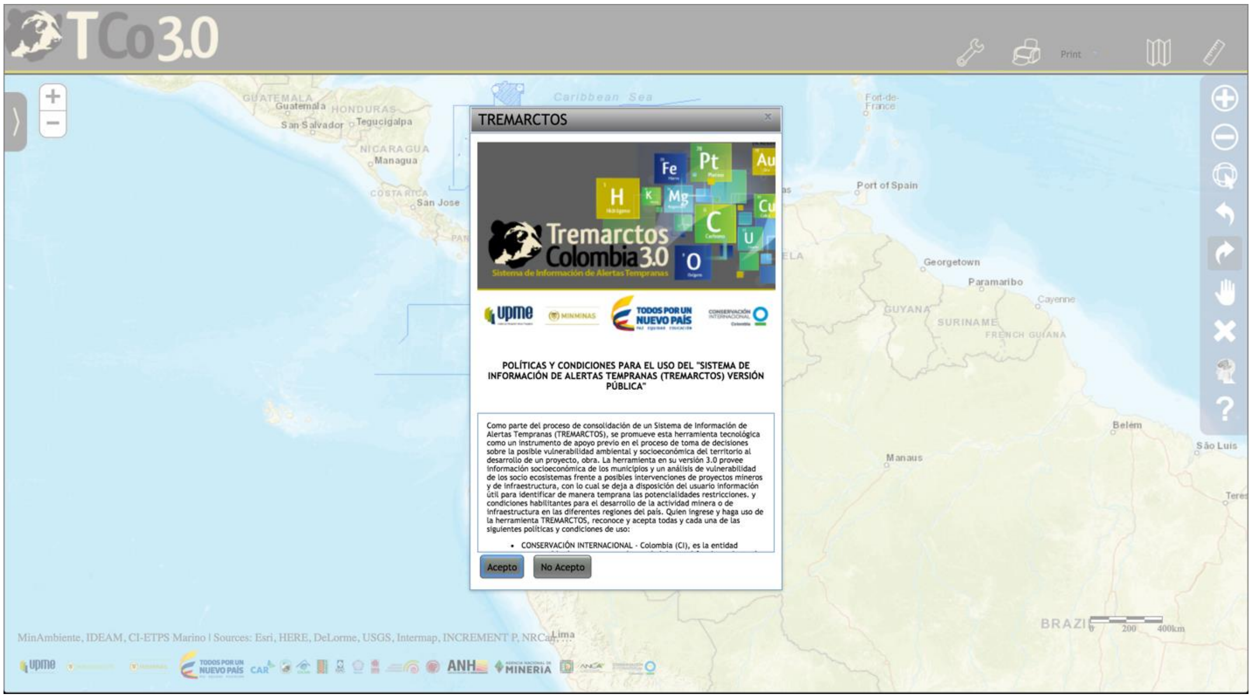

Figure 38. Web Portal of the *Tremarctos Colombia-3.0*, for the online early alert analysis of development projects.

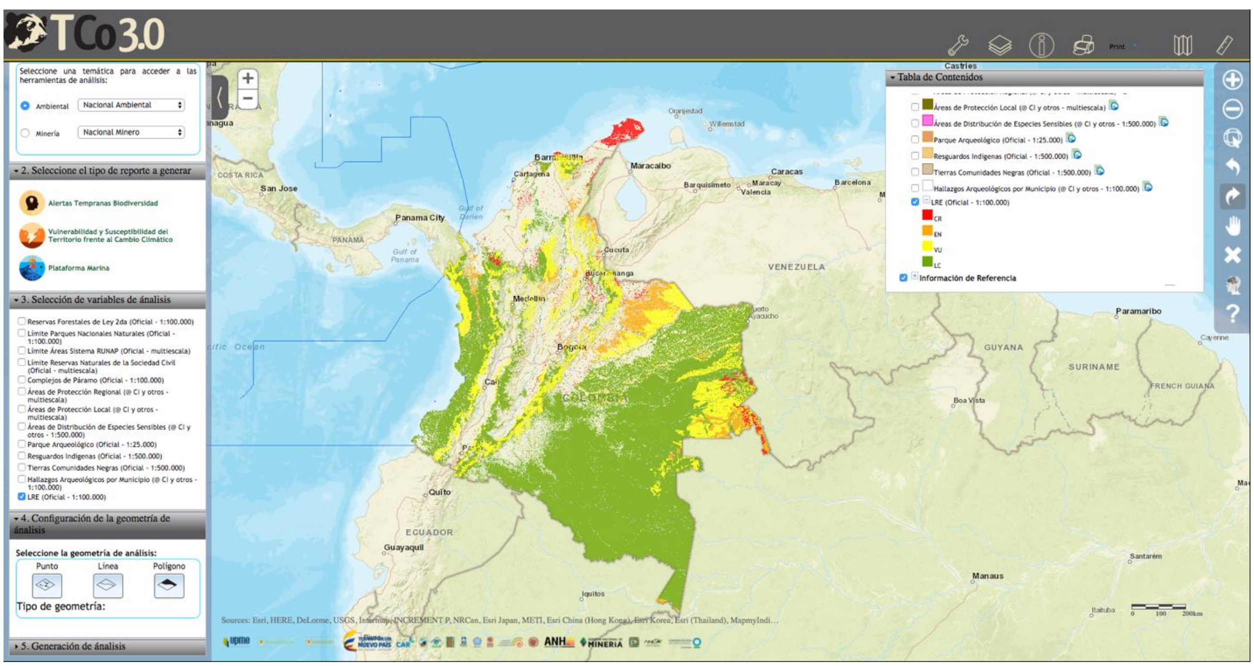

Figure 39. Visualization of the RLE in the *Tremarctos Colombia-3.0* web platform.

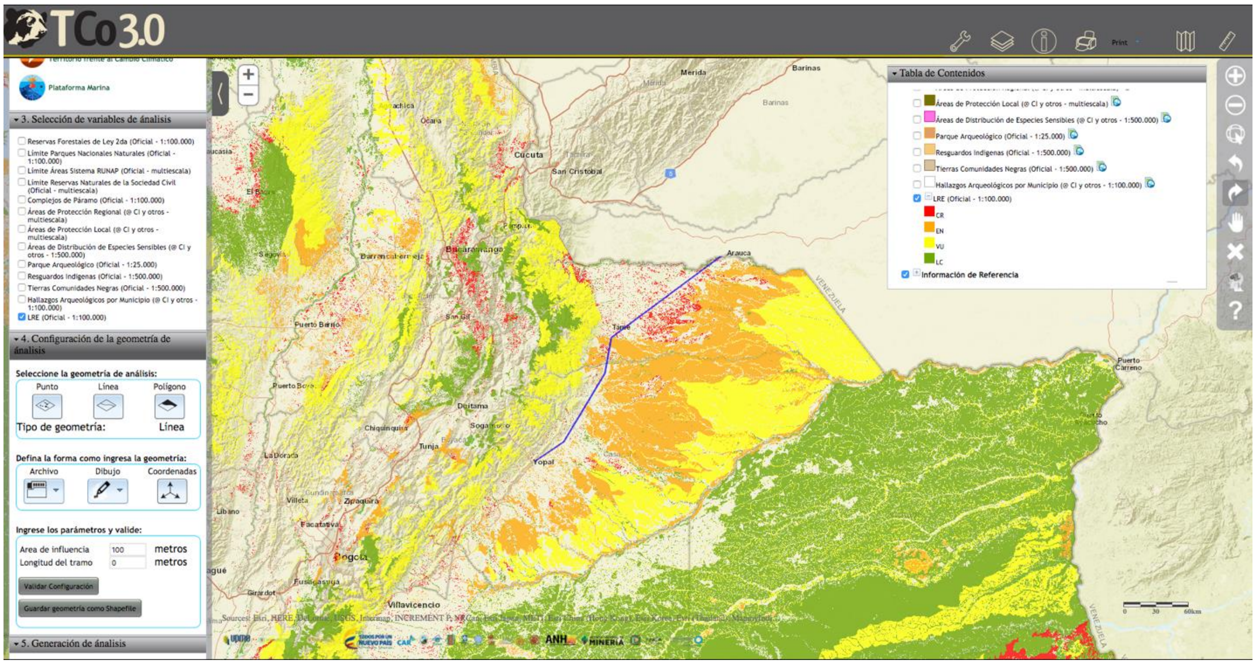

Figure 40. Visualization of the affectation of endangered ecosystems identified in the RLE, by the 4G road infrastructure Project Arauca-Tame-Yopal (ANI 2017).

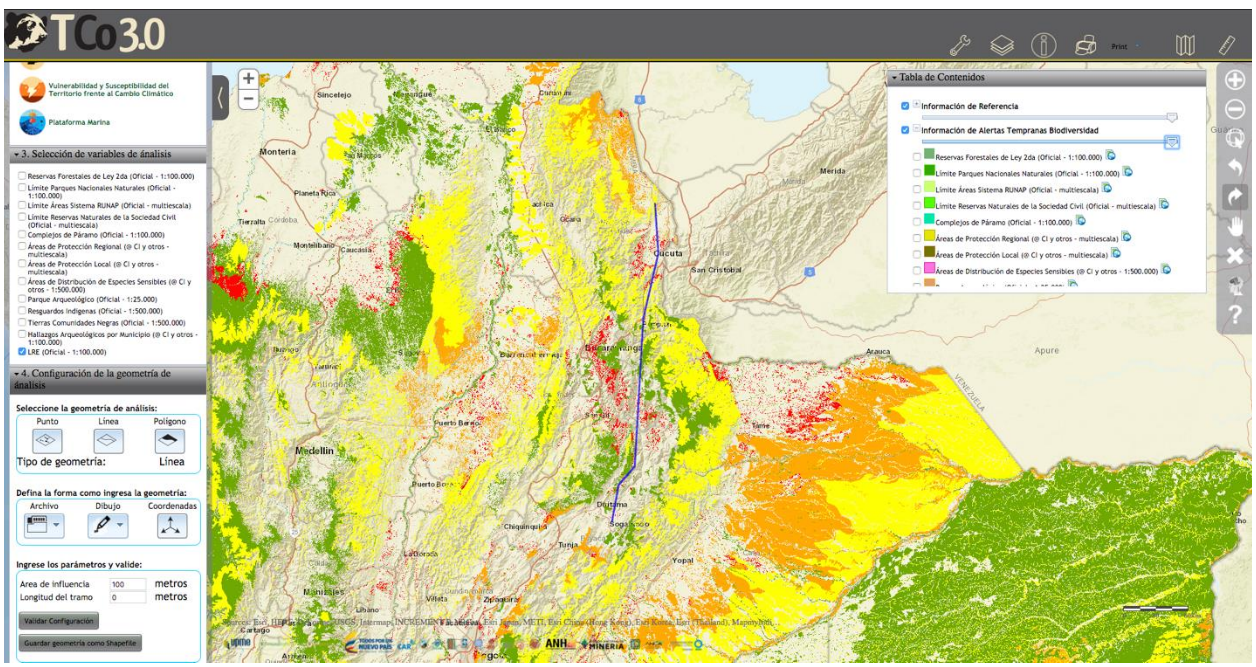

Figure 41. Visualization of the affectation of endangered ecosystems identified in the RLE, by the 4G road infrastructure Project Cucuta-Pamplona-Sogamoso (ANI 2017).

Figure 42 shows the potential affectations of a gold mining concession in the northwest of the country in Antioquia department with a total área of 5,846 Ha, which would affect important areas of endangered ecosystems of categories CR (1,993 Ha) and EN (711 Ha).

Figure 42. Visualization of the affectation of endangered ecosystems identified in the RLE, by a gold mining concession.

5. DISCUSSION

5.1. Overview

For a country such as Colombia, that prides itself on having an especially valuable natural heritage, the knowledge on human impact on it and its consequences is very relevant. Without ignoring the available knowledge, the RLE assessment provides a new complementary vision that allows dimensioning and understanding the impact of human transformations on ecological systems in their different spatial and temporal scales, expanding the base that will allow assessing the status of the ecosystems and implementing a more effective management and conservation of this heritage.

The first application of the Red List of Ecosystems scheme in Colombia corroborated the general knowledge on the impact of human activities on Colombian ecosystems contained in previous studies such as Chaves and Arango (1998), Etter (1998), Armenteras et al. (2003), Chaves and Santamaría (2006), IDEAM (2007), Etter et al. (2011a) and Bello et al. (2014) among many, which indicate an impact concentration and intensity on the ecosystems of the Andean and Caribbean regions. In addition, it added valuable information when identifying threats and assessment on specific ecosystems.

The RLE shows a good correspondence between the assessment rating and the human spatial footprint index (Etter et al. 2011a); with ecosystems classified as CR having indexes greater than 50. However, there were also cases where this is not met, which allows assessing the possibility of complementing the RLE's threat analysis. Specifically, there were ecosystems such as P_ZBH-S11 (Caribbean savannas) that showed a high footprint despite having a relatively high remaining proportion.

This version of the Red List of Ecosystems scheme in Colombia focused on the expansion and methodological adjustment of criteria C and D, which allowed improving the understanding of the risks derived from the degradation of the biotic and abiotic process components of ecosystems. Criterion D considered a significant number (130) of mutualistic relations of plant-animal interactions, such as seed dispersal and pollination, permitting a more robust assessment of the changes in area and number of relationships. Regarding criterion C, the new methodological approach assessed the changes (monthly and annual) in water availability based on the CC values with respect to historical average precipitation.

Although this second version confirms the impact concentration on the ecosystems of the Andean and Caribbean regions, it permitted complementing the spatial analysis and yields

important data on the historical and foreseeable changes in the future due to climate change, on biotic and abiotic processes in other regions such as Orinoquia, the Amazon and the Magdalena valley.

In regards to the application done in other countries (Crespin and Simonetti 2015; Rodríguez, Rojas and Giraldo 2010; Lindgaard and Henriksen 2011) the application to the Colombian case offers a national vision based on a homogeneous cartography with adjusted multi-temporal transformation series.

The RLE reveals challenges related to the information requirements imposed by the methodology, since the information gaps result in approaches with low reliability levels. Important challenges remain, as to a comprehensive application of ecosystem process evaluation due to the limitations in the knowledge on the structure and operation of the assessment objects, especially for the assessment of criteria C and D, which mostly reflect the complexity of the ecosystems.

5.2. Limitations

This study was carried out nationally with a spatial resolution of the ecosystems' cartography, imposing some limitations for its local use due to the level of detail that it allows visualizing. On the other hand, since the delimited ecosystems are actually mosaics of associations or consociations of smaller units which are not delimited, this study does not allow to assess the effect of the transformation or the threat level for ecosystems that are components of the mosaic in question.

The application of Criteria C and D in a uniform manner for the country is currently still limited by the level of information available, this is in particular for past information (C1 and C3). The possibility of applying these criteria broadly and with high reliability requires conceptual and investigative work to identify functionally critical factors, as well as to increase the level of information on them.

For aspects related to biotic processes such as those initially analyzed (dispersal, pollination), additional work is required to outline the complex of relationships that occur within and between ecosystems, to corroborate the occurrence of interaction processes in space, as well as to consider aspects such as the species' adaptive sensitivity and capacity in the exposure to climate change for the modeling processes. So far, the application of Criterion D had dispersal and pollination as representatives of biotic processes, but there are other relationships that model the functioning and dynamics of ecosystems (predation, competition,

resource-consumer interactions, parasitism, among others) and that if included, would provide valuable information for the final assessment.

In particular, information on soil or groundwater degradation condition applicable to criterion C, and which are important factors of collapse of many ecosystems, are not well documented. Recent studies show how the effect of climate change on the severity of extreme drought events varies in ecosystems of different climatic zones (Zhou et al. 2015), and in Colombia there is no record or broad knowledge on the temporal and spatial variability of these data. Similarly, according to the methodological approach used in this new version, the limitation has to do with the availability of data to perform interpolations, especially in the Pacific, Amazon and Orinoco regions, where the extension of IDEAM's hydro-climatologic monitoring network is not enough.

This second version of the RLE implementation tries to gradually correct the intrinsic subjectivity on the variables that are used for the assessment (Boitani et al. 2014). However, there is still the opportunity to involve new approaches and complementary information to assess the ecosystems' level of risk of collapse.

5.3. Proposed updating and monitoring schedule of the Colombian RLE

One of the purposes of tools such as the RLE is to be able to impact in decision making for land use and conservation planning. Because the risk of dynamic entities such as ecosystems change over time, this needs to be regularly updated.

Two main reasons to update are, first, that the threats that build the risk change over time; and second because the availability of data improves the understanding of the threats, and permits an improvement of the risk assessment. Two main update processes are suggested:

a) A **National** update **every 5 years**.

