Forest Biodiversity Indicators in the Colombian Andes

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1. Abstract

The northern Andean montane tropical forests in Colombia are currently one of the major global conservation priorities due to not only their biological richness and high levels endemism but also because they are being subject to high levels of human pressure. Some estimates suggest that only 25 percent of the original forest extent remains, however current deforestation rates figures do not yet exist. Monitoring strategies are essential for determining changes or trends in forests ecosystems and in external factors that might influence them. Humboldt Institute has developed a methodology for mapping ecosystems that is currently being applied in the Andes. This methodology involves repeated measurements over time of vegetation cover variables based on remote sensing and GIS. Indicators of ecosystem condition were derived at the landscape level and we analyzed forest condition indicators such as forest cover, fragmentation, ecosystem diversity, and representativeness of protected natural areas.

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2. Introduction

The Northern-Andean eco-region harbours some of the 200 priority sites for global biodiversity conservation (WWF, 1997), due to its unique biodiversity and degree of threat. The eco-region hosts a great variety of habitats that have favoured the evolution of a large number of animal and plant species, which contributed to Colombia being recognized as one of the five more diverse countries of the world (Mittermeier *et al.* 1999).

The Colombian Andes have been severely affected by human activities. This combination of high biological diversity and human disturbance led to the recognision of the area as one of the first global priorities for conservation (Myers, 1988, Mittermeier *et al.* 1999). Due to the rate of natural landscapes transformation, and with that, the loss of biodiversity, complete ecosystems and a high number of species present a high risk of extinction. Among those threatened are species endemics to the region. These losses have severe consequences for the many goods and services offered by the region and may affect the development of social and economic activities of the local human population (WWF 2001).

One way of understanding relations between individuals and their environment is to study the ecosystem and also identify occurring socio-economic processes. This approach allows environmental authorities to focus their attention to conservation priority areas or by developing models that can explain future scenarios (Rudas *et al.* 2002). The study of biodiversity on a regional or landscape scale has the ecosystem as the unit from which structure and composition are analyzed. The ecosystem serves as the base for a monitoring programme (Josse *et al.* 2003). Such monitoring requires standardized protocols that satisfy the needs of policy-makers (Trexler & Busch, 2003, Gaines *et al*. 2003).

Studies carried out in this country show that the Andean region has high rates of landscape tranformation mostly caused by deforestation and fragmentation (Armenteras *et al,* 2003). However few detailed studies are available that combine geographical data on the dynamics of ecosystem disturbance and fragmentation with socio-economic indicators (Sierra 2000). This combination could help to orientate the management of diversity in a particular ecosystem.

This study involved the analysis of ecosystem structure and socio-economic factors in the Colombian Andes, as a part of the project titled "Conservation and sustainable use of biodiversity in the Colombian Andes". This project is being carried out by the Humboldt Institute, and will serve as a basis for a biodiversity monitoring programme

3. Methods

Study Area

Colombia, sharing the tropical Andean region with Venezuela, Peru, Ecuador, and Bolivia, occupies about 23% of the total andean area in south america (28.771 km^2). The country exhibits a complex mosaic of ecosystems as a result of the diversity of climates, geology, geomorphology, and soils. These factors gave way to a set of very different vegetation types, represented by páramos, (high) andean forests and sub-andean forests. In addittion there are exceptional areas of dry and xerofitic ecosystemsrecognised ofnational and world-wide interest due to their fragility and uniqueness, but alsodue to absence of management and policy actions to protect them.

Further, human pressure strongly reduced the available habitats for locally growing species (Chávez y Arango, 1998; Garcés & De La Zerda, 1994).

The Colombian Andes stretches from the Serranía de Perijá (11° 10`N, 73° 30´ W), 2000 km southward up to the so-called Nudo de los Pastos on the Ecuadorian border (0° 30`N, 77° 30` W). The South American Andes divides into three mountain ranges when it reaches Colombia: the Cordillera Occidental, the Cordillera Central and the Cordillera Oriental, all of them are north-south orientated. These three ranges are separated by the valleys of the Magdalena and Cauca river (Mittermeier *et al*. 1999), each of them have distinct climatic, geological and structural characteristics. The lower limit is at about 400-500 m.a.s.l., and the upper at 4500 m.a.s.l.

