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Introduction

Scientists widely agree that species extinction has heavily accelerated in the last decades. The majority of the worlds species are found in tropical forests, covering a mere ten percent of the planets surface. A grave problem for the conservation of diversity is the still very fragmentary knowledge of the ecology of most species.

The Andes and the Amazon Basin represent one of the most important Biodiversity-Hotspots on Earth. Attempts of sustainable management and conservation must integrate local communities and their traditional knowledge. Management decisions need to include the high importance of natural resources in providing building materials, food and medicines for rural as well as urbanized communities. The traditional use of forest resources, particularly of non-timber products like medicinal plants, has deep roots not only in indigenous communities, but is practiced in a wide section of society. The use of medicinal herbs is often an economically inevitable alternative to expensive western medicine. The base knowledge of this traditional use is passed from one generation to the next. Especially the medical use represents a highly dynamic, always evolving process, where new knowledge is constantly being obtained, and linked to traditional practices.

An increased emphasis is being placed en possible economic benefits especially of the medicinal use of tropical forest products instead of pure timber harvesting, an approach particularly appealing to countries with difficult economic conditions. Most research efforts, due to lack of manpower, time end resources, focus only on either biodiversity assessments or ethnobotanical inventories, or try to implement management and use measures without having a sound scientific base to do so. Often the needs of the local populations, e.g. their dependency on plant resources for health care are entirely ignored.

In 2001, the 1. Congress of Conservation of Biological and Cultural Diversity in the Andes and the Amazon Basin in Cusco, Peru, attempted to provide a platform to bridge the existing gap between Scientists, Non Governmental Organizations, Indigenous Populations and Governmental Agencies.

The 2. Congress of this topic was held in Loja, Ecuador in 2003.

Lyonia has dedicated its 2004 issues to the publication of the most important contributions to the Loja congress.

Volumes 6 (1-2) contain papers on the Biodiversity Conservation and Management.

Volume 7 (1) deals with Flora and Vegetation of the Region

Volume 7 (2) focuses on Ethnobotany, Resource use and Zoology

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What is Lyonia?

What is Lyonia?

Lyonia is an electronic, peer-reviewed, interdisciplinary journal devoted to the fast dissemination of current ecological research and its application in conservation, management, sustainable development and environmental education. Manuscript submission, peer-review and publication are entirely handled electronically. As articles are accepted they are automatically published as "volume in progress" and immediatelly available on the web. Every six months a Volume-in-Progress is declared a Published Volume and subscribers receive the table of Contents via e-mail.

Lyonia seeks articles from a wide field of disciplines (ecology, biology, anthropology, economics, law etc.) concerned with ecology, conservation, management, sustainable development and education in mountain and island environments with particular emphasis on montane forest of tropical regions.

In its research section Lyonia published peer-reviewed scientific papers that report original research on ecology, conservation and management, and particularly invites contributions that show new methodologies employing interdisciplinary and transdisciplinary approaches. The sustainable development and environmental education section contains reports on these activities.

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Programas Alemanes de Investigación, relacionados con la comprensón y la conservación de la biodiversidad como ejemplo del impacto del Convenio de Rio sobre una nación industrializada

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German Research Programs, related to the understanding and conservation of biodiversity as an example of the impact of the Convention of Rio on an industrial nation

Abstract

An overview of the various German programs on biodiversity research, which are linked to, or result from the commitments of the Convention on Biological Diversity, and their source of funding, is presented. Referring briefly the aims of the individual programs the major topics of German biodiversity research, in particular inventories, functionality, dynamics and regeneration, protection, management, valuation, legal aspects, and benefit sharing with counterparts is addressed and commented. Connections of biodiversity research and global change research are worked out. Key words: Research German program, Biological diversity, global change

Resumen

Se presenta una descripción de varios programas alemanes sobre la investigación de biodiversidad que son unidos a, o que son resultado de los acuerdos de la Convención sobre la Diversidad Biológica, y su fuente de financiamiento. Se describe y se comenta brevemente los objetivos de los programas individuales, los temas de la principales investigaciones alemanas de la biodiversidad, particularmente los inventarios, la funcionalidad, la dinámica y regeneración, la protección, el manejo, evaluación, los aspectos legales, y la ventaja compartida con los homólogos. Están demostradas las relaciones entre la investigación de biodiversidad y la investigación de cambio global. Palabras clave: Programa de Investigación Alemán, Diversidad biológica, Cambio global

Introduction

Germany’s biodiversity is estimated as 28000 plant species, of which 6450 species are vascular plants, about 45000 species of animals and an uncounted number of fungi and microorganisms. Ecuador’s biodiversity is less well known, but estimating it five-fold higher at least with respect to plants, may be fair. In a plain sense, the term "biodiversity" refers to the number of species, genomes or genes of a selected area say Ecuador or Germany. However, in a figurative sense, biodiversity also implies the idea of communities and of interactions. Therefore biodiversity research connotes more than only inventory research. The dramatic loss of species caused by global change, and the increasing public interest in sustainable utilization of ecosystems, resulted in governmental and non-governmental activities for the worldwide conservation of activities for the worldwide conservation of biodiversity and finally in 1992 in the Convention of Rio, the "CBD".

Germany’s participation in international programs and activities

Germany has signed the CBD and is a member of Conference of the Parties (COP) since 1993. Biodiversity protection and research are therefore genuine tasks and obligations shared by a great number of governmental and non-governmental authorities. In addition to their own terms of reference, the Federal Ministries and Authorities fulfill the national tasks and international commitments of the Biodiversity agreements.

A "National Committee on Global Change Research" and a "Scientific Council for Global Change of the Federal Government" (http://www.wbgu.de) were established in Germany which strongly emphasized the importance of biodiversity conservation and the necessity of biodiversity research. Several secretariats have been set up, e.g. a CBD-secretariat (http://www.biodiv.org), a secretariat for the Clearinghouse-Mechanisms (http://www.biodiv-chm.de/english/index) , a secretariat of Diversitas, and several Central Offices for documentation of biodiversity, e.g. for agriculture, forestry and fishery.

As a member of the European Union, Germany participates in the 5th and the 6th framework programs. In the scope of the 5th framework biodiversity-research was and is performed under the aspects of "Quality of life and management of living resources" and "Global Change, Climate and

Species Diversity". In these days the 6th framework programs have just started. There is a research priority "Sustainable Development and Global Change" which addresses research into "Biological diversity, Conservation of genetic resources, Functionality in terrestrial and aquatic ecosystems and Interaction of man and ecosystems".

Exact figures about financing of biodiversity-research by the German government are not available. However, extrapolations on the basis of the major programs may come up to a magnitude of 100 million $ per year.

Nature Conservation in Germany

Nature Conservation has a long history in Germany. Originally only endangered species were protected, but after World War II, habitat protection came into practice. Nature Conservation has been taken into the Federal as well as most of the Federal States Constitutions and is a matter of the German basic law. It is taught as a subject in primary and secondary schools. Two Universities offer Diploma Studies in Nature conservation. Establishment and gazetting of the more than 5000 protected areas range as affairs of the individual states but have to be agreed upon by the Federal authorities. This holds also for the 14 National Parks which have been established in Germany since 1978.

Botanical Gardens. An important contribution to the commitments of the CBD, is accomplished by the 101 German Botanical Gardens, which are either affiliated with Universities or directly financed by the public. About one fifth of the worldwide known vascular plants are *ex-situ* cultivated in these Gardens. Several species which have been eradicated in their natural habitat have survived in Botanical Gardens and in a few cases from there have been reintroduced to their home-country, e.g. *Sophora toromino*, the only tree of the Easter Island, which was exterminated according to the records of IUCN. In 1988 one individual was detected in the Botanical Garden of Bonn and an international propagation program was started. In 1996 the first juveniles could be reintroduced to the Easter Islands.

Non-governmental organizations: In a similar way numerous NGOs and scientific societies work in the fields of biodiversity-research and -conservation. Such NGOs, e.g. the German Botanical Society (http://www.deutsche-botanische-gesellschaft.de), Ecological (http://www.uni-giessen.de/gfoe) and Zoological Societies (http://www.dzg-ev.de/index.html) not only pursue the protection of endangered species, but also monitor and map the occurrence of the individual species and often investigate their biology. The most important NGO for nature protection in Germany is the BUND (http://www.bund.net/).

Grant-funded Biodiversity Research in Germany

Biodiversity research on a higher instrumental level, such as genetic population demarcation, analysis of ecological fitness and survival strategies, and of a potential economic use is the task of institutions which have the necessary equipment at their disposal, such as Universities, major research associations, e.g. the institutes of the Max Planck Society (http://www.mpg.de/instituteProjekteEinrichtungen/index.html), several Academies, Federal and Non-Federal research departments.

Main areas of biodiversity-research

According to the programs, biodiversity-research in Germany takes place at 3 levels: Molecular biodiversity-research, organismic biodiversity-research and ecosystem-related biodiversity-research (Figure 1).

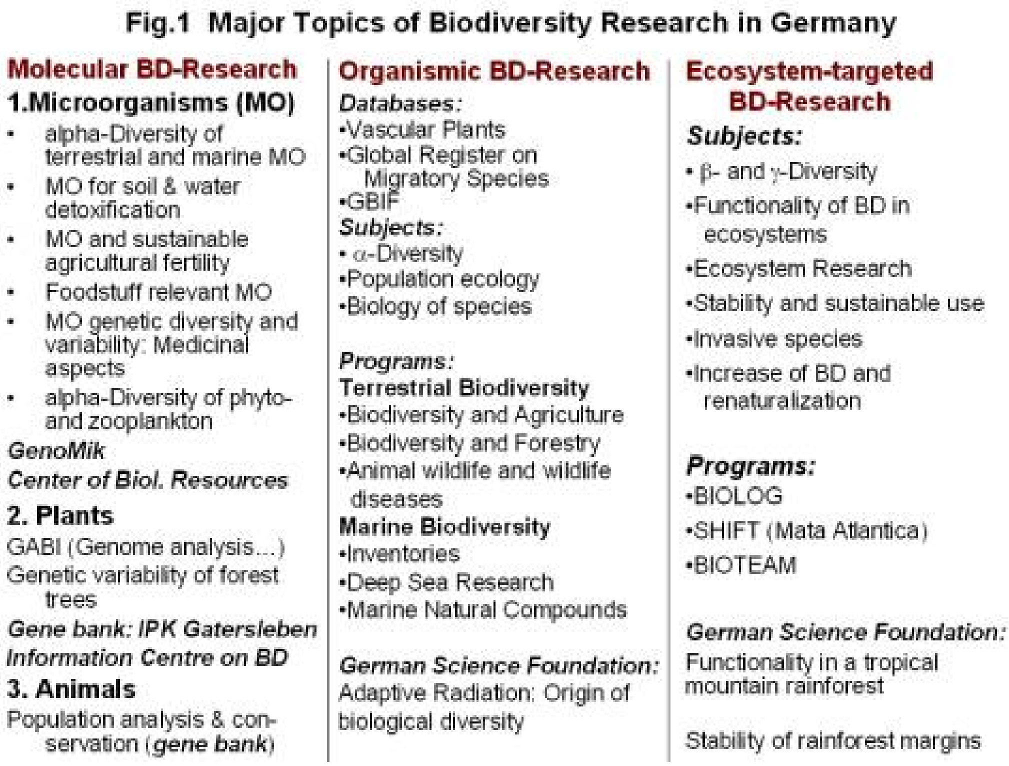

Figure 1. Major Topics of Biodiversity Research in Germany

Molecular biodiversity-research

Molecular genome inventories are investigated from all kinds of organisms: Microorganisms, fungi, plants and animals. These inventories aim at basic research as well as at useful organisms or at least genes.

Molecular biodiversity of microorganisms

Microorganisms accomplish a great multitude of services in natural and anthropogenic habitats, both terrestrial and marine, and are used in many applications, mostly in foodstuff production and pharmacy; and many of them are pathogenic. Major research programs in Germany [[(Figure 1)]] in which usually several institutions participate aim at:

Inventories of terrestrial microorganisms and marine microorganisms

Detection and cultivation of microorganisms which can be used for detoxification of polluted soils and waters

The contribution of microorganisms to a sustainable fertility of agricultural soils

Food-stuff-relevant microorganisms: Diversity of producers, spoilers and pathogenic organisms

Genetic diversity and variability of microorganisms of medicinal interest is mainly investigated in cooperation with industry and hospitals medicinal aspects of microbial

Species diversity and monitoring of marine phyto- and zooplankton

GenoMik (http://www.genomik.uni-goettingen.de) is a research program launched in October 2000 by the Federal Ministry of Education and Research (http://www.bmbf.de/) which covers most of the listed topics. It is financed with about 20 Million € for 5 years.

The German Collection of Microorganisms and Cell Cultures (http://www.dsmz.de/), maintains the so-called Center of Biological Resources. It harbors the worldwide biggest collection of plant viruses, plant cell cultures and about 13000 bacterial strains.

Molecular Biodiversity-Research in Plants

Modern methods of plant breeding require the knowledge of the genetic diversity of crop and forest plants. In 1998 the Federal Government launched a 7-years program "Genome Analysis of Plants as

Biological Systems" (GABI) (http://www.fz-juelich.de/ptj/datapool/page/455/gabiengl. pdf) focusing on *Arabidopsis* as model organism and on barley, sugar beet, potato and other important crop plants and fruit trees. Genome sequencing, but also the functions of the genes, proteomics, is the major goals of that program. Many governmental research institutions and universities participate in that program which has a financial volume of 80 Million $ for 7 years. A special program is on the genetic variability of forests. A comprehensive gene-bank with viable seeds of more than 100000 accessions of 2000 useful plants is maintained at the Institute of Plant Genetics and Crop Plant Research (IPK) in Gatersleben (http://www.ipk-gatersleben.de/en/).

For the documentation of all the *ex-situ* stocks of crop plants, medicinal plants and forest plants which are cultivated in the individual German institutions an "Information Centre on Biodiversity" (http://www.zadi.de/ibv/) has been established in the Central Office of Agronomic Documentation in Bonn (http://www.bmvel-forschung.de/).

Molecular biodiversity-research in domestic animals

Ongoing loss of many breeds of domestic animals is a worldwide problem. In Germany genetic diversity of domestic cattle is one of the major subjects of a Federal Research Institute (http://www.fal.de/) maintaining a gene bank of endangered races.

Organismic biodiversity research

Organismic biodiversity-research is predominantly performed on the level of species and populations. It comprises

species diversity of a territory, the so-called -diversity,

the biology of species

and the specific characters of populations such as growth, radiation, maintenance and decline.

Many research institutions contribute with a great multitude of individual or collaborative projects to organismic biodiversity research, which is sponsored by the Federal as well as the Federal States' governments and by the German Research Foundation. It is quite obvious that the knowledge of floristic and faunistic inventory of Germany is much more complete than in tropical countries. Consequently setup and operation of databases with comprehensive information about the organisms on the one hand and basic research into biodiversity on the other dominates the organismic biodiversity research in Germany. The database "Vascular Plants" (http://www.csdl.tamu.edu/FLORA/gallery.htm) is one of the most outstanding projects collecting and providing data on the diversity of plants in Germany. Today it contains more than 14 million records of species, populations, plant communities, habitats and ecological and other relevant data. By networking with other databases, information can be easily amplified. In a related project, the potential natural vegetation of Germany is recorded and can be provided for the establishment of the vegetation map of Europe.

A global database headed by the Zoological Museum in Bonn is the "Global Register on Migratory Species" (http://www.groms.de/) where all the data on migrations are compiled.

In context with these data bases the "Global Biodiversity Information Facility" GBIF (http://www.gbif.org) und (http://www.gbif.de) must be mentioned in which Germany participates with a National platform ("node"). GBIF has been established in 2000 and meanwhile more than 70 countries are contributing members.

Programs of Organismic biodiversity-Research in Germany

There are several focal points of Organismic biodiversity-research in Germany which I will briefly mention:

Biodiversity of agricultural areas, as influenced by the various agricultural methods and crops is investigated by several institutions, aiming also at an assessment of potential effects of genetically modified organisms or of invasive species on the organismic communities.

A similar program refers to the accompanying flora of forests, Ecology, reproduction biology and medicinal aspects of the animal wildlife in Germany are investigated in a special program connected to a database for wild animal diseases which also covers animals from outside Europe. Several governmental institutions investigate in collaboration with universities selected issues of marine faunistic and floristic biodiversity:

The German Research Foundation (http://www.dfg.de/) which primarily finances projects of basic research has launched a Priority Program "Adaptive Radiation-Origin of Biological Diversity" (http://mansfeld.ipk-gatersleben.de/radiationen/). The objective of that research program is a critical assessment of hypotheses on evolutionary (adaptive) radiations as a source of biodiversity. Evolutionary mechanisms are investigated, that promote morphological and physiological diversity. This Priority Program is sponsored with 2.5 Million € per year.

Ecosystem-related biodiversity research (Figure 2)

Ecosystem-related biodiversity-research takes place at levels of higher complexity, starting with the inventory of the diversity of organismic communities (the ß-Diversity) and the diversity of habitats (the -Diversity). Another topic is the analysis of the functions of biodiversity in the ecosystem which leads further to the question of stability of the ecosystem. An experiment was performed called BIODEPTH at 8 locations distributed from the very North of Europe to the very South. Increasing numbers of similar herbal species were planted on separate plots of cleared soil, to mimic different degrees of biodiversity. After 2 years the above-ground biomass was harvested. The results show a clear positive correlation between the biodiversity and biomass production. At that level biodiversity research becomes part of ecosystem research. Key stone species and their functions have to be identified which, however, is possible at most to some extent. Here, also man comes into play, as a user and competitor of biodiversity and as that creature that carries the burden of responsibility for our planet's biodiversity. The striven aim is therefore "protection by adequate, that means sustainable, use of the resources of the ecosystems".

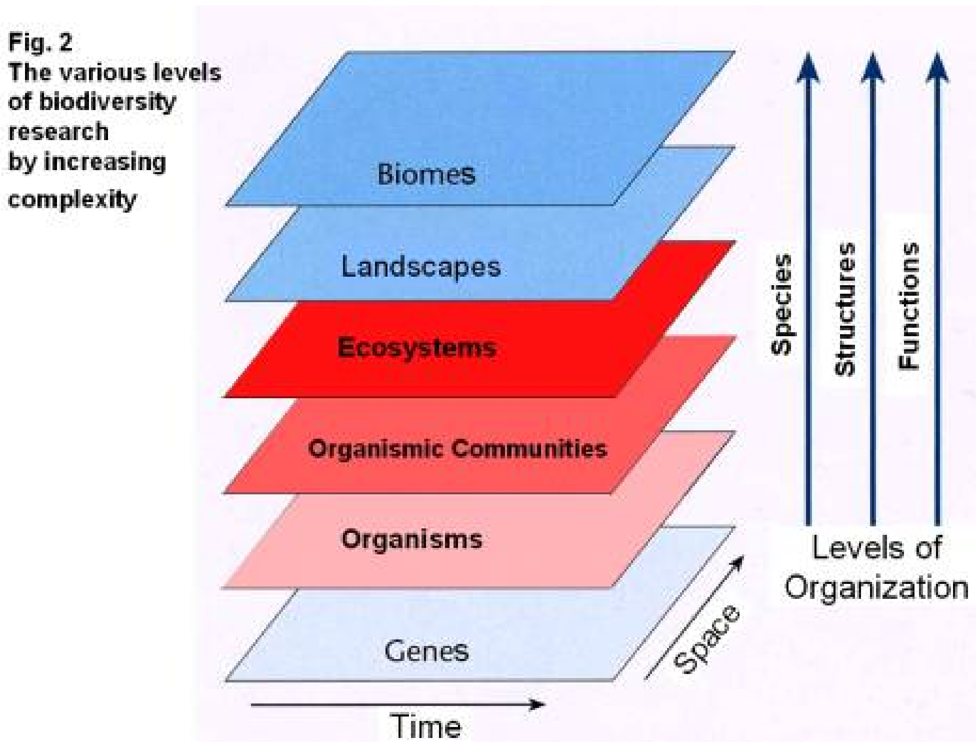

Figure 2. The various levels of biodiversity research by increasing complexity

In Germany biodiversity-related ecosystem research is a genuine task of many governmental institutions and departments. Focal research points are

strategies for a sustainable use and maintenance of rural areas of agricultural use,

biological problems arising from the invasion of exotic species, such as hybridization with and out competing of indigenous species.

strategies for the renaturalization of abandoned mining areas.

Special German programs of ecosystem-related biodiversity-research

In fulfilling the obligations of the CBD, German Government has launched several research programs dedicated to ecosystem-related biodiversity-research in Germany as well as in developing countries. The two major programs are BIOLOG and SHIFT.

BIOLOG (http://www.biolog-online.info) was started in 1999 and 93 projects most of which are clustered, were selected for funding. Work of the projects started out in 2000 and 2001.

The topics of BIOLOG (Figure 3)

There is no doubt that global change is also relevant to marine ecosystems. However, it is of particular and urgent importance to the terrestrial world, in which it gives rise to a great multitude of socio-economic problems. Therefore BIOLOG concentrates on research into terrestrial biodiversity. But since the success of integrated research into biodiversity is dependent on the accessibility of all kinds of species data, biodiversity informatics is another focal point of BIOLOG. Economists enquire as to the value of biodiversity. For that reason, socio-economic aspects of biodiversity and of biodiversity conservation have also been included in the projects of BIOLOG.

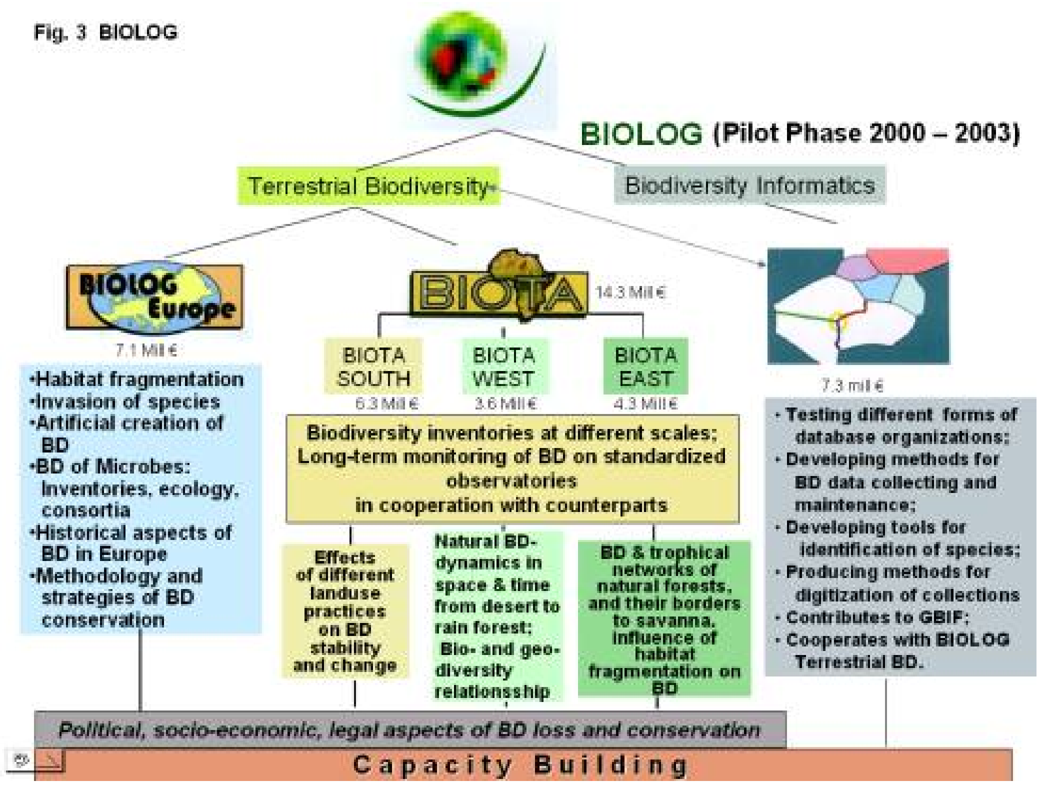

Figure 3. BIOLOG

The Pilot Phase: Research into biodiversity requires capacity building

BIOLOG has therefore given priority to integrative Research and Development Projects, which are based on a fair degree of capacity building, especially on the international level. For a proper placement of the approved projects, BIOLOG was started with a pilot phase of 3 years and successful projects are continuing into the main phase for another 6 or 7 years.

BIOLOG: Why Africa, why Europe?

BIOLOG's policy, as a research program, is to concentrate the projects

in regions expressing different levels of biodiversity,

in regions of different levels of relevant knowledge and expertise, and

in regions of differently endangered biodiversity.

Projects in Central Europe (BIOLOG EUROPE) are being funded because of the well-developed scientific background, on the basis of which even complicated biodiversity-related problems can be investigated. In the BIOLOG EUROPE projects,

the effects of fragmentation of the landscape, and

of intentional and accidental invasion of exotic species and other impacts on biodiversity are being studied, as well as the diversity, dynamics and function of microorganisms in terrestrial ecosystems.

Socio-economic implications which are connected with biodiversity as a natural and cultural heritage can also be readily focused upon in Central Europe.

Projects operating in several regions of sub-Saharan Africa (the so-called BIOTA-projects) were selected to start BIOLOG AFRICA. This continent was chosen with respect to the enormous deficiency of even basic knowledge in the fields of biodiversity and ecosystem functions and the urgency of environmental problems related to global change in this continent. In the BIOTA projects special emphasis is given to biodiversity inventories at different scales, combined with long-term monitoring. For that purpose "observatories" were established, which are standardized plots of usually 1 km2 left untreated or subjected to selected kinds and intensities of utilization. Selected features of the observatories, such as climate, soil, vegetation, wildlife and livestock are monitored at meaningful intervals and in meaningful area sizes. Monitoring will go for a time period of at least 10 years to obtain reliable data. Respective legal stipulations are necessary for the establishment of an observatory. The concept of such observatories has been approved by the International Program DIVERSITAS and will be soon adopted also by the U.S. and hopefully by other countries.

BIOLOG: Biodiversity Informatics (Figure 3)

In addition to the Terrestrial biodiversity programs, the subprogram "Biodiversity Informatics" was set up. An immense number of organismic specimens and related data are deposited in the various Natural History Museums of Germany. A substantial proportion of these data is not yet readily accessible or is incomplete; in particular molecular genetic data is still missing for the majority of the collected specimens. The aims of "Biodiversity Informatics" are to

improve the methods of biodiversity data capture and maintenance,

to digitalize and network the wealth of the already available data collections, and

to interlink biodiversity-related infrastructures nationally and worldwide by joining with the program GBIF.