Besides updating with new land cover and land use data, and ongoing threats, y should specifically also include an upgrade of the evaluation of criteria C and D, possibly adding new processes to the general evaluation, or specific evaluations for better-known ecosystems. For example using the new IPCC models of CC; or linking changes in water availability from CC with national communications.

It is urgent to extend the evaluation process to marine ecosystems.

Also, make a link between losses of processes with Ecosystem Services.

Updating should preferably be under coordination of national institutions such as the Alexander von Humboldt Institute for Biodiversity Research, with the support of Universities and NGOs. Also local/regional institutions such as the SINCHI Institute in the Amazon.

b) A regional or local update for **CR** and **EN ecosystems** to arrive at a more detailed and targeted monitoring process **every 2 years**.

This should include more detailed mapping as well as up the ground updating of the threats and ecosystem degradation indicators of species, soils, biomass/carbon, amongst other. For example ecosystems such as the central part of the Eastern Cordillera, the Orinoquia region, or the departments of Cesar and Magdalena.

It will be important to budget these processes carefully in order to guarantee its success. A national government institution, presumably the Alexander von Humboldt Institute for Biodiversity Research, should coordinate the overall process. However, it will need to ensure the engagement of other institutes of the National Environmental Information System (Sistema Nacional de Información Ambiental - SINA) such as IDEAM, SINCHI, INVEMAR, and the National Geographic Institute (IGAC). Also the multiple academic research and NGO institutions that are able to provide important inputs to the process.

6. CONCLUSIONS

The application of the Red List of Ecosystems in the Colombian case provides an expanded level of knowledge on the risk status of the country's ecosystems. The study confirms that the environmental deterioration process is real, and identifies some critical areas in this regard. In particular, it allows qualifying, with additional objective criteria, the threat levels of the different ecosystems, and identifying geographic areas that warrant rapid attention in terms of environmental management, as well as identifying areas that require greater knowledge. This can become a support for the construction and assessment of alternative scenarios for future land use, and will help to improve the dialog between the information generators and the decision makers.

To the extent that the interaction of human societies and their biophysical environment are dynamic, due, among others, to societies' changing demands, these assessment processes should become permanent monitoring processes to support management. The Red List of Ecosystems with its spatially explicit and multi-temporal framework is a promising way to achieve this goal.

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8. ANNEXES

Annex 1. Routine for the validation of the map of potential ecosystems in C5.0.

C5 USE PROTOCOL for validation of the Map of Potential Ecosystems

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A "decision tree" model was implemented for the validation of the Map of Potential Ecosystems, which is a classification technique used for the prediction of finite numerical values, in which case they are called "classification trees" (Frank et al. 1998). One of these models is C5.0, an algorithm developed by Quinlan (1993), used to build decision trees based on training data, where the objective is to predict the response of Y as of independent variables X1, X2, ... Xp, through a binary tree that extracts information patterns from the data.

1. The first step is to prepare the inputs:
   1.1 Adapt the input shapefile (.shp): the map must have a column that shows the ecosystem's code, in our case it is COD. If the codes in this column do not all start with a letter, it is suggested that a column be created with a letter that is before each COD. If in any case the code has a backslash (/), remove it, since this could generate errors.

   1.2 Selection of points for each polygon of the map for model training: It can be done according to the options a or b below. The difference between the two is the number of points selected, where option b generates a greater number of points, which influences the accuracy of the predictions.

Option a:

- A column is created where a number of points is assigned according to the area, with the following allocations:

  <1000 km - 30 points
  1000 to 10000 - 60 points

10000 to 25000 - 90 points
Greater than 25000 - 120 points

In our case, it was assumed that those polygons with an area smaller than 0.025 km were errors, so they were assigned a value of zero in the points' column.

OBJECTID *	Shape *	COD	COD2	Shape_Length	Shape_Area	Area	Puntos
5362	Polygon	34	C34	4128023,009899	5322341072,351661	5322,341	60
1038	Polygon	16c	C16c	2178544,062609	5830576532,480827	5830,577	60
1455	Polygon	19a	C19a	3475573,532359	6248061480,811402	6248,062	60
14226	Polygon	8	C8	1256480,431835	6453490597,842455	6453,491	60
1350	Polygon	18b	C18b	4187130,471035	6599031765,783694	6599,032	60
885	Polygon	14b	C14b	2163244,850764	6630182058,900724	6630,182	60
5303	Polygon	34	C34	5699814,172928	6667817179,1289	6667,817	60
7368	Polygon	3a	C3a	2413630,918036	7166671940,009597	7166,672	60
3071	Polygon	2a	C2a	2107055,237569	7169416096,916091	7169,416	60
1226	Polygon	18a2	C18a2	3356731,538193	7554189042,88221	7554,189	60
3138	Polygon	2a	C2a	1516428,462781	7593627593,609883	7593,627	60
1178	Polygon	18a1	C18a1	2476215,765942	7663582993,110894	7663,583	60

Figure 1. Snapshot of table of attributes where the Ecosystem Codes (COD) are observed with their correction (COD2) and the allocation of points.

Creating a point layer for model training: Create a layer of random points with the "Create Random Points" tool, where you specify that the number of points will correspond to the Points column.

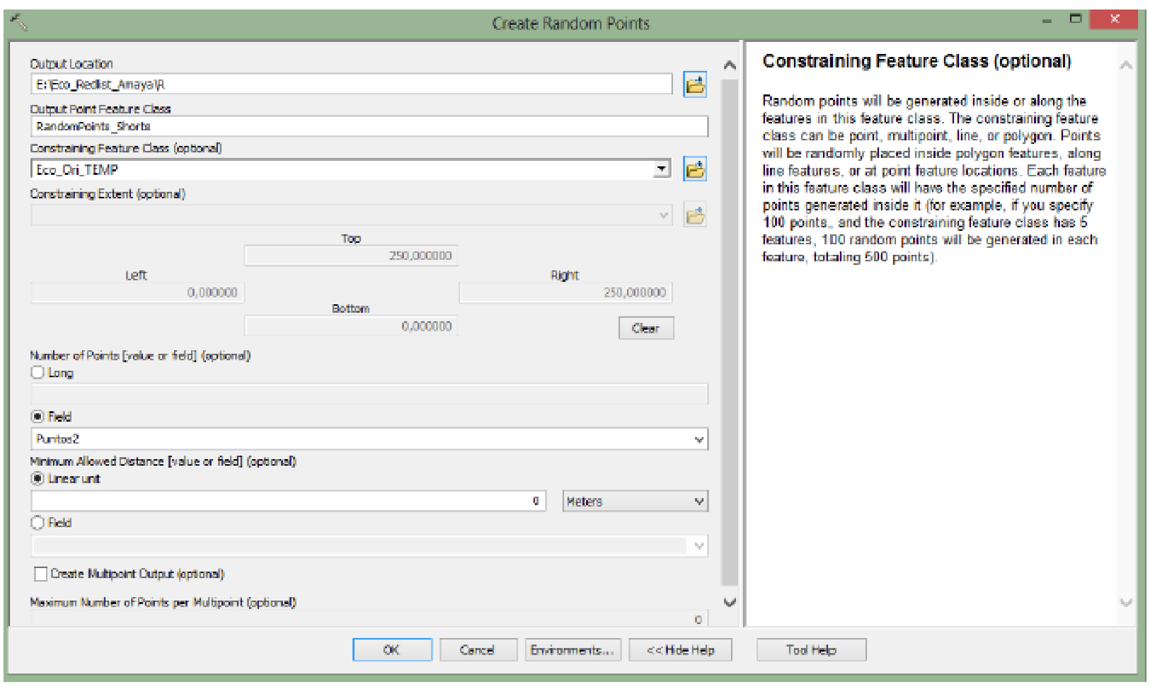


Figure 2. Visualization of the "Create Random Points" tool, through which the reference points for the model are created.

Note: with this procedure, a layer of 397,630 points was obtained.

Option b:

The second option creates the points from a FISHNET. A FISHNET is created with a 1km grid.

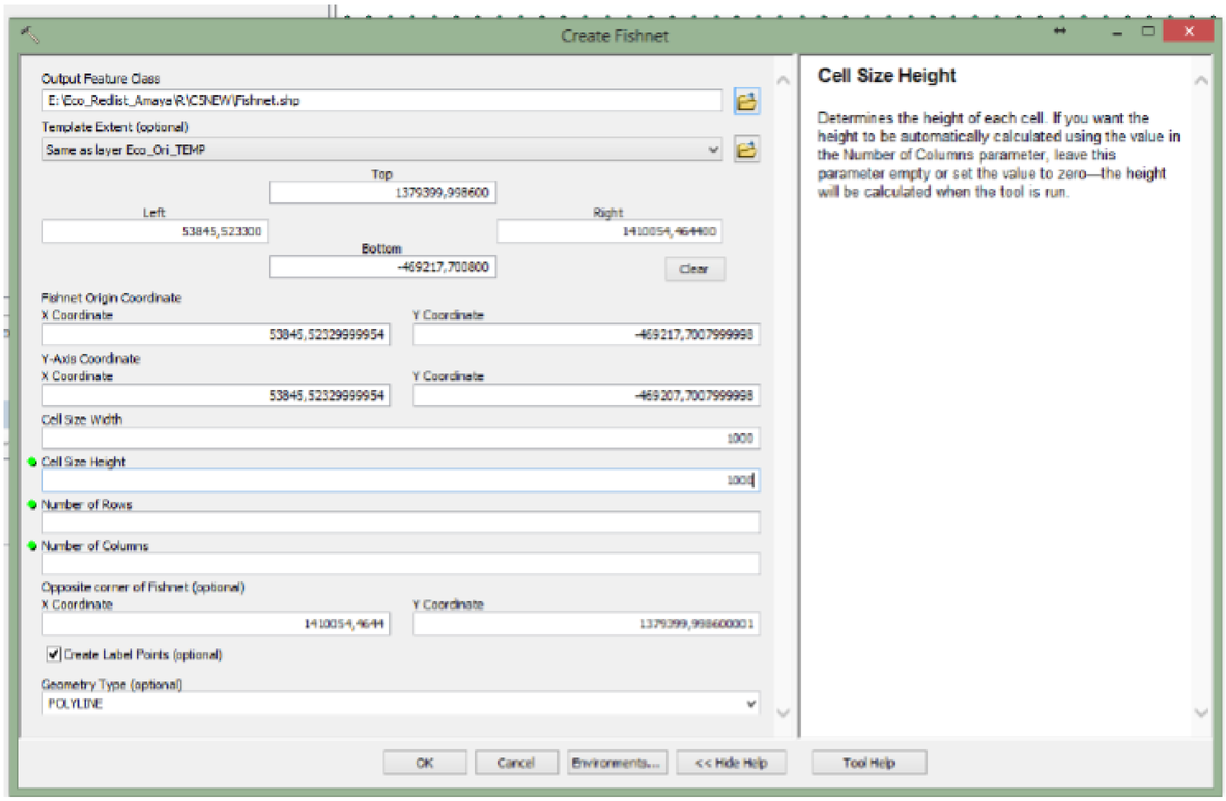


Figure 3. Visualization of the "Create fishnet" tool, through which the reference points for the C5 model are created.

Take the resulting points' layer and cut it with the reference polygon, in this case the one for Colombian.

Note: with this procedure, a layer of 112,694 points was obtained.

Figure 4. FISHNET visualization of reference points.

1.3 Allocation of variables for each point: the variables to be assessed in the regression tree, 19 climatic variables in our case were obtained from WorlClim, region, soils, geo-pedology, slope and digital terrain model (DEM).

COD2	REGION	DXF_TEXT	GEO	aster_slop	aster_qdem	Full_bio1	Full_bio2	Full_bio3	Full_bio4	Full_bio5
C42	AMA_S	158ai	CA	2,00167	118	264	93	85	462	317
C42	AMA_S	158ai	QA1i	1,3571	142	263	93	86	455	316
C42	AMA_S	157a	QA1n	2,82964	129	263	93	85	478	317
C42	AMA_S	158ai	QA1i	2,00167	144	263	93	86	459	316
C42	AMA_S	157a	QA1n	2,81048	150	262	93	86	466	315
C42	AMA_S	157a	QA1n	1,64558	166	262	93	86	480	315
C42	AMA_S	157a	QA1n	9,19657	166	262	93	86	479	315
C42	AMA_S	157a	QA1n	4,15686	173	262	93	86	480	315
C2b	AMA_S	101Acd	QA1n	4,42023	166	262	93	86	467	315
C2b	AMA_S	101Abc	LH5n	4,61065	137	262	92	85	461	315
C2b	AMA_S	101Abc	LH5n	3,83344	158	262	92	85	461	315
C2b	AMA_S	101Abc	LH5n	0,329203	160	263	92	85	452	316
C2b	AMA_S	101Abc	LH5n	3,23885	175	262	92	85	476	315
C2b	AMA_S	101Abc	LH5n	5,19096	169	262	92	85	465	315
C2b	AMA_S	101Abc	LH5n	0,931054	184	262	92	85	468	314
C2b	AMA_S	157a	QA1n	5,19096	177	261	92	85	477	314
C42	AMA_S	157a	QA1n	7,8783	170	262	92	85	480	314
C2b	AMA_S	157a	QA1n	7,1822	172	262	92	86	475	314
C2b	AMA_S	101Abc	LH5n	4,32182	165	262	92	85	460	315
C42	AMA_S	157a	QA1n	3,74817	175	261	92	85	485	314
C42	AMA_S	157a	QA1n	3,97144	169	262	92	85	453	315
C42	AMA_S	101Abc	LH5n	3,0323	174	262	92	85	460	315
C2b	AMA_S	157a	QA1n	1,1868	173	262	92	85	501	315

Figure 5. Table of attributes where the climatic variables, region, soils, geo-pedology, slope and the DEM are associated.

1.4 <u>Coordinate calculation of each point:</u> For each point, calculate the coordinates "x" and "y" using the Add XY Coordinates tool.

2 The second step is the implementation of the Decision Tree of C5 in the R1 software.

2.1 Export the points layer to a .CSV file to be used from R, or you can also open the dbf from R:

```
library(foreign)
PointsFishnet<-read.dbf("E:/Eco_Redlist_Amaya/R/PointsFishnet2.dbf")
```

2.2 Create partitions of 2, 4, 6, 8, 10, 20, 30, 40 and 50% to observe in which partition the accuracy is stabilized. These can be created through the following code, changing the "p", the train name and the test name:

```
library(caret)
split2<- split(RandomPoint_Large, RandomPoint_Large$COD2)

train<-list()
DFtrain<-list()
DFtest<-list()
Train04<-data.frame()
Test04<-data.frame()

for (i in 1:82){
temp2=split2[[i]]
train[i]<-as.matrix(createDataPartition(temp2$COD2, p=0.04))
DFtrain[[i]]<-temp2[train[[i]],]
DFtest[[i]]<-temp2[-train[[i]],]
Train02<-rbind(Train02,DFtrain[[i]])
Test02<-rbind(Test02,DFtest[[i]])
}
```

2.3 Apply the model to each partition, where the model is trained with the "train" partition and assessed with the "test". This code allows you to add the prediction to a column in the Test dataframe, as well as generating a .CSV where the confusion matrix is observed, where you can see how the regression tree classified each point. You can also analyze the sensitivity and specificity table for each COD.

```
library(C50)
library(e1071)

Final_colnames<-colnames(Train50)
varNames<-Final_colnames[-c(1:2, 27:28)]

M50 <- C5.0(x=Train50[,varNames],y=Train50$COD2,
        trials=5,control=C5.0Control(winnow=TRUE))

pred50<-predict(M50,Test50[,varNames])
postResample(pred50, Test50$COD2)

Test50$COD2_pred<-pred50

CM50<-confusionMatrix(pred50, Test50$COD2)
write.csv(CM50$byClass, "CM/CM50.csv")
```

Prediction	C1	C11	C12	C14a	C14b	C15a	C15b	C15
C1	6039	0	0	3	0	0	0	
C11	0	1935	0	2	4	0	0	
C12	0	0	217	0	0	0	0	
C14a	5	0	0	1296	14	0	2	
C14b	0	9	0	2	386	1	10	
C15a	0	0	0	0	4	36	2	
C15b	0	0	0	0	10	1	487	1
C15c	0	0	0	0	5	4	20	7
C16a	0	0	0	60	12	0	6	
C16b	0	0	0	0	5	0	1	
C16c	0	0	0	10	31	2	16	
C171	0	0	0	0	0	0	1	
C172	0	0	0	0	0	0	0	
C173	0	0	0	0	0	0	0	
C18a1	0	0	0	11	0	0	4	

Statistics by Class:

	Class: C1	Class: C11	Class: C12	Class: C14a	Class: C14b
Sensitivity	0.92339	0.860000	0.780576	0.778846	0.690519
Specificity	0.99558	0.997838	0.999914	0.998235	0.999329
Pos Pred Value	0.87661	0.819915	0.927350	0.788321	0.743738
Neg Pred Value	0.99739	0.998396	0.999693	0.998133	0.999128
Prevalence	0.03290	0.011318	0.001398	0.008370	0.002812
Detection Rate	0.03038	0.009733	0.001092	0.006519	0.001942
Detection Prevalence	0.03465	0.011871	0.001177	0.008270	0.002611
Balanced Accuracy	0.95949	0.928919	0.890245	0.888540	0.844924

	Class: C15a	Class: C15b	Class: C15c	Class: C16a	Class: C16b
Sensitivity	0.8000000	0.756211	0.6990291	0.707104	0.8409091
Specificity	0.9999698	0.999415	0.9997786	0.998696	0.9998993
Pos Pred Value	0.8571429	0.807629	0.6206897	0.714917	0.8473282
Neg Pred Value	0.9999547	0.999208	0.9998440	0.998646	0.9998943
Prevalence	0.0002264	0.003239	0.0005181	0.004603	0.0006640
Detection Rate	0.0001811	0.002450	0.0003622	0.003254	0.0005583
Detection Prevalence	0.0002113	0.003033	0.0005835	0.004552	0.0006589
Balanced Accuracy	0.8999849	0.877813	0.8494038	0.852900	0.9204042

Figure 6. Visualization of the confusion matrix and statistics for each ecosystem class, obtained after running the C5 model.

