Management of Natural Forests and Reforestation

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Introduction

The Ecuadorian policy is considering the extraordinary biodiversity of the country and aims on benefitting appropriately through its conservation and sustainable use. Ecosystem conservation and restoration is supported by the National System of Protected Areas (SNAP), the program of incentive payments for private forest owners (SocioBosque), and several multi-stakeholder initiatives (e.g. FORAQUA). Also, sustainable use involving the management of natural forests and reforestation of abandoned areas is considered in a normative and supporting framework. Nevertheless, there are still many knowledge gaps that are related to both topics.

Management of natural forests

Beside the high biodiversity and a variety of ecosystem services, the mountain rainforest ecosystem has also an important provisioning function for timber production (56.2 m³/ha commercial volume according to the national forest inventory; forest type: *Bosque Siempre Verde Andino Montano*). The normative framework for sustainable management of mountain forests was introduced in the year 2006 and is a valuable tool to prevent forest destruction. However, the measurable criteria and indicators defined in these norms are predominantly intended to limit harvesting operations to an ecologically compatible level. The development of an incentive program entitled *SocioManejo* is in progress, which will provide assistance for technical and marketing issues in order to enhance the sustainable management of natural forests.

Information about the impact of micro-site parameters on species distribution is basic for the consideration of specific conditions in management activities. In the RBSF area we have realized forest inventories in three micro-catchments (Figure 1): the spatial distribution of selected species has been analysed by digital terrestrial modeling and the impact of environmental variables on the spatial distribution was assessed by using two common modeling techniques (Figure 2). The results indicate elevation and topographic position as main determinants for the distribution of most of the species.

Stand dynamics and the effects of silvicultural management techniques have been investigated by thinning experiments and recurrent inventories: Improvement thinning is considered to enhance the growth of selected individuals as well as tree regeneration. We selected potential crop trees (PCTs) of nine valuable timber species in order to test the effects of removing competitor trees

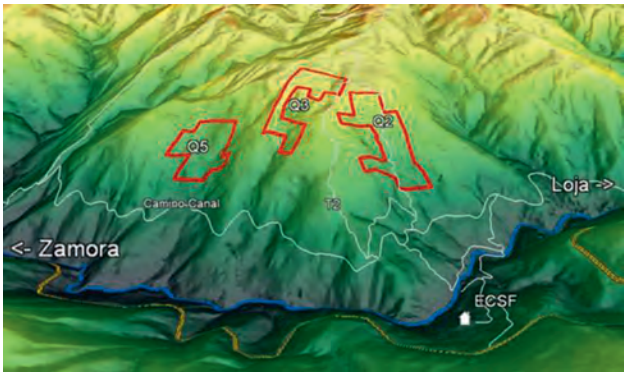

Figure 1. Distribution of 52 inventory plots (2500 m²; 13 ha in total) on three different micro-catchments Q2, Q3, Q5 in the study area.