SHIFT: Studies on Human Impact on Forests and Floodplains in the Tropics (http://www.internationale-kooperation.de/)

The SHIFT program (Figure 4) which is financed by the Federal Ministry of Education and Research with 25.6 Mio € was started in 1989 as a milestone in a long-lasting scientific and technological cooperation between Germany and Brazil. Many projects have already come to an end, and funding of the actual 12 projects shall finish by the end of 2003. SHIFT is closely tied to the International Pilot Program for the Conservation of the Brazilian Rain Forest and it contributes to the global UNESCO research program "Man and Biosphere". The 5 major goals of SHIFT are:

Increase of knowledge about structure and key functions of tropical ecosystems

Knowledge about regulatory ecosystem factors in order to develop concise concepts for sustainable land use and for protection of endangered areas

Developing of measures and management concepts for recuperation of degraded and abandoned areas

Figure 4. SHIFT and Mata Atlantica

Improvement of the scientific assessment of human actions with respect to environmental risks and reduction of anthropogenically induced environmental problems

Training of specialists and capacity building for environmental research

The projects are all performed in cooperation of German and Brazilian researchers and are located in four geographic regions with unique ecological, economic and social impacts:

Central Amazonia (which represents the new frontier of agrarian movements into the rain forest and the inundated river margins).

Eastern Amazonia, (a transition zone from forestry systems to pastures and new sustainable land use forms)

The Pantanal (as a central ecosystem of high biological diversity and a social conflict area due to high population pressure).

The Atlantic Forest, Mata Atlantica that is impaired by heavy industrial and agro-industrial activities and a concentration of the population.

Biodiversity research of SHIFT will be continued in the scope of the new program "Ecosystem, Economy and Society in the Region MATA ATLANTICA" of the Federal State Rio de Janeiro (http://www.biolog-online.info/PT/Umwelt/F70000/F73000). It was started last year and focuses on the remnants (5 % of originally 1 million km²) of the previous rain forests of the Atlantic Coast.

BIOTEAM

The German programs of biodiversity research show that biodiversity is understood not only as a matter of biology, but is also recognized as an issue of man, especially with respect to the tremendous increase in population. Therefore biodiversity-research must also cover socio-economic problems of biodiversity utilization and conservation. This claim is not new, but the problems are very complex and promising research strategies are scarce. Biologists and sociologists, economists and lawyers must cooperate. In 2002, a program has been implemented by the Federal Ministry of Education and research, termed "Biosphere research - integrative and application-oriented model projects", "BIOTEAM" (http://www.biolog-online.info/PT/Umwelt/F70000/F73000) ([[Figure 5]]). BIOTEAM aims at

an economic validation of conservation measures on the basis of cost-benefit-analyses,

an interlinking of ecosystem-targeted research in hotspots of biodiversity with bioprospecting for new

pharmaceutical and construction materials, and a fair benefit sharing,
the development of strategies for a local or regional biodiversity management for industrialized areas and against the invasion of Neobiota into the indigenous flora and fauna.
Nine projects have been approved, four of which are working in Ecuador, 1 in Chile, 1 in Africa, and 3 in Germany. From the Ecuadorian projects 3 are focusing on benefit sharing with respect to use of indigenous plants. The program is financed with about 9 Million € for 3 years.

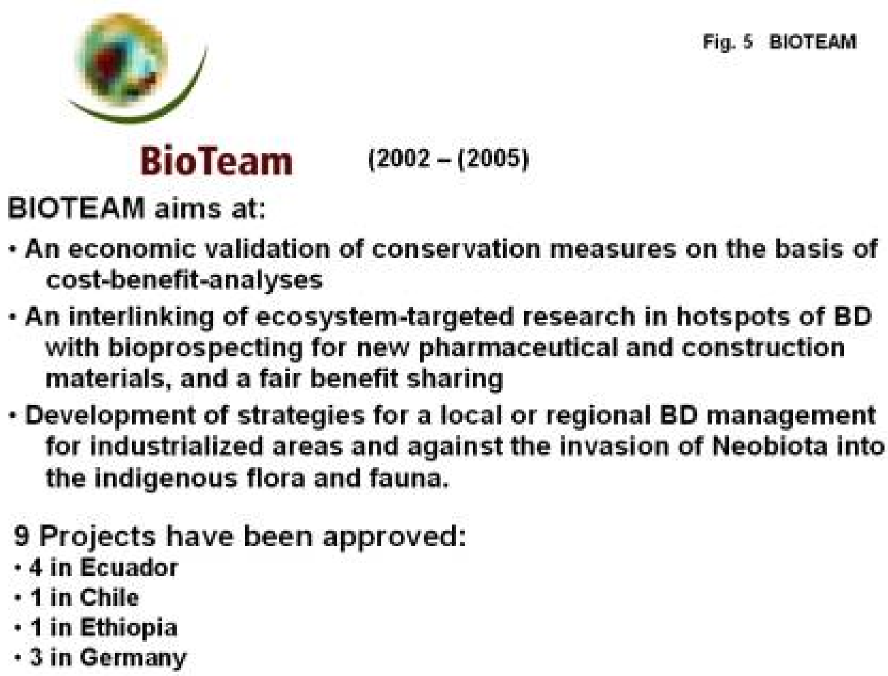

Figure 5. Bioteam

German Science Foundation
The German Science Foundation (DFG) in several programs also finances ecosystem-related biodiversity-research. Well known in Ecuador is the DFG-Research Unit: Functionality in a tropical mountain rainforest: Diversity, dynamic processes and potentials of utilization under ecosystem perspectives (http://www.bergregenwald.de). This is the project working since 1997 in South Ecuador in the forest of the San Francisco valley and on the previous forested areas, which have been cleared for agricultural purposes (Figure 6). The project is centered around the research Station "Estacion Cientifica San Francisco" which is run by the Foundation NCI. In a multidisciplinary study, comprising at present 32 major projects in relevant bio- and geosciences, in forestry and in sociocultural research, the German-Ecuadorian research group aims at an understanding of the ecosystem "mountain rain forest" in the San Francisco Valley between Loja and Zamora and to develop protocols for reforestation and sustainable use. The study is supported with approximately 2 Million € per year.

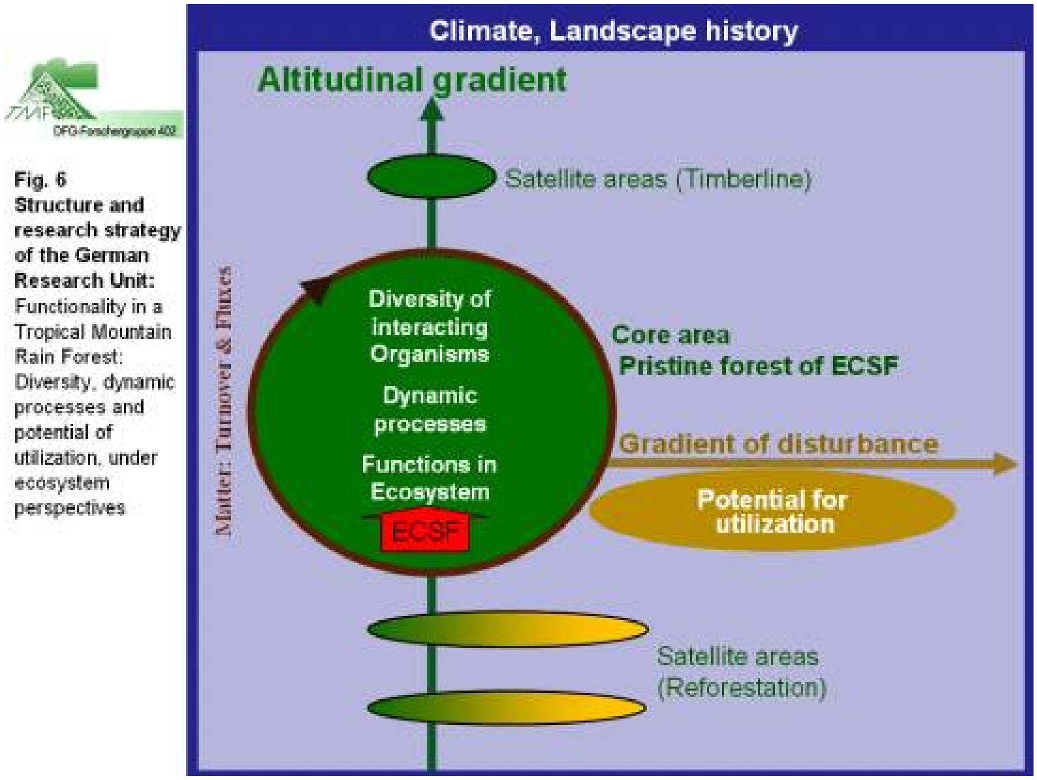

Figure 6. Structure and research strategy of the German Research Unit: Functionality in a Tropical Mountain rain Forest: Diversity, dynamic processes and potential of utilization under ecosystem processes.

Benefit Sharing in Biodiversity Research and Utilization

Monetary biodiversity research

Benefit sharing in biodiversity research is understood mainly with respect to the exploitation of biological and genetic resources, in particular of developing countries where most of the world's biodiversity is found. The CBD recognizes national sovereignty over all biological and genetic resources, and provides that access to valuable biological resources has to be carried out on "mutually agreed terms" and is subject to the "prior informed consent" of the country of origin. When a microorganism, plant, or animal is used for a commercial application, the country of its origin has the right to benefit, but on the other hand the country has to facilitate access to that resource. As the BONN-Guidelines of 2002 state, benefits can include cash, samples of what is collected, the participation and training of national researchers, the transfer of biotechnology equipment and know-how, and shares of any profit from the use of the resources. Although the field of bio-patents still requires much skill and legislation, the regulations of the CBD provide more or less clear elements for the development of practically applicable measures and many models have already been presented. At least a dozen countries have already established rules for control over access to their genetic resources such as the Philippines, Costa Rica, the OAU, and the countries of the Andean Pact.

Non monetary biodiversity research

Neither the CBD, nor the BONN Guidelines provide clear ideas about benefit sharing in context with basic and therefore non-monetary biodiversity research. Such kind of research is very much on the upswing in Germany as it was shown before. In this context, benefit sharing is mainly understood as capacity building, training of indigenous scientists and establishment of common data bases. Through the CBD, the industrial nations have agreed to provide financial support to the developing countries to defray the incremental costs of the fulfillment of the obligations of the CBD. However, the regulations how the support meets the obligations are not very precise, and with respect to non monetary biodiversity research are mainly focusing on the Global Taxonomy Initiative (http://www.biodiv.org/doc/lists/nfp-gti.pdf). It is felt that there is a lack of guidelines for benefit sharing in basic biodiversity research, especially with regard to research into ecosystem aspects undertaken in developing countries.

A working group on benefit sharing in biodiversity-research has therefore been installed in the German Research Foundation and the issue has been taken up by the International Union of Biological Sciences to work on respective guidelines in January 2004. In view of the many promising programs in BIODIVERSITY research which have been started during the last few years, not only in Germany, obstruction of that kind of research due to ill-defined legislative framework must be avoided in any case.

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Seed Conservation of the Latinamerican flora – an international opportunity.

La conservación de semillas de la flora latinoamericana – una oportunidad internacional.

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Seed Conservation of the Latinamerican flora – an international opportunity.

Resumen

Las acciones de conservación *ex-situ* complementan en una forma importante las actividades de manejo *in-situ*. Los bancos de semillas representan uno de los métodos más efectivos para conservar la diversidad genética *ex-situ*, ya que la mayoría de especies silvestres producen semillas tolerantes a la desecación que pueden sobrevivir por más de 200 años en condiciones sub zero. Es posible capturar la mayor parte de la diversidad genética de las especies de fecundación cruzada en una sola muestra. La conservación de muestras de semillas representa una "póliza de seguro" contra las amenazas *in-situ* y al mismo tiempo permite el desarrollo de protocolos de germinación, técnicas de propagación etc. que contribuyen al uso potencial de la especie. El proyecto Banco de Semillas del Milenio es un programa de 10 años, coordinado por el Real Jardín Botánico de Kew, que pretende conservar semillas de especies silvestres útiles, endémicas y amenazadas. Se ha establecido colaboraciones con alrededor de 30 organizaciones en 16 países para recolectar, conservar e investigar semillas de plantas nativas. Un proyecto piloto con CNCRF-MARNR (Venezuela), colectó e investigó al menos 40 especies. Proyectos actuales con el INIA (Chile) y FESI-UNAM (México) han conservado mas de 287 especies, capacitando a 38 personas y estableciendo programas de investigación conjunta. Es esencial fortalecer las capacidades y redes existentes y crear nuevos enlaces para proyectos de conservación de semillas que complementará iniciativas nacionales de manejo de ecosistemas y uso sustentable de la biodiversidad Palabras claves: ex situ, especies silvestres, desecación, zonas áridas, capacitación.

Abstract

Ex situ conservation actions are an important complementary measure to *in situ* habitat management. Seed-banking is one of the most effective and useful ways of conserving genetic diversity *ex situ*, as the majority of wild plant species from dryland environments produce desiccation tolerant seeds that can be successfully stored for over 200 years. In most out-breeding species, the majority of the genetic diversity of the species may be captured by a single large seed sample. Conservation of population seed samples from these species provides insurance against loss of the wild population, whilst allowing biologists to develop germination protocols, propagation techniques etc. to support use of the species. The Millennium Seed Bank project is a 10-year global initiative led by RBG Kew aiming to conserve seed of useful, endemic or threatened wild plant species. Partnerships with around 30 organisations in 16 countries are building local scientific and technical capacity to collect, conserve, and study seeds of local plants. An initial pilot project with CNCRF-MARNR, Venezuela lead to seed collection and associated studies of at least 40 species. Current projects with INIA, Chile and FESI-UNAM, Mexico have conserved more than 287 species, trained 38 people and established joint research programmes. It is essential that seed conservation projects strengthen existing capacities and networks, create new links and complement national initiatives in ecosystem management and sustainable use of biodiversity. Key Words: ex situ, wild species, drying, arid zones, training.

Introducción

Las amenazas contra la diversidad de especies son permanentes y en aumento. Un diagnóstico de la situación de la biodiversidad en los países andinos lista varias amenazas, entre ellas los altos niveles de pobreza, la insuficiente educación ambiental, el incremento de población y desarrollo urbano, la expansión de la frontera agropecuaria, la extracción forestal, la apertura de nuevos caminos, el sistema de desmonte, el sobre pastoreo, la quema de pastizales, la sobreexplotación de recursos biológicos, la actividad petrolera, la minería de oro, el comercio, el turismo, la introducción de especies exóticas y la contaminación (Comunidad Andina de Naciones 2002). Frente a esta situación se hace urgente nuevas acciones de conservación y uso sostenible de la biodiversidad.

Ningún método de conservación satisface todas las necesidades. Factores como la biología de la especie, el tipo de amenaza, los recursos disponibles para la conservación, la capacidad técnica y las necesidades de los usuarios influirán en las decisiones. La conservación *in situ* conserva tanto la diversidad genética, como los procesos ecológicos y evolutivos, y las interrelaciones entre especies. Sin embargo, no es posible proteger todas las poblaciones y especies *in situ* con los recursos actuales. Siempre existirán especies amenazadas que no están incluidas en ningúna área protegida y por lo tanto requerirán otro método de conservación. Squeo et al. (2001) determinó que las actuales áreas protegidas de la región Coquimbo (Chile), conservan sólo un 39% y 56% de las categorías de plantas "en peligro" y "vulnerables" respectivamente. Aún incorporando unas 5 áreas prioritarias quedaría 30% de las plantas"en peligro" y 26% de las "vulnerables" sin protección alguna.
El Articulo 9 del Convenio sobre Diversidad Biológica (CDB) compromete a las partes contratantes (principalmente a fin de complementar las medidas *in situ*) a adoptar "medidas para la conservación *ex situ* de componentes de la diversidad biológica, preferiblemente en el país de origen de los mismos". (CDB 1992). La Decisión VI/9 de La Conferencia de las Partes de la CDB adoptó la 'Estrategia mundial para la conservación de las especies vegetales', cuyos objetivos incluye: viii) El 60% de las especies vegetales amenazadas en colecciones accesibles ex situ, de preferencia en el país de origen, y el 10% de ellas incluidas en los programas de recuperación y restauración (CDB 2002). La Estrategia Regional de Biodiversidad para los países del trópico andino, aprobada por el Consejo Andino de Ministros de Relaciones Exteriores por medio de la Decisión 523, reconoce que la conservación *in situ* necesita de un complemento *ex situ* "que permite asegurar a largo plazo la propagación de especies raras y en peligro de extinción…(y) reforzar los mecanismos de conservación de las poblaciones silvestres" (CAN 2002).
Entre los diferentes métodos para conservar la diversidad genética *ex-situ*, los bancos de semillas son muy efectivos y económicos (Linington & Pritchard 2001; Hawkes et al. 2000). La mayoría de las plantas silvestres producen semillas tolerantes a la desecación (Tweddle et al. 2002) aptas para conservación en bancos de semillas. Comparado con otros métodos de conservación *ex-situ*, los bancos de semillas conservan la diversidad genética de un gran número de especies en un espacio mucho más pequeño y a un costo relativamente bajo. Aparte de representar una "póliza de seguro" contra las amenazas *in-situ,* los bancos de semillas tambiénpermiten el desarrollo de protocolos de germinación y técnicas de propagación, que podrían contribuir a programas de uso sostenible o de recuperación y restauración de la especie *in-situ*.
Los bancos de semillas han sido ampliamente utilizados para la conservación de especies para la alimentación y la agricultura (FAO 1996) pero hay limitados ejemplos de su uso para la conservación al largo plazo de especies silvestres (Laliberté 1997). Inspirado por la conferencia de las Naciones Unidas sobre el Medio Ambiente y Desarrollo ("Cumbre de la Tierra", Rió de Janeiro, 1992), y fundamentado por el Convenio de Diversidad Biológica, el Proyecto Banco de Semillas del Milenio (PBSM) es un programa de 10 años, coordinado por el Real Jardín Botánico de Kew, (RéJB Kew) que pretende lograr la conservación *ex situ* de semillas de las zonas áridas y semi-áridas.
El objetivo del PBSM es conservar semillas de 24,000 especies silvestres (principalmente especies útiles, endémicas y amenazadas) a través de colaboraciones bilaterales de capacitación e investigación conjunta. Hasta la fecha (abril 2004) se ha establecido colaboraciones con alrededor de 30 organizaciones en 16 países para recolectar, conservar e investigar semillas de plantas nativas. El actual artículo describe los procedimientos básicos de la conservación *ex situ* de semillas y presenta las experiencias de un proyecto piloto en Venezuela y las colaboraciones actuales en México y Chile.

Métodos

Priorización
Es importante utilizar los recursos disponibles óptimamente con el fin de conseguir los mejores beneficios posibles a nivel local, regional y nacional, para ello la priorización juega un papel muy importante en la conservación. En México, la Comisión Nacional para el Conocimiento y Uso de la Biodiversidad (CONABIO) ha identificado regiones prioritarias para la conservación (Arriaga et al. 2000) y en la Región de Coquimbo, Chile, el libro rojo de la flora nativa y de los sitios prioritarios para su conservación (Squeo et al. 2001) soporta la priorización de las acciones.

Muestreo

Los principios generales sobre la distribución de la diversidad genética indican que se puede capturar la mayor parte de la variabilidad de una especie de fecundación cruzada en el muestreo de una sola población 'tipica' (Brown & Marshall 1995; Way 2003). La mayoría de las plantas silvestres son de fecundación cruzada, así que una sola muestra de semillas conservará efectivamente la diversidad genética de la especie.

Conservación

La gran mayoría de especies de las zonas áridas y semi-áridas, regiones prioritarias del PBSM, poseen semillas tolerantes a la desecación (Tweddle et al. 2003). Para este tipo de semilla, al secarlas, y reducir la temperatura de almacenamiento, se limitan los procesos fisiológicos de envejecimiento y se incrementa la longevidad, o potencial de almacenamiento (Ellis 1998; Probert & Hay 2000). Al reducir el contenido de humedad de las semillas desde condiciones ambientales hasta 4-7% ch, se incrementa su longevidad hasta 1000 veces. Almacenar las semillas en condiciones sub-zero prolonga aún más la longevidad de las semillas. El PBSM almacena las semillas a -20 °C.

Colaboraciones del PBSM

Los programas de colaboración se fundamentan en combinar el conocimiento local con la larga experiencia en conservación de semillas del RJB Kew. Los proyectos son diversos, obedeciendo las capacidades, intereses y prioridades de las contrapartes institucionales, el país y la región (León-Lobos et al. 2003; Smith et al. 2002). Cada proyecto está fundado en colectar semillas, conservarlas a largo plazo, y hacerlas accesibles para la investigación. Las actividades pueden incluir, por ejemplo:

Prospección y documentación de la flora existente

Rescate de germoplasma frente a una amenaza inmediata

Colecta de germoplasma para suministro inmediato a viveros, campesinos etc. para restauración, propagación y/o producción.

Programas coordinados de investigación

Todas las colaboraciones incluyen actividades de capacitación de personal y de fortalecimiento de la infraestructura necesaria para la conservación exitosa de semillas de plantas silvestres. Según los preceptos del CDB, las colaboraciones se rigen por acuerdos legales de acceso y distribución justo y equitativo de los beneficios. Estos acuerdos entre RJB Kew y sus contrapartes científicos nacionales han sido aprobados por las autoridades competentes nacionales. En todo caso se prohíbe el uso comercial por parte del RJB Kew del material genético transferido.

Resultados

Resiultados de PBSM en America Latina

Venezuela

Un proyecto piloto con el Centro Nacional para la Conservación de Recursos Fitogenéticos - Ministerio del Ambiente y de los Recursos Naturales Renovables (CNCRF-MARNR), Venezuela con la asistencia local del ONG PROVITA, colectó y estudió al menos 40 especies de la Isla Margarita con el propósito de investigación, restauración de hábitat y almacenamiento a largo plazo. Las semillas están conservadas en el CNCRF, Venezuela y duplicados en el Banco de Semillas del Milenio, Reino Unido. Muestras de 8 accesiones han sido pedidas como material para investigación no-comercial a través de la lista de semillas publicado por RJB Kew.

Chile

El proyecto con el Instituto de Investigaciones Agropecuarias (INIA) se inicio en julio del 2001. Se han realizado colectas de semillas en la III, IV, V y RM regiones de Chile; desde los 28º a los 34º S. En las regiones III y IV, las colectas se han realizado principalmente en la franja costera y en las Regiones V y Metropolitana, desde la costa hasta los pisos subandinos de la Cordillera de los Andes. Las semillas están conservadas en el Banco Base de Semillas de INIA localizada en Vicuña, y se depositó un duplicado en el banco de semillas del RJB Kew. Desde el inicio del proyecto hasta abril 2003 se colectó 170 accesiones correspondientes a 149 especies, de las cuales un 73% son endémicas de Chile (León-Lobos et al. 2003). En Marzo 2002 se organizó un curso de "Colecta de semillas de especies nativas para su conservación *ex-situ*" en Olmué, Chile. El curso reunió a 14 participantes y 7 tutores, de 13 institutos diferentes. Se establecieron varios enlaces nuevos y esto ha facilitado una red creciente entre organizaciones gubernamentales, académicas y técnicas de colección y conservación de semillas de plantas chilenas endémicas, vulnerables y amenazadas.

México

Entre febrero 2002 y enero 2003 la Facultad de Estudios Superiores Iztacala (FESI) de la Universidad Nacional Autónoma de México (UNAM) colectó más de 150 accesiones de 138 especies en el Valle de Tehuacán-Cuicatlán, México central. Se espera una posible expansión del proyecto, dependiendo de las provincias florísticas reconocidas dentro de las regiones xerofíticas de México. La división del país en regiones florísticas es basado en las afinidades geográficas de la flora, características eco-geográficas generales e información sobre endemismo. Esto provee un útil armazón para objetivizar acciones de conservación *ex-situ.*

Se ha remodelado un cuarto del banco de semillas de la FESI-UNAM, creando una cámara de secado para recibir las semillas recolectadas. Las condiciones controladas de temperatura y humedad relativa (16°C, 16% HR) ha permitido reducir los niveles de humedad de las semillas y así mantener la viabilidad y mejorar la longevidad de las colecciones. También ha facilitado un manejo más efectivo y coordinado de las colecciones. Después de la remodelación del cuarto de secado un técnico del RJB Kew visitó al FESI-UNAM para capacitar sobre aspectos de procesamiento, evaluación de calidad y viabilidad de las colecciones de semillas y desarrollar protocolos y técnicas para evaluación y manejo de las semillas. Anteriormente, un curso de teoría y práctica capacitó a 24 personas, de varios institutos. Se han integrado un grupo de investigadores en fisiología vegetal, cultivo de tejidos, bioquímica molecular y conservación de semillas en la FESI-UNAM, para estudiar diversos aspectos de la biología de las especies *Beaucarnea gracilis* y *Hechtia podantha.* Ambas especies forman componentes importantes de las comunidades vegetales de la región de Tehuacán-Cuicatlán y se integrará los resultados con otros estudios biológicos para entender mejor el rol biológico, el valor o utilidad de las especies.

Discusión

La conservación de germoplasma vegetal a través de los bancos de semillas es práctica y eficiente en costo. Existe mucha experiencia en los bancos de semillas de especies cultivadas pero se necesita mejorar las capacidades para trabajar con un rango diverso de especies silvestres. Al mismo tiempo existen trabajos de investigación botánica y estudios ecogeográficos que proveen información clave para la priorización de especies y áreas a colectar. Por ejemplo, en el Ecuador se ha definido 32 Áreas Prioritarias para la flora en base de 4 criterios, incluyendo el grado de endemismo y amenaza de especies o habitats (Josse & Cano 2000). Es esencial fortalecer las capacidades y redes existentes y crear nuevos enlaces para proyectos de conservación de semillas que complementará iniciativas nacionales de manejo de ecosistemas y uso sustentable de la biodiversidad. Las áreas prioritarias a trabajar podrían incluir el bosque seco latifoliado, los pastizales, arbustos, los matorrales xéricos y desiertos, los mismos que pueden estar amenazados por cambios climáticos futuros.