2.4 With the accuracy values you may generate a graph that shows where the curve is stabilized with respect to the accuracy reached per partition, so that you can know what the minimum partition level appropriate to train the data is.

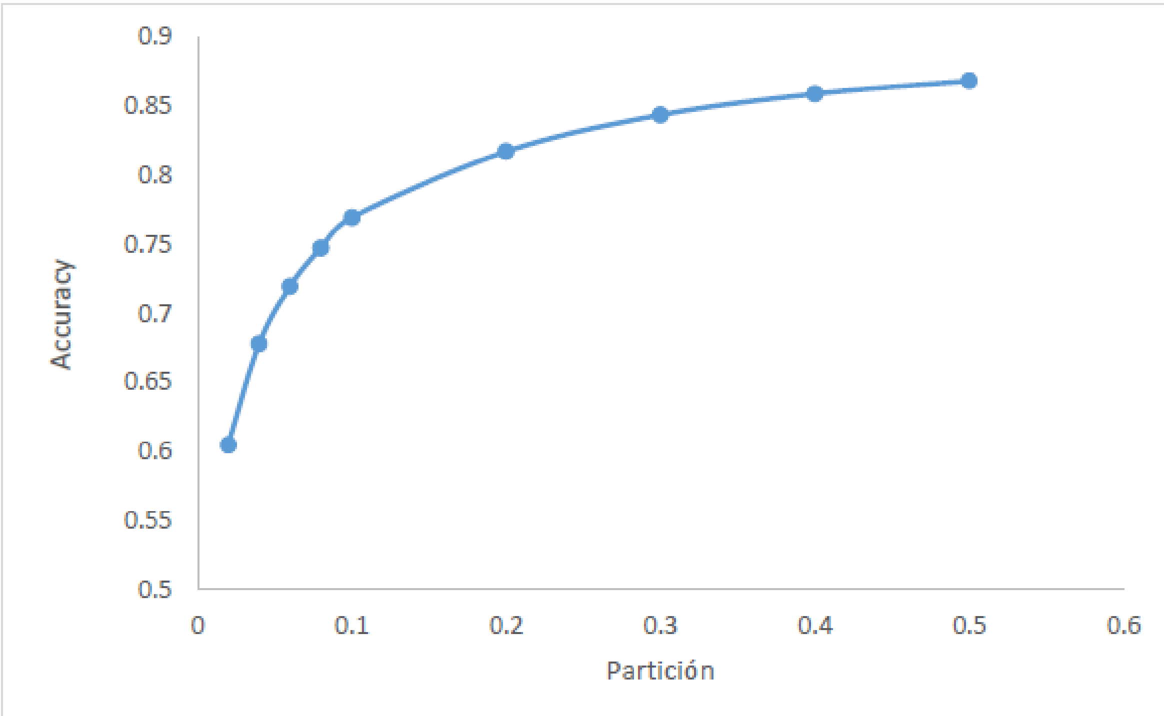


Figure 7. Accuracy stabilization curve of the models according to the partition.

3 The final step is the transformation of the results to Raster format in order to be able to visualize them.

```
library(raster)
library(rgdal)

Test02_Copy <- Test02[c(28,26,27)]
coordinates(Test02_Copy)<-Test02_Copy[c("POINT_X","POINT_Y")]
gridded(Test02_Copy) = TRUE
R02=raster(Test02_Copy)
writeRaster(R02, "Pred/Pred02.img", datatype= 'INT1U')
```

In Figures 8 and 9 you can see the results of the prediction of 2 and 5% of the data, where the background raster is the one that produced the model with the Test data, and the lines are

the limits of the potential map of ecosystems of the input. As you can see when analyzing the limits of the projected units, the 5% partition is the most accurate.

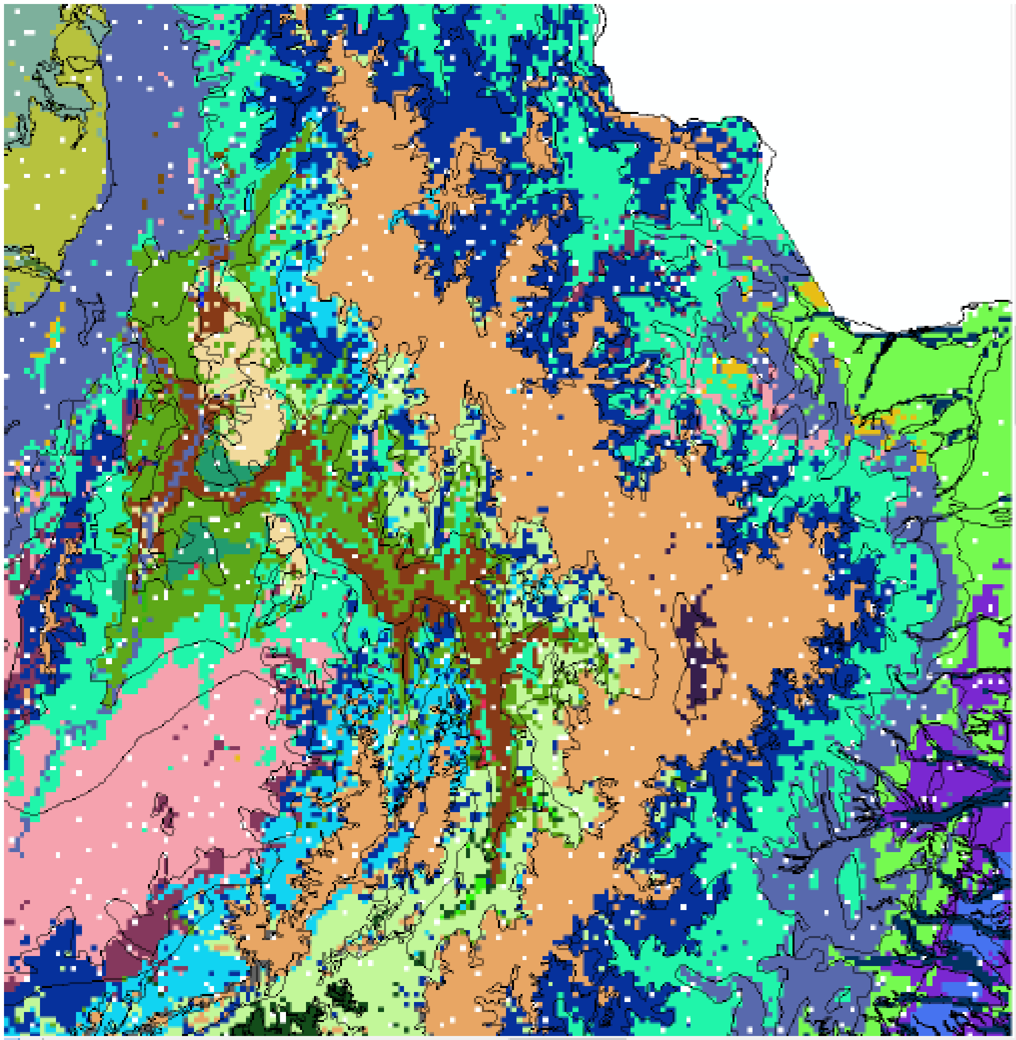


Figure 8. Raster of the reconstruction resulting from using the 2% partition for training.

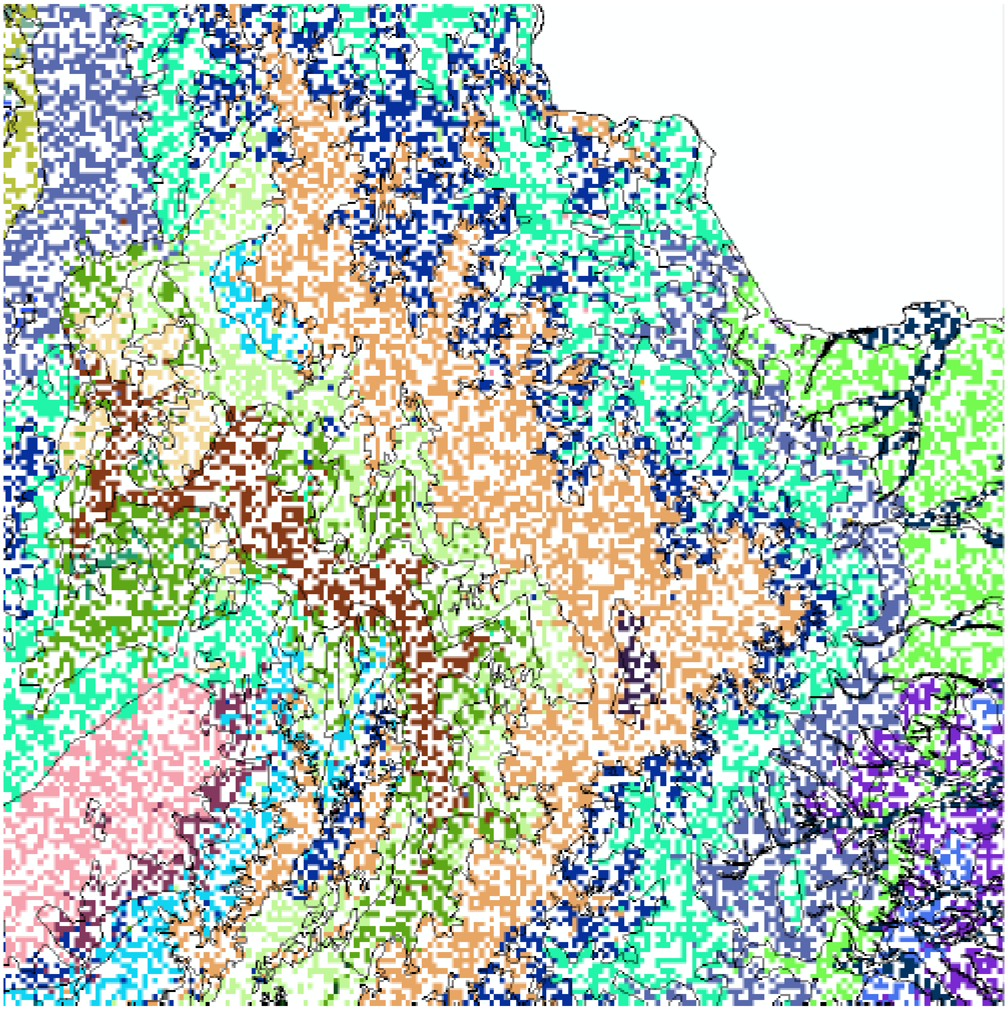


Figure 9. Raster of the reconstruction resulting from using the 2% partition for training.

Annex 2. Table of current processes and interactions that threaten ecosystems.

CODE	Biome	Physiognomy	Landscape	Current processes and interactions
ZBH-B1a	Zonobiome of Tropical Humid Forests	*High Dense Forests*	Ancient terraces of large rivers	Border expansion and agricultural intensification. Local degradation of soils by compaction and surface erosion
ZBH-B1b				Agricultural intensification, agricultural mechanization, high fragmentation
ZBH-B1c				Agricultural intensification, agricultural mechanization, high fragmentation. Deforestation and illicit crops
ZBH-B1d				
ZBH-B2a1			Slightly rolling erosional surfaces	Frontier expansion with pastures introduced for livestock (+ illicit crops). Local degradation of soils by compaction and surface erosion
ZBH-B2a2				
ZBH-B2b				
ZBH-B2c				
ZBH-B2d				Border expansion and agricultural intensification. Local degradation of soils by compaction and surface erosion
ZBH-B3a1			Strongly rolling erosional surfaces	Frontier expansion with pastures introduced for livestock (+ illicit crops). Local soil degradation due to severe erosion
ZBH-B3a2				Frontier expansion with pastures introduced for livestock (+ illicit crops). Local soil degradation due to severe erosion
ZBH-B3b				Frontier expansion with pastures introduced for livestock (+ Mining). Local soil degradation due to severe erosion
ZBH-B4a		*Half Dense Forests*	Sandy structural plains	-
ZBH-B4b			Slightly rolling residual sandy plains of the Guiana Shield	-
ZBH-B4c			Rolling residual sandy plains of the Guiana shield	-
ZBH-B4d			Heavily rolling residual sandy plains of the Guiana Shield	-
ZBH-B5		*Half Dense Forests*	Rolling erosional surfaces of the Llanera Highland Plains	Highland forest PLAINS; erosion due to concentrated runoff and localized laminar and wind erosion; Extensive livestock farming
ZBH-B6			Hillsides of the structural mountains of the Guiana shield	Illicit Crops, Mining, Hydrocarbon Exploration, Deforestation
ZBH-B7			Hills and Mountain Ranges	Deforestation
ZBsH-B8	Zonobiome of Tropical Sub-Humid Forest	*High Dense Forests*	Slightly rolling erosional surfaces	Expansion of agricultural frontier. Soil erosion due to livestock.

