

Aspects of human influence on upper-Andean forest line vegetation

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Abstract. A dense Andean forest at 3400–3750 m elevation, dominated by *Weinmannia mariquita* and *Miconia* spp., in the Colombian Parque Nacional Natural Los Nevados, was studied with aerial photographs and vegetation relevés. Five main land use types were distinguished: intact upper-Andean forest, upper-Andean forest with selective cutting, the "socola" system, pasture with scattered trees, and total clearings. These land use types represent increasing levels of human impact. Usually some type of wood extraction precedes cattle grazing. Implications of these results for management of the forest line vegetation are discussed.

Resumen. Por medio de fotografías aéreas y levantamientos de vegetación se estudió un bosque andino dominado por *Weinmannia mariquita* y *Miconia* spp. en el Parque Nacional Natural Los Nevados, Colombia, a 3400–3750 m de altitud. Se diferenciaron cinco tipos de uso de la tierra: bosque altoandino intacto, bosque altoandino con tala selectiva, sistema de "socola", pastizales con árboles dispersos y claros. Estos tipos de uso de la tierra representan crecientes niveles de impacto humano. Algún tipo de extracción de madera usualmente precede al pastoreo. Se discuten implicaciones de estos resultados para el manejo de la vegetación del límite del bosque.

Introduction

Under natural conditions, upper altitudinal limits of many species are determined by temperature and radiation (Lauer and Klaus, 1975; Grubb, 1977). There is some evidence that the average elevational ranges of tree species of the montane forest belt decline with altitude (Hamilton and Perrott, 1981). Near the upper limit of their tolerance range, productivity is low, which has been documented for post-fire regeneration of tropical high-elevation woody vegetation (Janzen, 1973; Corlett, 1987). Artificial lowering of the forest line by man has occurred in many tropical montane forest zones (Ellenberg, 1975; Hamilton and Perrott, 1981; Corlett, 1984, 1987;

Uhlig and Uhlig, 1991). Following human colonization, the transition between páramo and upper-Andean forest is no longer determined by climatic factors alone, but also by type and intensity of the use of these ecosystems. Quantitative data relating to changes of forest structure and floristic composition are hardly available. The importance of assessment of anthropogenic impact on forest lines was stressed by Ives (1978).

The objective of our study of the upper forest line zone was to describe the impact of different land use types on vegetation structure and floristic composition. The present contribution concentrates on a selected aspect of vegetation structure: the vertical stratification of vegetation.

Knowledge about the use made of the upper forest line zone is important for planning the sound management of these vulnerable ecosystems. Although our study is not yet concluded, we herewith present a summary of our preliminary results.

Materials and methods

Study area. We selected the western part of the Colombian Parque Nacional Natural Los Nevados (4°35–60'N, 75°10–30'W), where agricultural colonization started around the 1920s. Zonal vegetation in the altitudinal range of 3400–3750 m is a dense Andean forest dominated by *Weinmannia mariquitae* and *Miconia* spp. (Salomons, 1989). Human influence includes cutting of wood for fuel and fences, extensive cattle grazing, and potato cultivation. Although the national park was established in 1973, utilization of the Andean forest ecosystem has continued as before.

Vegetation analysis. Aerial photographs were used to select sites which differ in vegetation structure, but have a similar topography (moderate slopes) and aspect (NW). In 54 homogeneous plots, information was recorded on geomorphology, soils, topography, drainage, vegetation characteristics, and human impact. The size of the relevés depended on species–area curves and varied from 49 square meters for grasslands to 225 square meters for forests. Vegetation structure was described by estimating coverage per structural layer, each stratum being defined by a predominant growth form and height. The data of all relevés were classified, using the TWINSpan program (Hill, 1979), into final vegetation structure types.

Analysis of human impact. Independently from the structure classification, characterization of human impact variables was based on interviews and the observation of signs of human impact in the field. Grazing intensity was estimated by taking as indicators presence and abundance of cow droppings, cow paths, fences, and grazing traces in the vegetation. According to type and intensity of wood extraction, four classes of wood cutting were distinguished: selective cutting, cutting of the lower woody layer, forest clearing with the exception of some scattered trees, and total

forest clearing. Finally, occurrence of potato cultivation in the past, as seen on older aerial photographs and deduced from presence of small terraces, was registered. The relevés were grouped manually, based on similarity, according to the mentioned human impact variables in order to define different land use types. Vegetation structure was then compared to land use.