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Important advances in biodiversity conservation in Peruvian Amazonia

Avances importantes en conservación de la biodiversidad en la Amazonía Peruana

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Important advances in biodiversity conservation in Peruvian Amazonia

Resumen

El ambiente está deteriorándose rápidamente en todo el mundo, incluyendo áreas que se pensaban eran remotas, como es la Amazonía peruana. La deterioración continua ha resultado en una serie de convenios internacionales, como el Convenio sobre la Diversidad Biológica, para disminuir y mitigar estos problemas ambientales, proteger derechos de las comunidades indígenas, y conservar flora y fauna, ecosistemas y genes. En este contexto, especialmente vulnerable es la Amazonía peruana que es un mosaico de ecosistemas asociados con los Andes y biológicamente muy diversa y que representa una gran variedad biológica y física que forma la base para una rica diversidad cultural. Esta megadiversidad está seriamente amenazada por la tala de bosques y uso de la tierra no sostenible que extiende ya áreas remotas. Para combatir estos problemas ambientales se inició el Proyecto Diversidad Biológica de la Amazonía Peruana, Perú-Finlandia (BIODAMAZ) que es un proyecto de cooperación entre los gobiernos del Perú y de Finlandia (Fase I 1999-2002, Fase II 2003-2005). El proyecto BIODAMAZ ha contribuido significativamente a la conservación y uso sostenible de la biodiversidad a través de los siguientes resultados: fortalecimiento de administración ambiental; mejoramiento de acceso a fuentes internacionales de financiamiento en conservación de la biodiversidad; fortalecimiento de capacidad de negociación de los actores ambientales peruanos; mejoramiento de sistematización, organización y acceso de información sobre biodiversidad; fortalecimiento de Zonificación Ecológica Económica; mejoramiento de conocimiento sobre patrones de distribución de biodiversidad amazónica para planificación de uso de la tierra; y fortalecimiento de capacidades regionales y colaboración institucional. Palabras clave: Conservación, Biodiversidad, Perú

Abstract

Environment is rapidly deteriorating everywhere, including even areas once thought to be remote, such as Peruvian Amazon. The ongoing deterioration has led to a series of international agreements and conventions, such as the Convention on Biological Diversity, in order to diminish and mitigate these environmental risks, protect indigenous communities rights, and conserve flora and fauna, ecosystems and genes. In this context, especially vulnerable is the biologically diverse Peruvian Amazonia which is a mosaic of ecosystems that are associated with the Andes, representing a wide range of biological and physical variations that also form the basis for a rich cultural diversity. This megadiversity is seriously threatened as logging and unsustainable land use practices reach ever remoter areas within the region. In order to deal with the pressing environmental problems the Project Biological Diversity of Peruvian Amazonia, Peru-Finland (BIODAMAZ) came into being. It is a cooperation project between the governments of Peru and Finland (Phase I 1999-2002, Phase II 2003-2005). The project BIODAMAZ has contributed significantly to biodiversity conservation and sustainable use in Peruvian Amazonia through the following results: strengthening of environmental administration and management; enhancement of possibility to access international biodiversity conservation funding sources; strengthening of negotiation capacities of Peruvian environmental actors; systematisation and organization of and improvement of access to biodiversity information; strengthening of the regional land use planning tool, the Ecological Economic Zoning; enhancement of knowledge on Amazonian biodiversity distribution patterns for land use planning; strengthening of regional capacities in biodiversity management and institutional collaboration. Key word: Conservation, Biodiversity, Perú

Introduction

Environment is rapidly deteriorating everywhere, including even areas once thought to be remote, such as Peruvian Amazonia. This ecological crisis is a global process that is generating much concern and discussion on environmental problems at a worldwide scale, especially on destruction of habitats and the resulting unavoidable loss of species (UNEP 1995). The Earth is suffering from irreversible deterioration which at some point ought to change attitudes towards conservation and sustainable use of biodiversity to more favourable for those. This should happen especially in countries that harbour vast richness of species, habitats and ecosystems and whose inhabitants are largely dependent on the resources provided by biological diversity in their daily lives. An example of such an area is Peruvian Amazonia where people's economies are still largely based on extractive activities that prey on biodiversity resources.

The ongoing deterioration have led to a series of international agreements and conventions, such as the Convention on Biological Diversity (United Nations Conference on Environment and Development, Rio de Janeiro, Brazil 1992), in order to diminish and mitigate these environmental risks, protect indigenous communities rights, and conserve flora and fauna, ecosystems and genes. These are to be achieved by the fulfilment of the three Convention objectives: 1) conservation of biological diversity, 2) sustainable utilization of its components, and 3) equitable sharing of benefits derived from genetic resources of biological diversity (Convention on Biological Diversity 1992).

In this context, especially vulnerable is the biologically diverse Peruvian Amazonia which is a mosaic of ecosystems that are associated with the Andes, representing a wide range of biological and physical variations that also form the basis for a rich cultural diversity. (Kalliola et al. 1993). Peruvian Amazonia is also megadiverse representing one of the richest environments on the Earth. This megadiversity is also seriously threatened as logging and unsustainable land use practices reach ever remoter areas within the region. Uncontrolled and informal logging also threatens the livelihoods and cultures of some native peoples, especially those peoples that are so called "not contacted" who have chosen to carry on their lives as they have done for thousands of years and who do not want to have any contacts with the modern society.

Although many areas of Peruvian Amazonia still remain remote the region faces some serious environmental problems, such as contamination of waters, especially of rivers close to large human settlements such as the city of Iquitos. An example of contamination endangering people's lives was the contamination of the Nanay River by mercury pollution which was used in gold mining upriver. Traces of mercury were found in the people's blood and the riverside people started to show signs of mercury poisoning. This lead to a large-scale questioning of the legality of the practice of gold mining in the river by the local people, and also by the city dwellers of Iquitos, largest city in Peruvian Amazonia with ca. 350 000 inhabitants that also get their daily drinking water from the Nanay River. After the problem was brought to the attention of the media and received much interest, the Government finally acted to prohibit gold mining in the river.

Peru has also showed interest in the protection and conservation of its vast natural and biological resources, this is evident in the legislation of the last ten years. The Peruvian Constitution calls for conservation of biodiversity as do a number of laws, such as, for example, the law on biodiversity and the law on protected areas. In 2001 Peru finalized its National Biodiversity Strategy (CONAM 2001) thus fulfilling one of the requirements of the Convention on Biological Diversity. This Strategy contains the Regional Biodiversity Strategy of Peruvian Amazonia (BIODAMAZ 2001a) which was finalized with the support of the Project Biological Diversity of Peruvian Amazonia (BIODAMAZ), a technical cooperation project between the governments of Peru and Finland. In 2002, Peruvian political leaders signed a National Agreement that explicitly calls for conservation of biodiversity and makes it one of the national priorities to promote its research.

In order to deal with the pressing environmental problems in the complex Amazonia the Project Biological Diversity of Peruvian Amazonia, Peru-Finland (BIODAMAZ) came into being. It is a cooperation project between the governments of Peru and Finland which in 1999-2002 was implemented through two agreements: first one for the Components 1 and 2 was signed on the 29th of September in 1999 and the second one for the Component 3 was signed on the 17th of January in 2001. The implementation phase for the Components 1 and 2 was until the 30th of September, 2002, and for the Component 3 until 31st of

December, 2002.

The Second Phase of the Project was deemed necessary in order to continue the work started in the first phase. The agreement regarding the second phase of the project was signed on the 21st of April in 2003 and the implementation period is from 2003 to 2005.

The national counterpart for the project is the Peruvian Amazonian Research Institute (Instituto de Investigaciones de la Amazonía Peruana, IIAP) and as the Finnish counterpart there is a consortium formed by the environmental consulting company, Biota BD Oy, and the University of Turku.

The project works in four Peruvian Amazonian provinces: Loreto, Ucayali, San Martín and Madre de Dios, focusing mainly on the lowland rain forest areas (below 500 meters above sea level). The project offices are located in the headquarters of the IIAP in Iquitos.

In this article the main results of this project are presented as important advances in biodiversity conservation in Peruvian Amazonia, including an assessment of the importance and impacts of these results.

Necessity of action in biodiversity conservation in Peruvian Amazonia

The necessity of this project rises from the compromise of the both countries to fulfil the requirements of the Convention of Biological Diversity. Also it was the first project to really tackle the complex biodiversity context of Peruvian Amazonia and to implement the requirements of the Convention at a regional level in Peru. One of these requirements is the development of biodiversity strategies and action plans for conservation and sustainable use of biological diversity. The presentation of strategies and action plans would allow access to different financing mechanisms of the Convention, such as the Global Environment Facility (GEF), for Peru. At the onset of the project, the Peruvian national and regional environmental authorities needed also strengthening of their capacities to implement the Convention of Biological Diversity at the national and regional level.

The information that exists on Peruvian Amazonian biodiversity is very scarce and scattered in different institutions and thus not easily available to the users, such as decision makers, planners and educators. Many areas in Peruvian Amazonia have not been exhaustively studied as to their biological diversity, for example due to their inaccessibility and remoteness, resulting in incipient biological collections only covering certain areas. Institutions working on issues related to biological diversity tend to guard their information from others, giving no room for a real development of an information culture: openness, accessibility and transparency.

In order to overcome these problems in the biodiversity sector in Peru the objective of the project BIODAMAZ was to contribute to conservation and sustainable use of Amazonian biological diversity by development of administrative and management tools and research methodologies for sustainable management of Amazonian biological diversity. The objective of the second phase of the project is to contribute to conservation and sustainable use of Amazonian biological diversity in order to promote sustainable development and poverty alleviation through strengthening of decentralized capacities and developing of administrative and managerial tools and research methodologies for sustainable management of biological diversity.

Advances in administrative and managerial tools for conservation and sustainable use of biodiversity

The project BIODAMAZ contributed to the finalization of the Regional Biodiversity Strategy of Peruvian Amazonia (ERDBA), which was compiled by biodiversity administrator, manager, planner and user organizations of Peruvian Amazonia. It is a planning tool whose objective is to set priorities and adopt actions and measures for adequate conservation and sustainable use of biodiversity. ERDBA is integrated to the National Biodiversity Strategy of Peru (ENDB) and it orients policies and practices of how to conserve and sustainably use the Amazonian biodiversity in the next 20 years, emphasising the management of the natural biological and cultural capital, promotion of investment and employment, and access for the local communities to the benefits derived from sustainable use of biodiversity. The Strategy and its action plans contribute to the decentralized environmental administration at the national and Amazonian level and facilitate the access to funding and national and international cooperation in prioritised projects and activities. ERDBA is published and it is now being disseminated and promoted in order to guarantee its sustainability.

As an integral part of the ERDBA are the biodiversity action plans (BIODAMAZ 2003f) which the project BIODAMAZ facilitated to develop in the process of the strategy formulation, and which specify the needed steps to implement the strategy, developing practical aspects. In order to take into account the particular characteristics of the different administrative regions, action plans were also developed for the four regions separately: Loreto, Ucayali, Madre de Dios and San Martín.

The project BIODAMAZ together with specialists from institutions of the public and private sector proposed an action plan on *in situ*and *ex situ* conservation in Loreto (BIODAMAZ 2003e) as a part of the action plans of the ERDBA. It focuses on the region of Loreto that represents a third part of the national territory and which represents biodiversity that is the least altered in Peruvian Amazonia. Loreto is situated in the lowland Amazonian rain forest and harbours many areas of unique importance for *in situ* and *ex situ* conservation. It is considered fundamental to integrate *in situ* and *ex situ* conservation strategies to guarantee adequate conservation and sustainable use of biological diversity. The action plan contains a conceptual framework for conservation, strategic objectives and actions and projects.

Closely linked to the *in situ* and *ex situ* conservation action plan are the development plan of Botanical Garden-Arboretum El Huayo (JBAH) (BIODAMAZ 2003g), which is a conservation area that belongs to the National University of Peruvian Amazonia (UNAP), and the scientific and technical bases and proposals of guidelines for management practices and zoning of Allpahuayo-Mishana Reserved Zone (ZRAM) (BIODAMAZ 2003a) that have been developed by the project BIODAMAZ, as well as the proposal for development of tourism along the Iquitos-Nauta road (BIODAMAZ 2003h). The JBAH development plan includes actions to strengthen the JBAH in order to conserve economically and scientifically important plant species, especially tree species, of Peruvian Amazonia. The plan also includes sections on tourism and environmental education in order to strengthen the integration of the local communities to biodiversity conservation and sustainable use actions within the JBAH. The ZRAM is an important centre of biodiversity in the vicinity of Iquitos, as it is a mosaic of different ecosystems leading to high biodiversity and as it presents a largest concentration of white sand forests known in Peru, harbouring many endemic and unique species of fauna and flora. Its protection is of utmost importance as it is threatened by not sustainable utilization of its resources.

An essential part of biodiversity management is the management of information on biological diversity. An information system is seen as a system where information is located in different institutions that organize and maintain information on Amazonian biological diversity, institutions being linked to each other through different means of communication. It acts as a network that coordinates information, tries to systematize institutional and personal scientific research and information at regional, national and international level. It permits to coordinate standards for information management, including the immediate inclusion of this information to scientific and technical archives, avoiding thus dispersal of information on biodiversity. The Biodiversity and Environment Information System of Peruvian Amazonia – SIAMAZONIA – was designed by the project BIODAMAZ with these ideas in mind (BIODAMAZ 2001b). Now it is operating on the Internet giving services to different actors in conservation and sustainable use of biodiversity. It can be found at www.siamazonia.org.pe. Related information systems developed by the project are the Information System of the JBAH (SIHUAYO www.siamazonia.org.pe), Information System of the Allpahuayo-Mishana Reserved Zone (SIZRAM www.siamazonia.org.pe) and the Tourist Information System on Iquitos-Río Amazonas (SITURISMO www.siturismo.org.pe) that were designed in close collaboration with local sector actors and Faculty of System Engineering of the UNAP.

Advances in information on biodiversity patterns in Peruvian Amazonia

The project BIODAMAZ produced the first mosaic of satellite images with 42 images covering the whole of lowland Peruvian Amazonia which allows appreciate the great environmental variation within the area. The mosaic is an essential tool in biogeographical studies of biodiversity: the mosaic can help to locate areas that could have interesting biodiversity patterns and that could be important for conservation. For the first time at a simple glance it is possible to take in the whole of Peruvian Amazonia and the environmental variation within. The mosaic is very useful in basic studies; it is also essential in land use planning. IIAP has now a team of professionals that have capacity to develop satellite image mosaics, this capacity can be used for further development of satellite image based maps (BIODAMAZ 2003c). It serves also as basis for the map of vegetation diversity, showing the vast diversity of different vegetation types in Peruvian Amazonia, and map of environmental macro units, depicting areas relatively homogenous as to their physical and biological characters. The making of the environmental macro unit's map also required development of the methodology for the determination of these macro units (BIODAMAZ 2003d). To define these maps a series of ground-truthing studies were conducted in three plant (ferns, family Melastomataceae and palms) and three animal (ants, anuran amphibians and birds) groups in thirteen localities in the lowland rain forest in the northern, central and southern parts of Peruvian Amazonia. These studies were done and the results analysed using standardized methods (BIODAMAZ 2003b). The results indicate that it is possible to use these groups of plants associated with certain environmental characteristics to explain patterns of other groups of plants, such as trees. Some light tendencies were observed in animals as well but the sampling was not extensive enough to provide concrete results on that. For that more studies are needed. One key result was that vegetation patterns can be observed in the satellite images which provide a remote sensing tool for assessment of biodiversity patterns.

The mosaic, the map of vegetation diversity and the map of environmental units are all freely available on the Internet through SIAMAZONIA.

Other field studies were also carried out by the project BIODAMAZ in the JBAH and in the ZRAM. In the JBAH an inventory of the Arboretum was carried out in order to identify the tree species in the area. In the ZRAM three research projects were conducted in order to provide information for the ZRAM management plan process: game fauna inventory, white sand forest classification and mapping of path network.

The game fauna inventory showed that there are certain areas within the ZRAM that are under intense hunting pressure by locals and outsiders. Within the area there are still certain areas that have good numbers of game animals present, even rarer ones (Oversluijs 2002). These studies are very important in the zoning of the area. In the white sand forest classification study it was possible for the first time tentatively classify the forests into five white sand forest type categories as the categorization was done using quantitative as well as qualitative methods (Garcia et al*.* 2002). The classification is essential to better understand how the white sand forest systems function and to show the existence of a mosaic of different forest types in the area in order to enhance the protection of different forest types and their characteristic and unique flora and fauna. The mapping exercise showed for the first time on a map the path network, this information is very useful for zoning and planning of ZRAM.

Capacity building in biodiversity issues in Peruvian Amazonia

The project BIODAMAZ emphasized the importance of capacity building during all of its activities. Capacity building in the following fields was considered very important: information systems with map servers, mosaic of satellite images, scientific research, environmental units and their integration to land use planning, scientific field work methodologies, conceptual framework for conservation and planning of conservation and sustainable use of biodiversity and biodiversity management.

Lessons learned in biodiversity conservation and sustainable use in Peruvian Amazonia

The implementation of the project has not only allowed the project to acknowledge the fruitful Peruvian-Finnish cooperation but also to identify lessons learned that will be of use for future research and development work in Peruvian Amazonia. Several of the lessons learned are presented here.

It is assessed that the conceptual framework for sustainable development requires that a fourth dimension is added, the political-institutional, to the three usual dimensions of environmental, social and economic, also in the Peruvian Amazonian region.

Information management through information systems accessible to decision-makers making decisions on policy questions and investment issues, is the key to an effective management of research and development.

Use of contemporary methodologies and technologies, such as remote sensing, facilitates substantially the increase in knowledge on biodiversity patterns, especially in spaces so complex and extensive as Peruvian Amazonia.

The Amazonian biodiversity issues are to be addressed in a multi-institutional and multidisciplinary manner in order to achieve sustainability through time and involvement of different actors in the biodiversity sector, including local communities.

There is a necessity in the region to strengthen capacity building and scientific rigor in order to increase the understanding of conservation, sustainable use and culture of valorisation of biodiversity for Amazonian development.

There is a need to look for solutions to the problems of conservation and sustainable use of biodiversity beyond mere means, to decide what is wanted and needed, develop attitudes for change; these are key issues in development.

Decentralization of capacities and opportunities is feasible and generate new and better opportunities for the country.
The wide integration and shared confidence between the Peruvian and Finnish teams has enriched visions and focuses, giving fruit to a productive cooperation.

Conclusions

The results of BIODAMAZ are an important support to conservation and sustainable use of biodiversity in Peruvian Amazonia. The advances in biodiversity conservation brought by these results are presented in the Table 1, along with an assessment of their importance and impacts. Nevertheless, it is important to learn from this experience and strengthen the sustainability of the results, by strengthening of the processes commenced and by implementing managerial and administrative tools developed. This is to be done during the second phase of the project BIODAMAZ.
Table 1. Main advances in conservation and sustainable use of biodiversity in Peruvian Amazonia by the project BIODAMAZ and their importance in conservation and sustainable use of biodiversity and long-term impacts.
Tabla 1. Avances en conservación y uso sostenible de biodiversidad en la Amazonía Peruana en el proyecto BIODAMAZ y su importancia en conservación y uso sostenible de biodiversidad y impacto de largo tiempo.

Advances	Importance of the advances	Impacts of the advances
Advances in administrative and managerial tools		
Methodology of concept, design and construction of information systems; Methodology for the design and consultation of managerial and administrative tools for conservation and sustainable use of biodiversity; Validation and enrichment of the methodology for design, monitoring and evaluation of research and cooperation projects; Plans for conservation and sustainable use of biodiversity.	Strengthening of environmental administration and management; Possibility to access financing sources of CDB; Strengthening of negotiation capacities; Biodiversity information more accessible, systematized and organized.	Raising of the level of the environmental consciousness amongst the people through training, more knowledge and functioning information system on biodiversity; Strengthening of decentralization; Situation of *in situ* and *ex situ* conservation made better as knowledge base, capacities and administrative and managerial environmental tools increase; Increase in the opportunities of financing and technical assistance for conservation and sustainable use of biodiversity for a better understanding of these processes, targeting of projects and actions needed and a fulfilment of the requirements of international conventions, typically the Convention of Biological Diversity; Enrichment of the conceptual framework of research of biodiversity, conservation and sustainable development in Peruvian Amazonia.
Advances in information on biodiversity		
Methodology for developing digitalized mosaic of satellite images; Methodology for evaluation of vegetation diversity and identification of environmental units as support to the land use planning process; Methodology to evaluate biodiversity, using indicator species of plants and animals.	Strengthening of Ecological Economic Zoning (*Zonificación Ecológica Económica*; a regional land use planning tool); New knowledge on Amazonian biodiversity distribution patterns; New information for land use planning.	More baseline data on the Peruvian Amazonian lowland biodiversity, development of methodologies for analysis of biodiversity and support to land use planning; Enrichment of the environmental culture of different social actors of the care and valorisation of biodiversity based on new knowledge and information systems available and functioning.
Capacity building and institutional cooperation	Strengthening of regional capacities; Strengthening of institutional cooperation and collaboration.	Institutional strengthening and strengthening of relations between institutions and sectors as the information base augments for the decision-making on biodiversity, through administrative and managerial instruments such as plans, strategies and information network, and through capacity building.

The Peruvian government within the development priorities has oriented policies towards sustainable use of Amazonian forests, especially timber resources, sustainable tourism and other resources and services of Amazonian biodiversity. These decisions have to be supported by solid knowledge of technical and scientific base to guarantee favourable socioeconomic and environmental impacts.
The project BIODAMAZ, as a result of a significant cooperation between the governments of Peru and Finland, has started and strengthened some processes in order to increase knowledge and strengthen biodiversity conservation and sustainable use through sustainable management. The achievement of these results, in the framework of participative and integrated approach between conservation and development, would contribute to democratic practices and decentralization, as well as increase opportunities of investment and employment, with positive impacts in the alleviation of poverty, aspects that are priorities in the cooperation policy of Finland and renowned aspiration of the Peruvian society.

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Priority conservation areas and management alternatives for the five ecoregions of Latin America.

Areas prioritarias para la conservación y sus alternativas de manejo en cinco ecoregiones de America Latina (GEF/1010-00-14)

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Priority conservation areas and management alternatives for the five ecoregions of Latin America.

Resumen

El proyecto "Áreas prioritarias para la conservación y sus alternativas de manejo en cinco ecoregiones de América Latina" es ejecutado por instituciones de investigación en Panamá, Colombia, Ecuador, Perú, Bolivia y Paraguay. El proyecto da a conocer a la comunidad internacional la selección científica de 5 áreas prioritarias para la conservación dentro de 5 ecoregiones de alta importancia mundial: el Chocó Biogeográfico, las vertientes andinas orientales de Ecuador, Perú y Bolivia y el Chaco Seco. Entre los resultados que condujeron a dicha selección, existe el análisis de más de 6470 especies de flora y fauna (cada una con mapa de distribución) y la producción de más de 6500 mapas temáticos indicando tipos de vegetación, centros de alta diversidad y endemismo, amenazas, fragmentación de bosques, infraestructura, etc. La segunda fase del proyecto consiste en analizar las condiciones ambientales y socioeconómicas de las áreas seleccionadas y formular propuestas de alternativas de manejo para quienes toman decisiones de conservación a nivel nacional y local. Este proyecto, que se caracteriza por la participación de instancias gubernamentales y locales, es administrado por The Nature Conservancy Ecuador y apoyado por instituciones como NASA, Naciones Unidas, NatureServe, Universidad de Maryland y el Centro de Tecnologías Espaciales GRID en South Dakota. Palabras clave: Conservación, Ecoregiones, América del sur

Abstract

The project "Catalyzing Conservation Action in Latin America: Identifying priority sites and best management alternatives in five global significant ecoregions" is executed by conservation/science organizations in Panama, Colombia, Ecuador, Peru, Bolivia and Paraguay. The project provides to the international community a science-based selection of priority conservation sites in five global priority ecoregions: the Choco, the eastern slopes of the Andes in Ecuador, Peru and Bolivia, and the Dry Chaco. Among the results conducing to the site selection, more than 6470 species of flora and fauna have been analyzed (each one with a geographic distribution map) and more than 6500 thematic maps have been produced, indicating vegetation types, centers of high diversity and endemism, current and potential threats, forest fragmentation, infrastructure, etc. The second phase of the project analyzes the environmental and socio-economic conditions of the selected sites and formulates alternative management proposals for decision-makers both at national and local levels. This project is characterized by the participation of different organizations at local and national levels. The project is administrated by The Nature Conservancy and technically supported by organizations such as NASA, United Nations, NatureServe, University of Maryland and the Center for Spatial Technologies, GRID, South Dakota. Key words: Conservation, Ecoregions, South-America

Introducción

El objetivo principal del proyecto es el de identificar, sobre bases científicas, los sitios de alta prioridad para la conservación en cinco ecoregiones de importancia mundial en América Latina. Para cada uno de los sitios prioritarios se propondrán alternativas prácticas de conservación y manejo de recursos naturales, las cuales serán presentadas ante las autoridades y tomadores de decisiones a nivel nacional y local en: Colombia, Ecuador, Perú, Bolivia y Paraguay. El proyecto se caracteriza por la participación de instituciones nacionales, gubernamentales y locales para su desarrollo. Las ecoregiones son: el Chocó Biogeográfico (Panamá, Colombia y Ecuador), la Cordillera Real Oriental (Colombia, Ecuador y Perú), las Yungas Peruanas (Perú), los Yungas Bolivianos (Bolivia) y el Chaco Seco (Bolivia y Paraguay). Para escoger las ecoregiones se tomó inicialmente el esquema ecoregional del WWF y Banco Mundial (Dinerstein et. al. 1995).

El análisis comprende tres grandes componentes: (1) el estudio biológico- ecológico, basado en el análisis de más de 4750 especies de flora y fauna (todos los mamíferos, todas las aves, todos los anfibios y todas las especies de dos familias botánicas por ecoregión), cada una con un mapa de distribución. El objetivo del análisis biológico-ecológico es el de identificar los centros de alta biodiversidad y de endemismo, de especies amenazadas, etc. (2) Luego viene el análisis del estado de conservación (también amenazas) y de fragmentación de bosques y vegetación natural, basado en análisis de imágenes satelitarias 1999 al 2002 y (3) el estudio del Sistema Nacional de Áreas Protegidas (SNAP) de los 6 países, incluyendo ubicación de áreas y sistemas de manejo. El objetivo del estudio de los SNAP es identificar las zonas que comprenden un cierto grado de protección legal y aquellas que a pesar de su estatus dentro del Sistema, necesitan ser reforzadas.

La integración de estos 3 grandes ejes (centros de diversidad y endemismo, etc x fragmentación x áreas verdaderamente protegidas) provee elementos necesarios para identificar sitios que deberían ser conservados prioritariamente. Generalmente son sitios con alta diversidad, endemismo, con cierto grado de amenazas y que en general no formen parte de un SNAP (excepto las áreas que a pesar de su estatus de protección no alcancen los requerimientos mínimos para su conservación).