CODE	Biome	Physiognomy	Landscape	Current processes and interactions
ZBsH-B9			Heavily rolling hills and erosional surfaces	
ZBS-B10	**Zonobiome of the Tropical Dry Forests**	*High Dense Forests*	Ancient terraces and slightly rolling erosional surfaces	Livestock, agricultural mosaics. Soil degradation due to laminar erosion. Frequent burns
ZBS-B11		*Half Dense Forests*	Hills	Livestock, agricultural mosaics. Soil degradation due to laminar erosion. Frequent burns
ZBS-B12			Hills and Mountain Ranges	Soil degradation due to laminar and concentrated erosion
ZBS-B13		*Low forests and dense shrublands*	Slightly rolling erosional surfaces and hills	Soil degradation due to laminar erosion
ZD-A1	**Zonobiome of the Tropical Deserts**	*Open and succulent shrublands*	Slightly rolling erosional surfaces	Soil degradation due to goat grazing, deforestation, frequent burns, logging
ZD-A2			Rolling erosional surfaces	
ZD-A3		*Low open shrublands and desert areas*	Erosional surfaces with dunes	
P_ZBH-B14	**Pedobiomes of the Zonobiome of Tropical Humid Forests**	*Low dense sclerophyllous forests (high Amazonian Caatingas)*	Lightly rolling residual sandy plains of the Guiana shield	-
P_ZBH-B15		*Low forests and dense sclerophyllous shrublands (Middle Amazonian Caatingas)*		-
P_ZBH-S1		*Pastures (Amazonian campinas)*	Flat sandy concave residual sandy plains of the Guyanese shield	"Flor de Inírida" extraction
P_ZBH-A4		*Shrublands and Low Dense Sclerophyllous Forests*	Plateau summits of tables and structural hills of the Guiana shield	-
P_ZBH-S2		*Casmophyta and pastures*		-
P_ZBH-S3		*Herbaceous savannas and shrublands*	Ancient tilted terraces of the piedmont	Replacement of savannas by introduced pastures
P_ZBH-S4			Villavicencio-San Martin Piedmot Terraces	Removal. Replacement of savannas by introduced pastures and intensive agriculture (rice, African palm). Total suppression of fire
P_ZBH-S5			Flat highlands	Expansion of agricultural frontier with introduced pastures and intensive

CODE	Biome	Physiognomy	Landscape	Current processes and interactions
				agriculture of semi-annual crops. Soil degradation due to superficial erosion by mechanization and washing. Compaction and apparent reduction of infiltration with effects on hydrology. Suppression of fire.
P_ZBH-S6			Rolling highlands	Localized expansion of agricultural frontier with introduced pastures in mechanized areas. Exotic forest crops (*Acacia mangium*). Soil degradation due to superficial and concentrated erosion by mechanization and washing. Suppression of fire.
P_ZBH-S7			Sandy highlands with influence of the Guiana shield	Traditional extensive cattle breeding.
P_ZBH-S8			Piedmont dunes	
P_ZBH-S9			Alluvial floodplain and piedmont terraces	Expansion of agricultural frontier with introduced pastures and intensive agriculture of semi-annual crops. Soil degradation due to superficial erosion by mechanization and washing. Drainage of floodplain hydrology. Suppression of fire.
P_ZBH-S10			Alluvial/Aeolian plain of the piedmont	Expansion of agricultural frontier with introduced pastures and intensive agriculture of semi-annual crops. Suppression of fire.
P_ZBS-S11	**Pedo/Peinobiomes of the ZBST and BsHT**	*Herbaceous savannas with shrublands*	Ancient terraces and rolling plains	Expansion of agricultural frontier with introduced pastures and intensive agriculture of semi-annual crops. Soil degradation due to superficial erosion by mechanization and washing. Compaction and apparent reduction of infiltration with effects on hydrology. Suppression of fire.
P_ZBS-S12			Rolling plains	
O_ZBH-B16	**Orobiomes of the Zonobiome of Tropical Humid Forest**	*High Dense Forests*	Hills and sub-mountainous mountains of the Serranía de la Macarena	Expansion of the agricultural frontier with introduced pastures and colonization agriculture (+ illicit crops).
O_ZBH-B17			Hills and mountains of the Serranía de la Macarena	-
O_ZBH-B18		*Half Dense Forests*	Hills and mountains high mountains of the Serranía de la Macarena	Illicit crops
O_ZBH-B19a		*High Dense Forests*	Humid sub-Andean hills and mountains	Expansion of the agricultural frontier with introduced pastures and colonization agriculture (+ illicit crops). Soil degradation due to livestock (cow hooves and surface erosion). Expansion of

CODE	Biome	Physiognomy	Landscape	Current processes and interactions
				introduced pastures (*Melinis minutiflora, Brachiaria spp*.).
O_ZBH-B19b			Very humid sub-Andean hills and mountains	Mining, Expansion of the agricultural frontier
O_ZBH-B20a		*Half Dense Forests*	Humid Andean hills and mountains	Coffee belt. Semi-intensive dualpurpose cattle breeding. Soil degradation due to livestock (cow hooves and surface erosion). Expansion of introduced pastures (*Cynodon spp.*).
O_ZBH-B20b			Humid Andean hills and mountains	Coffee belt (Coffee)
O_ZBH-B21a			Humid high-Andean hills and mountains	Expansion of agricultural frontier with introduced pastures and colonization agriculture. Soil degradation due to livestock (cow hooves / livestock terraces). Expansion of introduced pastures (*Pennisetum clandestinum*).
O_ZBH-B21b			Very humid high-Andean hills and mountains	Expansion of the agricultural frontier with introduced pastures and colonization agriculture (+ illicit crops). Soil degradation due to livestock (cow hooves / livestock terraces). Expansion of introduced pastures (*Pennisetum clandestinum*).
O_ZBH-B21c			Sub-humid high-Andean hills and mountains	A stable agricultural frontier but with introduced pastures such as the Kikuyo (*Pennisetum clandestinum*). High frequency of forest fires. Coal mining.
O_ZBH-B21d			Humid to sub-humid high-Andean hills and mountains	A stable agricultural frontier but with introduced pastures such as the Kikuyo (*Pennisetum clandestinum*). Wood extraction. Soil degradation due to livestock (cow hooves / livestock terraces).
O_ZBH-B22			High Andean high plateau	Removal. Expansion of the agricultural frontier with introduced pastures such as the Kikuyo (*Pennisetum clandestinum*).
O_ZBH-S13		*Dense pastures and shrublands*	Very humid moor high-Andean hills and mountains (glacial origin)	Localized agriculture. Extensive cattle and sheep breeding. Soil degradation due to cattle trampling. Degradation and drying of peat bogs. Burns. Introduced pastures (*Anthoxantum odoratum* & *Holcus lanatus*)
O_ZBH-S14			Humin moor high-Andean hills and mountains	Localized agriculture. Extensive cattle and sheep breeding. Soil degradation due to cattle trampling. Degradation and drying of peat bogs. Burns. Coal mining. Contamination of water sources. Introduced pastures (*Anthoxantum odoratum & Holcus lanatus*)

CODE	Biome	Physiognomy	Landscape	Current processes and interactions
O_ZBH-S15		*Pastures*	Dry moor high-Andean hills and mountains	Extensive sheep breeding. Burns. Introduced pastures (*Anthoxantum odoratum & Holcus lanatus*)
O_ZBH-N		*Open grasslands and snow*	Super-moor high-Andean hills and mountains	Loss of glacier cover due to heating. Tourism and sheep and goat breeding.
O_ZBH-B23	**Zonal orobiomes of the Zonobiome of Humid Tropical Forest**	*Dense shallow forests and shrublands*	Dry Andean hills and mountains of intra-Andean valleys	Localized agriculture. Extensive sheep and goat breeding. Soil degradation due to trampling. Expansion/invasion of introduced grasses (*Melinis minutiflora*). Erosion in the shape of gullies
O_ZBH-A5		*Shrublands and dense cacti*		
O_ZBH-A6		*Xerophytic shrublands*	High Andean high plateau	Extensive sheep and goat breeding. Soil degradation due to trampling. Mining of construction materials. Agriculture (mixed crops). Water and Eolic erosion.
O_ZBH-S16		*Herbaceous savannas with shrublands*	High Andean high plateau	Agricultural intensification, agricultural mechanization, high fragmentation
O_ZBH-P1	**Helobiomes O_ZBH**	*Forests, grasslands and wetlands*	High Andean high plateau	Desiccation of wetlands, landfills; canalization of channels. Hydrological flow interruption. Severe organic and inorganic contamination.
He_ZBH-B24	**Helobiomes of the Zonobiome of Tropical Humid Forest**	*High Dense Forests and wetlands*	Alluvial floodplains of Andean rivers	Semi-permanent agricultural intensification, agricultural mechanization. Extraction of commercial woods.
He_ZBH-B25			"Catival" alluvial floodplain	Drainage and artificial desiccation; canalization of channels. Extraction of commercial woods. Semi-permanent agricultural intensification, agricultural mechanization.
He_ZBH-B26		*High Dense Forests*	Erosional alluvial plains of Andean rivers	Extraction of commercial woods. Deforestation for livestock and crops. Agricultural intensification with agricultural mechanization.
He_ZBH-B27			White water erosional alluvial plains	Extraction of commercial woods. Deforestation for livestock and crops.
He_ZBH-B28		*Half Dense Forests*	Clear water erosive alluvial plains	Localized coltan and gold mining.
He_ZBH-B29			Flat erosive alluvial plains	Wood extraction. Localized expansion of the agricultural frontier.
He_ZBS-B30		*Low forests and dense shrublands*	Blackwater erosive alluvial plains	Localized coltan and gold mining.
He_ZBH-B31		*Medium and Low Dense Forests*	"Morichales" erosional alluvial plains	Clogging of channels due to erosion of adjacent plains. Vegetation and soil degradation due to cattle trampling and "entry" of burns.

CODE	Biome	Physiognomy	Landscape	Current processes and interactions
He_ZBH-B32			Very humid fluvial-marine floodplains	Extraction of woods and resources such as "palmito" (*Euterpe oleracea*), "guandal" and "sajal". Hydrological alteration due to the construction of channels for wood extraction.
He_ZBH-P2		*Low forests, grasslands and floating vegetation*	Alluvial overflow plain	Wetlands draining to create roads for the transport of wood
He_ZD-B33	**Helobiome of the ZDT**	*Medium and Low Dense Forests*	Erosive alluvial torrential plains	Clogging of channels due to erosion of surrounding areas. Semi-permanent and permanent agriculture. Vegetation and soil degradation due to cattle trampling and "entry" of burns.
HE_ZBS-B34	**Helobiomes of the Zonobiome of Dry Tropical Forest**	*High and Medium Dense Forests*	Erosive alluvial plains	Localized gold mining. Extraction of commercial woods. Deforestation for livestock and crops.
He_ZBS-P3		*Low forests, grasslands and floating vegetation*	Alluvial floodplain	
He_ZBS-P4				Organic and inorganic contamination
Ha_ZBH-B35	**Halobiome of the ZBHT**	*Dense high mangrove forests*	Humid and very humid active marine and fluviomarine plains	Wood extraction.
Ha_ZBS-B36	**Halobiome of the ZBST**	*Dense low forests and mangrove shrublands*	Dry to subhumid active marine and fluviomarine plains	Wood extraction. Invasion with fillings and desiccation.
Water	**Hydrobiomes**	*Lakes, lagoons, permanent wetlands, and major riverbeds*	Depressions	Organic and inorganic contamination

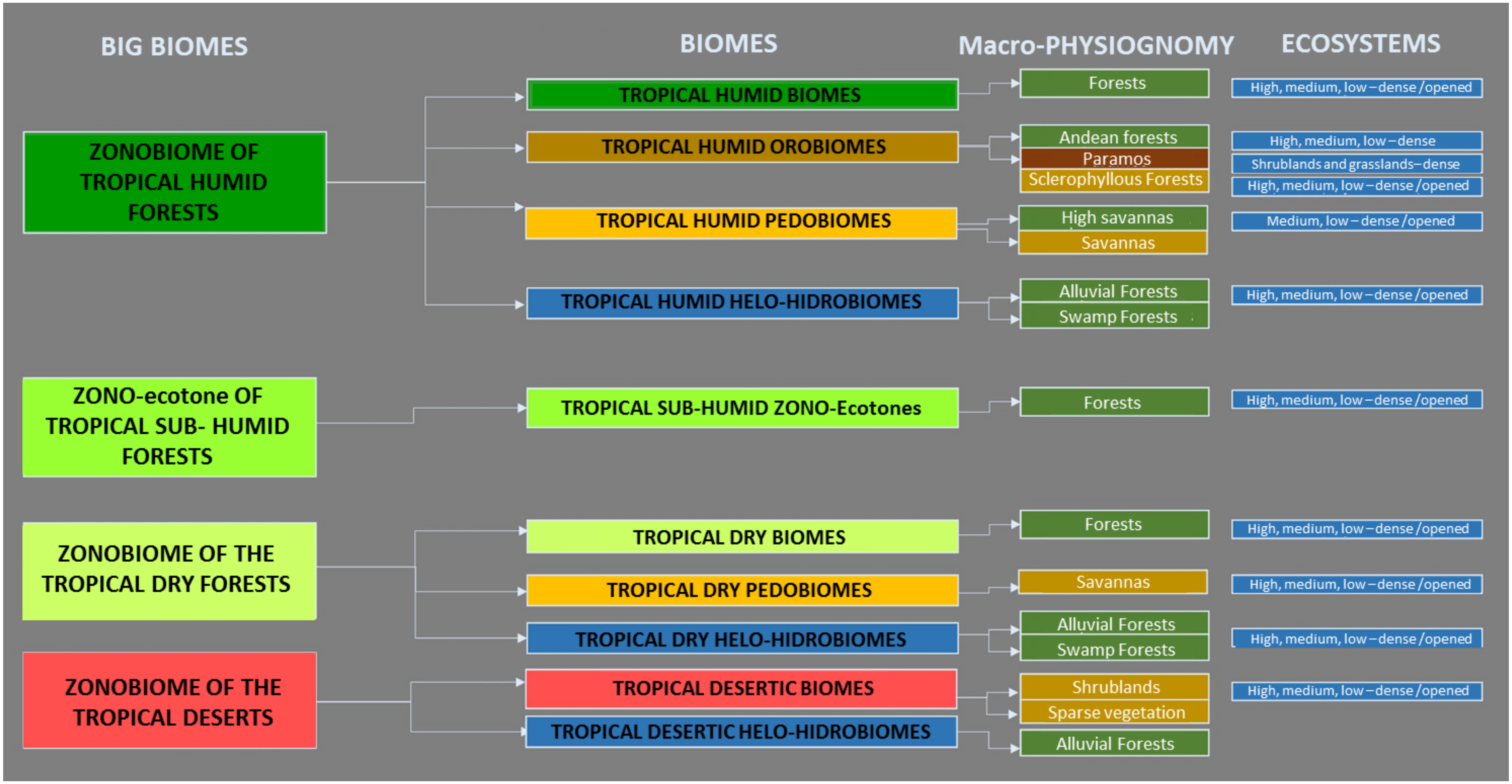
Annex 3. Species and processes used to inform changes in the distribution of biotic processes to assess criterion D.

	FAUNA SPECIES	FAMILY	FLORA SPECIES	FAMILY	PROCESS
BIRDS	*Aratinga weddellii*	Psittacidae	*Erythrina fusca*	Fabaceae	Pollination
	Anisognathus somptuosus	Thraupidae	*Aniba muca*	Lauraceae	Dispersion
	Arremon aurantiirostris	Emberizidae	*Urera caracasana*	Urticaceae	Dispersion
	Atlapetes schistaceus	Emberizidae	*Clusia multiflora*	Clusiaceae	Dispersion
	Aulacorhynchus haematopygus	Ramphastidae	*Miconia acuminifera*	Melastomataceae	Dispersion
	Brotogeris cyanoptera	Psittacidae	*Erythrina fusca*	Fabaceae	Pollination
	Capito niger	Capitonidae	*Palicourea lasiantha*	Rubiaceae	Dispersion
	Cotinga cayana	Cotingidae	*Hebepetalum humiriifolium*	Linaceae	Dispersion
	Dendroica fusca	Parulidae	*Miconia notabilis*	Melastomataceae	Dispersion
	Eubucco bourcierii	Capitonidae	*Miconia theaezans*	Melastomataceae	Dispersion
	Glaucis hirsuta	Throchilidae	*Besleria aggregata*	Besleriaceae	Pollination
			Costus scaber	Costaceae	
			Duroia hirsuta	Rubiaceae	
			Heliconia stricta	Heliconiaceae	
			Palicourea lasiantha	Rubiaceae	
			Psychotria platypoda	Rubiaceae	
	Ortalis columbiana	Cracidae	*Cupania latifolia*	Sapindaceae	Dispersion
			Eugenia florida	Myrtaceae	
			Miconia minutiflora	Melastomataceae	
			Miconia rubiginosa	Melastomataceae	
			Myrcia popayanensis	Myrtaceae	
			Ocotea aurantiodora	Lauraceae	
	Phaethornis atrimentalis	Throchilidae	*Psychotria poeppigiana*	Rubiaceae	Pollination
	Phaethornis bourcieri	Throchilidae	*Besleria aggregata*	Besleriaceae	Pollination
			Centropogon cornutus	Campanulaceae	
			Costus scaber	Costaceae	
			Duroia hirsuta	Rubiaceae	
			Heliconia stricta	Heliconiaceae	
			Psychotria poeppigiana	Rubiaceae	
	Phaethornis hispidus	Throchilidae	*Besleria aggregata*	Besleriaceae	Pollination
			Centropogon cornutus	Campanulaceae	
			Costus scaber	Costaceae	
			Duroia hirsuta	Rubiaceae	
			Heliconia stricta	Heliconiaceae	
			Palicourea lasiantha	Rubiaceae	
	Phaethornis malaris	Throchilidae	*Besleria aggregata*	Besleriaceae	Pollination
			Centropogon cornutus	Campanulaceae	
			Costus scaber	Costaceae	
			Duroia hirsuta	Rubiaceae	
			Erythrina fusca	Fabaceae	
			Heliconia stricta	Heliconiaceae	
			Palicourea lasiantha	Rubiaceae	
			Psychotria platypoda	Rubiaceae	
	Phaethornis ruber	Throchilidae	*Besleria aggregata*	Besleriaceae	Pollination
			Calathea altissima	Marantaceae	
			Psychotria poeppigiana	Rubiaceae	
	Pipra mentalis	Pipridae	*Densiflora clidemia*	Melastomataceae	Dispersion
	Pteroglossus azara	Ramphastidae	*Palicourea lasiantha*	Rubiaceae	Dispersion
	Pteroglossus pluricinctus	Ramphastidae	*Euterpe catinga*	Arecaceae	Dispersion
	Querula purpurata	Cotingidae	*Hebepetalum humiriifolium*	Linaceae	Dispersion
	Ramphastos tucanus	Ramphastidae	*Euterpe catinga*	Arecaceae	Dispersion