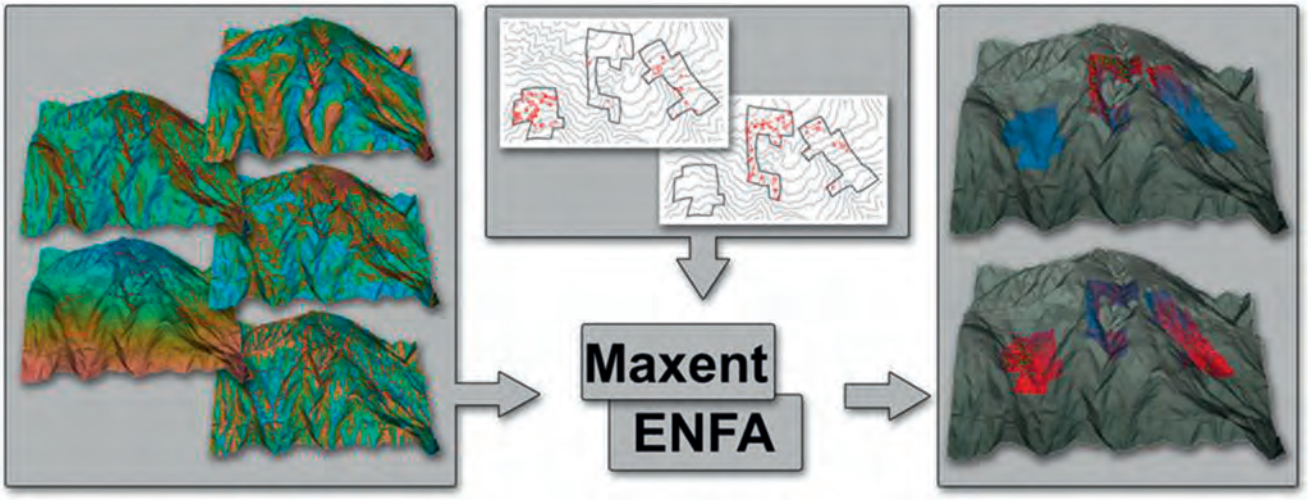

Figure 2. Analysis of the impact of environmental variables (left, top to bottom: elevation, slope, exposition, humidity, topographic position) on spatial distribution (center) of 16 most common tree species (Alchornea grandiflora, Alzatea verticillata, Cecropia andina, Cecropia angustifolia, Cedrela montana, Clusia ducuoides, Graffenrieda emarginata, Guarea kunthiana, Heliocarpus americanus, Hyeronima asperifolia, Meriania franciscana, Nectandra lineatifolia, Nectandra membranacea, Sapium glandulosum, Tabebuia chrysantha and Tapirira guianensis) using two common modeling techniques (Maxent, ENFA). The result illustrates the suitability of sites (right: red = good, blue = poor).

(Figure 3). After several years of monitoring, the results show in general an improved diameter increment for promoted individuals in comparison to untreated reference trees (Figure 4).
In addition, the recurrent inventories allow for evaluation of stand dynamics under natural and managed conditions: tree regeneration but also growth and mortality of remaining trees are still under observation (Figure 5) and the results will provide further insights on the possibilities of improving the management of natural mountain rain forests by silvicultural interventions.

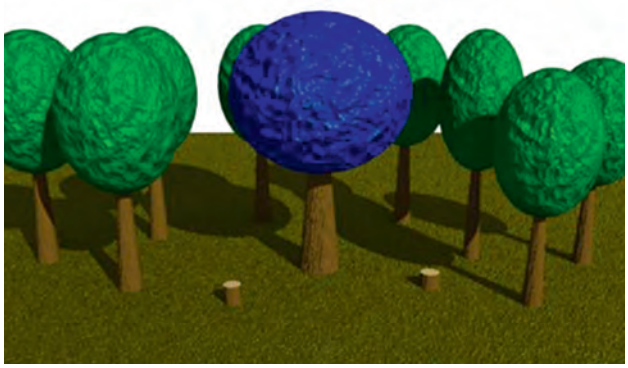

Figure 3. Potential crop trees of 9 valuable timber species (Cedrela montana, Podocarpus oleifoilus, Tabebuia chrysantha, Ficus citrifolia, Nectandra membranacea, Hyeronima asperifolia, Hyeronima moritziana, Clusia ducuoides, Inga acreana) *have been selected and competitor trees have been removed.*

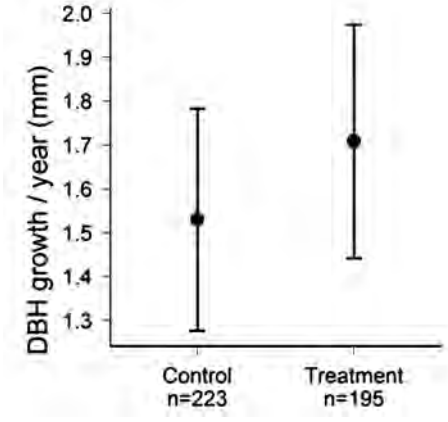

Figure 4. Effect of competitor removal on PCTs. In general the potential crop trees (Treatment) showed enhanced diameter increment in comparison to the corresponding reference trees (Control); however, we also detected a negative impact in case of three species and site effects.