Durante la primera parte del proyecto el estudio se desarrolló a una escala geográfica de 1:500.000 y se identificaron 5 sitios prioritarios, uno por ecoregión. La selección del sitio prioritario por ecoregión, entre muchos otros identificados como importantes por el estudio, se basó en el análisis de los valores (o pesos) asignados a las variables de biodiversidad, endemismo, especies amenazadas, fragmentación, estatus de protección, etc.

En la segunda fase del proyecto se están analizando los sitios seleccionados en la fase anterior, a una escala más profunda (1:50.000 o 1:100.000). En esta fase se identificarán las mejores alternativas de conservación y manejo para los sitios. Se integra elementos socio-económicos (talleres, decisiones conjuntas con las comunidades, etc) y de oportunidades de conservación, más acentuadamente que en la fase precedente. Además, la segunda fase basa sus estudios en lo siguiente: delimitación del área, mapas base, mapas de vegetación, identificación de objetivos (especies, hábitats) principales para conservar (incluyendo mapas), definición de amenazas y sus orígenes (incluso con mapas), el mapa de zonificación para manejo del área y la identificación de las mejores alternativas de conservación de los sitios.

Los sitios seleccionados son: el enclave de vegetación xerofítica de Dagua en el Chocó Biogeográfico; la zona Shuar de Tsurakú en la Cordillera Real Oriental; estribaciones del alto Huallaga en las Yungas Peruanas; la zona de Irupana en los Yungas Bolivianos y los Médanos del Chaco en el Chaco Seco (ver resultados).

La identificación de estos sitios ha sido realizada para este proyecto GEF, pero la gran cantidad de información producida por el proyecto invita a que otras instituciones, en base a esta y otra información, seleccione más áreas para desarrollar sus actividades de conservación.

Durante el desarrollo del proyecto se han capacitado más de 70 técnicos latinoamericanos en materia de ciencias para la conservación, sistemas de información geográfica (SIG), análisis de sensores remotos, GPS, etc. Las instituciones ejecutoras del proyecto se han visto fortalecidas tanto desde el punto de vista institucional como técnico. El carácter altamente participativo del proyecto ha llevado a contactar más de 100 instituciones (gubernamentales, privadas y locales) en toda la región.

Las agencias ejecutoras son: ANCON Panamá; Corporación Valle del Cauca CVC, Colombia; Alianza Jatun Sacha / CDC-Ecuador; Universidad Agraria La Molina, Centro de Datos para la Conservación CDC-Perú; Fundación TROPICO, Bolivia y la Secretaría del Ambiente, CDC-Paraguay. La agencia administradora es The Nature Conservancy – Ecuador, la agencia implementadora es el PNUMA y la agencia financiadora es el GEF. Entre las instituciones que brindan apoyo técnico se encuentran NatureServe, NASA, Universidad de Maryland y el Centro de Tecnologías Espaciales GRID, South Dakota.

Metodología (Resumen)

El proyecto ha seguido las metodologías más avanzadas desde el punto de vista cartográfico-matemático (modelamientos, etc.), biológico, ecológico, análisis de variables ambientales y socio-económicas. Debido a la complejidad de dichos modelos, se presenta a continuación un resumen de los principales aspectos metodológicos. La metodología incorpora igualmente los métodos más recientes de biología de la conservación, como la "Planificación Ecoregional" y la "Planificación para la Conservación de Sitios" (The Nature Conservancy 2002).

A.- Cartografía Principal

1.- Mapa Base: Escala 1:500.000
Hidrografía
Carreteras y caminos
Centros Poblados
Curvas de Nivel: cada 100 metros
Limites Políticos de tercer nivel: (Ej. País, Provincia, Cantón)
Cuadrícula de un grado
2.- Mapas de Vegetación Actual:
Provienen de la interpretación de imágenes de satélite. Identifican vegetación natural y antrópica.
3.- Mapa de Clasificación Vegetal (diferentes tipos de vegetación natural)
4.- Mapa Áreas Protegidas
Áreas Protegidas reconocidas legalmente por el gobierno de cada país.
5.- Bases de Datos Biológicas y Mapas de Distribución de Especies
Las Bases de Datos de Distribución provienen de fuentes confiables (material publicado o registros revisados). Se han considerado los siguientes grupos para cada ecoregión: todos los mamíferos, todas las aves, todos los anfibios; además se incluyen dos familias de plantas por ecoregión. Las bases de datos contienen los siguientes campos en cada ecoregión:
Orden
Familia
Género y especie
País
Departamento o Provincia
Localidad
Altitud (m.)
Longitud y latitud (mínimo grados y minutos) y/o Coordenadas Planas
Hábitat u otra información ecológica
Fecha de reporte o colección
Responsable de la observación o colección
Fuente bibliográfica
Referencia de colección (Museo y número de catálogo)
Esta información sirve para la elaboración de los Mapas de distribución de especies. El mapa de distribución de una especie se basa en un polígono en el cual se determinan los límites externos del área de ocurrencia, basándose en los rangos altitudinales y/o en otros límites geográficos como ríos, cadenas montañosas, etc.
Una segunda base, Base de Datos de Especies, incorpora información sobre cada una de las especies consideradas y contiene los siguientes campos:
Orden
Familia
Género y Especie
Número de registros contabilizados en la Base de Datos
Endemismo, donde:
0 = Especie de amplia distribución
1 = Entera o parcialmente en la ecoregión de estudio y otra ecoregión más
2 = Solamente en la ecoregión de estudio
Estatus de Conservación, basado en las categorías de la UICN, donde:
CR (peligro crítico) = 3
EN (en peligro) = 2
VU (vulnerable) = 1
Otras categorías = 0
Sensibilidad, donde las especies:
Muy sensibles a la destrucción de su hábitat = 2
Medianamente sensibles = 1
Poco o nada sensibles = 0
B.- Creación de Información Alfanumérica y Cartográfica

1. Criterios Biológicos

1.1.- Diversidad y Mapas

Dado que el análisis es de tipo Raster, usando píxeles con un tamaño tentativo de un kilómetro, se resalta el número de especies que potencialmente se encuentran en cada kilómetro cuadrado.

Los mapas de distribución de todas las especies pueden ser visualizados simultáneamente. Donde convergen muchos polígonos, éstos obtendrán los mayores valores en diversidad.

1.2.- Endemismo y Mapas de Endemismo

Se consideran dos aspectos fundamentales:

El rango de distribución global (RDG) de la especie, que se encuentra valorado en la Base de Datos de Especies y,

El Tamaño del área de distribución (TAD) de la especie en la ecoregión de estudio.

Las especies que solamente se encuentran presentes en una ecoregión tienen mayor valor de endemismo. Mientras más pequeña es el área de distribución de la especie, el valor de endemismo de esa especie es mayor. Por lo tanto, nuestra valoración es: (RDG x TAD)

Los valores obtenidos son asignados a cada polígono (área de distribución de la especie). Las áreas de convergencia de muchos polígonos obtienen altos valores de endemismo.

1.3.- Especies Amenazadas y Mapas

Cada uno de los polígonos correspondientes al área de distribución de cada especie es valorado en función de la categoría de amenaza; donde especies en peligro crítico (CR) tienen tres puntos, especies en peligro (EN) dos puntos, especies vulnerables (VU) un punto y las otras categorías reciben cero puntos.

Los valores obtenidos de esta categorización, son asignados a cada polígono (área de distribución de la especie). Las áreas de convergencia de muchos polígonos obtienen altos valores de amenaza.

1.4.- Sensibilidad (vulnerabilidad de una especie ante disturbios de su hábitat) y Mapas

Como en el caso anterior, cada especie es valorada de 0 a 2 y la sumatoria de los valores de todas las especies del grupo es considerado para cada píxel. Los píxeles con mayores valores asumen una caracterización de 5 puntos y subsecuentemente hasta un punto.

1.5.- Especies Especialistas y Mapas

Especies especialistas son aquellas que viven en un determinado tipo de hábitat, son importantes porque la perdida de su hábitat repercute directamente en su supervivencia.

Para determinar cuales y cuantas son las especies especialistas de hábitat, primero es necesario trabajar en un modelo cartográfico que represente los diferentes hábitats. Para el Mapa de Hábitats se cruza la siguiente información:

Mapa de la Clasificación Vegetal

Mapa de Geomorfología y Pendientes

Mapa de Suelos

Posteriormente se colocan los mapas de distribución de las distintas especies y se cuentan cuantas especies viven en cada uno de los hábitats. Las especies especialistas estarán presentes en un solo hábitat y las generalistas en varios hábitats. A las primeras se les asignará un valor alto (3) y a las últimas un valor de cero.

Los polígonos analizados representan los diferentes hábitats. Cada hábitat, por sumatoria, tendrá mayores valores con relación a la cantidad de especies especialistas que posee.

1.6. Valoración de los Criterios Biológicos

En este punto se califica cada uno de los criterios anteriormente expuestos (diversidad, endemismo, especies amenazadas, sensibilidad y especies especialistas). A cada criterio se le designa un determinado peso:

$(a*x)+(b*x)+(c*x)+(d*x)+(e*x)$

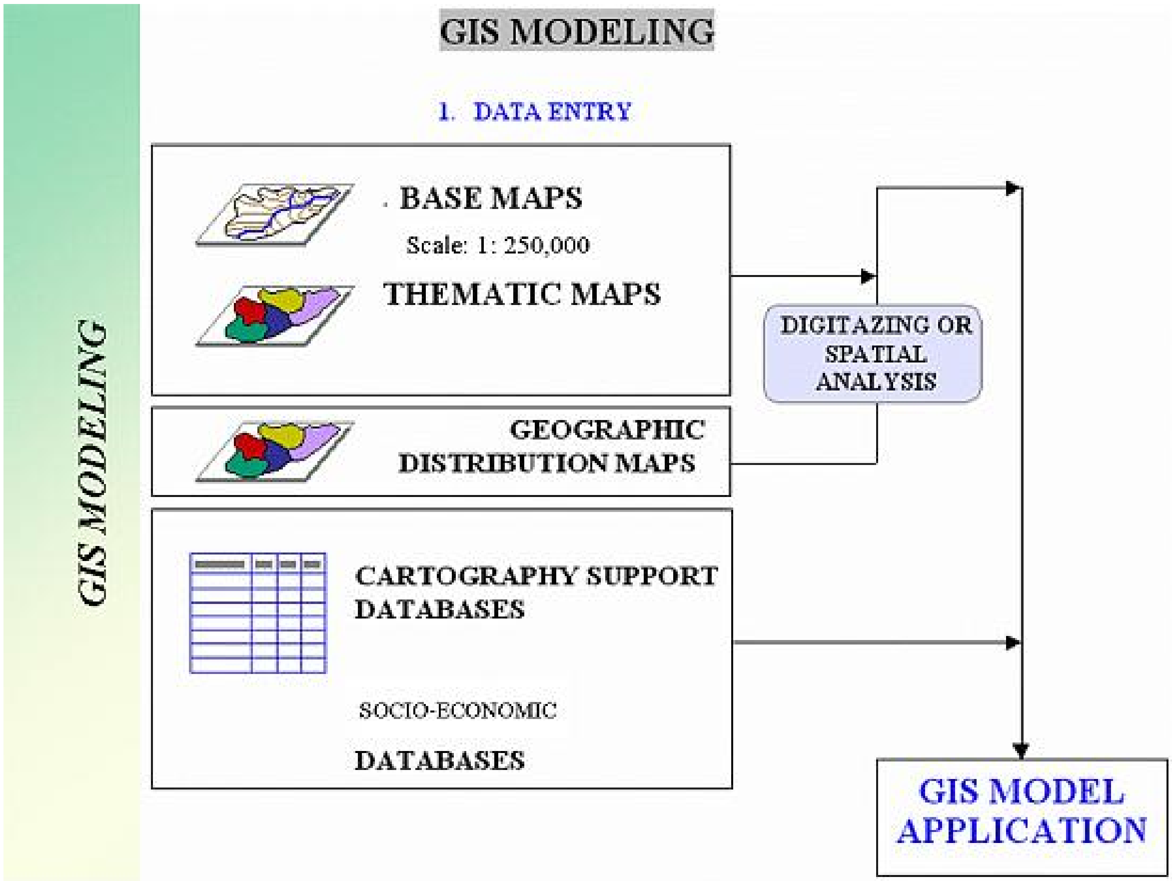
El resultado de la sumatoria total de los Criterios Biológicos ponderados, corresponde al primer resultado del análisis: Criterios Biológicos

2. Criterios Paisajísticos.

2.1.- Mapa de Remanencia

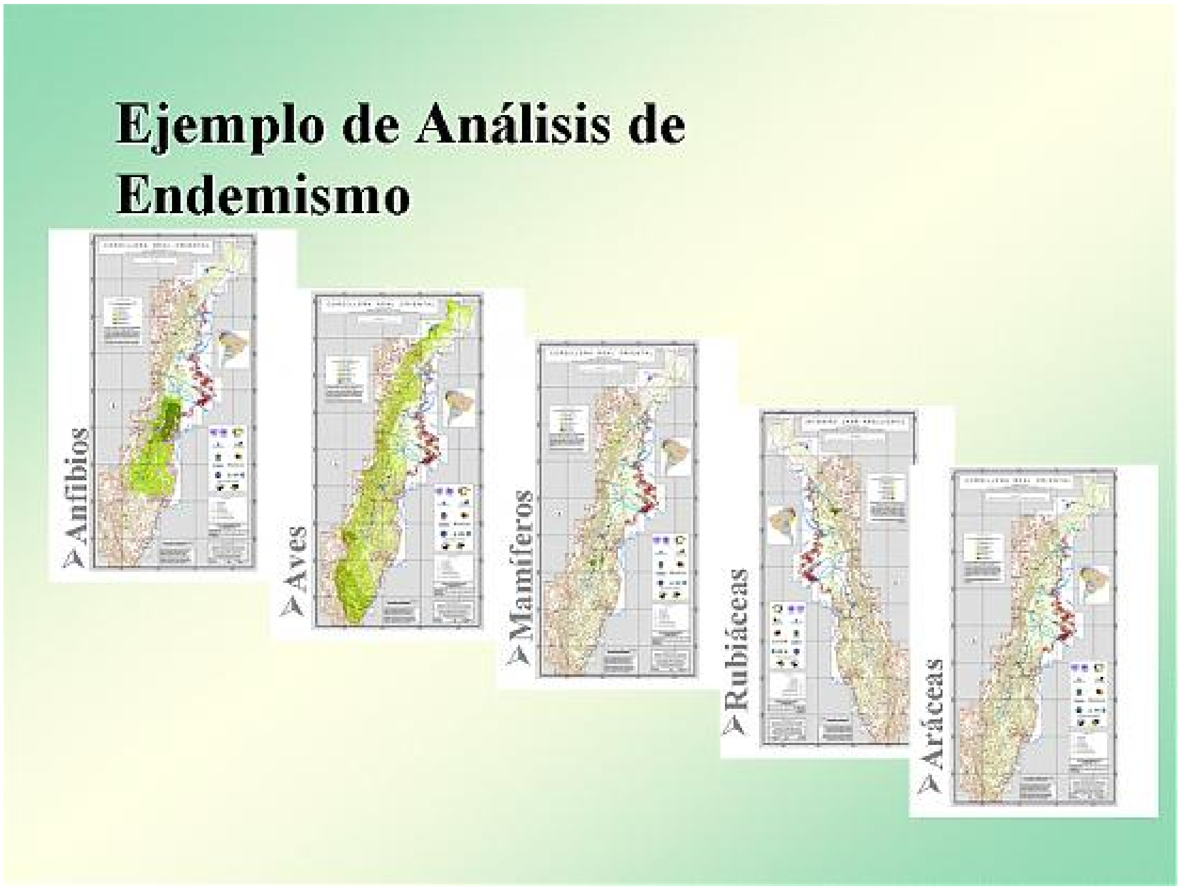
Remanencia significa cuanta vegetación natural de cada tipo existe actualmente, con relación al total original. Para la obtención del Mapa debe integrarse la siguiente cartografía:

Mapa de Clasificación Vegetal
Mapa de Vegetación (producido por la interpretación de las imágenes de satélite)
Para la valoración de este criterio, se asume que aquellos tipos de vegetación que han perdido un alto porcentaje de su cobertura, obtienen valores altos (hasta 5).
2.2.- Mapa de Fragmentación
Para la conservación de remanentes de vegetación, existen algunos parámetros que deben evaluarse: Es mejor conservar áreas grandes que pequeñas, es mejor conservar áreas con bordes regulares que áreas con bordes irregulares, es mejor conservar áreas de apariencia ancha que áreas de apariencia delgada, etc.
Usando la cartografía de Vegetación Actual (vegetación remanente), cada uno de los fragmentos se ha analizado y valorado en función de su forma.
2.3.- Diversidad de Hábitats
Este análisis trata de evaluar aquellos lugares donde convergen varios tipos diferentes de hábitats, ya que en los lugares en los cuales se encuentran varias unidades de paisaje, generalmente existe una alta diversidad.
Para este proceso, se requiere el cruzamiento de la cartografía básica producida en el Mapa de Hábitats, con el Mapa de Vegetación Actual (remanentes). Los fragmentos de bosque, o polígonos de vegetación remanente, que representan diferentes tipos de hábitats son posteriormente analizados mediante un modelo Raster de tipo Kernell, que calcula la presencia y proximidad de los diferentes tipos de hábitat, para cada píxel. Aquellos píxeles de un determinado tipo de hábitat, que estén próximos a otros hábitats diferentes, obtendrán valores altos.
2.4.- Efecto de Borde por Presión Humana
Las zonas de borde de los parches de vegetación natural se ven más afectados que las zonas internas. Las áreas morfológicamente irregulares, presentan más perímetro que las áreas regulares, y por lo tanto, a pesar de tener la misma extensión de superficie que un parche regular, la porción de vegetación intacta es notoriamente menor.
La sumatoria del área perimetral de todos los polígonos de un mismo tipo de vegetación, indicará (aproximadamente) cuanta presión existe sobre este.
2.5.- Valoración de los Criterios Paisajísticos
En este punto se califica cada uno de los criterios anteriormente expuestos (Remanencia, Fragmentación, Diversidad de Hábitats y Efecto de Borde). Se define cuales son los criterios más importantes y se les asigna un peso:
(a*x)+(b*x)+(c*x)+(d*x)
El resultado de la sumatoria total de los Criterios Paisajísticos corresponde al segundo resultado del análisis: Criterios paisajísticos.
3. Criterios Políticos de Conservación. Representación de tipos de Vegetación y Mapas de Áreas Protegidas
El Criterio Representación se refiere a la cantidad de cada tipo de vegetación que se encuentra protegido por un SNAP. En unos casos, puede darse que un determinado tipo de vegetación este ampliamente representado y otro sub-representado. Para la UICN, 1992, es adecuado la protección de al menos el 10% de cada uno de los diferentes hábitats que conforman el paisaje natural de un país o región.
Para este análisis se requiere una cartografía del SNAP de cada país, en cruce con el Mapa de Vegetación Actual Remanente. Los llamados "parques de papel" serán considerados como no-protegidos. Los tipos de vegetación sub-representados obtendrán valores altos.
C. Valoración Final y Priorización (Selección) de Sitios
Consiste en atribuir pesos (ponderación) a los Criterios Biológicos, Paisajísticos y Políticos (de conservación), e integrar todas las capas de información para obtener polígonos considerados como:
Áreas prioritarias de conservación = (Criterios Biológicos * x) + (Criterios paisajísticos * x) = (Criterios Políticos * x)



Flujograma Modelamiento Fase 1: Gráfico 1.

MAPA DE VALORACION DE CRITERIOS DE PAISAJE Layer resultante de la ponderación de los criterios anteriormente citados



Ejemplos Cartográficos: Gráfico 2.

Fase 2: Estudios de caso y definición de las alternativas de manejo (en curso)
Pautas:
Mapa Base (1:100.000 o 1:50.000)
Mapa de Vegetación
Verificaciones de Campo
Varias Reuniones con Comunidades Locales
Objetos de Conservación y Mapas
Amenazas, sus Fuentes y Mapas
Mapa de Zonificación para Manejo
Identificación de las Mejores Alternativas de Manejo (resultado final, para septiembre 30, 2003).

Resultados

A. Sitios Seleccionados
1. Enclave Xerofítico de Dagua y Loboguerrero (Chocó Biogeográfico, Colombia):
A pesar de que más del 90% del Chocó Biogeográfico esté constituido de formaciones boscosas húmedas, en esta ecoregión se seleccionó un enclave de vegetación seca, rodeado de vegetación húmeda (bosque húmedo tropical hacia el oeste y diferentes niveles de bosque nublado al norte, sur y al este). El Valle de Dagua comprende varios pisos altitudinales entre aproximadamente los 2.000 m y los 400 m en su parte más occidental.
Dicha selección responde al carácter único del Valle de Dagua (por ser un valle aislado), en el cual se encuentran varias especies endémicas, como de cactus (*Frailea colombiana, Melocactus loboguerreroi, Opuntia bella*) y *Anthurium buenaventurae* (Araceae), *Tillandsia mima* (Bromeliaceae) y varias subespecies de otras plantas e incluso animales, como es el caso de una raza endémica de

venado de cola blanca (*Odocoileus virginianus daguae*).

El valle se encuentra bajo una intensa presión humana por concepto de expansión agrícola, lo que genera deforestación de ambientes naturales, quemas extensas de vegetación y erosión del suelo tanto de tipo laminar como por cárcavas.

La Corporación Autónoma Regional del Valle del Cauca (CVC) lleva algunos años trabajando en la zona para controlar básicamente la pérdida de suelos. Mediante este proyecto se dará un enfoque de conservación de hábitats y de especies endémicas y en peligro. El área de estudio comprende aproximadamente 100.000 hectáreas.

2. Zona Shuar de Tsurakú (Cordillera Real Oriental, Ecuador):

Esta zona está comprendida entre los 1.000 m y los 600 m en las estribaciones externas de la Cordillera Oriental, Provincia de Pastaza, Ecuador. Posee varios pisos altitudinales de bosque premontano hasta llegar al inicio del bosque húmedo tropical propiamente dicho de la Cuenca Amazónica, en su parte más oriental. En su lado occidental cruza de norte a sur la carretera que conduce de Puyo a Macas; los bordes de la misma presentan áreas dedicadas a la agricultura de subsistencia y a la ganadería. El resto de las 110.000 hectáreas está cubierto por bosque de buena calidad y comprende varios caseríos aislados de comunidades Shuar. El área está comprendida entre los ríos Pastaza y Copataza.

Dicha zona se caracteriza por poseer una de las más altas concentraciones de caoba (*Swetenia macrophyla*) en el Ecuador. Las compañías madereras están ya presentes en la zona explotando la caoba sin control forestal; los árboles en pié son comprados a bajo costo a los propietarios (de parcelas no comunitarias) de la zona. Otra amenaza es la cacería intensa llevada a cabo por los mismos miembros de las comunidades. Ellos identifican varias especies que han sido sobre-explotadas. Tal es el caso de 6 especies de Crácidos (pavas de monte) cuyas poblaciones se encuentran muy disminuidas actualmente. De estas quizás la especie *Mitu salvini* presenta aún poblaciones estables, debido básicamente a sus hábitos nocturnos. Otra especie de ave sobre-explotada por cacería es el tucán grande (*Ramphastos tucanus*). En cuanto a los mamíferos de caza, como puercos saínos (*Tayassu* spp.), venados mazama (*Mazama americana*), danta (*Tapirus terrestris*) y varias especies de monos, sus poblaciones están declinando igualmente.

La alianza estratégica entre 2 organizaciones de ciencia y conservación, Fundación Jatun-Sacha y el Centro de Datos para la Conservación (CDC-Ecuador), ha llevado a cabo varias visitas y reuniones con miembros de las comunidades Shuar de la zona, quienes están muy interesados en desarrollar alternativas de manejo que no afecten sus recursos naturales.

3. Bosques Nublados del Alto Huallaga (Yungas Peruanas):

En las Yungas Peruanas se seleccionó un franja de bosque nublado (desde los 1.3000 m aproximadamente, hasta la divisoria de aguas de la Cordillera Andina Oriental). Esta franja se encuentra en el centro-norte de la ecoregión en Perú. Es una zona única y de extremada importancia para la conservación puesto que allí habitan 3 especies de monos endémicos a la zona (uno de los récords mundiales en endemismo de primates). La alteración de este hábitat provocaría la extinción de dichas especies.

Las principales amenazas son la expansión agrícola desde las partes bajas del Valle del Huallaga y la explotación minera, proveniente principalmente desde las zonas más altas. Algunas sub-cuencas transversales han sido ya colonizadas y utilizadas para dichos fines.

Esta zona puede considerarse como un corredor biológico y ecológico entre el Área Protegida Río Abiseo al norte y el Parque Nacional de Tingo María al sur. La distancia de esta zona desde los centros poblados en donde operan organismos de conservación, hace que el desarrollo de actividades de conservación sea más complicado.

4. Zona de Irupana (Yungas Bolivianos):

La región de Irupana en las vertientes orientales andinas del Departamento de La Paz, Bolivia, presenta un gran interés desde el punto de vista ecológico ya que en el valle en donde se encuentra existe un verdadero mosaico de formaciones vegetales, desde las formaciones xéricas (vegetación seca) hasta las muy húmedas.

Son varios los impactos humanos que se presentan en la zona, entre otros la expansión de la actividad minera, la cual acarrea una intensa actividad de colonización, con la consecuente tala del bosque para la agricultura, erosión excesiva de las fuertes pendientes existentes en la zona,

sedimentación y especialmente contaminación de las aguas.
La Fundación TROPICO de Bolivia ha trabajado intensamente con las comunidades de la zona para promover el uso sustentable de los recursos naturales y la conservación de bosques, como áreas de protección de pendientes y de la biodiversidad de la región. La respuesta de las comunidades locales ha sido muy positiva hasta el momento.
5. Médanos del Chaco (Chaco Seco, Paraguay):
En la ecoregión del Chaco Seco (Norte del Gran Chaco) se seleccionó una zona que presenta una interesante y rica variedad de sistemas ecológicos de vegetación seca, desde sabanas tropicales, hasta matorrales espinosos densos e incluso vegetación abierta sobre dunas (médanos). La zona escogida se encuentra en el extremo nor-oeste de Paraguay, cercana a la frontera boliviana. Existen variedades vegetales únicas al Chaco Seco, como la Rosa del Chaco (*Cordia bordasii, Schinopsis cornuta*) y el Palo Papel (*Cochlospermum tetraporum*) además de algunas especies animales, como el recientemente "redescubierto" Pécari Taguá (*Catagonus wagneri*) e incluso una especie endémica (a la zona) de Tinamú (*Eudromia formosa*). Además presenta una característica abiótica excepcional, como es la de poseer en el subsuelo (entre 50 y 200 metros de profundidad) uno de los acuíferos más grandes de América del Sur; el agua proviene de los Yungas Bolivianos y se infiltra progresivamente en la región arenosa del Chaco Seco.