	FAUNA SPECIES	FAMILY	FLORA SPECIES	FAMILY	PROCESS
			Osteophloeum platyspermum	Myristicaceae	
	Tangara cyanicollis	Thraupidae	*Maclura tinctoria*	Moraceae	Dispersion
	Thraupis episcopus	Thraupidae	*Erythrina fusca*	Fabaceae	Pollination
	Thirteen leucurus	Throchilidae	*Duroia hirsuta*	Rubiaceae	Pollination
			Heliconia stricta	Heliconiaceae	
			Palicourea lasiantha	Rubiaceae	
INSECTS	*Danaus plexippus*	Nymphalidae	*Bidens pilosa*	Asteraceae	Pollination
	Heliconius clysonymus	Nymphalidae	*Bidens pilosa*	Asteraceae	Pollination
			Erato vulcanica	Asteraceae	
	Bombus rubicundus	Apidae	*Ageratina asclepiadea*	Asteraceae	Pollination
			Espeletia grandiflora	Asteraceae	
			Gaultheria anastomosans	Ericaceae	
			Gaultheria rigida	Ericaceae	
			Vaccinium meridionale	Ericaceae	
	Bombus funebris	Apidae	*Espeletia grandiflora*	Asteraceae	Pollination
			Gaultheria anastomosans	Ericaceae	
			Gaultheria rigida	Ericaceae	
	Euglossa mixed	Apidae	*Spathiphyllum friedrichsthalii*	Arecaceae	Pollination
	Eulaema meriana	Apidae	*Miconia serrulata*	Melastomataceae	Pollination
	Oxytrigone daemoniaca	Apidae	*Sabal mauritiiformis*	Arecaceae	Pollination
	Trigona angustula	Apidae	*Astrocaryum malybo*	Arecaceae	Pollination
			Euterpe precatoria	Arecaceae	
			Iriartea deltoidea	Arecaceae	
			Mimosa pigra	Fabaceae	
			Syagrus orinocensis	Arecaceae	
			Wettinia praemorsa	Arecaceae	
	Xylocopa frontalis	Apidae	*Crescentia cujete*	Bignoniaceae	Pollination
			Gliricidia sepium	Fabaceae	
			Handroanthus chrysanthus	Bignoniaceae	
			Hymenaea courbaril	Leguminosae	
			Miconia serrulata	Melastomataceae	
			Tabebuia rosea	Bignoniaceae	
	Cochliomyia macellaria	Calliphoridae	*Laguncularia racemosa*	Combretaceae	Pollination
PRIMATES	*Alouatta palliata*	Atelidae	*Brosimum alicastrum*	Moraceae	Dispersion
			Poulsenia armata	Moraceae	
	Alouatta seniculus	Atelidae	*Ficus insipida*	Moraceae	Dispersion
			Pseudolmedia laevis	Moraceae	
	Ateles belzebuth	Atelidae	*Coussapoa orthoneura*	Urticaceae	Dispersion
			Oenocarpus bataua	Arecaceae	
	Ateles geoffroyi	Atelidae	*Brosimum lactescens*	Moraceae	Dispersion
			Ficus insipida	Moraceae	
	Lagothrix lagotricha	Atelidae	*Brosimum lactescens*	Moraceae	Dispersion
			Pourouma bicolor	Urticaceae	
			Sorocea pubivena	Moraceae	
CHIROPTERA	*Artibeus lituratus*	Phyllostomidae	*Cecropia ficifolia*	Urticaceae	Dispersion
			Cecropia telenitida	Urticaceae	
			Ficus insipida	Moraceae	
			Solanum aphyodendron	Solanaceae	
			Vismia cayennensis	Hypericaceae	
			Vismia guianensis	Hypericaceae	
	Artibeus planirostris	Phyllostomidae	*Cecropia peltata*	Urticaceae	Dispersion
			Ficus obtusifolia	Moraceae	
			Ficus tonduzii	Moraceae	
			Piper peltatum	Piperaceae	
			Vismia cayennensis	Hypericaceae	

	FAUNA SPECIES	FAMILY	FLORA SPECIES	FAMILY	PROCESS
			Vismia guianensis	Hypericaceae	
	Carollia brevicauda	Phyllostomidae	*Cecropia ficifolia*	Urticaceae	Dispersion
			Piper aduncum	Piperaceae	
			Vismia guianensis	Hypericaceae	
	Carollia castanea	Phyllostomidae	*Piper arboreum*	Piperaceae	Dispersion
			Vismia baccifera	*Hypericaceae*	
	Carollia perspicillata	Phyllostomidae	*Cecropia ficifolia*	Urticaceae	Dispersion
			Cecropia peltata	Urticaceae	
			Maclura tinctoria	Moraceae	
			Myrcia popayanensis	Myrtaceae	
			Piper marginatum	Piperaceae	
			Vismia gracilis	Hypericaceae	
			Vismia cayennensis	Hypericaceae	
			Vismia guianensis	Hypericaceae	
	Glaucous derma	Phyllostomidae	*Piper marginatum*	Piperaceae	Dispersion
	Dermanura phaeotis	Phyllostomidae	*Cecropia obtusifolia*	Urticaceae	Dispersion
			Piper aduncum	Piperaceae	
			Solanum aphyodendron	Solanaceae	
	Sturnira lilium	Phyllostomidae	*Cecropia obtusifolia*	Urticaceae	Dispersion
			Ficus obtusifolia	Moraceae	
			Maclura tinctoria	Moraceae	
			Vismia cayennensis	Hypericaceae	
	Uroderma bilobatum	Phyllostomidae	*Cecropia obtusifolia*	Urticaceae	Dispersion
			Ficus obtusifolia	Moraceae	

Annex 4. Hierarchy of the classification of potential Colombian ecosystems.



Annex 5. Extended key of the ecosystem map.

CODE	CHARACTERISTIC NATIVE BIOTA	PHYSICAL ENVIRONMENT							REGION / DEPARTMENT	ORIGINAL ECOSYSTEM AREA (Ha)	REMAINING PROPORTION (2014)	REFEREN_ CES*
		Substratum	Average altitude (m)	Slope (%)	Minimum temperature (°C)	Maximum temperature (°C)	Average Temperature (°C)	Average annual precipitat ion (mm)				
ZBH-B1a	*Goupia glabra, Clathrotropis macrocarpa, Swartzia shomburgkii, Mezilaurus Dacryodes, Heterostemum, Virola callophyloidea, Oenocarpus sp*	Ancient alluvials of flat topography and infertile soils	130	2.24	19.92	32.19	26.93	3522	Amazon	1,507,550	0.93	3,4
ZBH-B1b	*Bombacopsis quinata, Pouteria anibaefolia, Attalea, Trichilia, Manilkara, Hymenaea, Pseudolmedia*	Ancient alluvials of flat topography and fertile soils	261	3.04	19.46	32.03	26.5	2413	Arauca, Meta (Villavicencio)/ Arauca, Casanare	1,413,013	0.42	
ZBH-B1c	*Cariniana pyriformis, Anacardium excelsum, Ceiba, Pseudosamanea, Maclura*		119	2.53	20.18	31.91	27.05	2288	Magdalena	507,163	0.17	
ZBH-B1d	*Anacardium excelsum, Cariniana pyriformis, Sterculia apetala, Vochysia lehmanii, Ceiba pentandra, Ochotereanea colombiana*		125	4.46	20.23	31.93	27.06	3130	Catatumbo	97,781	0.31	28
ZBH-B2a1	*Pseudolmedia, Dialium, Chrysophyllum, Macoubea, Lindacheria, Goupia glabra, Clathrotropis macrocarpa*	Very washed tertiary sediments of alluvial origin loamy to sandy	270	3.15	19.49	33.99	26.52	3141	Guaviare, Meta, Vaupés	10,321,644	0.79	3,27,49
ZBH-B2a2	*Pseudolmedia, Eschweilera, Matisia*		111	2.36	20.00	34.55	27	3297	Caquetá, Amazon	4,092,163	0.99	3,49
ZBH-B2b	*Hymenaea, Cariniana, Cochlospermum*		207	7.97	19.60	34.17	26.62	2534	Magdalena	1,213,663	0.29	
ZBH-B2c	*Eschweilera, Cavanillesia, Prioria, Dacryodes*		113	7.4	20.30	34.06	27.2	5450	Pacific	1,760,456	0.80	44,51

CODE	CHARACTERISTIC NATIVE BIOTA	PHYSICAL ENVIRONMENT							REGION / DEPARTMENT	ORIGINAL ECOSYSTEM AREA (Ha)	REMAINING PROPORTION (2014)	REFEREN_ CES*
		Substratum	Average altitude (m)	Slope (%)	Minimum temperature (°C)	Maximum temperature (°C)	Average Temperature (°C)	Average annual precipitation (mm)				
ZBH-B2d	*Anacardium excelsum, Gustavia hexapetala, Cariniana pyriformis, Sterculia apetala, Vochysia lehmanii, Ceiba pentandra*		210	14.75	19.51	34.40	26.46	3359	Catatumbo	300,838	0.55	28
ZBH-B3a1	*Brosimum, Lecythis, Oenocarpus, Protium, Cedrelinga, Swartzia, Clathrotropis, Pouteria*	Tertiary alluvial sediments loamy to sandy	201	3.43	19.83	34.77	26.85	3332	North Amazon	9,147,931	0.92	3,49
ZBH-B3a2	*Eschweilera, Virola, Cedrelinga*	Clayey fluviomarine tertiary sediments	109	3.01	20.00	34.16	27	3312	South Amazon	2,507,119	0.99	3,49
ZBH-B3b	*Anacardium, Cavanillesia, Manilkara*		223	15.37	19.81	35.00	26.77	6404	Pacific	2,549,400	0.90	44,51
ZBH-B4a	*Pseudolmedia laevigata, Irynathera ulei, , Phenakospermum guianensis, Annona excellens, Pourouma bicolor, Goupia glabra, Aphelandra macrostachya, Dendropanax arboreus, Attalea insignis*		305	2.52	19.50	35.00	26.55	3350	Guaviare, Vaupés	2,261,800	0.99	3,27,49
ZBH-B4b	*Leopoldinia piassaba, Virola, Qualea brevipedicellata, Protium paraense, Poraqueiba paraensis, Poraqueiba sericea, Xylopia, Euterpe caatinga, Hevea guianensis, Hevea pauciflora, Qualea paraensis*		146	2.07	20.00	34.88	27	3255	Guainía	513,675	0.96	10,11,27,28
ZBH-B4c	*Eperua leucantha, Eperua purpurea, Micrandra*		175	3.42	19.97	34.47	26.97	3329	Guainía, Vaupés	970,313	0.98	27,28

CODE	CHARACTERISTIC NATIVE BIOTA	PHYSICAL ENVIRONMENT							REGION / DEPARTMENT	ORIGINAL ECOSYSTEM AREA (Ha)	REMAINING PROPORTION (2014)	REFEREN_ CES*
		Substratum	Average altitude (m)	Slope (%)	Minimum temperature (°C)	Maximum temperature (°C)	Average Temperature (°C)	Average annual precipitation (mm)				
	spruceana, Gustavia pulchra, Monopteryx uaucu											
ZBH-B4d	*Eperua purpurea, Eperua leucantha, Clathrotropis macrocarpa, Oenocarpus bataua*		173	3.41	19.98	33.48	26.98	3428	Guainía, Vaupés	883,638	0.98	27,28
ZBH-B5	*Protium, Ficus, Caraipa, Xylopia, Nectandra, Bellucia, Aniba, Eugenia, Toccoca, Cupania, Phenakospermum*	Very washed tertiary sediments of alluvial origin	209	3.1	19.90	33.99	26.92	2624	Meta, Vichada	288,831	0.91	3,27,49
ZBH-B6	*Licania, Vochysia laxiflora, Manilkara bidentata, Bactris acantophora, Faramea, Iryanthera, Chrysophyllum, Roucheria punctata, Pouteria eugenifolia, Brosimum rubescens, Dryopteris patula.*	Acid igneous and metamorphic outcrops	251	7.5	19.44	35.00	26.47	3525	Caquetá, Guaviare, Vaupés	884,844	0.97	27,28
ZBH-B7	*Tapirira guinensis, Pachira sordida, Campnosperma gummifera, Xylopia aromatica, Psychotria cardiomorphis, Aspidosperma, Protium, Humiria, Clusia columnaris, Selaginella*		313	20.07	18.94	34.66	25.98	4229	Chocó and Antioquia	959,100	0.93	44,51
ZBsH-B8	*Bursera, Brosimum, Vochysia, Lindackeria, Cochlospermum*	Very washed tertiary sediments of alluvial origin	166	4.63	20.42	34.04	27.29	2852	The Caribbean and Antioquia	148,388	0.18	16,50
ZBsH-B9	*Bursera, Brosimum, Vochysia, Lindackeria, Cochlospermum*		149	6.77	20.05	33.91	26.95	2813	The Caribbean and Antioquia	764,619	0.16	16,50

CODE	CHARACTERISTIC NATIVE BIOTA	PHYSICAL ENVIRONMENT							REGION / DEPARTMENT	ORIGINAL ECOSYSTEM AREA (Ha)	REMAINING PROPORTION (2014)	REFEREN_ CES*
		Substratum	Average altitude (m)	Slope (%)	Minimum temperature (°C)	Maximum temperature (°C)	Average Temperature (°C)	Average annual precipitation (mm)				
ZBS-B10	*Cavanillesia, Bursera, Bombacopsis, Spondias, Meliccocus, Pithecellobium dulce, Enterolobium cyclocarpum, Gazuma*	Basic tertiary sediments of fluvial and alluvial origin	248	2.76	19.45	33.91	26.45	1369	Caribbean	3,099,488	0.06	7, 9, 16, 23, 29, 30, 31, 40, 41, 42, 43, 50, 59
ZBS-B11	*Senna reticulata, Gliricidia sepium, Senna obtusifolia, Platymiscium pinnatum, Senna occidentalis*	Tertiary sediments of marine origin (limestones and arcillolites)	259	7.48	19.34	33.91	26.33	1388		3,514,813	0.05	
ZBS-B12	*Guazuma ulmifolia, Ochroma pyramidale, Pithecellobium dulce, Enterolobium cyclocarpum,Indigofera suffruticosa*		771	26.22	16.34	21.61	23.6	1433		1,987,650	0.11	
ZBS-B13	*Prosopis, Bursera, Caesalpinia, Libidibia, Poponax*	Basic tertiary sediments of fluvio-marine and alluvial origin	58	2.05	20.62	27.81	27.49	606	Caribbean	432,094	0.77	
ZD-A1	*Capparis odoratissima, Prosopis juliflora, Acanthocereus sicariguensis, Cereus*	Sediments of fluvio-marine, alluvial and wind origin	79	2.8	20.57	34.86	27.49	315		562,950	0.90	5, 13, 34, 45, 55, 56
ZD-A2	*Acanthocereus tetragonus, Cercidium, Capparis odoratissima, Libidibia, Acacia farnesiana, Opuntia spp, Melocactus spp, Aspidosperma polyneura, Bulnesia carrapo, Maclura tinctoria, Pithecellobium dulce, Prosopis juliflora*		443	5.19	18.20	32.91	25.33	1054		43,013	0.01	