Ecosystem Mapping

Ecosystem mapping is based on the general assumption that ecosystems are delimited by properties of the landscape, and the scale of work (Figure 1). The database is made in such a way that the scale correlates with the level of detail of biota information. The ecosystem mapping is elaborated in a hierarchical way, permitting the application of the model on different parts of the country and can be used in spatially and temporally different scales (Bayle 1996, Rodríguez *et al.* 2004).

Using remote sensing and GIS tools, the ecosystems were identified by a supervised interpretation of 40 multi-spectral Landsat TM and ETM images, on a scale of 1:250.000.This was done for two periods: 1985-1987 and 1998-2003. The units were complemented by field investigation. The information was processed using ERDAS imagine v 8.3, ArcGis v 8.2, and was incorporated in a Microsoft Access® database. The visualization was done with ESRI Map Objects®.

Indicators

Following the state-pressure-response scheme, which assesses the biodiversity at a certain moment, the human activities threatening this, and the response of the society through environmental policy (Ortiz *et al*. 2004), some indicators were measured that help to identify and monitor key biodiversity components for its conservation and sustainable use.

Applying GIS and landscape ecology, we obtained the indicators (area, richness, fragmentation, and turnover) of the state of the ecosystems from the ecosystem map. The indicators of state and pressure, comprising economic, social, demographic and production factors, were calculated from data obtained from the Departamento Nacional de Planeación (DPN), Ministerio de Agricultura, Departamento Administrativo Nacional de Estadísticas (DANE) e Instituto de Hidrología, Meteorología y Estudios Ambientales (IDEAM). The representation of ecosystems within the set of protected areas in the Colombian Andes was used as the response indicator.

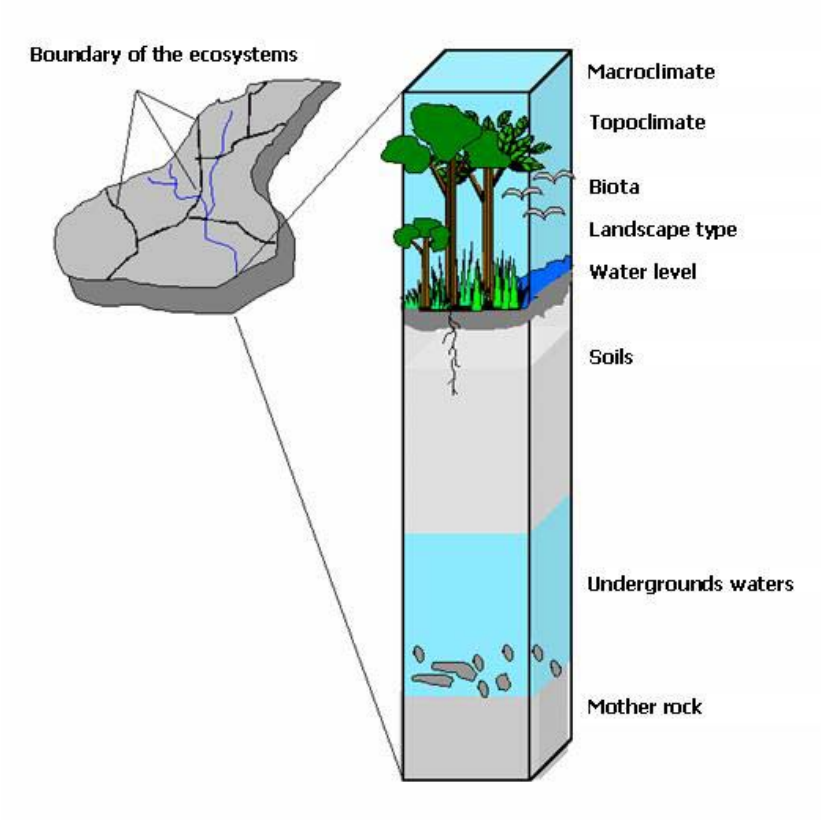

Figure 1. Structure of Ecosystems (Bailey, 1996)