Discusión

Es importante considerar que las áreas seleccionadas en este proyecto no son sino solo una por ecoregión. Esto se debe a razones prácticas, por la complejidad que significa el estudio de cada zona, para luego formular propuestas de alternativas de conservación y manejo. De los muchos sitios de importancia arrojados por el estudio en cada ecoregión, se seleccionó el que mejores visos reales de conservación presentaba. En este sentido el factor de oportunidad de conservación jugó un papel importante a la hora de seleccionar "el sitio clave" dentro de toda una ecoregión.
Los sitios seleccionados en este estudio representan aquellos que fueron identificados como tales dentro del marco del presente proyecto. Por ello exhortamos a otras organizaciones nacionales, locales e internacionales a utilizar la información producida en este proyecto para que seleccionen otros sitios de importancia, acordes con los criterios de cada institución.Uno de los productos importantes de este proyecto es el de ofrecer a la comunidad conservacionista, datos científicos sólidos, tanto para la identificación de áreas prioritarias, cuanto para el desarrollo de acciones prácticas de conservación dentro de las mismas.
Además, gracias a la información producida se han redefinido parámetros cartográficos realizados por estudios precedentes. Tal es el caso del ajustes de los límites ecoregionales propuestos por Dinerstein et. al. con respecto a las ecoregiones aquí estudiadas. En efecto el estudio de Dinerstein fue trabajado a una escala de 1:1’000.000 mientras que el actual proyecto se basó en un estudio de 1:500.000 lo que en cartografía significa cuatro veces más de precisión. De la misma manera se actualizaron bases de datos referentes a todo el grupo de: mamíferos, aves, anfibios y todas las especies de dos familias de plantas por ecoregión.
Debido al uso de imágenes de satélite recientes, el análisis del estado de los bosques y vegetación natural es bastante actualizado y da una visión más precisa de los procesos de fragmentación y de amenazas generales, como el avance de la conversión de las áreas naturales en pastos, zonas agrícolas u otro tipo de uso del suelo. De estos parámetros se han realizado estudios de los (grandes) remanentes de vegetación natural para evaluar su efecto de borde, etc.
En el transcurso del proyecto se han identificado importantes centros de biodiversidad y endemismo, los cuales no habían sido tomados en cuenta previamente. También se confirmó la importancia de otros sitios ya conocidos por ser de relevancia biológica. Se analizaron igualmente las áreas en las cuales existen más especies sensibles (vulnerables al cambio de hábitat), especies especialistas (dependientes de un solo tipo de hábitat) y las especies que poseen alguna clasificación dentro de la tabla de especies amenazadas de la UICN.
Otra de las intenciones del proyecto fue la de fortalecer a las organizaciones ejecutoras locales en cuanto a sus capacidades institucionales y técnicas. Gracias a procesos de capacitación directa, todos los técnicos de dichas instituciones fueron entrenados, en biología de la conservación, SIG, sensores

remotos, etc, al igual que algunos técnicos provenientes de otras instituciones, incluyendo gubernamentales y locales. Además este ha sido un proyecto con vocación francamente participativa; durante su desarrollo se contactaron más de un centenar de organizaciones de todo tipo (gubernamentales, privadas, nacionales, locales, internacionales), lo cual ha sido muy enriquecedor en términos de objetividad técnica y política (oportunidades de conservación).

No pretendemos que este sea un proyecto en el cual todos los datos producidos tengan precisión absoluta, entre otras razones, por el volumen de información elaborada ya que en las 5 ecoregiones se han analizado más de 6.470 especies y se han producido más de 6.500 mapas temáticos. Invitamos a todos los especialistas en biología, ecología, biología de la conservación, geografía, cartografía, etc, a proporcionarnos correcciones y comentarios.

Agradecimientos

En este proyecto participan unas 100 personas (más o menos directamente) y un gran numero de instituciones. Nombrar a cada persona e institución sería poco práctico, pero quisiéramos agradecer de manera especial a aquellas organizaciones que desde un principio prestaron apoyo para que el proyecto se cristalice; estas son las 6 agencias ejecutoras en cada país (CDCs), el GEF, institución que generó los fondos, el PNUMA, The Nature Conservancy, NatureServe y la NASA. Además extendemos un agradecimiento muy especial a las organizaciones gubernamentales y locales en cada uno de los países, sin los cuales el proyecto no hubiese tenido éxito.

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Visual Plants - An image based tool for plant diversity research.

Visual Plants - Un instrumento basando en imagines para la investigación en ecologia de plantas.

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Visual Plants - An image based tool for plant diversity research.

Resumen

Hay un proceso comenzando de hacer accessible información de biodiversidad tanto con programas para la computadora como en la red. El espectro se extiende de sistemas de información para herbarios y sistemas taxonomicas hasta sistemas de información visual mas faciles para el usario. Visual Plants es un exemplo para la ultima categoría presentando imagenes digitales junto con la información correspondiente y con caracteristicas para la identificación. Visual Plants es una base de datos basando en especímenes con función automatica para la compilación de una lista de especies. Se puede utilizar lo sin conección a la red para la educación de estudiantes, para la propagación de información botanica y para la investigación taxonomica y ecologica. Palabras clave: Imagen, digital, plantas, ecología

Abstract

There is an ongoing process to make biodiversity information available using computer programs as local as well as worldwide accessible Internet-based systems. The range of solutions reaches from information systems for herbaria, taxonomic diagnostic systems to more easy to use visual information systems. Visual Plants is one of the last category providing digitalized images from plants with all attached label information together with some characters for the identification of individual plants. Visual Plants is at first a specimen-based database with automatic function to compile the information as species-based. It can be used on-site without having an Internet connection for the education of students, for dissemination of information and for taxonomic and ecological research. Key words: Imagen, digital, plants, ecology

Introduction

Although the diversity of plants is quite smaller than of animals, especially insects, information about plant diversity is still not complete and disseminated completely. Especially the treatment of tropical regions still remains incomplete (Prance et al. 2000). Knowledge about the determination of certain plant groups (e.g. large tropical plant families like the orchids) is often concentrated as the knowledge of a small number of researchers. Research in tropical regions is therefore due to the high number of plant species in a given area catchy for young researchers, when information is not jet published and available in the country. But it is the most crucial question not only for taxonomical, but more for ecological research, that information about the plant taxonomy is available for local researchers. Not only the availability of information is a critical issue, the ongoing and rapid destruction of tropical rain forests needs a comprehensive and integrated effort of scientists for the inventory of species in the tropics (Hamilton et al. 1994). Otherwise species will disappear without being known by science.
Not only the lack of availability of information causes problems for researchers but also the rapid evolving plant taxonomy and systematic. Systematic of plant species now uses modern taxonomic tools adopted from genetics, and relations between large plant groups are seen in different manner: families and genera are rearranged (see Judd et al. 1999) and genera are grouped into several smaller or larger genera. The effect of renaming or differentiation of taxa into smaller groups is not a new problem. It follows new insights into the relations between certain taxa. As a consequence the knowledge on plant taxa follows a certain notion which sometimes causes serious confusion. Berendsohn (1995) mentioned three different categories under which biological information can be seen: first the purely nomenclature point of view, where a name can be understood as a hypothesis, "as a set of biological objects within a classification unit supposedly linked by phylogenetic descent, or as a set of criteria applying to such objects". In the second category practising taxonomists follow a more vague concept of a taxon, which was described as a collection of objects and the sum of herbarium specimen and living plants with the same set of criteria. The third group are all users of botanical names with the demand of an operational definition of a taxon. The resulting confusion, which may occur, can be described as the lack of description or references to which a specimen (!)

not a taxon refers to. The misunderstanding is, that not all specimen which may have the same name, really belong to the same taxa due to differences in nomenclature or the underlying concept. As a consequence Berendsohn (1995) stated the necessity of specimen-based information with all attached information about the context, the references etc.

Asking a simple question: How many plant species exist on our planet? At the moment this question cannot be answered satisfactorily, because we do not know exactly how many species exist on our planet or, caused by different opinions of researchers and taxonomists, the numbers differs. But the question, how many species do we already know from our planet cannot be answered very easily because the information is stored regionally. This means that we know more or less exactly the number of plant species in Germany or Middle Europe, but it is quite problematic to have access to this information from another regions.

[[subheadinh text="What must be concluded from these problems?"]]

1. Information should be stored in a central institution, where the state of the art is transparent for all interested researchers (see Godfray 2002). This new idea of a more or less virtual taxonomical institute is a little bit revolutionary, but has a lot of advantages, if the existing specialists agree and contribute to this idea. Several main aspects must be fulfilled: New information about the taxonomical grouping of taxa must be updated regularly including the information about their former systematic state (see Güntsch et al. 2002). Information should be automatically mirrored to other institutions for a more rapid access, and updating of information must be automatically proceeded.

2. Information must be easily accessible. This demand has at least two main implications:

a) Information must be accessible for all researchers using the Internet; this technique is now accessible from most places in the world. But, to be honest, in developing countries the access to the Internet is sometimes rather slow and not very stable which means that the dissemination of information is somewhat restricted.

b) Information must be easily accessible due to an easy to use interface without having special knowledge about data basing of information. This issue is likewise important to the others, because the user-interface can be understood as the window to have an insight to the information itself.

3. Information must be extractable for the use in the field when no Internet is available. In case of developing countries information must be extractable from this central system to carry the information to remote places and use it in the field, where no Internet is available.

What kind of information should be stored?

This question can be discussed controversially, because it depends on the needs and the main intentions, for what purposes it is meant and for which persons the information is thought. Managers of herbaria may have other needs; they may prefer to store specimen-based information about their herbarium specimen, geo-referenced collecting sites etc. Research scientists working in ecological fields may prefer to store information about the ecological needs of the plant species and may need therefore a species-based system. Additionally a key system for the identification may be helpful for ecologists and related research areas or neighbouring disciplines. This, of course should be easy to use and, in case of tropical trees, based more on vegetative information, if possible. But, "information on plants is used and processed by many people outside the taxonomic community, who often will not know what a specimen looks like" (Berendsohn, 1995). Therefore, images of plants may be helpful to control the identification and give an "idea" on the habit of a plant. These images must show most of the relevant information, which is necessary to identify a plant. Because this is mostly impossible with only one image, a series of images (an assemblage) may show different aspects or parts of the plant.

Data-basing provides an excellent chance for managing and disseminating the vast biological data in natural history collections such as museums and at the same time making it reachable widely to specialists and the public. Capturing much of the data as images and text is also a good back-up of specimen data, which would otherwise completely vanish if the voucher specimens were to be destroyed by normal wear and tear or some other catastrophic factors such as fire, flooding, pest attacks, or war and lawlessness. Imaging and data-basing specimens is quite useful from the long term preservation point of view, because it allows users to access data without necessarily handling the original specimens and thus greatly reduces the hazard of destruction for the specimens and also drastically reduces the time required to access information.

The complex relationships in ecosystems between and among the various biotic and abiotic factors necessitate the sharing of information generated by persons working on aspects of biodiversity. Capturing much of the already collected data in museums in electronic form is an essential step towards making taxonomic information easily accessible and also acts as a back-up of taxon data, that would otherwise completely vanish if the vouchers were to be destroyed by normal wear and tear or some other catastrophic factors.

Most of the initiatives in the field of biodiversity informatics concentrate on applications, which provide information on the Internet (see [[Table 1]]). Visual Plants (Dalitz 2002) follows another approach: information is provided locally as an on-site application, which can be used in the field for three main tasks. First it allows the data capturing including the visual information using plant images. Secondly it provides information about plant specimen, species and families. Thirdly a set-based key system is included which allows a low level determination using mainly vegetative characters. The user-interface is very easy to use and special knowledge about databases is not necessary. This means that Visual Plants may be useful as a tool for the work in the field, but it cannot fulfil all needs which are mentioned above.

Problems of ecologists and vegetation researchers in the tropics

Determination of plants is sometimes a task only for specialists, especially when difficult groups are involved. But also for easy to determine plant species there are some specific problems when working in the tropics. The diversity of plants is rather high and there is often a lack of fertile characters because plants, especially trees, do not flower every time or every year (Newstrom et al. 1994). Getting the material as well can be a difficult task when tree flowers hang in 30 or 40 m height. Within difficult taxonomic groups specimens from herbaria and specialists are needed for a correct determination. Literature is often very comprehensive, incomplete or in revision. Herbarium specimens are often not stored in the tropical field stations because of the high humidity in the field stations. Field guides are often not available or incomplete. All these difficulties can be solved with technical solutions at a field station, but research in really remote areas will still be under the proviso that taxonomical literature or herbaria cannot be taken into these places. This means that long-term experience is necessary for a correct determination in the field.

Visual Plants was developed as an on-site database program to give researchers in the field a tool for their work. On-site means, that the researcher can carry all the information stored in Visual Plants to his remote research places on a mobile computer. Different types of images can be stored in the database with all attached label information: flat-bed scans of living plant material (see [[Figure 6]]), digitized slides (Figure 4), digitized herbarium specimens (Figure 5) or illustrations can provide information about the habit, the leaf and floral characters of a plant species in a series of images of these different types. This information can be used for comparisons between the collected specimen and the information in Visual Plants either in the field or in a herbarium. With the help of specialists the information may be updated regularly, to ensure that this information can be used as a reference.

Biodiversity information management

In several attempts different projects try to make biodiversity information accessible for a broader audience, e.g. the DELTA-project (CSIRO division of Entomology, Canberra, Australia; see Dallwitz 1974, 1980), GBIF (Global Biodiversity Information Facility), SysTax (University of Ulm, Germany; see Hoppe et al. 1996) or the program "Biodiversity informatics" funded by the German Ministry of Science and Technology (Berendsohn et al. 1999) with two main goals: first to make accessible the information which is stored in herbaria and secondly to provide taxonomical software, which allows the determination of selected groups, especially for insects. Most of these attempts are Internet-based, and require therefore a fast net access.

Advantages of these attempts which have developed since longer time are on the one hand the compatibility between the systems (see Standard of the International Taxonomic Databases Working Group TDWG, Conn 1996), and on the other hand the possibilities for the identification of species through different key systems. Additionally these systems are used for the systematic acquisition of information for a further processing. A comparative study about seven systems with their different approaches can be found in Dallwitz (2000). One problem, which still occurs, is the discrepancy between the general characters of one species and the existence or non-existence of a character, which can be found of a single individual of this species.

A particular attribute of computer aided information systems is the user-interface, which allows the user to access the information. Especially for taxonomic solutions there are often many steps needed to come to an accepted identification of a specimen or species (see Dallwitz 2000). This is an important criticism, because a difficult to use interface, which is not consistent, may frustrate the user or the information cannot fully be reached.

In [[Table 1]] some important Internet sites were listed, which provide a substantial overview on current systems.

Conception and description of Visual Plants

Information about plant diversity is often given as a check-list of species in a given area or in floras. Species keys, usually dichotomous keys, are given to assist in the identification of taxa. Such information is of limited practical use to non-specialists, because most people have no idea about what the many species look like. The process of finding out what the species look like can be quite taxing. Therefore identification keys and descriptions alone are not sufficient for most people to identify species. The use of images of voucher specimens in addition to descriptions and keys greatly simplify the identification of plants by local researchers, non-specialists, students, and the general public. Images speak for themselves and users may not need to understand the complex terminology that may be used in keys and descriptions in order to identify a species. Imaging of plant species is thus important in making information widely available and easily understood by participants, local researchers and the public.

For this reasons Visual Plants is an image-based system, which can contain an unlimited number of images of one species. These images may show different aspects of information. A flatbed-scan of fresh collected material shows the specific colour of the plant parts (see (Figure 6). After the process of herbarisation a second image may show the plant after drying the voucher specimen, which demonstrates in some cases different colours (see. (Figure 5). Digitized slides provide an "idea" of the three-dimensional arrangement of plant parts, especially flowers, and may help to identify a plant (in (Figure 4) the characteristic bark of *Bursera simarouba* is shown). Illustrations show extracted and interpreted information of the whole plant or of parts of it with all relevant taxonomic features of the plants. All images were coded with the name of the photographer (see (Figure 1), the country (see (Figure 2) and type of the image, but not with taxonomical information. All images were prepared in the same manner and a copyright sign is included in one corner of the image due to international copyright behaviour.

This means that Visual Plants is therefore not specimen-based in the common sense, because there may be several images of the same specimen. But, browsing through these images gives a clear impression about the appearance of the plant. Additionally the context of information, finding places, references, habitat, altitude are stored together with each image.

All images were stored with the complete set of label information including the habitat as geo-referenced information (either with UTM or latitude and longitude coordinates), which allows a further processing in a GIS-system. Names of genera and families are provided from internal lists (using trigger functions), to avoid writing errors, which would make it impossible to find these images.

The main list therefore is called "List pictures" and shows a list window in two views with different information. The header of the list window is multi-functional with buttons for searching genera, families and selected records. An input window allows the description of the image and provides the information separated in topics in so-called register cards (see [[Figure 1 to 4]]). One of these register cards provides information about the family, if the image is already determined. This gives a possibility to test the correctness of the determination.

Each record gives the possibility to state characters for the same plant with different character statements ((Figure 2). As characters easy detectable features of plants are used such as "Life form", "Leaf characters", "Stipules" (absent or present) or "Colour of flower". Some of the character statements can be chosen from an internal list, other must be typed with additional information. In case of "Stipules" the user can state the position or the shape of stipules, when they are present. This gives the opportunity to describe the habit of a species for each specimen (or image) separately.

The information is used in a special search dialogue, which allows a set-based search for these character statements (see (Figure 7). This set-based search dialogue provides a rapid and easy to use interface as a helping tool for the identification of plants. The results are shown in the lower part of the "Search"-dialogue and images can be easily browsed for a visual identification.

Depending on the completeness of the character information, specimens can be found using their character information and compared with already determined specimens. At the moment 7 characters with 123 different combinations are programmed, each containing up to 10 character statements. In the next version ten characters will be used with 1023 combinations of characters. This will raise the chances for better identifications.

The command "List families" shows a list of families with some of their most common attributes and the possibility of inclusion of up to 12 characteristic images. The information of one family (Figure 8) will be displayed in all records, which belong to this family.

A second feature of Visual Plants tries to come over the separation between the concepts "Specimen-based" or "Species-based". Automatic functions create new records in the table "Species" (see (Figure 9), whenever a new species is detected in the image table. The resulting record entry will hold general information about the attributes of the species, which may differ from the found specimen. For instance it may be possible that a specimen is only a small treelet or shrub in one region, but a big tree in another region or altitude. This information can be observed and a list of all connected specimen can be examined.

There are several possibilities for printing the information out of Visual Plants. As an example in [[Figure 10 a report is shown which is generated by the program. This report can be chosen by the user and is not fixed. This solution follows the idea that the program should be as flexible as possible for the needs different users may have.

The already included menu items are shown in (Figure 11).

Future plans will implement the concept of "potential taxa" (see Berendsohn, 1995) and the compatibility with the TDWG standard will be improved. As a second main aim Visual Plants will be searchable on the internet and data-sharing with other institutions will be provided using the technique of Webservices.

Advantages and disadvantages of Visual Plants

Main objective for the development of Visual Plants was the creation of an on-site system, which can be used not only by specialist, but only by students and untrained, but interested persons. Therefore the effort laid on the design of the user-interface. The use of Visual Plants should be possible without understanding the technical aspects of database systems. The program should run on the most common platforms (Windows and Macintosh), which makes it necessary to program it with a Rapid Application Development tool, which supports both platforms. Although 4th-Dimension (see www.4D.com) is not a common RAD-tool, it serves as a rather easy to use platform for developing the application.

The main functional aspects, which should be realised, are the concept of an image-based database with attached information about family and species characteristics.

As one of the main advantages of Visual Plants the easy to use user-interface may be seen which has been tested in student courses and on field stations (ECSF, Loja, see: www.bergregenwald.de, or RBAB, Costa Rica, see: http://www.ucr.ac.cr/otros/r-alberto.htm)

The rapid database engine enables the user to search in large series of records and the images were shown at each level of information. No additional window will open to see the information stored in the images.

As described in the introduction, the necessity is quite obvious to concentrate the efforts of all taxonomic and systematic work in the world to support an online system, which stores all the information about plant diversity at one place. This will enable all interested researchers (and the public) to use this information for their research and for making decision, which may have influence the diversity (see Güntsch et al. 2002 for the description of an example for taxonomical revisions which may be concentrated on the Internet). For this purpose, Visual Plants is at the moment not a proper tool, because the data-exchange is still restricted although an Internet-interface is now available (www.visualplants.de). Plans for the near future will focus on this and the technique of so-called "web services" will be used for international data-exchange.

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Prance, G.T.; H. Beentje; j. Dransfield & R. Johns. 2000. The tropical flora remains undercollected. *Annals of the Missouri Botanical Garden*, 87: 67-71.

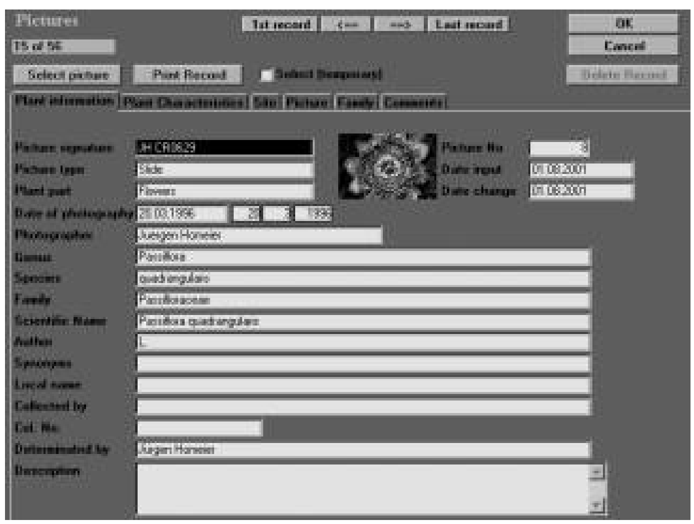

Figure 1. Main data entry in Visual Plants. In a window with six register cards all relevant information about a specimen is stored. The first register card shows the general information.
Figura 1. Registro de datos en Visual Plants. En una ventana de seis tarjetas de registro se graba toda la información de una especies. El registro primero representa la información general.

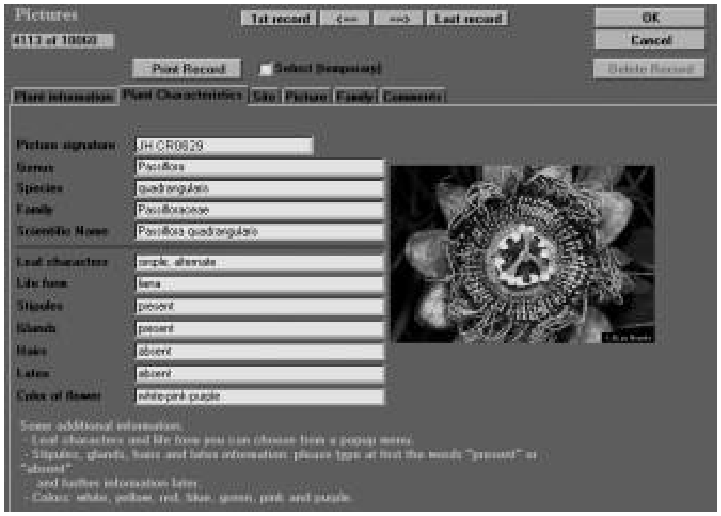

Figure 2: Main data entry in Visual Plants. The second register card allows the input of specimen characters. Figura 2. Registro de datos en Visual Plants. Este segundo registro permite la entrada de caracteristicas del espécimen.

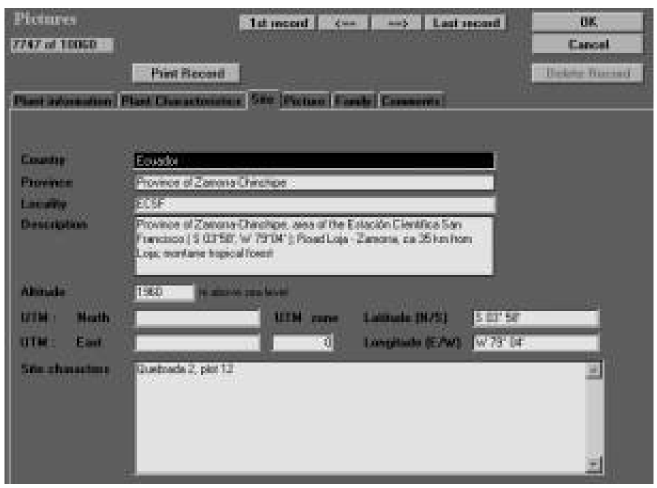

Figure 3. Main data entry of Visual Plants. The third register card shows the information about the collecting site. Figura 3. Registro de datos en Visual Plants. La tercera ventana indica la información sobre el lugar de colleción.

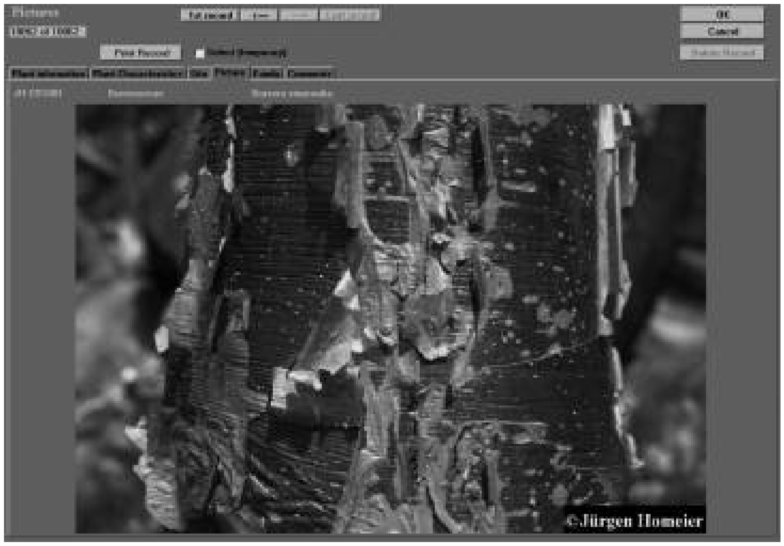

Figure 4. Main data entry of Visual Plants. The forth register cards shows the image or picture, in this example the bark of *Bursera simarouba* (Burseraceae) from a digitized slide.
Figura 4. Registro de datos en Visual Plants. El cuarto registro muestra la imagen of dibujo de la planta, en este ejemplo la corteza de *Bursera simarouba* (Burseraceae) de un slide digitalizado.