CODE	CHARACTERISTIC NATIVE BIOTA	PHYSICAL ENVIRONMENT							REGION / DEPARTMENT	ORIGINAL ECOSYSTEM AREA (Ha)	REMAINING PROPORTION (2014)	REFEREN_ CES*
		Substratum	Average altitude (m)	Slope (%)	Minimum temperature (°C)	Maximum temperature (°C)	Average Temperature (°C)	Average annual precipitation (mm)				
ZD-A3	*Castella, Cereus,Calotropis procera, Prosopis juliflora*	Aeolian sediments	48	1.78	19.89	33.54	26.53	249		150,700	1.00	
P_ZBH-B14	*Compsoneura debilis, Protium heptaphyllum, Humiria balsamifera, Pithecellobium claviflorum, Cybianthus spicatus, Macrolobium, Pachira, Aldina latifolia, Pleonotma*	Residual peneplain with sands on granite	211	3.17	19.91	34.59	26.92	3359	Guainía, Vaupés	314,544	0.99	3, 27, 49
P_ZBH-B15	*Aspidosperma spruceanum, Aldina discolor, Mauritia carana, Retiniphyllumschomburgkii, Dimorphandra cupre, Anthurium bonplandii*		164	2.65	19.99	33.99	26.99	3184	Guainía	3,466,706	0.97	3, 27, 49
P_ZBH-S1	*Schoenocephalium martianum (flor de Inírida), Annona, Borreria, Clusia, Ormosia*		128	1.95	20.00	34.30	27	3091	Guainía	577,981	0.86	3, 27, 49
P_ZBH-A4	*Bonettia martiana, Gongylolepis martiana, Protium heptaphyllum, Clusia, Ormosia, Rodognaphalopsis, Byrsonima amoena, Hevea nitida*	Cretaceous sandstones and meta-sandstones	310	9.44	18.94	33.59	25.99	3521	Caquetá, Guaviare, Vaupés	377,638	0.93	3, 27, 49
P_ZBH-S2	*Vellozia tubiflora, Navia , Acanthella sprucei, Lagenocarpus pendulus, Macairea thrysiflora, Monotrema artrophyllum, Bulbostyilis, Cladonia*		329	7.01	18.99	17.54	26.03	3437	Caquetá, Guaviare, Vaupés	476,750	0.89	3, 27, 49

CODE	CHARACTERISTIC NATIVE BIOTA	PHYSICAL ENVIRONMENT							REGION / DEPARTMENT	ORIGINAL ECOSYSTEM AREA (Ha)	REMAINING PROPORTION (2014)	REFEREN_ CES*
		Substratum	Average altitude (m)	Slope (%)	Minimum temperature (°C)	Maximum temperature (°C)	Average Temperature (°C)	Average annual precipitat ion (mm)				
P_ZBH-S3	*Paspalum, Andropogon, Bulbostylis, Curatella, Byrsonima*	Quaternary ancient alluvial sediments loamy to sandy	313	3.82	19.15	27.56	26.2	2626	Casanare	134,531	0.42	36, 47, 39
P_ZBH-S4	*Trachypogon, Andropogon, Axonopus, Panicum*		349	1.58	18.92	33.65	25.97	2745	Meta	269,075	0.14	12, 47
P_ZBH-S5	*Trachypogon, Axonopus, Panicum, Paspalum, Leptocoryphium*	Tertiary alluvial sediments loamy to sandy partially covered with aeolian silt	116	1.08	20.00	33.73	27	2522	Meta, Vichada	2,595,956	0.78	12, 47
P_ZBH-S6	*Paspalum, Andropogon, Bulbostylis, Trachypogon*		187	2.17	19.82	33.60	26.84	2598	Meta, Vichada	4,755,519	0.91	12, 47
P_ZBH-S7	*Trachypogon, Leptocoryphium, Bulbostylis, Byrsonima, Curatella*	Residual peneplain with sands on granite and tertiary sandy sediments	69	1.39	20.05	35.00	27	2530	Vichada	740,481	0.97	12, 47
P_ZBH-S8	*Paspalum, Andropogon, Byrsonima, Curatella*	Quaternary sandy wind sediments	105	0.77	20.00	35.00	27	2033	Casanare, Arauca	69,869	0.98	35, 36
P_ZBH-S9	*Paspalum, Andropogon, Leersia*	Loamy to sandy quaternary alluvial sediments	163	0.65	19.93	34.45	26.94	1860	Casanare, Arauca	2,034,981	0.86	36, 47, 39
P_ZBH-S10	*Andropogon, Mesosetum, Byrsonima, Curatella*	Alluvial sediments covered with eolian silt	123	0.5	19.99	34.99	26.99	2030	Casanare, Arauca	1,883,406	0.93	35, 36
P_ZBS-S11	*Trachypogon, Andropogon, Byrsonima, Miconia*	Quaternary ancient alluvial sediments loamy to sandy	79	2.12	20.46	34.99	27.32	1914	The Caribbean, Magdalena	362,569	0.79	16, 50
P_ZBS-S12	*Andropogon, Trachypogon, Cereus, Acrocomia, Byrsonima, Curatella*		108	1.47	20.53	34.77	27.24	1424	The Caribbean, Magdalena	179,919	0.72	16, 50
O_ZBH-B16	*Roucheria, Anacardiaceae, Lauraceae, Fabaceae*	Cretaceous sediments and metamorphic rocks	1647	21.43	16.58	31.13	23.8	1685	Meta	118,150	0.92	47

CODE	CHARACTERISTIC NATIVE BIOTA	PHYSICAL ENVIRONMENT							REGION / DEPARTMENT	ORIGINAL ECOSYSTEM AREA (Ha)	REMAINING PROPORTION (2014)	REFEREN_CES*
		Substratum	Average altitude (m)	Slope (%)	Minimum temperature (°C)	Maximum temperature (°C)	Average Temperature (°C)	Average annual precipitation (mm)				
O_ZBH-B17	*Cariniana,Brosimum utile, Billia, Eschweilera sessilis*		2046	15.7	17.44	34.92	24.58	2654	Meta	73,244	0.99	47
O_ZBH-B18	*Weinmannia, Ocotea*		2660	19.45	17.27	34.59	24.49	2698	Meta	17,294	0.99	47
O_ZBH-B19a	*Cedrela odorata, Dendropanax,*		703	26.01	17.17	34.53	24.35	3560	Andes	2,886,994	0.70	2, 4
O_ZBH-B19b	*Billia rosea, Ficus gigantosyce*		632	27.83	17.20	31.37	24.38	2638	Andes, Sur de Bolivar, Sierra Nevada de Santa Marta	3,365,144	0.46	2, 4
O_ZBH-B20a	*Ocotea,Cinchona, Ceroxylon*		1602	34.89	11.72	34.63	19.37	2857	Andes	4,516,450	0.49	2, 4
O_ZBH-B20b			1461	35.28	12.03	34.81	19.65	1983	Andes, Southwest of Guajira and Sierra Nevada de Santa Marta	5,099,881	0.37	2, 4
O_ZBH-B21a	*Weinmania, Ocotea, Hedyosmum, Brunellia, Cedrela*		2381	37.93	6.40	34.92	14.5	2229	Andes	2,613,831	0.62	2, 4
O_ZBH-B21b			2525	37.84	5.92	26.88	14.05	1786	Andes and Sierra Nevada de Santa Marta	3,022,781	0.50	2, 4
O_ZBH-B21c	*Weinmania, Cedrela montana, Nectandra/Ocotea, Bilia,*		2711	25.87	4.86	27.15	13.06	1095	Andes	969,100	0.22	2, 4
O_ZBH-B21d	*Quercus humboltii, Colombobalanus excelsa, Podocarpus, Magnolia spp, Genoma, Aniba, Cinchona, Nectandra, Clethra,*		2745	34.57	5.10	22.13	13.28	1694	Andes	519,219	0.69	2, 4
O_ZBH-B22	*Ilex kunthiana, Vallea stipularis, Solanum ovalifolium, Myrcianthes leucoxyla, Cedrela montana, Myrica*	Andic Dystrudepts and Pachic Melanudands	2514	5.46	5.82	21.69	13.89	869	Cundinamarca, Boyacá	192,081	0.01	60

CODE	CHARACTERISTIC NATIVE BIOTA	PHYSICAL ENVIRONMENT							REGION / DEPARTMENT	ORIGINAL ECOSYSTEM AREA (Ha)	REMAINING PROPORTION (2014)	REFEREN_ CES*
		Substratum	Average altitude (m)	Slope (%)	Minimum temperature (°C)	Maximum temperature (°C)	Average Temperature (°C)	Average annual precipitat ion (mm)				
O_ZBH-S13	*Espeletia, Swallenochloa chusquea, Aragoa, Espeletia dugandii, Espeletia estanislana, Espeletia pescana*		3349	35.85	0.74	34.92	8.57	1685	Andean	863,394	0.88	6, 18, 25, 48, 58
O_ZBH-S14	*Espeletia, Aragoa, Espeletia dugandii, Espeletia estanislana, Espeletia pescana*		3356	36.04	1.06	34.93	8.87	1731	Andean	1,187,900	0.67	
O_ZBH-S15	*Espeletiopsis, Calamagrostis effusa, Espeletiopsis petiolata, Espeletiopsis tibamoensis y Espeletiopsis sclerophylla*		3244	25.62	1.46	16.34	9.8	1203	Andean	161,713	0.71	
O_ZBH-N	*Calamagrostis, Senecio, Lycopodium*		4295	42.67	0.00	33.54	3.4	1665	Andean	78,094	1.00	25
O_ZBH-B23	*Pithecellobium, Prosopis, Gyrocarpus, Randia, Zanthoxylum fagara, Acalypha schiedeana, Tabebuia chrysantha, Bursera graveolens*		1405	21.6	12.72	20.72	20.28	1421	Boyacá, Santander	351,369	0.14	45, 56
O_ZBH-A5	*Cestrum, Senna, Cordia, Cercidium, Stenocereus cf. griseus, Opuntia tunicata, Melochia, Mammillaria colombiana, Ceratozamia*		1915	37.11	9.50	24.91	17.33	1153	Boyacá, Santander	349,338	0.11	
O_ZBH-A6	*Dodonaea viscosa, Salvia bogotensis, Fourcraea, Agave spp, Opuntia schumannii, Wigginsia vorwerkiana, Caesalpinia spinosa, Aristida adscensionis, Tillandsia suescana*		2541	18.05	5.62	21.42	13.76	816	Cundinamarca, Boyacá	59,744	0.03	

CODE	CHARACTERISTIC NATIVE BIOTA	PHYSICAL ENVIRONMENT							REGION / DEPARTMENT	ORIGINAL ECOSYSTEM AREA (Ha)	REMAINING PROPORTION (2014)	REFEREN_ CES*
		Substratum	Average altitude (m)	Slope (%)	Minimum temperature (°C)	Maximum temperature (°C)	Average Temperature (°C)	Average annual precipitation (mm)				
O_ZBH-S16	*Trachypogon, Andropogon, Palicourea rigidifolia*		1301	20.81	12.49	16.63	20.09	1146	Santander	47,744	0.17	
O_ZBH-P1	*Salix, Alnus, Schoenoplectus californicus, Juncus effusus, Typha latifolia, Polypogon elongatum, Lemna minor, Eichornia crassipes, Hydrocotile ranunculoides, Pennisetum clandestinum, Rumex conglomeratus.*		2489	4.14	5.57	34.85	13.76	1044	Cundinamarca, Boyacá and Nariño	628,569	0.15	18
He_ZBH-B24	*Theobroma obovatum, Pouteria, Oxandra, Pouruma, Endlicheria, Parkia multijuga, Swartzia cardiosperma, Guarea purusana, Inga spectabilis, Astrocaryum aculeatum, Sorocea*		118	1.49	20.22	20.94	27.2	2224	Andes, Hydrographic Basins	1,709,975	0.51	
He_ZBH-B25	*Prioraria copaifera, Lecythis tuyrana, Castilloa elastica, Anacardium excelsum, Terminalia lucida, Carapa guianensis, Pterocarpus officinalis, Gustavia nana, Tabernaemontana chocoensis, Brosimun alicastrum*		59	1.4	20.99	21.46	27.98	3617	Chocó	494,963	0.52	44
He_ZBH-B26			219	2.29	19.71	34.25	26.73	3009	Hydrographic Basins of the Orinoquia and Amazon Regions	3,042,525	0.76	

CODE	CHARACTERISTIC NATIVE BIOTA	PHYSICAL ENVIRONMENT							REGION / DEPARTMENT	ORIGINAL ECOSYSTEM AREA (Ha)	REMAINING PROPORTION (2014)	REFEREN_ CES*
		Substratum	Average altitude (m)	Slope (%)	Minimum temperature (°C)	Maximum temperature (°C)	Average Temperature (°C)	Average annual precipitat ion (mm)				
He_ZBH-B27			139	6.19	20.52	34.44	27.43	6039	Watersheds of the Pacific Region	432,344	0.73	44, 51
He_ZBH-B28	*Macrolobium, Didymicistus chrysadenius, Licania longistyla, Cynometra, Euterpe precatoria, Eschweilera, Mabea, Strychnos, Gustavia, Olyra*		165	2.71	19.90	34.38	26.91	3255	Amazon	2,761,313	0.89	3, 8, 49
He_ZBH-B29	*Caraipa llanorum, Guatteria, Mauritia flexuosa, Protium,Pithecellobium, Eugenia, Olyra*		118	2.06	20.01	34.80	26.99	2667	Meta, Vichada	601,281	0.95	
He_ZBH-B30	*Gustavia, Vochysia, Acosmium, Roupala, Minquartia, Miconia, Myrcia*		171	2.93	19.94	34.72	26.95	3338	Amazon	959,500	0.94	3, 8, 49
He_ZBH-B31	*Mauritia, Guatteria, Caraipa, Protium, Erithroxylon, Psychotria*		150	1.97	19.96	34.39	26.96	2512	Orinoquia	1,600,431	0.94	33, 46
He_ZBH-B32	*Mora megistosperma, Campnosperma panamensis, Otoba gracilipes, Euterpe cuatrecasana*		29	3.28	20.83	35.00	27.76	4489	Pacific	471,963	0.86	44,51
He_ZBS-P2	*Montrichardia arborescens, Nypa, Blechnum serrulatum, Acrostichum aereum, Scleria secans, Scleria melaleuca*	Alluvial sediments	13	0.57	21.00	34.77	28	3041	Chocó	37,592	0.35	44, 51, 53, 54
He_ZD-B33	*Pithecellobium, Guazuma, Ficus*		52	1.27	20.61	34.13	27.45	616	Guajira	133,538	0.51	56
He_ZBS-B34	*Anacardium, Cavanillesia, Manilkara*		233	4.7	19.63	35.00	26.59	1862	Caribbean	507,950	0.14	16, 50

CODE	CHARACTERISTIC NATIVE BIOTA	PHYSICAL ENVIRONMENT							REGION / DEPARTMENT	ORIGINAL ECOSYSTEM AREA (Ha)	REMAINING PROPORTION (2014)	REFEREN_ CES*
		Substratum	Average altitude (m)	Slope (%)	Minimum temperature (°C)	Maximum temperature (°C)	Average Temperature (°C)	Average annual precipitation (mm)				
He_ZBS-P3			27	1.02	20.92	34.74	27.88	2174	Caribbean	558,988	0.11	16, 50
He_ZBS-P4	*Eichornia crassipes, Pistia stratiotes, Lemna sp, Wolffia sp, Tonina fluviatilis, Najas arguta*		28	0.99	20.90	11.25	27.87	2142	Caribbean	36,031	0.14	16, 50, 52
Ha_ZBH-B35	*Pellicera rhizophorae, Mora megitosperma, Rizophora mangle, Laguncularia racemosa, , Conocarpus erectus, Avicennia germinans*		6	2.6	20.68	34.58	27.57	4995	Pacific	414,213	0.88	44, 51
Ha_ZBS-B36	*Rizophora mangle, Avicennia germinans, Conocarpus erectus, Laguncularia racemosa*		12	1.12	20.09	34.23	26.78	1082	Caribbean	139,069	0.56	16, 50
Water			188	4.02	19.38	33.38	26.22	2719		1,942,056	0.66	

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Annex 6. Protocol for using the **EcoRedList_Toolbox**