Non-timber forest products

Non-timber forest products (NTFPs) are supposed to be a suitable option for generation of additional income. Former studies revealed that at least 589 species are used for NTFPs in Ecuadorian forests; the exports of NTFPs amounted to US$ 13 million per year between 2006 and 2008. Ethnobotanical studies in the tropical mountain

Figure 5. Monitoring of tree regeneration

forest confirmed the substantial role of NTFPs for the people living in this ecosystem, demonstrating different intensities of use by several ethnic groups: Shuar communities for instance use 139 forest species whereas Saraguro (43 species) and Mestizo (51 species) communities indicated lower numbers. Own surveys in a limited area of the San Francisco watershed (Parroquia Sabanilla) revealed 75 species of trees, shrubs, herbs, lianas, and epiphytes that are used for various purposes like medicine, food, construction, and others. These results illustrate the importance of NTFPs for natural forest management and the potential for further development by e.g. domestication of selected species.
Another important topic is the role of natural forests as a source of reproductive material (seeds, seedlings, material for vegetative propagation). Exploitation and land use changes involve the risk of genetic degradation and the continuous supply with reproductive material of high quality is a basic part of sustainable forest management and a precondition for successful reforestation or restoration. Nevertheless, the knowledge about suitable seed sources, periods of flowering and fruiting, seed storage and germination for native species is limited (Stimm et al. 2008). We realized several seed storage and germination trials with native species and monitored the flowering and fruiting of the selected PCTs and the corresponding reference trees (Figure 6).

Reforestation

The Ecuadorian government also provides a program that includes incentive payments for reforestation with native and exotic species for commercial purposes in order to generate timber resources and reduce the pressure on natural forests. In that case, the establishment costs for plantations are covered by 100% (local autho-