Figure 5. Main data entry of Visual Plants. In this example an image of a herbarium specimen of *Parinari* spec. (Chrysobalanaceae) is shown.
Figura 5. Registro de datos en Visual Plants. En este ejemplo una imagen de un espécimen de herbario de *Parinari* spec. (Chrysobalanaceae).

Figure 6. Main data entry of Visual Plants. The inclusion of flatbed scans can help to store and present a lot of relevant information from fresh material. As an example a still undetermined specimen from the Simaroubaceae is shown.

Figura 6. Registro de datos en Visual Plants. Los scans pueden ayudar para almacenar y presentar mucha información importante de material vegetal fresco. Como un ejemplo la especie aún no-determinada de Simaroubaceae.

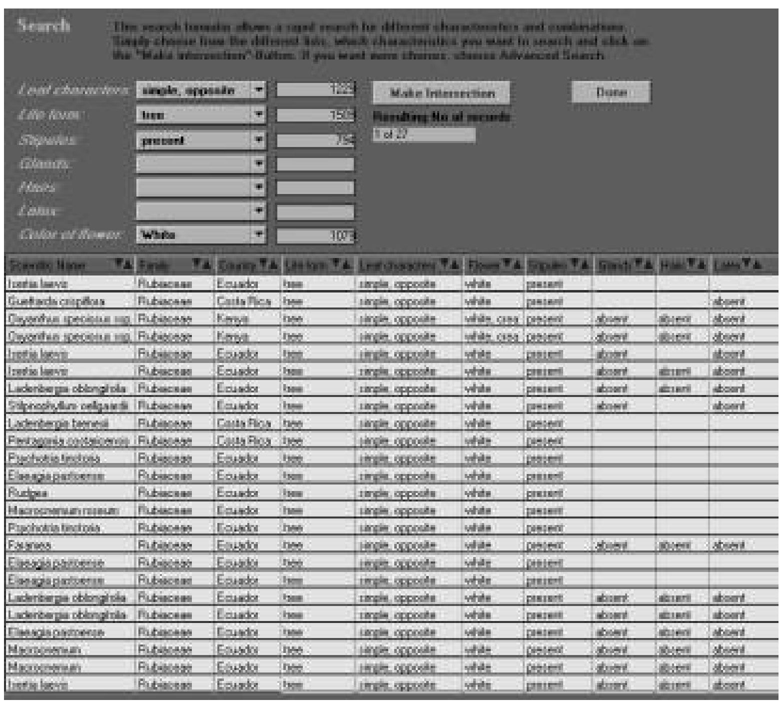

Figure 7. The "Search"-dialogue. In the upper part character statements can be chosen from internal lists. The program searches through all record and stores the information for each character statement in a so-called "set". The button "Make Intersection" combines the information stored in these sets and presents a list of records for which all chosen character statements are true. This list is clickable and shows the data entry window with all specimen-based information. In this example with only four characters a list is presented with specimens which all belong to the family Rubiaceae. The main advantage of this dialogue is that the user can "play" with the information, because every query result for a single character statement is stored separately, the user can switch between different character statements rapidly, whereas the program executes only the query for the new character statement decision.

Figura 7. El dialogo de buscar. En la parte alta se puede elegir de diferentes caracteres de una lista interna. El programa busca todos los registros y graba la información para cada caracter en un set. El boton "maker intersection" combina la información de estos sets y presenta un listado de especímenes que tienen estos caracteres. Se puede elegir

de este listado y se muestra la ventana con todos los datos. En este ejemplo se presentan las especies de Rubiaceae. La mayor ventaja de este dialogo es que el usario puede jugar con la información y cambiar los caracteres facilmente.

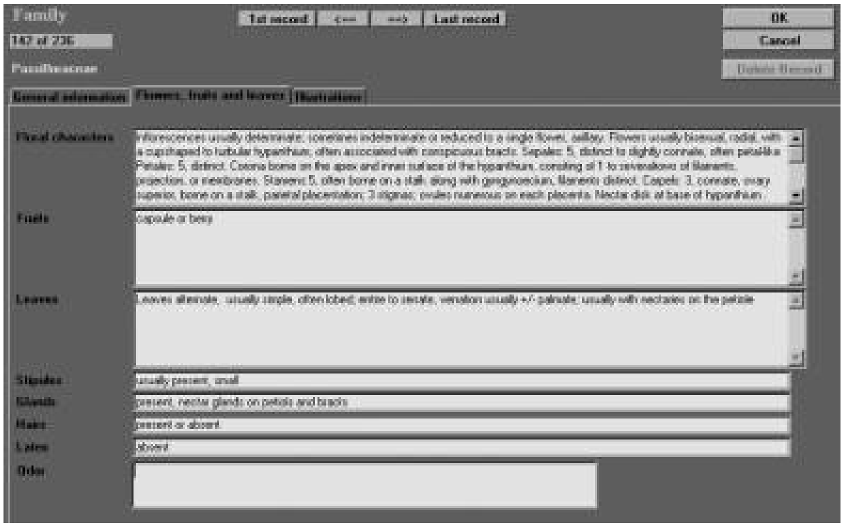

Figure 8. Information about family characteristics of the Passifloraceae. As an example is shown one of the three register cards, holding the information about this family .
Figura 8. Información sobre caracteres de la familia Passifloraceae. Un ejemplo muestra una de las tres tarjetas de registro que contienen la información de la familia.

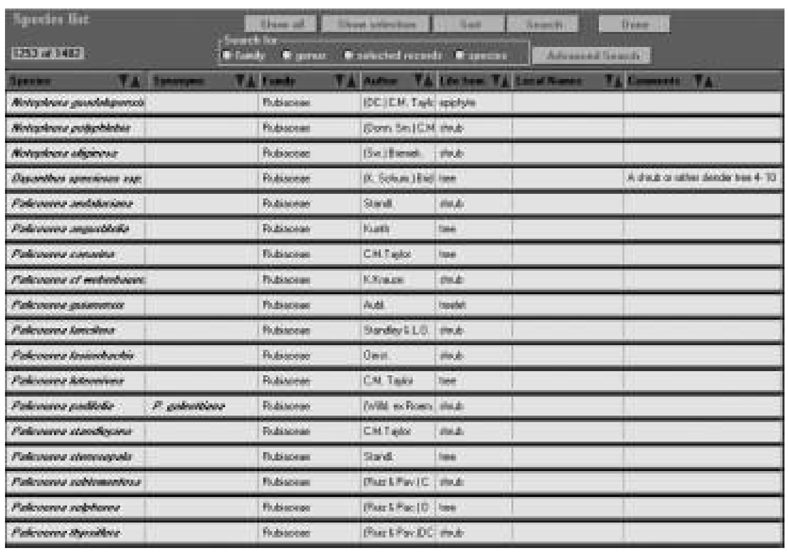

Figure 9. List window of the menu item "List Species". The records are clickable and the data entry window shows most of the relevant information about the species (not shown). The list is generated automatically with each record in the picture list, which is determined to the species. For each record in the species list there is provided a clickable list for all available specimen in the database.
Figura 9. Ventana de "Lista de Epecies". Se puede elegir de los refistros y la ventana de datos musetra la información mas importante de especies (no se puede ver). El listado se genera automaticamente con enlace a las figures. Para cada registro en el listado de especies se presenta un listado con posibilidad de elegir especímenes en la base de datos.

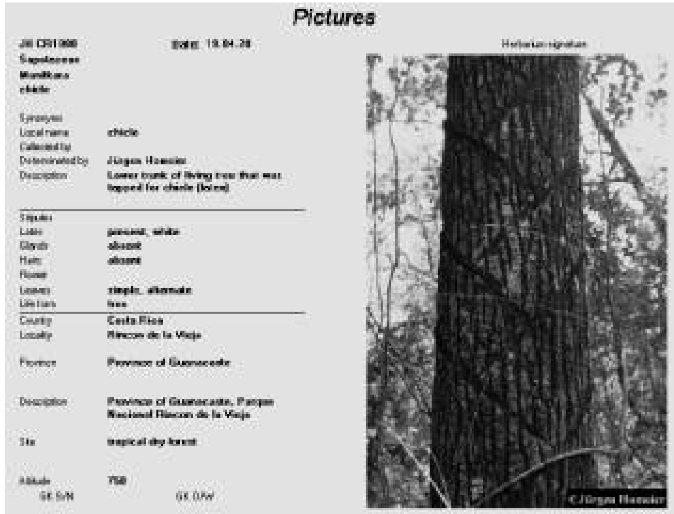

Figure 10. One example for a possible output of data in a report.
Figura 10. Un ejemplo para un posible informe de datos.

Figure 11 The menu items of Visual Plants.
Figura 11. El menu de Visual Plants.

Organisation	Adress	Topic
Missouri Botanical Garden, St. Luis, Missouri, USA	http://www.mobot.org/manual.plantas/lista.html	Plant list of Mesoamerica in Spanish, no taxonomical approach
Missouri Botanical Garden, St. Luis, Missouri, USA	http://mobot.mobot.org/W3T/search/vast.html	Plant list of Mesoamerica, no taxonomical approach
CSIRO Division of Entomology, Canberra, Australia	http://biodiversity.uno.edu/delta	DELTA-format and DELTA programs for taxonomic and systematic work on taxa
Digital Taxonomy, an Internet site of Cavalcanti, Rio DeJaneiro, Brasil	http://www.geocities.com/Rainforest/Vines/8695	List of programs for taxonomical informationsystems
Global Biodiversity Information Facility GBIF, Stuttgart, Germany	http://www.gbif.org	Worldwide network of databased information on biodiversity
Botanical Garden and Botanical Museum Berlin Dahlem, Berlin, Germany	http://www.bgdm.org	Biodiversity informatics, information about different systems with various approaches
Visual Plants, Germany	www.visualplants.de	Example of an on-site solution with some determination capabilities

Table 1 Important Internet addresses for biodiversity informatics and realisations of information systems.
Tabla 1. Direciones de internet importantes para información sobre informatica de biodiversidad y sistemas de información.

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Health state of Páramos: an effort to correlate science and practice.

El estado de salud de los páramos: un esfuerzo para relacionar la ciencia con la práctica de manejo sustentable.

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Health state of Páramos: an effort to correlate science and practice.

Resumen

El páramo como ecorregión Andina presenta atributos ecológicos, geográficos y socioeconomicos que le dan un valor estratégico alto: su vulnerabilidad, su importancia hídrica, su alto grado de endemismo, su carácter de corredor y su uso para la gente. Una de las grandes urgencias para que los tomadores de decisiones (gobiernos, administración de áreas protegidas, campesinos, etc.) puedan aplicar un manejo integral de este paisaje es el conocimiento del estado de salud en que se encuentra el páramo, tomando en cuenta todos estos atributos. El estado de salud es un concepto más integral y más dinámica que el estado de conservación, que es meramente ecológica. El estado de salud se basa sobre los criterios vigor, resiliencia y organización, los cuales que se pueden aplicar tanto a attributos geo-biológicos y socioeconómicos. Se desarrollaron unos indicadores integrales, que son (1) la capacidad de prestar bienes y servicios ambientales, (2) las diferentes opciones de manejo y (3) la salud de la población del ecosistema. En el Ecuador se hizo un estudio en los Páramos con el objetivo de hacer un primer acercamiento al estado de salud, y de probar algunas indicadores botánicas y sociales. De este ejemplo, se aprendió que el reto para establecer el estado de salud es identificar indicadores sencillos objetivos para los diferentes atributos, a diferentes escalas, que además sean comparables o ponderables y luego monitoreables. En esto, las ciencias biológicas, sociales, agrícolas y económicas encuentran un espacio idóneo para desarrollar y aplicar la información necesaria en forma conjunta. Palabras claves: Páramo, Ecuador, estado de salud, estado de conservación, indicadores.

Abstract

Páramo as an Andean ecoregion has ecological, geographical and socioeconomical attributes that determine its high strategic value: its vulnerability, its hydrologic importance, its high degree of endemism, its corridor character and its direct use by people. One of the urgent demands of decision makers (governments, protected area managers, farmers, etc.) to apply an integrated management of this landscape is to know the health status of páramo, taking into consideration all these attributes. The health status of an ecosystem is a more integral and dynamic concept that the conservation status, which is merely an ecological concept. Health status is based on three criteria: vigor, resilience and organization, which can be applied on geo-biological attributes as well as on socio-economical attributes. Three integral indicators are defined: (1) the capacity to provide environmental goods and services (2) the amount of different options for management and (3) the health of the population of the ecosystem. In Ecuador, a study was executed in páramo aiming at a first approach towards the health status of an ecosystem, and to test some botanical and social indicators. From this example, it became clear that the challenge in ecosystem health studies it the identification of objective indicators for the different attributes, on different scales. Moreover, these indicators must be comparable and possible to monitor. In this challenge, biological, social, agricultural and economic sciences find an excellent platform to develop and apply in a joint manner the necessary information. Key words: páramo, Ecuador, health state; conservation state; indicators

Introducción

Los páramos del Ecuador y su importancia

Los páramos son ecosistemas (semi)húmedos y fríos que en el Ecuador se encuentran formando un corredor casi intacto sobre la Cordillera de los Andes, por encima del límite superior actual o potencial de bosque (Mena et al. 2001). Forman un ejemplo ideal para aplicar la visión de ecosistema de la Convención de Diversidad Biológica, porque su importancia para la sociedad ecuatoriana y para el mundo en general se caracteriza por sus atributos biológicos, pero también sus atributos geográficos, sociales y económicos apoyan a su gran valor.

Los atributos biológicos que determinan la singularidad son su relativamente rica biodiversidad: es el ecosistema de alta montaña más diverso del planeta (Smith & Cleef 1988). Pero más aún que el número de especies, impresiona el porcentaje de especies endémicas para el ecosistema: alrededor del 60% de todas las especies de plantas vasculares no se encuentran en otros ecosistemas (Luteyn 1992). Este endemismo es un resultado del hecho que las plantas están muy adaptadas a las condiciones climáticas extremas, que también resulta en una gran fragilidad de su biodiversidad: con poco disturbio, se pierde una gran cantidad de las especies típicas del páramo (Verweij 1995). Finalmente, un atributo que hace que el ecosistema páramo es importante biológicamente, es el hecho que está formando un corredor Norte-Sur de más de 2000 kilómetros entre Venezuela y el Perú, en una de las cordilleras más dinámicas, geológicamente y biogeográficamente hablando, del mundo (Jorgensen & Ulloa 1994).

Probablemente aún más llamativo para grandes grupos de pobladores Andinos que los atributos biológicos son los geográficos. Especialmente el rol del páramo como regulador hídrica determina probablemente más que cualquier otra característica su valor para la población. Todas las grandes ciudades de los Andes del Norte dependen para su agua potable y para la mayoría de su electricidad del agua de páramo, pero también el campo, especialmente en la Sierra seca de Venezuela y el centro del Ecuador produce los alimentos gracias al agua de riego proveniente del páramo (Medina & Mena 2001). Pero también el suelo en sí ayuda a que el páramo tenga este gran valor. En primer lugar, el suelo orgánico es la clave detrás de la regulación hídrica pero este suelo en sí, especialmente en zonas de origen volcánico, es un almacén de carbono y un potencial de productividad agrícola aprovechado para papas, habas, mellocos y pasto para ganado (Podwojewski & Poulenard 2000). Finalmente, el paisaje en sí, con volcanes espectaculares, valles planos con turberas y lagunas vistosas, pendientes y afloramientos rocosos aparentemente inaccesibles y la inmensidad del páramo lo hacen uno de los ecosistemas más apreciados por turistas nacionales y extranjeros y las lagunas como Cuicocha y nevados como el Cotopaxi hacen de las Áreas Protegidas en la cual éstos se encuentran, los lugares naturales más visitadas del país (Narváez 2001).

La diversidad del páramo no está reflejada solo en su flora, fauna y paisaje, sino también en sus habitantes. La diversidad cultural y étnica hacen que la alta montaña, aparte de la amazonía, sea el único lugar donde todavía se hallan rasgos del Ecuador nativo, indígena. La mayor población indígena Quichuahablante vive en los páramos, practica su agricultura con algunas prácticas muy tradicionales, habla su idioma, tiene su cultura y vestimenta y está en un continuo proceso de cambio y adaptación, lo que quiere decir que es una cultura diversa y viva (Ramón 2002). Lo que socialmente hace importante el páramo para la sociedad es que durante los siglos, desde épocas preincaicas hasta ahora, la gente ha intervenido en el páramo y lo ha modificado. Esto dio origen al concepto que en alguna manera se puede considerar el páramo como un paisaje cultural y, de todas maneras, como un espacio de vida para casi un millón de habitantes en los Andes (Suárez 2002).

Son los atributos económicos los que hacen que el páramo sea importante para un millón de usuarios directos pero también para muchos usuarios indirectos. Primero, su valor para la producción agrícola que, aunque estamos de acuerdo o no con este uso del ecosistema natural, nos beneficia a todos los que comemos papas y tomamos leche. Pero los servicios ambientales que presta el páramo en sí también representan un valor directo a la población, ya que el precio del agua sería mucho mayor si no fuera posible sacarla tan cerca desde la montaña. Y finalmente, el turismo, que es la tercera fuente de ingresos en el Ecuador, se beneficia también económicamente (Vega & Martinez 2000).

Una de las grandes urgencias para que los tomadores de decisiones (gobiernos, administración de áreas protegidas, campesinos, etc.) puedan aplicar un manejo integral de este paisaje es el conocimiento del estado en que se encuentra el páramo, tomando en cuenta todos estos atributos. Porque evaluando, estudiando o monitoreando este ecosistema únicamente tomando en cuenta sus atributos biológicos sería una actividad muy limitada y no representaría la verdadera importancia de los diferentes grupo de interés en este ecosistema, cada uno con iguales derechos de control y acceso.

Estado de Salud, un concepto relacionado con la visión de ecosistema

Reconociendo que un ecosistema es un espacio dinámico, en que, en muchos casos, interfieren pobladores con la biodiversidad y los aspectos abióticos, que está interrelacionado con otros ecosistemas y que presta servicios a diferentes grupos humanos interesados, llevó a nivel internacional a promover la visión ecosistémica en la conservación (Smith & Maltby 2003). Esta visión, entre otros, respeta los diferentes atributos y respeta las diferentes expectativas que tienen diferentes grupos de gente sobre un ecosistema o un área natural. Este respeto para diferentes expectativas intrínsecamente significa que no existe un solo estado "bueno" o "malo" del ecosistema ya que lo que es bueno para un grupo de interesados, es malo para otro. Por ejemplo, un páramo sembrado de papas de buena calidad seguramente es evaluado positivo por su dueño cultivador, pero negativo por un ambientalista o un empresario turístico. Un concepto para evaluar el ecosistema, tomando en cuenta diferentes atributos y diferentes expectativas de la gente, es el "estado de salud" del ecosistema (Woodley et al. 1993), concepto que ha sido aplicado a los páramos del Ecuador por Mena (2001).

En términos amplios, el enfoque del estado de salud de un ecosistema es más amplio que el de conservación. El enfoque de salud del ecosistema parece más apropiado para los páramos ecuatorianos (y posiblemente para cualquier ecosistema), porque el enfoque del estado de salud de un ecosistema integra de manera explícita las consideraciones estrictamente ecológicas con los procesos sociales del manejo de recursos y las implicaciones que esto tiene sobre la salud humana (Rapport et al. 1998). El estado de salud de un ecosistema es un tema complejo, holístico y unificador en comparación del más biológico y estátivo "estado de conservación" (Mena 2001). Para trabajar con él y evaluar en la práctica el estado de salud de un ecosistema se deben definir indicadores que dan lugar a criterios de evaluación. Los criterios fundamentales señalados por Rapport et al. (1998) son vigor, resiliencia y organización. Estos criterios pueden ser aplicados a las dimensiones biofísicas, socioeconómicas y de salud humana de los ecosistemas. Además, hay tres indicadores generales, o integradores, que están surgiendo, tales como la capacidad de mantener los servicios ambientales, la posibilidad de ofrecer alternativas de manejo y la propia salud de la población humana directamente relacionada con el ecosistema (Mena 2001).

Los tres criterios generales del estado de salud aplicados al páramo

"Vigor" en términos de salud ecológica se refiere a la productividad del ecosistema. Esto en términos biológicos es fácil de imaginar ya que entre mayor productividad de material vegetal o de fauna, en mejor "salud" se encuentra el ecosistema. En términos de hidrología, también casi siempre es deseable que haya mucha "productividad" de agua (léase: balance positivo de cuenca). También en el tema económico es claro: entre más cantidad de dinero puede generar un páramo por turismo o regulación de agua, mejor está su "salud". Sin embargo, hay que tener cuidado al evaluar el vigor de un ecosistema, porque en primer lugar se debe relacionar con un "nivel óptimo" de vigor para un ecosistema sano. Por ejemplo, el páramo es un ecosistema de productividad baja y continua a lo largo del año y una productividad alta durante poco tiempo es una señal de estrés. Lo mismo es verdad para productividad económica o social; se puede concluir que el ecosistema se encuentra en buena "salud económica y social" cuando el páramo produce la máxima cantidad de recursos económicos o que en él están viviendo una óptima cantidad de gente, sin que esto signifique sobreexplotación (Mena 2001). El "vigor" del agua igual hay que ver dentro de su nivel óptimo: es deseable tener un flujo constante durante el año en vez de unas pocas ocasiones de muy alto caudal.

El término resiliencia se refiere a la capacidad que tiene un ecosistema para recuperar la situación original luego de un cambió. La hipótesis básica en relación con la salud de los ecosistemas es que la resiliencia es mayor cuanto menos disturbado está un ecosistema (Rapport et al. 1998). Es obvio que la resiliencia ecológica está relacionada con su capacidad de recuperación después de, por ejemplo, una quema. Los páramos que están en un buen estado de salud, son menos frágiles y no sufren tanto en un incendio que los páramos que ya están algo degradados. Lo mismo se cumple para la población: si la gente tiene un buen nivel de recursos económicos o culturales (conocimiento tradicional o moderno), puede responder mejor a un estrés exterior como una helada o una crisis económica.

El criterio de organización se refiere, en términos de la salud del ecosistema, a la complejidad de éste. Normalmente, un ecosistema sin disturbios tiende a aumentar su complejidad a lo largo de su proceso de sucesión hasta llegar a un clímax dinámico. La complejidad se manifiesta a través de la riqueza de especies y de la intrincación de sus interacciones (mutualismos, competencia, etc., Rapport et al. (1998)). En el caso del páramo un ecosistema con alta organización puede ser un pajonal con alta diversidad, y que la vegetación dominante presente diferentes estratos, como son musgos, hierbas y arbustos aplastados al suelo y arbustos que sobresalen del pajonal. Un efecto típico de estrés en el páramo por quema y pastoreo es una homogenización de la estructura del páramo, hasta terminar con un pajonal sin otros estratos; o sea con una menor organización (Hofstede 1995; Verweij 1995). También la presencia de cadenas tróficas intactas es un señal de buena organización; esto requiere que haya presencia desde los invertebrados más pequeños hasta predadores como el Puma y carroñeros como el

Cóndor, y esta situación se encuentra en muy pocas áreas (Mena 2001). Si aplicamos el criterio de organización a la sociedad o a la economía de la población, se puede imaginar que si la comunidad está mejor organizada, o si tiene diferentes formas de sustento económica (o sea, mejor organizada la economía) mayores serán su resiliencia y su "salud".

Los indicadores integrales de estado de salud aplicados al páramo

La capacidad del páramo de prestar bienes y servicios ambientales es un excelente indicador integral, porque sencillamente casi se puede decir que el páramo es un ecosistema "diseñado" para servir como proveedor de agua a las tierras más bajas (Mena 2001). Otro servicio ambiental fundamental del páramo es la retención de carbono en el suelo. La cantidad de carbono retenido en la abundante materia orgánica de los suelos del páramo puede llegar a ser similar a la cantidad retenida en la vegetación de una extensión equivalente de bosque húmedo tropical (Hofstede et al. 2002). Para que el páramo esté en la capacidad de prestar servicios ambientales, debe estar en un buen estado de salud. Entre mejor conservado el suelo, más materia orgánica, mejor almacenamiento de carbono y mejor regulación hídrica. Para esto se requiere que los atributos biológicos y geográficos cumplan tanto con un alto vigor, resiliencia y organización. Pero, para poder aprovechar en una forma eficiente y equitativa de estos servicios ambientales, se necesita que también la sociedad esté cumpliendo los criterios generales. Porque ¿cómo se va organizar un sistema efectivo de pago por agua cuando no hay organización en la cuenca? o ¿cómo se puede entrar en un largo camino de gestión de carbono cuando no haya suficiente resiliencia?.

Lo que vale para el indicador integral "capacidad de prestar bienes y servicios ambientales" también es verdad para "la posibilidad de ofrecer alternativas de manejo". De un lado, un páramo con buena productividad de vegetación, gran profundidad de suelo, suficiente agua, como los que encontramos en Carchi, tiene mayor resiliencia y alta organización. Estos páramos tienen más opciones de manejo (inclusive agrícola) que los páramos sobre suelos delgadas y en condiciones secas en Azuay, donde la conservación estricta es casi la única opción viable. Sin embargo, para realmente emplear estas diferentes alternativas de manejo, se requiere una comunidad organizada y con opciones de invertir a mediano plazo (o sea, con resiliencia) y de un gobierno local bien organizado y con buen vigor (o sea, con dinero para apoyar la iniciativa), entre otros (Mena et al. 2001).