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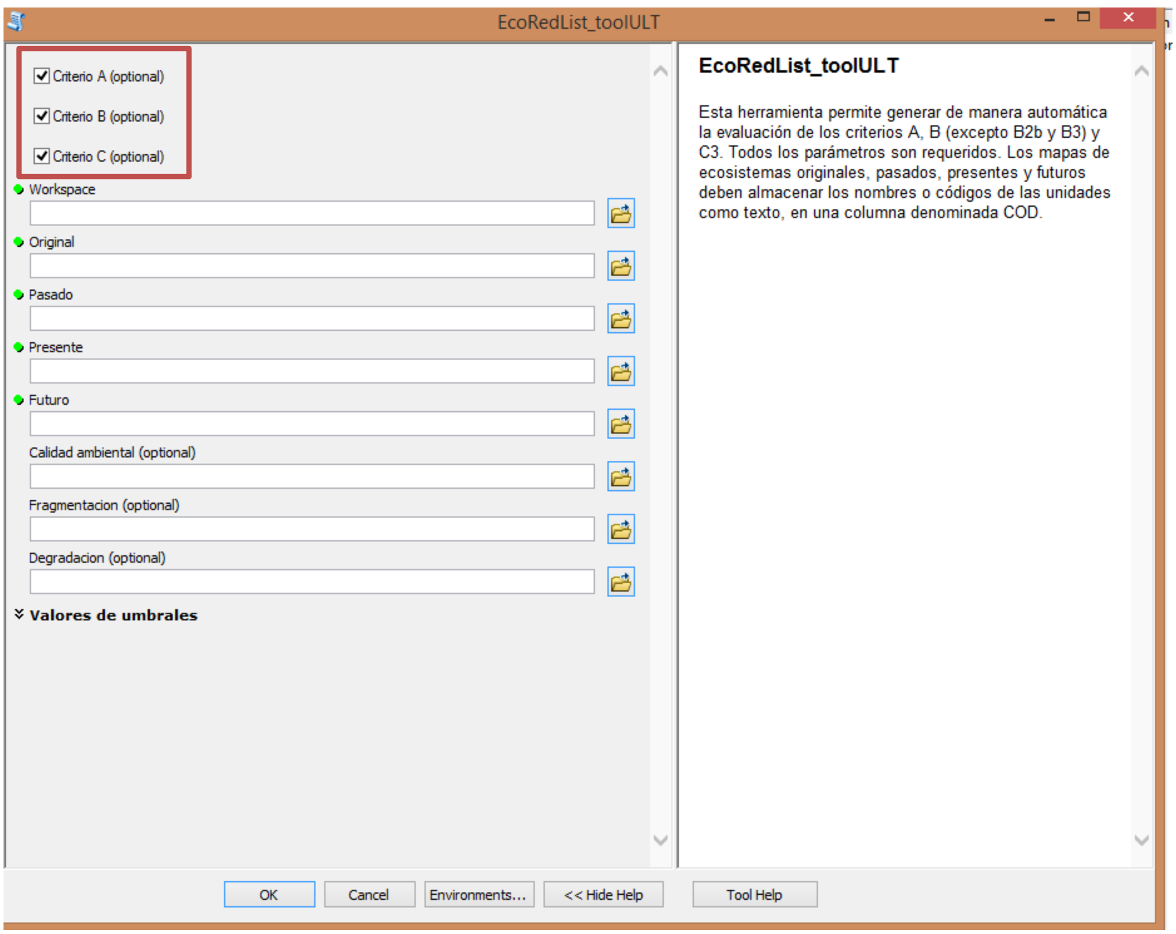
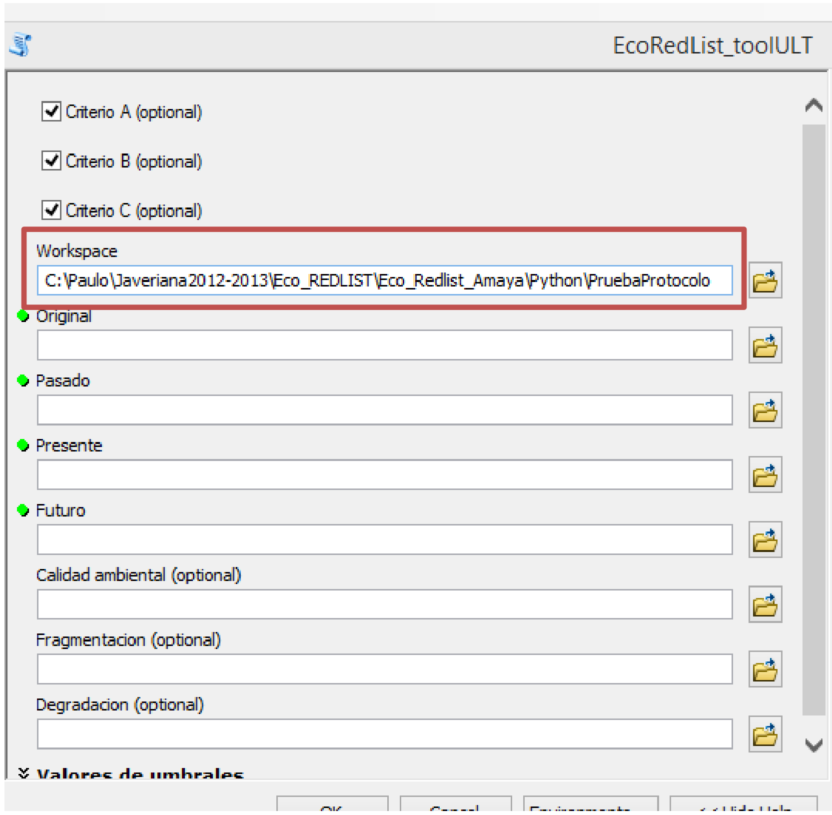
1. Open the tool from the Toolbox, and the following main screen will appear. Check the boxes of the criteria you wish to assess.

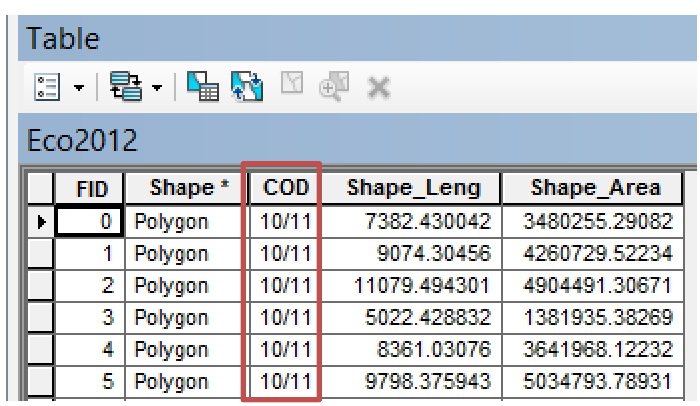


2. In the workspace box you must load the address where you want to obtain the results, which must be the same where the input files are. All the files must be in the same address.



General view of the EcoRedList_Toolbox tool with specification of the Workspace box.

3. All input files (Original, Past, Present and Future) must contain a column containing the ecosystems' codes and the column must be called COD. In the shp, the areas of each polygon must have been calculated, the column must be called Shape_Area.



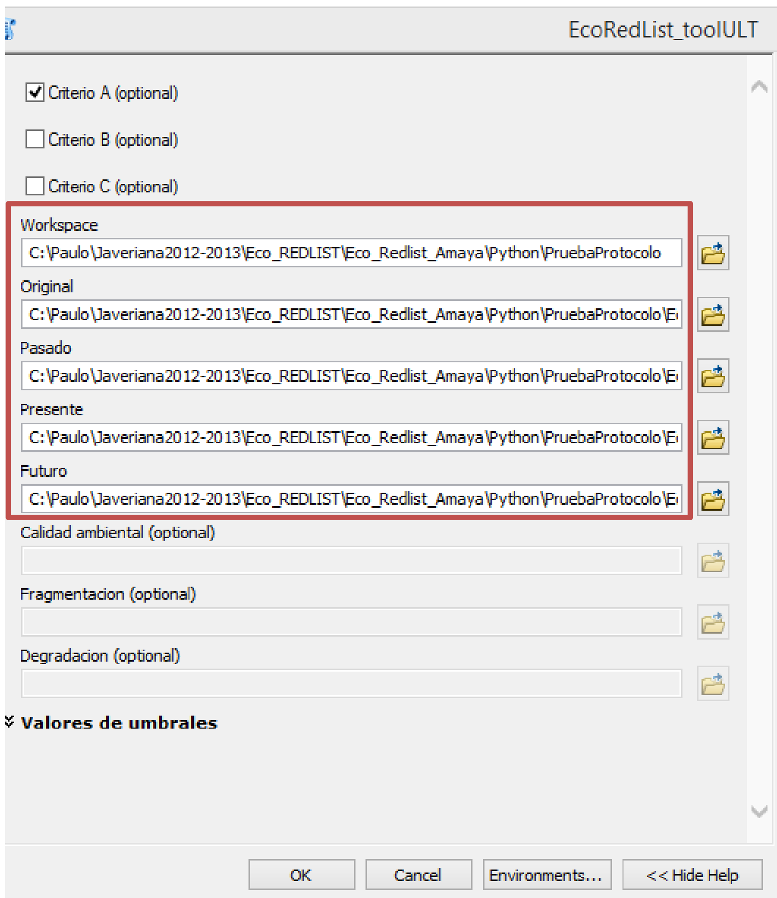
Table

Eco2012

FID	Shape *	COD	Shape_Leng	Shape_Area
0	Polygon	10/11	7382.430042	3480255.29082
1	Polygon	10/11	9074.30456	4260729.52234
2	Polygon	10/11	11079.494301	4904491.30671
3	Polygon	10/11	5022.428832	1381935.38269
4	Polygon	10/11	8361.03076	3641968.12232
5	Polygon	10/11	9798.375943	5034793.78931

Table of attributes that a column called COD should contain.

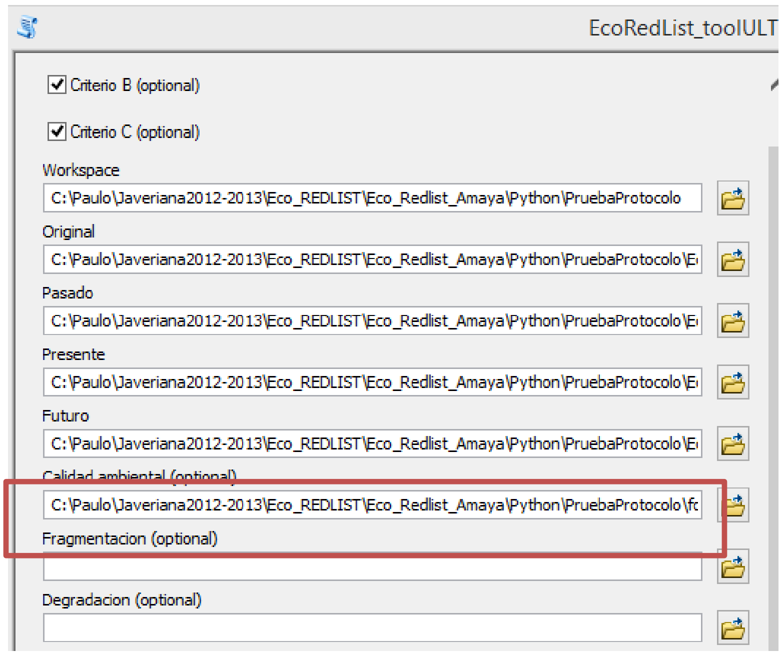
4. Then the following layers must be loaded:
   - Shapefile (shp) file with the original potential ecosystem units (1750).
   - Shp file with the remaining ecosystem units in a period comprised in the last 50 years. (e.g. 1990).
   - Shp file with the current or most recent remaining ecosystem units (eg 2012).
   - shp file with the ecosystems units projected in a period of maximum 50 years in the future (for example 2030)



Visualization of the EcoRedList_Toolbox tool with specification of the introduction of the Original, Past, Present and Future layers.

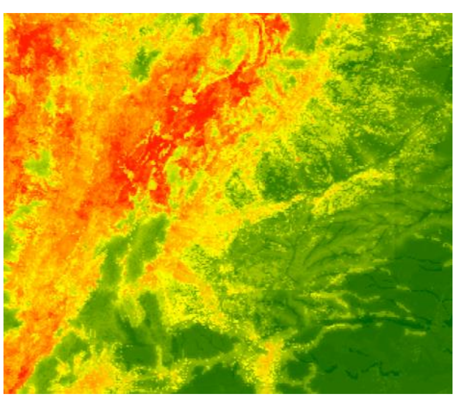
*Having loaded these files, you can already assess criterion A, press OK.

5. If you wish to assess criteria B and C you must add other input files. Enter an shp file that is a measure of environmental quality (parameter required for the assessment of criterion B).



View of the EcoRedList_Toolbox tool with specification of the introduction of the environmental quality layer.

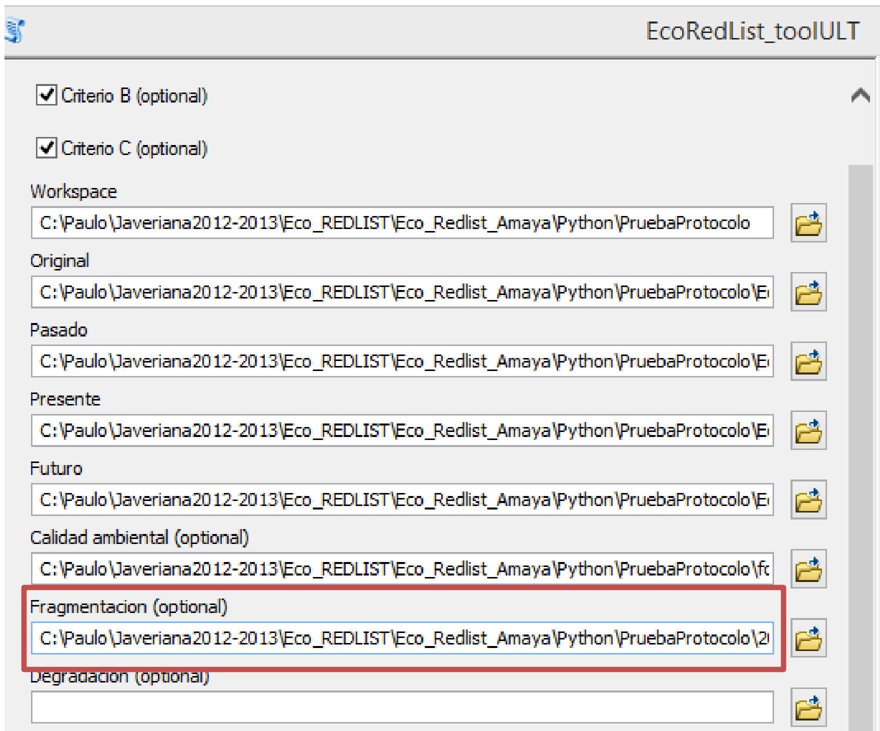
In the case of Colombia, the human fingerprint shp was used. The file must be in a raster format with an index of the human footprint level (or a measure of environmental quality) for the entire extension of the assessed area. The values must be on a scale from 0 to 100, where 0 corresponds to areas without human footprint (for example untransformed areas), and 100 corresponds to completely transformed areas. The image shows what the shp and the human footprint table in Colombia look like.



Rowid	VALUE *	COUNT
18	33	4354
19	34	4337
20	36	4006
21	37	3808
22	38	3964
23	40	3814
24	41	4063
25	42	4284
26	44	4706
27	45	4945
28	46	5228
29	48	5536

View of the human fingerprint layer.

6. Enter a shp file that is a measure of the alteration of biotic interactions (parameter required for the assessment of criterion B).



Visualization of the EcoRedList_Toolbox tool with specification of the introduction of the fragmentation layer.

Annex 7. Relation between the Key Biodiversity Areas and the threat categories of the Final Risk Assessment of the Ecosystems.