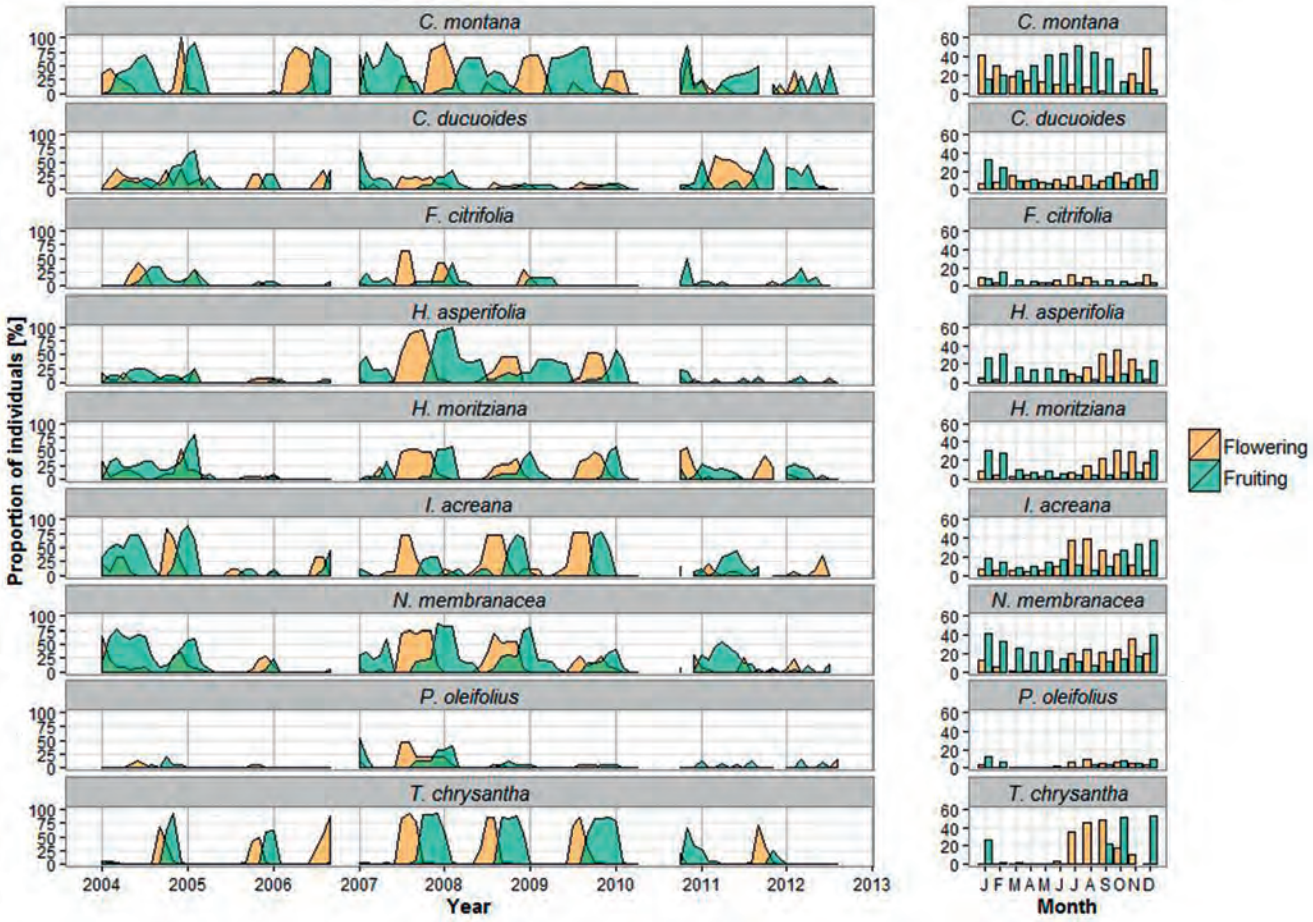

Figure 6. Monitoring of flowering (yellow) and fruiting (green) of 9 selected tree species; the monitoring period comprised almost nine years in order to detect annual variation (left) and to enable the estimation of consolidated probabilities of flowering and fruiting (right).

rities) or 75% (private landowners). However, reforestation with native species is still challenging in many cases: Because of the limited supply of reproductive material of high quality, widely lacking experiences regarding suitable silvicultural techniques for the diverse tree species, and the slow development of many native species on open areas, exotic species are often preferred. Thus, the incentive program considers for mountain regions *Alnus acuminata* as the only supported native species in addition to the exotic *Pinus patula, P. radiata, Eucalyptus globulus* and *Cupressus macrocarpa*. Our reforestation trials have also confirmed the competitiveness of *A. acuminata* with *P. patula* and *E. saligna*; nevertheless, *Tabebuia chrysantha* shows excellent survival rates and is supposed to improve its growth rate after an initial phase of establishing its root system. Moreover, a better timber quality resulting in higher timber prices could also compensate for longer production periods on the long run. As an alternative, native species could also be used for enrichment planting of plantations consisting of exotic species (Figure 7): the results of our trials in a plantation of *P. patula* are indicating that many native species benefit from the shelter which is not available on open areas (Aguirre et al. 2006). Currently we are testing the concept on several sites, including a variety of native species (Figure 8) and with different thinning intensities in order to assess the development under different levels of shade. As a consequence, exotic species might also be used to establish a forest cover which is subsequently transferred into a more natural composition with native tree species.

References

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Stimm B, Beck E, Günter S, Aguirre N, Cueva E, Mosandl R, Weber M (2008) Reforestation of abandoned pastures: Seed ecology of native species and production of indigenous plant material. In: Beck E, Bendix J, Kottke I, Makeschin F, Mosandl R (eds). Gradients in a tropical mountain ecosystem of Ecuador. Ecological studies 198. Springer, Berlin, pp 417-429

Figure 7a. Enrichment planting with Isertia laevis *in a plantation of Pinus patula.*

Figure 7b. An approximately 30 year old plantation of Pinus patula *as afforestation of abandoned pasture land.*

Figure 8. Production of seedlings of native tree species for enrichment planting on different sites.