Finalmente, la salud de la población humana probablemente es el indicador más integral, pero a la vez el indicador que más difícilmente se relaciona directamente con el ecosistema. La hipótesis aquí, que suena bastante lógica, es que en un ecosistema sano hay gente sana. La salud de la gente no solo se refiere a las condiciones físicas del aparato respiratorio o de otras funciones semejantes, sino también al estado anímico y psicológico de la gente: en un ecosistema rico y diverso la gente es más sana, feliz, positiva y productiva. En el caso del páramo, la situación de salud integral es grave. De acuerdo con Bernal et al. (2000) la "tasa de alfabetismo" tiene un promedio de 24,2%. La relación entre analfabetismo y condiciones bajas de salubridad es bien conocida. El porcentaje de hogares con saneamiento básico tiene promedio de 25,7%. Un tercer indicador, tal vez el más importante, es la incidencia de la pobreza, que tiene un promedio de 75,7% en los páramos de Ecuador. La relación de causa y efecto en el caso de la salud de la gente y la salud del ecosistema es difícil. ¿Es la gente (en su mayoría pobre, analfabeta, mal servida y abatida) la causa de un ecosistema maltratado? ¿O son las condiciones propias del ecosistema las que llevan a que la gente en él se empobrezca y se enferme? Esperamos que no hay lo uno sin lo otro, ni lo otro sin lo uno (Mena 2001) y por lo tanto hace que la salud de la gente misma es un excelente indicador integral del estado de salud de los páramos, porque hay una relación bidireccional, que involucra tanto los atributos biológicos, geográficos, sociales y económicos.

Indicadores objetivos y medibles: punto clave en el manejo de un ecosistema

Los indicadores integrales no se pueden medir directamente porque están compuestos de una serie de indicadores sencillos, que deben ser objetivos, medibles y, más que todo, no ser ambiguos: tienen que indicar con certeza si algo va bien o va mal. Por esto la definición de indicadores es considerada una ciencia en sí. O mejor dicho, la definición y validación de indicadores sencillos y objetivos es un buen reto para la ciencia moderna en general, ya que fundamentalmente son las herramientas que necesitan los tomadores de decisión para guiar sus acciones. En el proyecto Andes del Instituto Alexander von Humboldt (datos no publicados) se han tratado de identificar, con el apoyo de un grupo multidisciplinario de científicos, una serie de indicadores geo-biológicos y socio-económicos que en su conjunto deben poder sostener los tres indicadores integrales. Así, entre los indicadores biológicos identificaron la diversidad de especies, la estructura de la vegetación, la biomasa, y la cantidad de especies endémicas. Los indicadores geofísicos fueron la desecación de humedales, la compactación del suelo, la retención de humedad y la pérdida y transformación de materia orgánica en el suelo, entre otros. Los indicadores socioeconómicos incluyeron el uso del suelo, el sistema productivo, la accesibilidad, y el índice de calidad de vida. En las discusiones llevadas a cabo en el grupo, se concluyó que el reto no solamente era la identificación de indicadores y la comparación de indicadores sociales con biológicos, sino también la escala en la cual se evalúa un indicador (regional, sub-regional, local o puntual).

De la teoría a la práctica hay una distancia considerable. Coppus et al (2001) y Hofstede et al (2003) han publicado un estudio en el cual se hizo un primer intento de evaluar el estado de salud de los páramos de pajonal en el Ecuador. Aquí resumimos este estudio con el fin de demostrar la ambigüedad de los indicadores que a primera vista parecen muy claros.

El estado de salud de los páramos en el Ecuador

Coppus et al (2001) y Hofstede et al. (2003) procedieron en primera instancia a analizar con unos pocos indicadores, combinados con la opinión de expertos, el estado de conservación en los páramos de pajonal en el Ecuador. Luego, cruzaron este estado con otros indicadores biológicos y sociales para identificar la relación entre estos indicadores. Con base en el mapa preliminar de los páramos del Ecuador (Proyecto Páramo 1999) se diferenciaron las zonas de estudio. En total se analizaron 28 áreas de páramo, que comprendieron en su mayoría páramos de pajonal, que según la suposición son las unidades donde el paisaje ha sido modificado por el uso de la tierra. En cada sitio se determinó la composición botánica (especies), la pendiente, la altitud y la posición geográfica. Además, se evaluó visualmente la evidencia de quemas, pastoreo, degradación directa y otros tipos de disturbio humano. El contenido de materia orgánica y la actividad biológica fueron analizados en calicatas de suelo. Además se estimó la presencia de fauna silvestre. Estos datos fueron tratados en una formula matemática arbitraria, pero basada en supuestos lógicos para llegar a una aproximación del estado de conservación (Coppus et al. 2001), la cual resultó en un índice de estado de "conservacion" de cada sitio, con una escala entre 1 y 5. Una vez establecido este índice, se hizo una clasificación de los diferentes sitios (Figura 1).

Con los valores así obtenidos, resultó un orden de sitios según su estado de conservación bastante confiable y aceptable y se procedió a relacionar el estado con la cantidad de especies vegetales para determinar el valor de la diversidad de especies como indicador (Figura 2). Si bien la cantidad de especies encontradas en cada transecto fue relativamente alta (entre 39 y 64) no hubo una tendencia de mayor cantidad de especies en mejores condiciones. Sin embargo, si se analiza cuales son las especies de flora que se encuentran principalmente en los páramos evaluados como en "buen estado", se nota que son todas especies típicas del páramo. *Blechnum occidentale, Chusquea tesselata* y *Diplostephium hartwegii* (Verweij 1995; Luteyn 1999) solamente se han encontrado en páramos bien conservados ([[Figura 3]]). Con *Puya* y *Uncinia* no se encontró una correlación a nivel de especies, pero sí a nivel de genero. Finalmente, los líquenes sirvieron como indicador como grupo. Por otro lado, las especies consideradas oportunistas, tolerantes a pastoreo e inclusive "malezas" de páramo, tales como *Rumex acetocella, Trifolium repens* y *Lachemilla orbiculata* (Ferwerda 1987; Verweij 1995) están presentes tanto en los páramos evaluados en "buen" estado como en "mal" estado, pero su abundancia era mucho más alta en los páramos muy intervenidos ([[Figura 4]]). Esto quiere decir que la cantidad de especies en sí no es un buen indicador del estado del páramo, pero la presencia de especies típicas de páramo sí; y más aún, a veces no hay que evaluar la riqueza vegetal a nivel de especies pero si a nivel de género. Y, en el caso de indicadores de intervención, no vale analizar la presencia/ausencia pero si es necesario analizar la abundancia.

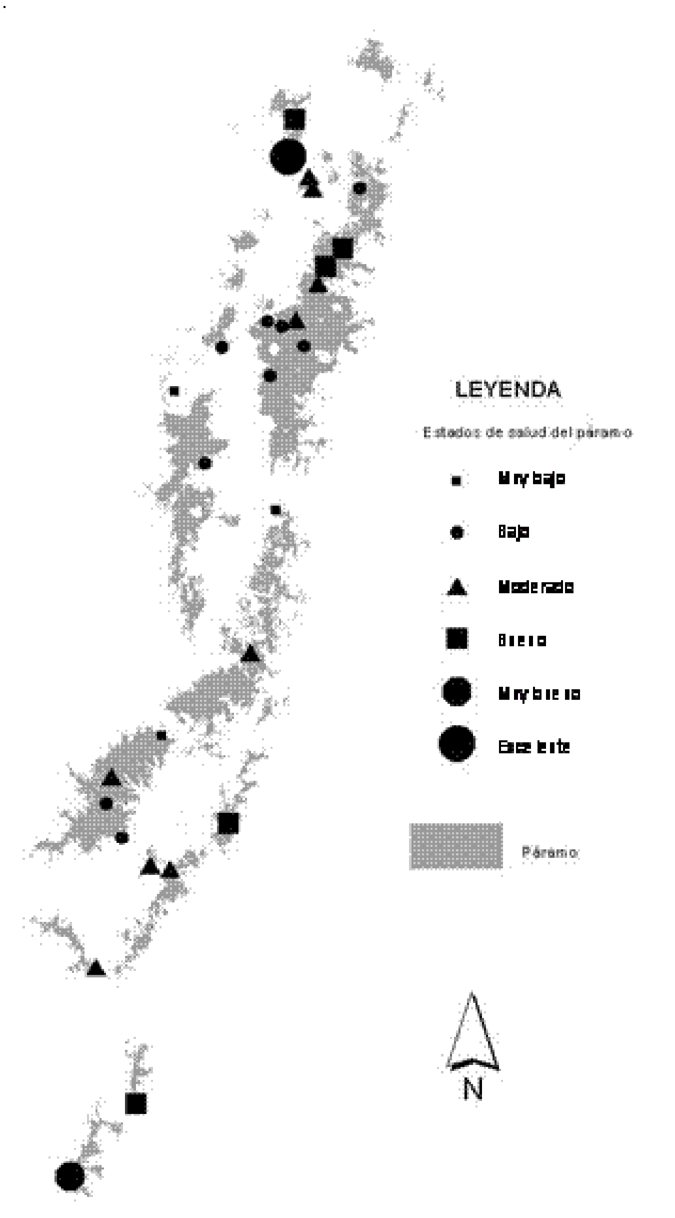

Figura 1: Distribución geográfica de todos los páramos en el Ecuador con la localización de los sitios de estudio en páramos de pajonal. El símbolo representa el estado de conservación evaluado mediante indicadores geo-biológicos (Coppus et al. 2001).
Figure 1. Geographical distribution of the Paramos in Ecuador, with location of study sites. The symbol repreesents the conservation status, evaluated according to geo-biologic indicators (Coppus et al. 2001).

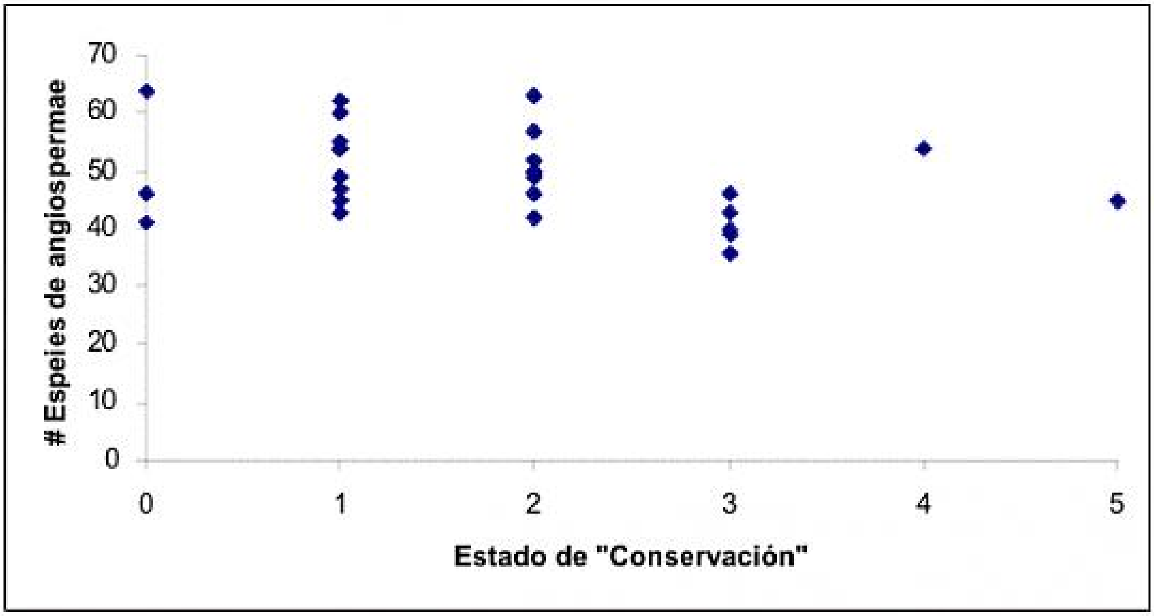

Figura 2: Relación entre número de especies de plantas vasculares y estado de "conservación" en 30 sitios de páramo (Datos de Coppus et al. 2001).
Figure 2. Relation between the number of vascular plant species and conservation status on 30 paramo sites (Data from Coppus et al. 2001).

Para avanzar hacia la evaluación del estado de salud, se procedió a correlacionar el estado de los páramos encontrados con variables socioeconómicas de censos sociales ver [[Figura 5]] (Infoplan 1999). Se puede concluir que en términos generales, los páramos con mayor estado de conservación están relacionados con índices bajos de desarrollo. La severidad de la pobreza, la brecha y la severidad de la indigencia, las personas económicamente activas, el índice de desarrollo social y de necesidades básicas no satisfechas tienen diferencias significativas para los tres estados de salud. El índice de desarrollo social y las personas económicamente activas decrecen con un mejor estado de salud del páramo, y todas las demás variables aumentan con un mejor estado de salud (Coppus et al. 2001). Estos resultados indican que los páramos en mejor estado de salud están situados en áreas con las poblaciones humanas más pobres, mientras que los que tienen peores estados de salud están relacionados con condiciones socioeconómicas más positivas. Sin embargo, esto puede ser una equivocación ya que los datos socioeconómicos están analizados a una escala diferente que los geo-biológicos. Por ejemplo, los datos de población están agrupados por parroquia, y esto en ciertos casos significa el estado de una población que no vive en los páramos si no en la cabecera parroquial a otra altitud (Recharte & Gearheard 2001). También la calidad de la información es un punto clave: una población indígena en el centro del país puede tener pocos recursos económicos, y por esto ser evaluada indigente, pero ser autosuficiente en alimentos y vestimenta (Mera 2001).

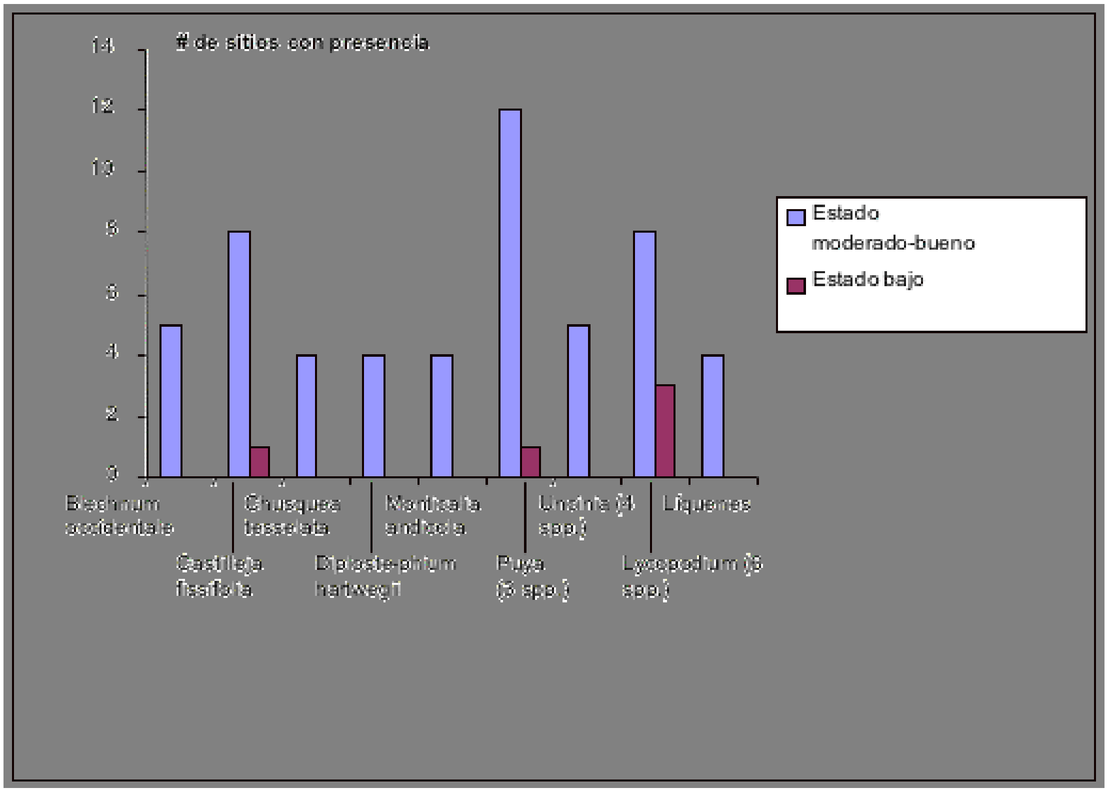

Figura 3: Especies de plantas con mayor presencia en páramos en buen estado de "conservación" (Bueno-moderado= valores 3-5, bajo= valores 1 y 2; Datos de Coppus et al. 2001).

Figure 3. Plant species with mayor presence in paramos in good state of conservation (Good-moderate= values 3-5, low=values 1 and 2: Data from Coppus et al. 2001).

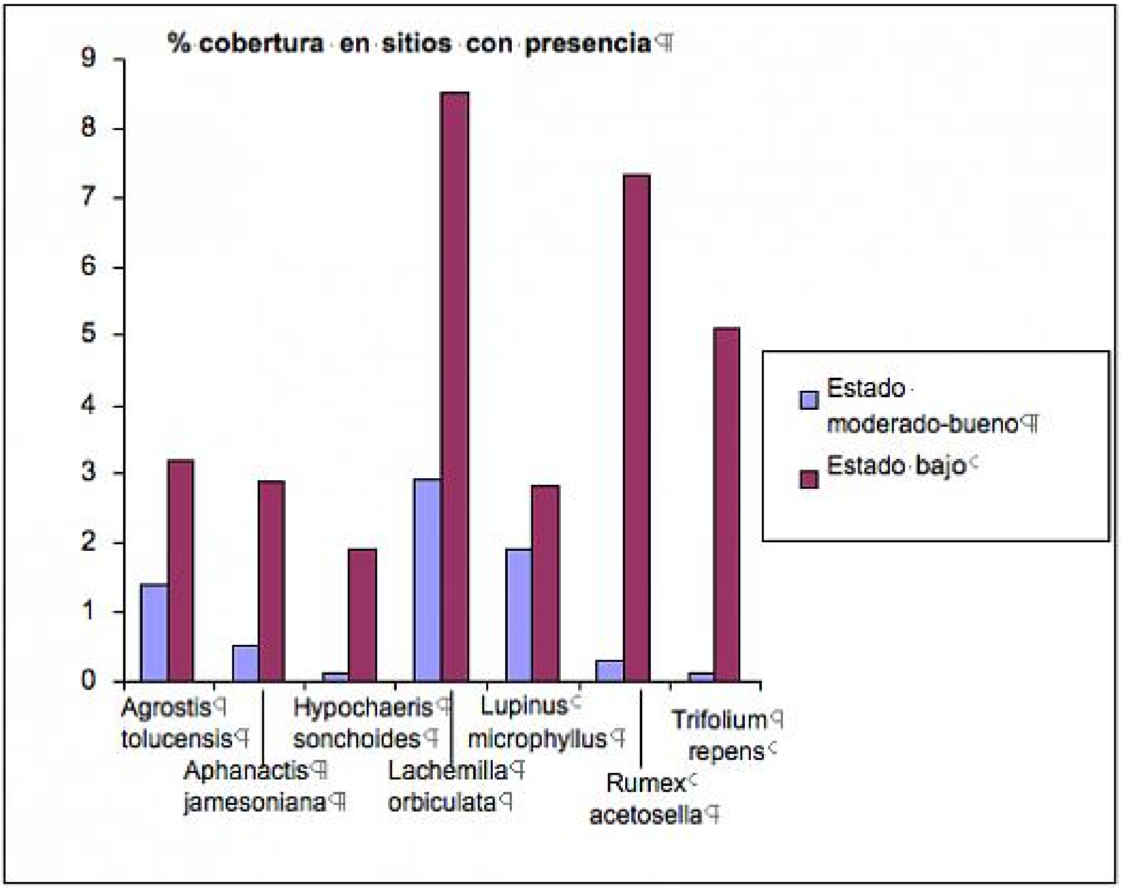

Figura 4: Especies de plantas con mayor abundancia en páramos en bajo estado de "conservación" (Bueno-moderado= valores 3-5, bajo= valores 1 y 2; Datos de Coppus et al. 2001)
Figure 4. Plant species with mayor presence in paramos in low state of conservation (Good-moderate= values 3-5, low=values 1 and 2: Data from Coppus et al. 2001).

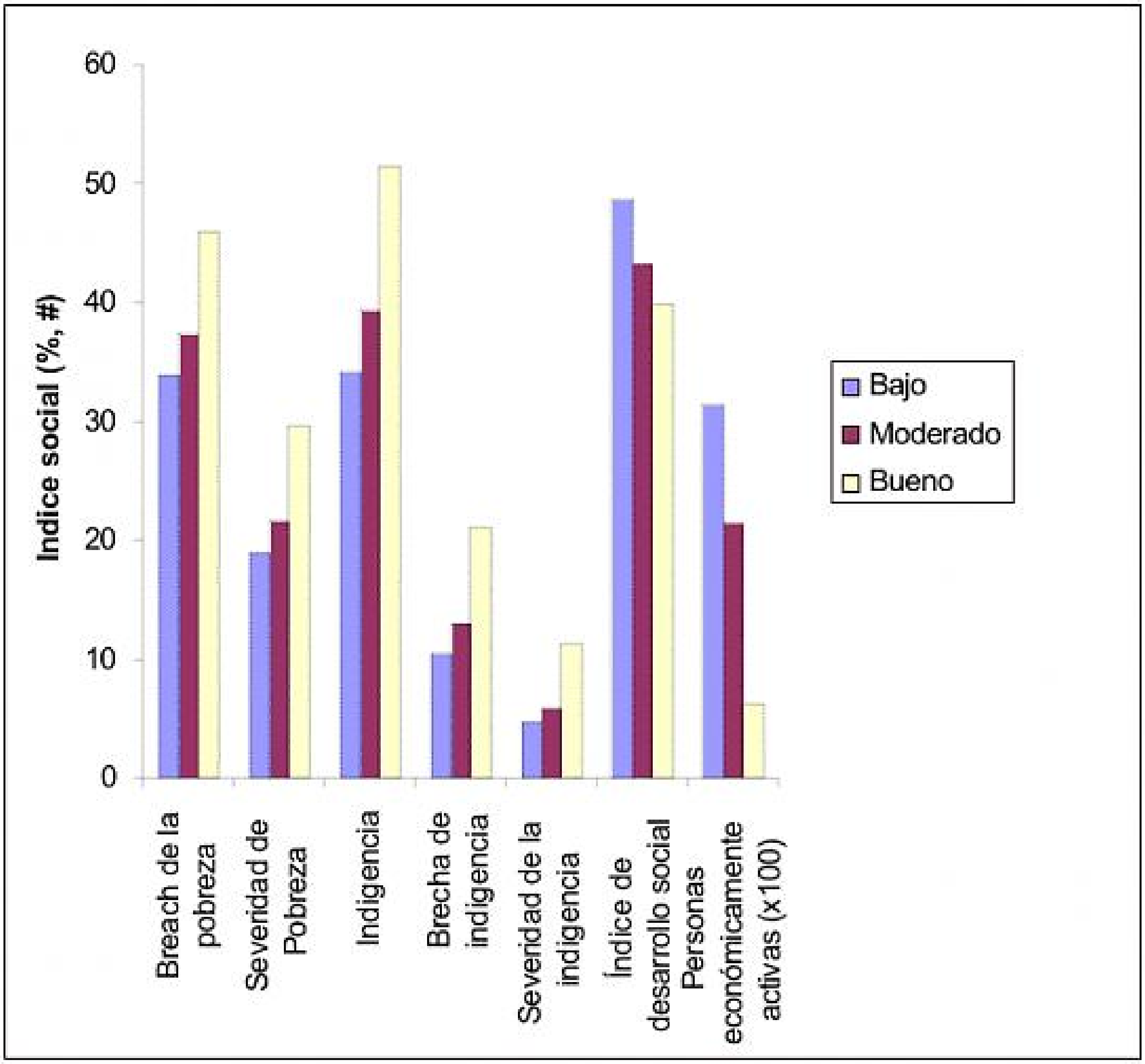

Figura 5: Relación entre indicadores sociales y estado de "conservación" de 30 sitios de páramo ("Bueno" es valor 4 y 5, "moderado" es valor 3, "bajo" es valor 1 y 2. Datos de Coppus et al. 2001).
Figure 5. Relation between social indicators and conservation status of 30 paramo sites (Good-moderate= values 3-5, low=values 1 and 2: Data from Coppus et al. 2001).

Conclusiones

En el Ecuador, tres cuartos de todos los páramos naturales son dominados por pajonales, los cuales sufren de algún grado de intervención humana. Sin embargo, todos los páramos brindan múltiples servicios a la población gracias a sus atributos biológicos, geográficos, sociales y económicos. Evaluando un páramo únicamente tomando en cuenta sus atributos biológicos sería una actividad muy limitada y no estaría acorde a la visión ecosistémica que respeta la interacción naturaleza-ser humano, la dinámica de ecosistemas y la interacción entre ecosistemas. Para que la sociedad pueda aplicar un manejo integral de este paisaje es necesario definir en que estado está el ecosistema y como es su respuesta a intervenciones y actividades de manejo. Considerando esta dinámica y la multidisciplinariedad de la evaluación, se propone avanzar hacia la determinación del estado de salud en vez del más estrictamente ecológico estado de conservación. El páramo forma un ecosistema en el cual es fácil de entender cómo es la interrelación entre los criterios generales y los indicadores integrales del estado de salud, tanto a nivel geo-biológico como socio-económico. Sin embargo, para realmente poder evaluar y monitorear el estado de salud, falta más conocimiento sobre indicadores sencillos, objetivos y medibles. Este articulo ha demostrado que algunos indicadores relativamente obvios, sin embargo presentan ambigüedades relacionadas con la falta o la calidad de la información, con la escala y con las interacciones entre indicadores sociales y biológicos. Es un reto para las diferentes disciplinas diseñar y aprobar esta clase de indicadores. Aqui, las ciencias biológicas, sociales, agrícolas y económicas encuentran un espacio idóneo para desarrollar y aplicar la información necesaria en forma conjunta. Pero además, es necesario una discusión continua entre científicos y los tomadores de decisiones para asegurar que la información sea aplicada de manera objetiva, equitativa y adecuada.

Agradecimientos

La teoría y los datos presentados en este articulo fueron desarrollados durante la ejecución del Proyecto Páramo en el Ecuador (Universidad de Amsterdam, EcoCiencia, Instituto de Montaña). El autor agradece en especial a Patricio Mena (EcoCiencia) y Pool Segarra (EcoPar), con quienes mantuvimos numerosas discusiones sobre este tema, y a Ruben Coppus, Lorena Endara, Susana León, Veronica Mera, Marieke Nonhebel y Jan Wolf, quienes ayudaron en el trabajo de campo y en el procesamiento de parte de los datos del estudio del estado de salud. Al Instituto Alexander von Humboldt (Colombia) agradezco la invitación a compartir experiencias con el desarrollo de indicadores para el páramo. Reconozco profundamente a los habitantes del páramo que colaboraron en discusiones y en el trabajo de campo. Este estudio fue financiado por el Instituto de Biodiversidad y Dinámica de Ecosistemas de la Universidad de Amsterdam y por la Embajada de los Países Bajos en el Ecuador.