4. Results and discussion

For the Colombian Andes four different types of biomes with 162 different ecosystems were identified (10141.jpg); of them, the *orobiome of the tropical humid zonobiome* was the one that contained the highest percentage in area of natural ecosystems (26.9%), followed by the *tropical humid zonobiome* (11.5%), the *alternohidric zonobiome* and/or tropical subxerofitic (0.84%) and the *azonal orobiome of the tropical humid zonobiome* (0.27%). The ramaining 60.5% corresponds to transformed ecosystems, located principally (23.7%) in the Subandean floor (Rodríguez *et* al., 2004, IAvH 2004) (Figure 1).

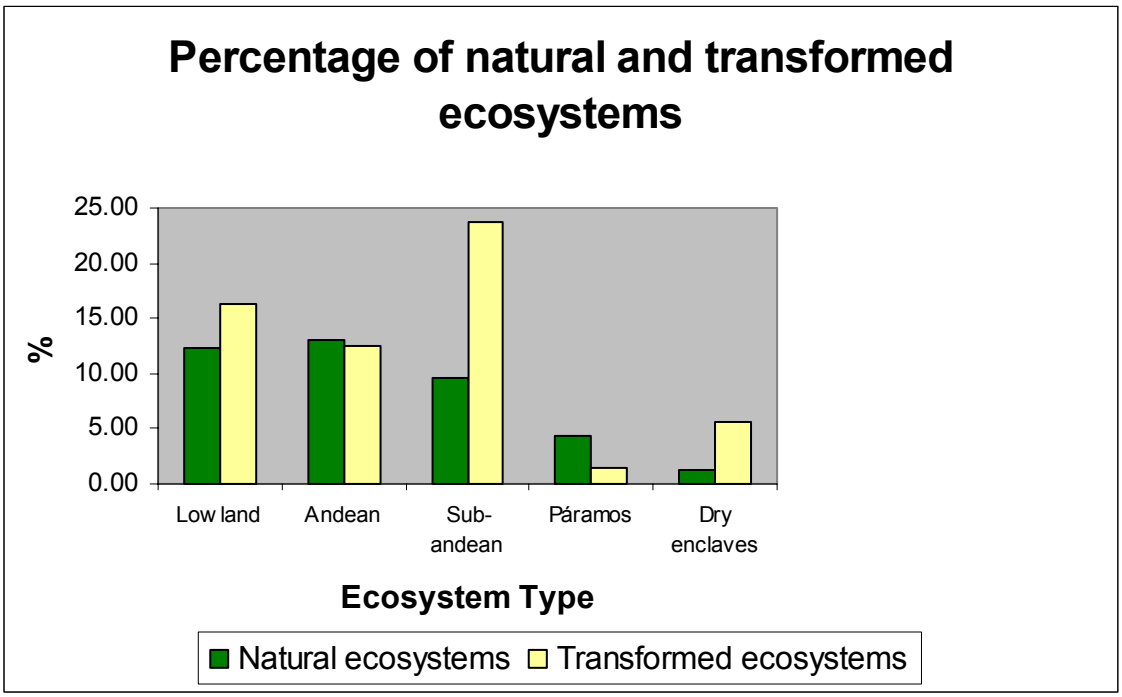

Figure 1. Percentage of natural and transformed ecosystems in the Colombia Andes

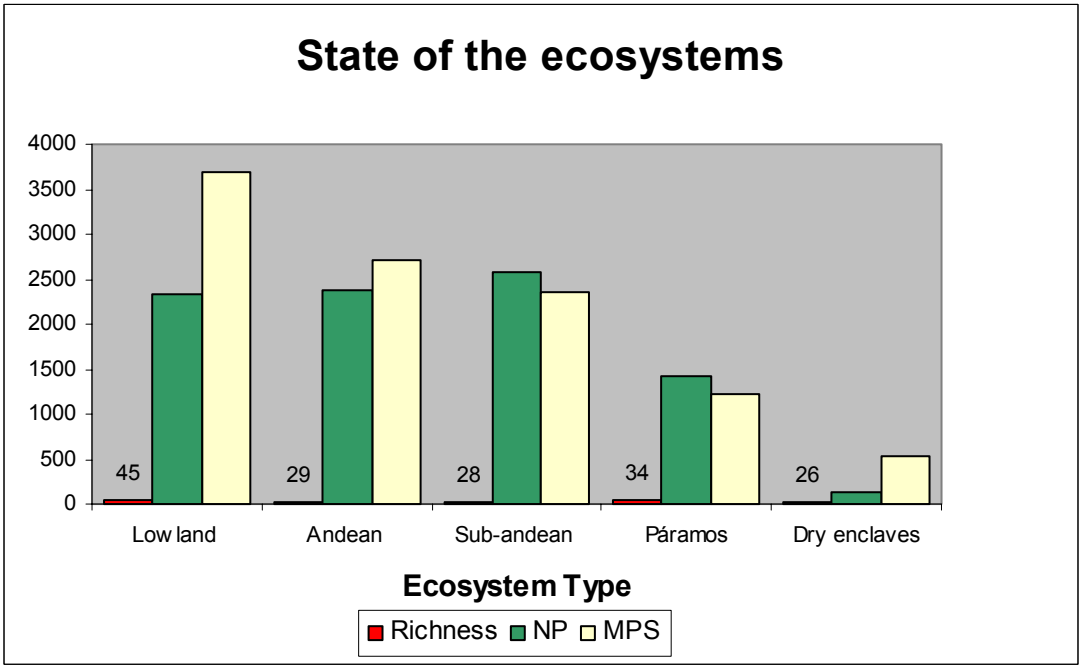

Figure 2. Indicators of the state of the ecosystems in the Colombia Andes

The higgest natural ecosystem richness is associated with the *orobiome of the tropical humid zonobiome* that groups the high, middle and low forested formations of the Subandean, Andean and high-andean floors. In this orobiome, 91 different types of

ecosystems were found that are a response to the wide altitudinal gradient that originates a relevant climatic, geomorphological and pedologic diversity. Forests associated with dry zones have the lowest richness and are the ones with higher ecosystem damage. In relation with the Media of the patch size (MPS) the lowland forests are the ones with the biggest surface, followed by the Andean forests. (Figure 2).

In general, there are high fragmentation processes in the region compared with other regions of the country and this is related with the socio-economic dynamics of the Andes; population density and economical activity, are potentially negative for biodiversity. This region gathers more than 69% of the country`s population with a population density that varies between 1.5 and 2.8 per/ha.

The degree of fragmentation varies inside the region and between the different ecosystems, being the forest ecosystems associated with the Subandean altitudinal range of the central cordillera (1000-2200 m), the more fragmented and deteriorated. This corresponds to the colombian coffee region, that in the last decade has had an increased tendency towards the reduction of the agricultural productive activite. This has led to a land use change into grassland matrix result his in an increase pressure to nearby regions (Rincón *et al.,* 2004). The more conserved mountain ecosystems in relation with the existence of natural intact patches are located in the Eastern Cordillera in limits of the Nariño- Putumayo and Amazonic foot hills and correspond to Andean forests. Nevertheless, this forest are affected by agricultural activities.

In the forests of the lowland floors (<1000 m) fragmentation is occurring throughout rivers and in small areas where physical conditions like lower slopes facilitate access to nearby roads. The degree of surface change in these ecosystems is more evident because of the colonization and displacement processes of the population towards the highlands (Figure 3)