N°	KBA Name	KBA Area(ha)	Proportion of transformed area	Proportion of KBA área in PNN	Proportion of KBA in other public and private areas	Proportion of KBA in CR	Proportion of KBA in EN	Proportion of KBA in VU
1	Reserva Natural El Garcero y Alrededores	17,437	0.90	0.00	0.02	0.00	0.00	0.00
2	Eco-Parque Los Besotes	1,660	0.98	0.00	0.44	0.02	0.00	0.00
3	Zona deltáica-estuarina del Río Sinú	18,629	0.55	0.00	0.90	0.00	0.33	0.00
4	Capurganá	1,460	0.58	0.00	0.00	0.00	0.00	0.00
5	Parque Nacional Natural Macuira	28,840	0.67	0.85	0.00	0.33	0.00	0.00
6	Región Ecodeltáica Fluvio-Estuarina del Canal del Dique	43,067	0.58	0.10	0.00	0.05	0.14	0.00
7	Parque Nacional Natural Amacayacu	266,293	0.01	0.98	0.00	0.00	0.00	0.00
8	Parque Nacional Natural Los Katíos	80,472	0.26	0.94	0.00	0.00	0.06	0.16
9	Santuario de Fauna y Flora Los Colorados	1,184	0.65	0.72	0.00	0.35	0.00	0.00
10	Complejo de Humedales Costeros de la Guajira	217,760	0.50	0.09	0.02	0.50	0.00	0.00
11	Ciénaga de Ayapel	27,055	0.45	0.00	0.99	0.00	0.00	0.06
12	Parque Nacional Natural Tayrona	21,133	0.54	0.86	0.00	0.46	0.00	0.00
13	Parque Nacional Natural Ensenada de Utria	77,189	0.29	0.80	0.00	0.00	0.00	0.63
14	Complejo cenagoso de la margen occidental del Río Sinú	10,011	0.87	0.00	0.05	0.00	0.00	0.00
15	Reserva de Biosfera RAMSAR Ciénaga Grande, Isla de Salamanca y Sabana Grande	249,907	0.46	0.34	0.00	0.02	0.11	0.00
16	Complejo de Ciénagas del sur de Cesar y Bolívar	13,109	0.34	0.00	0.00	0.00	0.00	0.33
17	Riberas de la Cuenca Baja del Río Inírida	5,076	0.04	0.00	0.00	0.00	0.00	0.48
18	Isla Mocagua y Zaragocilla	2,496	0.32	0.00	0.00	0.00	0.41	0.00
19	Parque Nacional Natural Chiribiquete	1,303,996	0.02	0.99	0.00	0.00	0.00	0.00
20	Estación Biológica Mosiro-Itajura	53,102	0.03	0.87	0.00	0.00	0.00	0.00
21	Riberas del Río Duda	12,787	0.05	1.00	0.00	0.00	0.00	0.00
22	Isla Mirití	1,061	0.06	0.00	0.00	0.00	0.00	0.00
23	Parque Nacional Natural Sanquianga	88,804	0.19	0.68	0.00	0.00	0.00	0.00
24	Parque Nacional Natural El Tuparro	555,818	0.12	0.93	0.00	0.00	0.00	0.12
25	Lagos de Yahuarcaca e Isla Ronda	2,138	0.47	0.00	0.00	0.00	0.27	0.00
26	Delta del Río San Juan	80,455	0.16	0.00	0.00	0.00	0.00	0.00
27	Jardín de las Delicias	312	0.60	0.00	0.00	0.08	0.00	0.32
28	Asarrio	1,586	0.97	0.00	0.00	0.00	0.00	0.00
29	Río Saija	42,567	0.06	0.00	0.00	0.00	0.00	0.00

N°	KBA Name	KBA Area(ha)	Proportion of transformed area	Proportion of KBA área in PNN	Proportion of KBA in other public and private areas	Proportion of KBA in CR	Proportion of KBA in EN	Proportion of KBA in VU
30	Parque Wisirare	1,296	0.03	0.00	0.00	0.00	0.00	0.97
31	Taparas	36,533	0.05	0.00	0.00	0.00	0.90	0.04
32	Chaviripa-El Rubí	2,924	0.01	0.00	0.00	0.00	0.17	0.78
33	Reservas de la vereda Altagracia	1,347	0.18	0.00	0.88	0.00	0.00	0.79
34	Bojonawi	5,170	0.11	0.00	0.49	0.00	0.00	0.09
35	Parque Nacional Natural Sierra de la Macarena	628,850	0.07	0.94	0.00	0.00	0.00	0.00
36	Cañón del Río Guatiquía	30,002	0.51	0.02	0.10	0.02	0.00	0.45
37	Cerro La Judía	8,556	0.43	0.00	0.43	0.33	0.00	0.00
38	Cerros Occidentales de Tabio y Tenjo	410	0.80	0.00	0.00	0.15	0.05	0.00
39	Cañón del Río Combeima	6,640	0.68	0.01	0.03	0.00	0.00	0.19
40	Cuenca del Río Jiménez	9,072	0.93	0.00	0.00	0.06	0.00	0.01
41	Parque Nacional Natural Cueva de los Guacharos	8,912	0.06	0.75	0.24	0.00	0.00	0.17
42	Parque Nacional Natural Las Orquídeas	29,729	0.12	0.92	0.05	0.00	0.00	0.37
43	Parque Nacional Natural Farallones de Cali	205,683	0.05	0.92	0.32	0.00	0.00	0.59
44	Valle de San Salvador	59,340	0.51	0.54	0.00	0.03	0.00	0.43
45	Gravilleras del Valle del Río Siecha	1,978	0.80	0.00	0.00	0.01	0.00	0.00
46	Complejo Lacustre de Fúquene, Cucunubá y Palacio	4,074	0.73	0.00	0.00	0.02	0.00	0.00
47	Embalse de Punchiná y su zona de protección	1,194	0.29	0.00	1.00	0.00	0.00	0.42
48	Reserva Biológica Cachalú	1,019	0.16	0.00	0.99	0.00	0.00	0.06
49	Reserva Natural Semillas de Agua	1,116	0.19	0.00	0.00	0.00	0.00	0.00
50	Embalse de San Lorenzo y Jaguas	2,244	0.23	0.00	1.00	0.00	0.00	0.33
51	Páramos y Bosques Altoandinos de Génova	11,044	0.20	0.00	0.54	0.00	0.00	0.34
52	Humedales de la Sabana de Bogotá	18,053	1.00	0.00	0.04	0.00	0.00	0.00
53	Reserva Natural Laguna de Sonso	825	0.89	0.00	1.00	0.00	0.00	0.00
54	Reserva Hidrográfica, Forestal y Parque Ecológico de Río Blanco	3,768	0.46	0.00	0.93	0.00	0.00	0.00
55	Valle del Río Frío	37,222	0.59	0.14	0.00	0.00	0.00	0.39
56	Cuchilla de San Lorenzo	55,213	0.21	0.20	0.01	0.08	0.00	0.70
57	Región del Alto Calima	19,400	0.11	0.00	0.19	0.00	0.00	0.60
58	Cañón del Río Barbas y Bremen	9,765	0.57	0.00	0.98	0.00	0.00	0.25
59	Cerro Pintado de la Serrania del Perijá	9,631	0.49	0.89	0.00	0.39	0.00	0.11
60	Serranía de las Quinchas	86,035	0.36	0.00	0.67	0.02	0.09	0.53
61	Reserva Natural Meremberg	1,965	0.30	0.00	0.00	0.00	0.00	0.14
62	La Forzosa-Santa Gertrudis	3,436	0.22	0.00	0.00	0.00	0.00	0.78

N°	KBA Name	KBA Area(ha)	Proportion of transformed area	Proportion of KBA área in PNN	Proportion of KBA in other public and private areas	Proportion of KBA in CR	Proportion of KBA in EN	Proportion of KBA in VU
63	Reserva Natural La Planada	3,146	0.11	0.00	0.66	0.00	0.00	0.78
64	Lago Cumbal	345	0.15	0.00	0.00	0.00	0.00	0.00
65	Parque Nacional Natural Nevado del Huila	157,159	0.03	0.93	0.01	0.00	0.00	0.03
66	Parque Nacional Natural Paramillo	517,657	0.11	0.97	0.00	0.12	0.00	0.28
67	Parque Nacional Natural Tatamá	51,496	0.02	0.62	0.00	0.00	0.00	0.34
68	Pueblo Bello	994	0.55	0.00	0.00	0.35	0.00	0.10
69	Reserva Natural El Pangán	7,132	0.03	0.00	0.00	0.00	0.00	0.78
70	Reserva Natural Tambito	113	0.23	0.00	0.00	0.00	0.00	0.66
71	Reserva Regional Bajo Cauca Nechí	118,386	0.28	0.00	0.00	0.01	0.00	0.00
72	Serraníade los Churumbelos	153,576	0.05	0.55	0.01	0.00	0.00	0.64
73	Serranía de San Lucas	674,522	0.26	0.61	0.00	0.00	0.03	0.51
74	Lagunas Bombona y Vancouver	6,381	0.53	0.20	0.06	0.00	0.00	0.00
75	Reservas Comunitarias de Roncesvalles	36,511	0.26	0.00	0.02	0.00	0.00	0.00
76	Cañon del río Alicante	2,762	0.55	0.00	0.71	0.00	0.02	0.43
77	Parque Nacional Natural Munchique y extensión sur	72,680	0.15	0.62	0.00	0.00	0.00	0.45
78	Alto Quindío	4,002	0.15	0.00	0.92	0.00	0.00	0.00
79	Bosques del Oriente de Risaralda	24,054	0.16	0.33	0.66	0.00	0.00	0.04
80	Bosques de Tolemaida, Piscilago y alrededores	20,012	0.99	0.00	0.00	0.01	0.00	0.00
81	Reserva Natural Ibanasca	2,091	0.08	0.51	0.57	0.00	0.00	0.11
82	Finca la Betulia Reserva la Patasola	1,306	0.20	0.00	1.00	0.00	0.00	0.00
83	Reserva Natural Río Ñambí	7,943	0.29	0.00	0.16	0.00	0.00	0.61
84	San Sebastián	5,686	0.17	0.00	0.77	0.00	0.00	0.00
85	Bosques Montanos del Sur de Antioquia	172,396	0.33	0.00	0.30	0.00	0.00	0.20
86	Alto de Pisones	1,192	0.10	0.00	0.09	0.00	0.00	0.61
87	Reserva Forestal Yotoco	450	0.39	0.00	0.93	0.61	0.00	0.00
88	Refugio Río Claro	450	0.61	0.00	0.00	0.00	0.00	0.37
89	La Victoria	662	0.75	0.00	0.21	0.00	0.00	0.25
90	Agua de la Virgen	100	0.88	0.00	0.00	0.00	0.00	0.12
91	Cuenca del Río Toche	21,403	0.37	0.04	0.01	0.00	0.00	0.05
92	Parque Nacional Natural Puracé	75,200	0.09	0.91	0.01	0.00	0.00	0.10
93	Cuenca del Río San Miguel	8,098	0.51	0.06	0.00	0.00	0.00	0.09
94	Finca Paraguay	10,951	0.69	0.04	0.03	0.00	0.00	0.00
95	Bosques Secos del Valle del Río Chicamocha	334,160	0.82	0.00	0.20	0.06	0.00	0.05
96	Soatá	997	0.57	0.00	0.00	0.02	0.00	0.00

N°	KBA Name	KBA Area(ha)	Proportion of transformed area	Proportion of KBA área in PNN	Proportion of KBA in other public and private areas	Proportion of KBA in CR	Proportion of KBA in EN	Proportion of KBA in VU
97	Laguna de la Cocha	58,484	0.49	0.00	0.44	0.01	0.00	0.29
98	Parque Nacional Natural de Pisba	49,789	0.66	0.67	0.02	0.00	0.00	0.17
99	Parque Nacional Natural El Cocuy	308,418	0.16	0.97	0.00	0.00	0.00	0.47
100	Parque Nacional Natural Sumapaz	211,884	0.19	0.96	0.00	0.00	0.00	0.34
101	Parque Nacional Natural Tamá	52,203	0.14	0.92	0.00	0.04	0.00	0.67
102	Parque Natural Regional Páramo del Duende	28,325	0.05	0.00	0.33	0.00	0.00	0.83
103	Reserva El Oso	4,569	0.07	0.00	0.84	0.00	0.00	0.00
104	Santuario de Fauna y Flora Galeras	8,206	0.20	0.92	0.00	0.00	0.00	0.30
105	Serranía de las Minas	99,966	0.48	0.06	0.29	0.00	0.00	0.04
106	Serranía de los Paraguas	150,118	0.36	0.00	0.00	0.00	0.00	0.32
107	Cuenca del Río Hereje	7,375	0.04	0.00	0.00	0.00	0.00	0.00
108	Bosque de San Antonio/Km 18	5,332	0.50	0.00	0.42	0.00	0.00	0.50
109	Bosques de la Falla del Tequendama	10,990	0.75	0.00	0.56	0.01	0.00	0.03
110	Enclave Seco del Río Dagua	7,549	0.97	0.00	0.54	0.01	0.00	0.00
111	Laguna de Tota	5,392	0.08	0.00	0.00	0.00	0.00	0.00
112	Páramo del Sur de Antioquia	12,099	0.08	0.00	0.00	0.00	0.00	0.00
113	Serranía del Pinche	4,427	0.06	0.00	0.24	0.00	0.00	0.04
114	9 km sur de Valdivia	6,834	0.74	0.00	0.00	0.00	0.00	0.25
115	Alto de Oso	306	0.00	0.00	0.00	0.00	0.00	0.00
116	Cañon del río Guatiquia y alrededores	28,760	0.99	0.00	0.00	0.00	0.00	0.01
117	Carretera Ramiriqui-Zetaquira	9,009	0.85	0.00	0.00	0.00	0.06	0.09
118	Cerro de Pan de Azúcar	15,872	0.52	0.00	0.90	0.00	0.00	0.48
119	Coromoro	14,959	0.88	0.00	0.00	0.00	0.00	0.11
120	Cuenca Hidrográfica del río San Francisco y alrededores	4,727	0.88	0.00	0.55	0.01	0.00	0.11
121	Fusagasuga	8,058	0.93	0.00	0.00	0.03	0.03	0.00
122	Hacienda La Victoria, Cordillera Oriental	11,846	0.97	0.00	0.00	0.00	0.00	0.02
123	La Empalada	9,125	0.82	0.00	0.23	0.00	0.00	0.08
124	La Salina	7,541	0.23	0.00	0.00	0.00	0.00	0.76
125	Municipio de Pandi	2,894	0.77	0.00	0.00	0.22	0.00	0.01
126	Orquideas - Musinga - Carauta	60,188	0.67	0.01	0.48	0.00	0.00	0.19
127	Parque Nacional Natural Chingaza y alrededores	83,654	0.13	0.86	0.03	0.00	0.03	0.40
128	Parque Nacional Natural Cordillera de los Picachos	273,631	0.05	0.99	0.00	0.00	0.00	0.46
129	Sierra Nevada de Santa Marta National Natural Park y alrededores	506,474	0.36	0.66	0.00	0.01	0.00	0.43

N°	KBA Name	KBA Area(ha)	Proportion of transformed area	Proportion of KBA área in PNN	Proportion of KBA in other public and private areas	Proportion of KBA in CR	Proportion of KBA in EN	Proportion of KBA in VU
130	Pueblo Viejo de Ura	13,640	0.79	0.00	0.00	0.00	0.00	0.00
131	Páramo Urrao	29,849	0.20	0.03	0.90	0.00	0.00	0.09
132	Páramo de Sonsón	62,532	0.69	0.00	0.05	0.00	0.00	0.04
133	San Isidro	9,649	0.58	0.00	0.13	0.00	0.16	0.25
134	Santo Domingo	6,862	0.98	0.00	0.00	0.00	0.00	0.02
135	Selva de Florencia	25,387	0.46	0.37	0.00	0.00	0.00	0.43
136	Serranía de los Yariguíes	242,447	0.44	0.24	0.65	0.01	0.06	0.39
137	Vereda Las Minas	9,939	0.31	0.00	0.87	0.00	0.00	0.00
138	Vereda el Llano	2,869	0.96	0.00	0.00	0.02	0.00	0.01
139	Villavicencio	3,327	0.72	0.00	0.00	0.00	0.00	0.20
140	Valle de Sibundoy y Laguna de la Cocha	152,857	0.10	0.03	0.15	0.00	0.00	0.35

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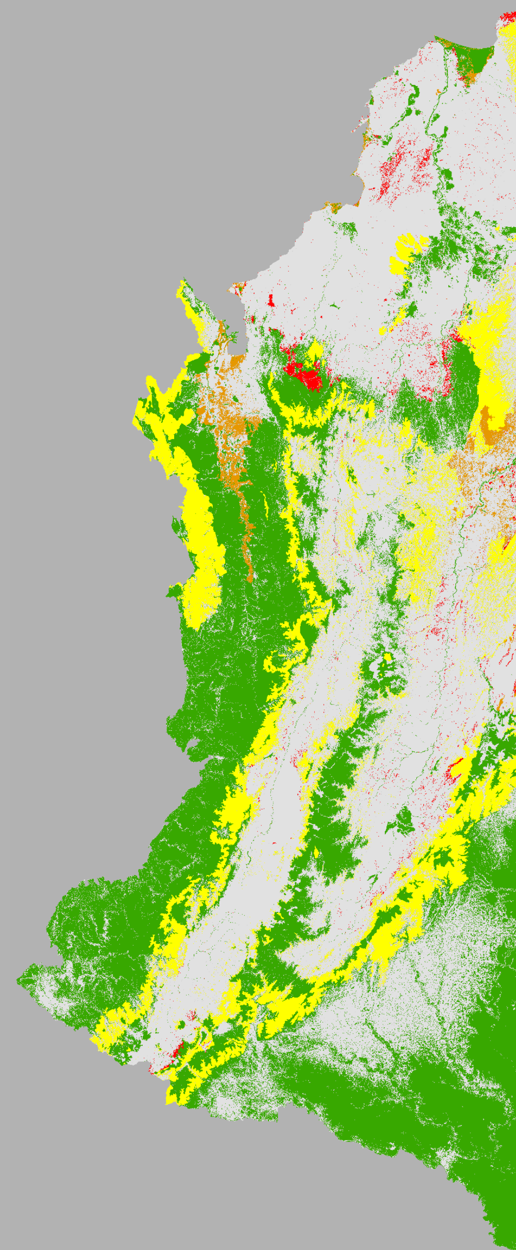

Bogotá D.C.
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