Results

Five main land use types were distinguished on the basis of human impact. The result of the TWINSpan classification of vegetation structure coincided on the whole with the land use types.

Intact upper-Andean forest. This unit is characterized by complete absence of signs of wood cutting and of any evidence of grazing activities. The vegetation structure type corresponds to a dense, two-layered forest. The upper tree layer is up to 33 m high and generally coverage is 50–60%. The lower tree layer reaches a height of 8 m with 25–50% coverage. Shrub coverage is 20–30%.

Upper-Andean forest with selective cutting. Selective cutting is a common management practice near the upper-Andean forest line. Locally, large trees are cut for fuelwood in farmers households. The overall grazing intensity is zero to very low. Sometimes a few cow paths or cow droppings are present. This type of use is only partly reflected in alteration of vegetation structure, e.g., dense, two-layered forest is still predominant, with a diminished shrub coverage (5–15%) in four out of eight samples. The coverage of both tree layers shows more variation, including complete removal in two cases of the upper tree stratum.

The "socola" system. In this unit lower trees and shrubs were removed some 10 years ago by farmers to facilitate access of cattle to the forest and to stimulate growth of the herb layer which is used as forage. Cows enter these managed forests only once or twice a year when forage is scarce in the pastures. This explains occasional presence of signs of grazing activities (4 and 9 cow droppings per 100 square meters; in other plots zero). Few cow paths are present, whereas fences are common. The corresponding vegetation structure is a dense two-layered forest with a low shrub cover, similar to the plots of selective cutting. The upper tree layer is intact, whereas the coverage of the lower tree layer is reduced to 5–15%.

Pasture with scattered trees. A type of clear-cutting was recognized where some trees were left for shading and as a source of wood for fencing and fuel. The resulting pastures with scattered trees showed two different grazing intensities: half were not used at the time of our sampling; no graz-

ing traces were found in the vegetation and only few cow droppings were present (0–1 per 100 square meters); shrub coverage ranged from 1–20% and was 9% on the average. Other pastures show considerably higher values of the grazing parameters studied and correspond to those currently used; observed cow droppings range from 5–14 per 100 square meters; cow paths and traces of grazing and trampling were frequent; shrub coverage of these wooded grasslands was lower (2% on average); and clearly visible microterraces indicated potato cultivation in the past.

Total clearings. Finally, total forest clearing also occurs for the purpose of extensive grazing, sometimes preceded by potato cultivation. The resulting vegetation structure depends on regeneration age and management of the recovering woody strata. The predominant structural type is a shrubland with a shrub coverage of over 30%. Regeneration stages are always combined with grazing activities due to absence of fences in most cases. Sometimes shrubs are removed actively in order to keep the vegetation open for cattle grazing. Grazing intensity is higher in those places (4–8 cow droppings per 100 square meters vs. 0–1 without shrub removal). Resprouting trees are used for fuelwood and fencing. Consequently, if regeneration of woody cover is possible at all, this is a very slow process. Only in one case was a low, open forest detected where trees sprouting from cut trunks had reached a height of about 10 m and a coverage of 70%. This occurred after more than 40 years and it must be noted that a shrub layer was almost absent, while young trees continued to be cut.

Conclusions

Cattle grazing, although extensive, is responsible for maintaining an open vegetation structure. Grazing is always preceded by some type of wood extraction and sometimes continued wood cutting enhances the negative impact upon the regeneration process. For the European Alps, Stern (1983) defined similar types of direct and indirect detrimental changes in the forest structure near timberline through logging and secondary utilization. Apart from narrowing of altitudinal ranges of species caused by selective cutting, he described shifts in age and diameter distribution either by utilization of the largest trees or removal of the small wood, development of sparse stands of mature trees with suppression of natural regeneration, and transformation into woodland pastures and permanent grass communities. In the case of "socola" management as described above, the forest can be considered a relict because regeneration of woody components is hardly possible. Still, these forests seem to possess, together with the sites of selective cutting, the largest potential for conservation of a community structure closely resembling the intact forest. If the cattle would be prevented from entering the forests, natural replacement by resprouting tree trunks and abundant seedlings would be possible. Analysis of changes in floristic

composition is fundamental, however, prior to any management recommendation that can be made. In the case of selective cutting these might be more dramatic than the observed changes in vegetation structure.

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