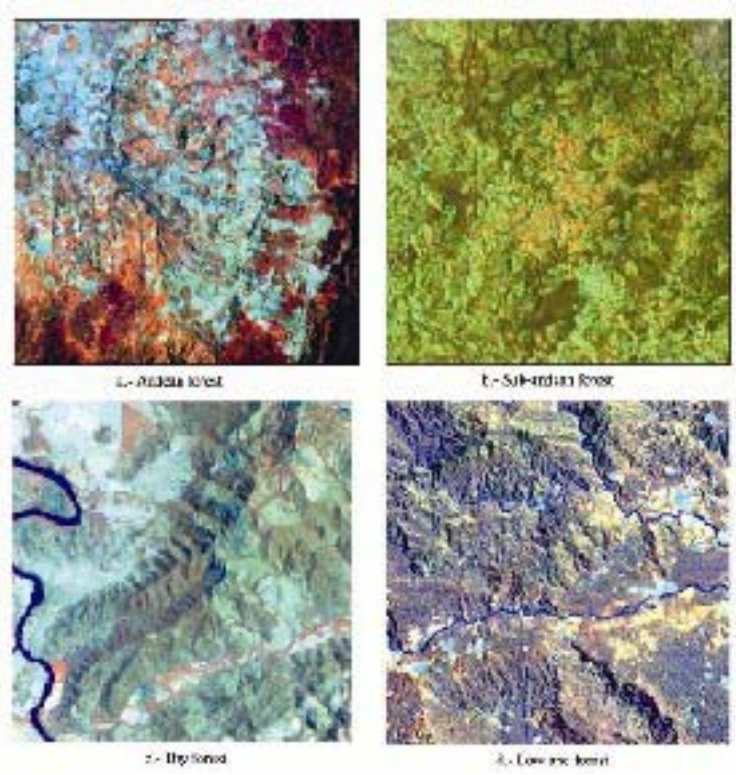

Figure 3. Patterns of deforestation in the forests of Colombian Andes. Landsat ETM 453

Table1 resumes the most important pressures towards the forest ecosystems in Colombia and specifically in the Andes in the last 15 years the human impact is associated with land tenure, illicit crops, and selective species extraction.

Factors of Pressure / Causal Aggravating	Establishment of plantations	Obtaining of firewood and coal	Selective extraction of species	Colonization	Shifting cultivation	Drug plant cultivation
Poverty						
Population pressure						
Land Tenure						
Legal and Institutional deficiencies						
Market influences						
Illegal Trade						

Table 1. Factors of pressure on the forest resource in Colombia

As a response indicator of ecosystem conservation; in the Colombian Andes are allocated 19 Natural national parks (PNN), 5 flora and fauna sanctuaries (SFF) and a unique natural area, all of them representing 7.62% of the total extent of the region and about 30% of all the protected areas in the country. Of these areas of special management (AME), 8 protect Andean and High-andean orobiomes, 7 paramo orobiomes, 6 Subandean orobiomes and 5 tropical humid zonobiomes. Dry ecosystems are not well represented in this system of protected areas.

Finally, from a punctual analysis in the coffee region of the central cordillera made by Rincón et al., 2004, they found that the best preserved forested ecosystems are located in places with populations with low quality of life and high levels of unfulfilled basic necessities and that for the region, the pressure caused for the population displacement towards conserved zones is affecting the water scarcity indexes.

5. Conclusions

Different approaches have been gathered towards ecosystem definition and the applicability of a package of biodiversity indicators, one of the biggest challenges of Latin-American and Caribbean countries is to standardize a schema that would help compare the different ecosystem units and the pressures they have so that better decisions could be made at the regional and national levels towards natural resources management. For the Andean region important efforts have been done in the topic, usually routed towards the identification of regional priorities in conservation and in the establishment of programs related with biodiversity knowledge and its monitoring.

The Colombian Andean region has been subject to high levels of population concentration and to intensive productive activities that have diminished its biodiversity. Change in soil use towards cattle and agriculture systems have transformed the existent forest formations. Fragmentation is one of the biggest problems because of the geographic isolation of the remaining ecosystems with its successive biodiversity loss, low genetic flow and population extinction.

This work is part of a high priority international project that has as main objective to increase the conservation, knowledge base and sustainable use of biodiversity in the region. This work is also part of the monitoring phase of the project, by which the change in biodiversity can be compared. We expect in the future to work in multiscale analysis of state indicators and in the identification of deforestation patterns that would help design and interpret predictive models related with forested ecosystems dynamics as a way to give tools in conservation management to decision makers towards biodiversity.

Further information on this project can be found in Spanish at
http://www.humboldt.org.co

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