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Silvicultural contributions towards sustainable management and conservation of forest genetic resources in Southern Ecuador.

Contribuciones silviculturales para manejo sostenible y conservacion de recursos geneticos forestales en el Sur del Ecuador.

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Silvicultural contributions towards sustainable management and conservation of forest genetic resources in Southern Ecuador.

Resumen

Bosques con una diversidad alta de árboles (por área) normalmente son caracterizados por una abundancia baja de muchas especies. Este hecho tiene implicaciones fuertes hacia un manejo sustentable de recursos genéticos forestales como también hacia la conservación. Después de la selección de especies prioritarias utilizando criterios ecológicos y económicos, se inició una evaluación de la variación genética dentro de cada especie prioritaria. Por ello se estudió la fenología de *Cedrela montana*, *Prumnopitys montana*, *Myrica pubescens* y *Clethra revoluta* durante por un plazo de dos años en dos sitios diferentes: ECSF (Valle de la Estacón Científica San Francisco) y "El Bosque"(cerca de San Pedro de Vilcabamba). Adicionalmente se realizaron inventarios forestales en la Reserva "Estación Científica San Francisco" y en la Reserva "La Ceiba" en el bosque seco. Los resultados demuestran una variación alta de datos de floración y fructificación, no solo entre las dos áreas geográficas, sino también dentro de ellas. Como consecuencia, esa variación se debe considerar en planes de manejo y conservación. Los inventarios demostraron que hay varias especies con subpopulaciones sin contacto o flujo de genes entre ellas o que son demasiado pequeñas para conservación estática de recursos genéticos. Para delinear zonas genecológicas (en la Provincia de Loja) para fuentes semilleros dentro de programas de manejo forestal sustentable como también para conservación de variación genética, los mapas existentes de condiciones ambientales en la Provincia de Loja fueron cruzados con SIG. Después de la identificación de las zonas genecologicas y sus superficies correspondientes se puede decidir si las superficies son suficientes para conservación en situ o si se debe realizar medidas adicionales como establecimiento de seed orchards, archivos clonales o amplificación de áreas protegidas.

Abstract

Forests with high tree species diversity (per area) are mostly characterized by a low abundance of the single species. This fact has strong implications on activities towards a sustainable management of forest genetic resources as well as towards their conservation. After selection of priority species using ecological and economical criteria, an assessment of the phenotypic and genetic variation within each priority species was started. For this purpose the phenology of *Cedrela montana*, *Prumnopitys montana*, *Myrica pubescens*, and *Clethra revoluta* was studied for a two-years period at two different sites: ECSF area (San Francisco valley) and "El Bosque" (close to San Pedro de Vilcabamba). In addition, forest inventories were carried out in the dry forest "La Ceiba" and at ECSF area. The results show a high variation in flowering dates and fructification intensity not only between the two geographical areas but also within. Consequently, this high variation must be considered in management as well as conservation activities. The inventories showed that there are several species with subpopulations that may have no contact between each other or might be too small even for static conservation purposes. To delineate genecological zones (i.e. provenance regions), which can act as seed sources for sustainable forest management programmes as well as for the conservation of forest genetic variation, the existing maps of environmental conditions in Loja and the vegetation cover were overlaid. After the identification of these zones and their size it can be decided if the areas will be sufficient for an "in situ" conservation and sustainable management or if additional measures have to be undertaken (e.g. establishment of seed orchards, clonal archives, amplification of conservation areas).

Introduction

The objectives of the conservation and sustainable management of forest genetic resources are to secure the ability of forest tree species to adapt to environmental changes and to maintain the basis for improving production and other benefits of growing trees (Graudal et al. 1997). This might be even more important if global change models become true.

Conservation and sustainable use of forest genetic resources is a major issue in national and international policies (Young et al. 2000). New Forest Management is no longer focused on the maximization of profits from timber and non-wood forest products, but it is also concerned about sustaining the integrity of forest ecosystems.

The strategies for conservation and the applied methodologies depend on the specific objectives and on the scope of the programme. There are two basic strategies for genetic conservation, the one is "in situ" (FAO et al. 2001), the other is "ex situ" conservation (FAO, IUFRO 2002). These two strategies are complementary.

Because natural ecosystems are not static but dynamic, genetic conservation should not be restricted at promoting the maintenance of a given state (i.e. "static conservation") forever, but shall be directed at ensuring the adaptability of the ecosystem and the enhancement of the genetic diversity presently available to meet future requirements (i.e. "dynamic conservation" or "evolutionary conservation").

The establishment of forest plantations is not only an option to provide sustainable supply with timber and NWFPs and to minimize the pressure on natural forests but can also be an important complementary contribution to dynamic conservation.

Before that background the continuous supply with high quality tree seeds or "forest reproductive material" of indigenous species is one of the fundamental challenges for sustainable forest management. The installation of a sound programme for managing tree seed resources on a national or regional level is a very first but nevertheless important step for the realization of successful tree planting activities. Hufford & Mazer (2003) point out that in general data are needed to delineate "seed transfer zones", or regions within which plants can be moved with little or no consequences for population fitness. This paper tries to address this problem for the Province of Loja, South Ecuador.

Regional programmes must be embedded in the national framework for conservation and management of forest resources. However, we are not reflecting in detail about the goals and considerations of the National Forest Programme of Ecuador (NFP) and its political, socio-economic, financial and organisational aspects or about strategic considerations therein (for details see Graudal et al. 1997, Graudal 1998), but we will focus on some technical aspects within a regional framework.

For instance: What can be the objectives of a regional Tree Seed Programme in the Loja Province?

According to Graudal (1998) we suggest to distinguish between long term and short term objectives:

Long term objectives can be: (1) improved wood production and provision of other benefits from growing woody plants to help meet the regions’ requirements for timber, poles, fuel, fodder, food, and shelter, (2) contribution to the rehabilitation of degraded environments (e.g. the reforestation of abandoned pastures), and (3) conservation of genetic resources of trees (Graudal 1998).

On the way to a successful realisation of the long-term objectives the achievement of the short-term objectives is mandatory. One of the most important short-term objectives is the provision and promotion of genetically suitable seed and other reproductive plant material of good physiological quality from selected seed sources of indigenous woody species. ‘

The provision and promotion of suitable seed requires an organisational backbone including a functioning seed procurement technology (Graudal 1998).

Suitable seed means the use and maintenance of defined and well-documented seed sources. In terms of environmental and genetic sustainability a preference should be given to native tree species and their provenances, which are well adapted to the specific site conditions. At the moment and as far as we know, no species specific conservation or management plans have been developed and implemented in Ecuador with the objective to protect these genetic resources for sustainable use in future.

Within the project "Afforestation with Native Species of Abandoned Pastures of South Ecuador" of the German Research Programme (DFG) " Functionality in Tropical Mountain Rain Forest of South Ecuador" at the Estación Científica San Francisco we try to develop the scientific basis which can be seen as a contribution to the establishment of a "provincial tree seed and plantation programme" which can function as a complementary for the conservation of forest genetic resources.

Materials and Methods

For technical implementation of the short-term objectives we suggest a stepwise approach (see *Graudal et al. 1997*).

1. Selection of priority species (economical and ecological criteria)
2. Assessment of the phenotypic and genetic variation within each species: *Evaluation of conservation status; Identification of populations to be conserved; development of conservation measures; Planning and organisation of specific conservation activities; formulation of management guidelines*
3. Identification and delineation of genecological zones (tree seed zones, provenance regions) as a prerequisite for seed supply with adapted forest reproductive material. Overlay of existing maps about environmental conditions with maps of forest cover or vegetation.
4. In situ conservation measures (amplification of conservation areas, establishment of 'in situ' conservation stands)
5. Ex situ conservation measures (establishment of 'ex situ' conservation stands, seed orchards, clonal archives, seed and gene banks)

Box 1. Steps to the conservation and sustainable management of forest genetic resources in South Ecuador.

Caja 1. Pasos para conservacion y manejo sostenible de recursos geneticos de los bosques del Sur de Ecuador.

The investigation within our project tries to develop and provide basic scientific knowledge and methods for the implementation of some of the above-mentioned steps.

Phenology:

Phenological studies were carried out from 15 of June 2001 to 15 of June 2003 at San Francisco Station in the Province of Zamora Chinchipe, 30 km west from Loja and at El Bosque, approx. 10 km southwest from San Pedro de Vilcabamba, Loja. Both sites lie at an altitude of 2100 m a.s.l. in the evergreen montane rainforest zone. Five clustered individuals of similar phenotype (height, diameter, crown position and crown form, vitality) with distances less than 25 m between each other were selected of each species at one site. The selection criteria should guarantee a minimum of natural variation of ecological parameters and phenotype. Under this precondition we suppose that a variation in the observed phenological traits exhibits a very first and preliminary estimate of possible genetical variation between conspecifics rather than a result from differences in ecological conditions. Phenological data of flowering and fruiting intensity were registered in a two-weeks rhythm for each site.

Inventories:

Data from forest inventories were analysed for the characterization of tree populations in the Reserva La Ceiba (dry forest) and Estación Científica San Francisco (cloud forest). In La Ceiba 153 of systematically distributed plots with 1000 m² each were established to study all tree vegetation with DBH > 5 cm. In San Francisco eight lines transects were installed in four microcatchments of 8 to 20 hectares each. For each microcatchment one transects was oriented along the ridge and another one along the creek. The transects were subdivided into subplots of 10 m in width and 20 m in length.

Maps:

Maps of soils, temperature (Plan Hidraulico) and dry months (The Nature Conservancy) have been modified and overlaid using the GIS programme *Arc View*.

Selection and survey of priority species:

Besides the vulnerability and danger of extinction of species the main criteria for including species in genetic resource conservation programs are their present and their possible future use (Graudal et al. 1997). Based on the timber market survey of Leischner and Bussmann (2002) we did a selection of priority species. The selected species are of high ecological value and economic importance not only for local use. The above-mentioned study refers to the wood market of the Province's Capital Loja and consists mainly of species from the lowlands of Zamora Chinchipe. Woods from the Province of Loja are very scarce due to high deforestation. Because of the necessity of well adapted species to the site conditions of the reforestation trials at an altitude of 2100 m close to Estación Científica San Francisco we modified the list and included species with either economic value (for example *Prumnopitys montana*, *Cedrela montana*, *Tabebuia chrysantha*) or known ecological characteristics like *Clethra revoluta* (pioneer), *Myrica pubescens*, *Alnus acuminata* (pioneer, nitrogen fixation), endangered species *(Prumnopitys montana, Podocarpus oleifolius, Cinchona pubescens*) among others.

We are aware about the high intrinsic value of other tree species in the mountain forest ecosystems of Southern Ecuador, which cannot be covered by our project.

Genetic variation in forest genetic resources is expressed in differences between species, populations, individuals and chromosomes. High levels of intraspecific genetic variation, which is needed to ensure the adaptability of the species as well as their continuing evolution, characterize many tree species.

It is well known that the ecological conditions in the Andes vary noticeably between the eastern and western slope of the cordillera as well as a matter of altitudinal zonation, mesoclimatic differences, or local climate systems.

The variety of ecological conditions within the natural distribution area of a species, e.g. *Cedrela spec*. supports the hypothesis of genetic differentiation between populations of the same species as a result of adaptation to the varying local conditions. Because of the separation of the populations by high elevation mountain borderlines gene flow via pollen and seed between these populations is very limited. Habitat heterogeneity, combined with natural selection, often results in multiple genetically distinct ecotypes within an single species (Hufford & Mazer 2003).

In a second step we started with phenological investigations (e.g. dates of flowering and fruit ripening) of four different tree species (*Cedrela montana*, *Prumnopitys montana*, *Myrica pubescens*, and *Clethra revoluta)* in two different areas of South Ecuador.

Results

(Figure 1) indicates the variation of flowering and fruiting of Cedrela montana in San Francisco during a two years period of observation. It is notable that the minimum of variation coincides with the culmination of the phenological phenomena. During the initial and the terminal phase one can see the maximum of variation. Even the lowest values of variation reach 56,7 % (flowering) and 77,4 % (fruiting). Practically this means that one can find fruiting and non-fruiting neighboring trees at the same time. The further species under observation show even higher values of variation [[Table 1]]. Fruiting is more variable than flowering, and the variation in San Francisco in general is much higher than in El Bosque. This could be explained by climatological features, i.e. more distinct dry and wet seasons in El Bosque, and indicates possibly an adaption of species to certain ecological conditions of each site.

The differences in phenology of *Clethra revoluta* between the two study areas are enormous. The beginning of flowering and fruiting in El Bosque starts about half a year earlier than in San Francisco. It is notable that both sites show a seasonal rhythm of phenological characteristics, although especially San Francisco area is considered as a perhumid site with very low fluctuation of climatic parameters. There are not only differences in the rhythm but also in the intensity of flowering and fruiting. Though a decline in flowering and fruiting was observed in the second year in San Francisco, an increase was registered in El Bosque. Similar differences in phenological phenomena were present in the other species, too. In general flowering and fruiting start earlier in El Bosque. *Myrica pubescens* had almost no seasonal rhythm in San Francisco, but a slight seasonality in El Bosque. This could indicate a more distinct seasonality of dry and rain season in El Bosque in comparison with San Francisco.

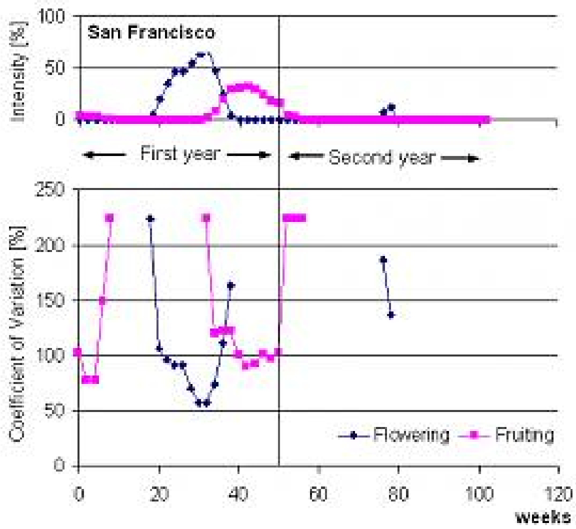

Figure 1. Intensity and Variation of Phenology of *Cedrela montana* in Estación Científica San Francisco in two years of observation.
Figura 1. Intensidad y variacion fenologica de *Cedrela montana* en la Estación Científica San Francisco an dos años de observacion.

	San Francisco		El Bosque	
Species	Flowering	Fruiting	Flowering	Fruiting
Cedrela montana	56,7	77,4	15,2	39,1
Clethra revoluta	81,4	99,3	52,7	67,5
Myrica pubescens	37,7	104,6	18,5	26,7
Prumnopitys montana	136,9	136,9	-	20,4

Table 1. Minimum Coefficient of Variation of Flowering and Fruiting Intensity during two years of observation. Different phenological behavior of a single species at the two study sites
Tabla 1. Coeficiente minimo de variacion de intensidad de floracion y frutificacion durante dos años de observacion.

Problem of isolated subpopulations in the study areas La Ceiba and ECSF

In (Figure 3) and (Figure 4) we show the distribution of *Prumnopitys montana* and *Cedrela montana* in four watersheds of the San Francisco area. We identified three clusters of *Prumnopitys montana* and four of *Cedrela montana*, each cluster in gorges and separated from each other by pronounced ridges. *Prumnopitys montana* is a dioecious species and an unbalanced female-to-male ratio in subpopulations can cause malfunction of the reproductive system. On the other hand insects make pollination efficient and facilitate recombination. Under these marked topographical structures it is questionable whether gene flow between subpopulations of *Cedrela montana* via pollination by wind is efficient as well. Nevertheless the monoecy of *Cedrela* may compensate for this difficulty.

The subpopulations of *Prumnopitys montana* and *Cedrela montana* within the gorges pass the critical size for static conservation of 50 defined by Graudal et al. (1997) but dynamic conservation only can be guaranteed when there is gene flow between the subpopulations.

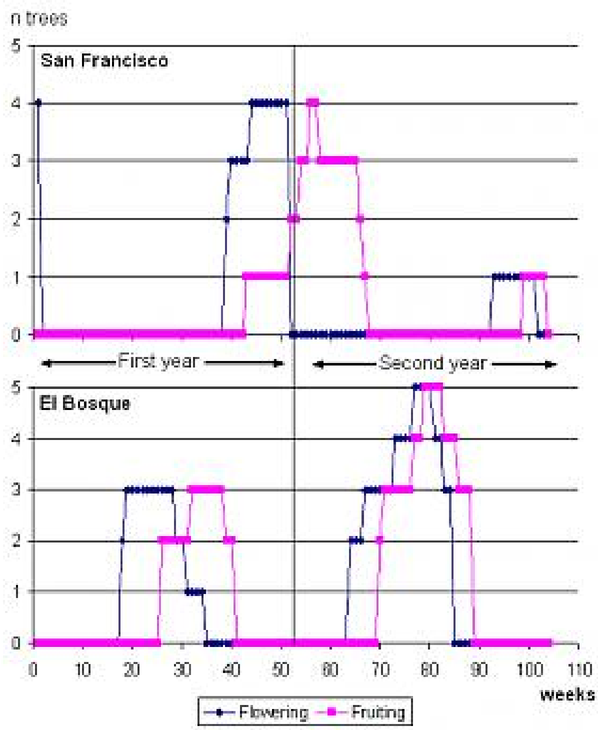

Figure 2. Differences of flowering and fruiting of *Clethra revoluta* between the study areas San Francisco and El Bosque.
Figura 2. Diferencias en floracion y frutificacion de *Clethra revoluta* entre San Francisco y El Bosque.

Species	N (total)	Forage species	Wood
Cavanillesia platanifolia	346	X	
Guazuma ulmifolia	346	X	
Lonchocarpus sp.	346		
Maclura tinctoria	346		X
Cordia macrantha	693		
Maclura sp.	693		
Triplaris sp.	693		
Ipomoea sp.	1039		
Bejuco Bejuco???	1386		

Table 2. Total number of individuals (DBH > 5 cm) of rare species in the Reserva La Ceiba with high distances between clusters of individuals*
*** Mean distance between clusters = 391 m. The distances between clusters were calculated on basis of frecuency (cluster size of 1000 m²)**
Tabla 2. Numero total de individuos (DBH > 5 cm) de especies raras en la Reserva La Ceiba, con densidad alta entre los clusters de especies.

In la Ceiba especially, forage-species for roaming goats and cattle as well as exploited woody species don't regenerate very well (Rivas et al. 2003). The high mean distances between clusters of rare species like *Cavanillesia platanifolia*, *Guazuma ulmifolia* or *Maclura tinctoria* (Table 2) could cause a reduced gene flow between clusters of a single species so that in future the clusters could become isolated and dynamic conservation impeded. *Maclura tinctoria* is considered as an endangered species for the region of South Ecuador by Cabrera et al. (2002).

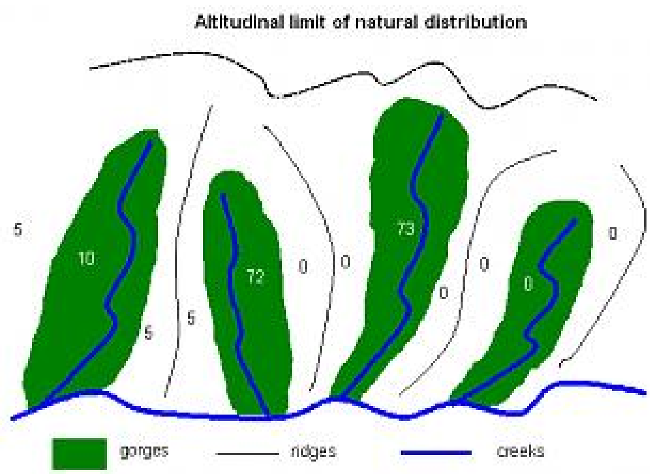

Figure 3. Model of distribution of subpopulations of *Prumnopitys montana* (zoochor) with DBH > 10 cm in the 4 studied watersheds of ECSF-forest.
Figura 3. Modelo de distribucion de sub-populaciones de *Prumnopitys montana* (zoochor) con DBH > 10 am en las 4 microquencas del bosque ECSF.

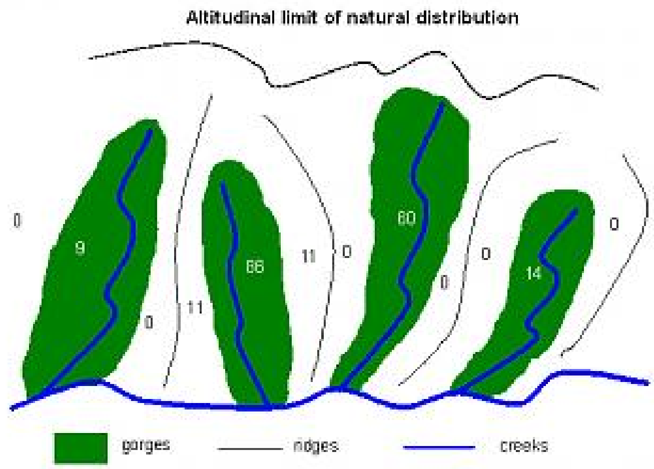

Figure 4. Model of distribution of subpopulations of *Cedrela montana*(anemochor) with DBH > 10 cm in the 4 studied watersheds of ECSF-forest.
Figura 3. Modelo de distribucion de sub-populaciones de *Cedrela montana* (anemochor) con DAP > 10 cm en las 4 microcuencas del bosque ECSF.

Deforestation in San Francisco valley is mainly caused by conversion of forest into pastures for cattle (Beck, pers. comm.). The remaining subpopulations of *Cedrela montana* or *Prumnopitys montana* are at the upper limit of their natural distribution. We argue that these subpopulations located in micro-watersheds become isolated this way because pollen and seeds may hardly be able to overcome the surrounding natural barriers [[Figure 3 and 4]].
Nevertheless further investigation is necessary to proof whether geographical distance and/or natural barriers implicate the development discontinuous genetical variation.
Delineation of genecological zones
Based on these observations we suggest the delineation of so-called "genecological" zones, where the variation of environmental conditions is investigated and uniform zones are formed based on available data. Three ecological parameters (temperature, humidity and soil types) were used for delineation of genecological zones. A very broad range of environmental conditions can be observed in the Province of Loja: The mean temperatures range from 8 to 26 degrees centigrade, the humidity between 0 and 12 humid months, and the provincial watershed management plan has identified eleven major soil types. We defined 4 distinct classes of temperature and 6 classes of humidity. The three ecological maps were overlaid to deduce possible genecological zones. From the 264 theoretically possible zones (11 soils x 4 temperature x 6 humidity) 134 potential genecological zones resulted for the Province of Loja. This very high number derives from the high diversity of environmental conditions. Table 3 indicates the high variability of possible genecological zones in the Province of Loja that results from overlaying the maps of ecological factors.

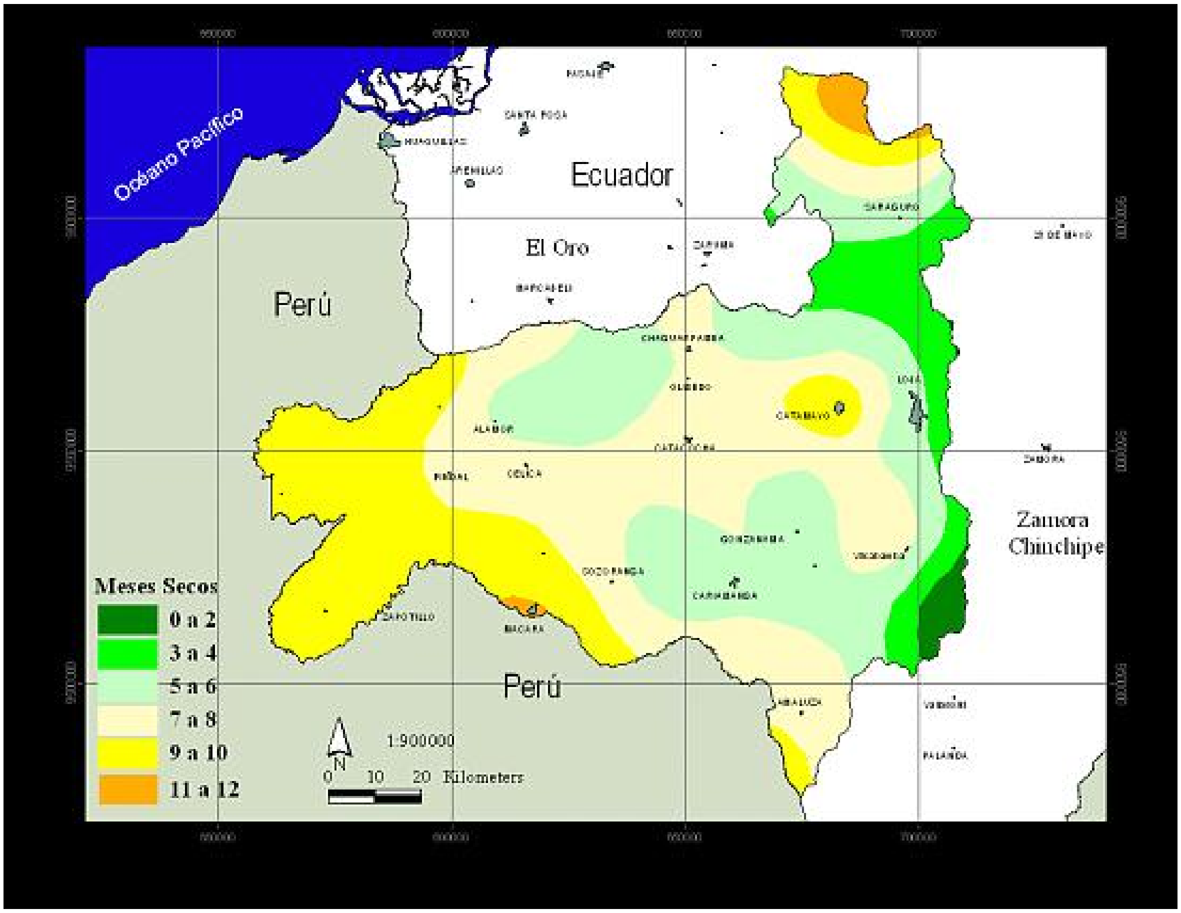

Figure 5. Number of dry months in the Province of Loja (Source: The Nature Conservancy)
Figura 5. Numero de meses secos en la Provincia de Loja (Datos de Nature Conservancy).

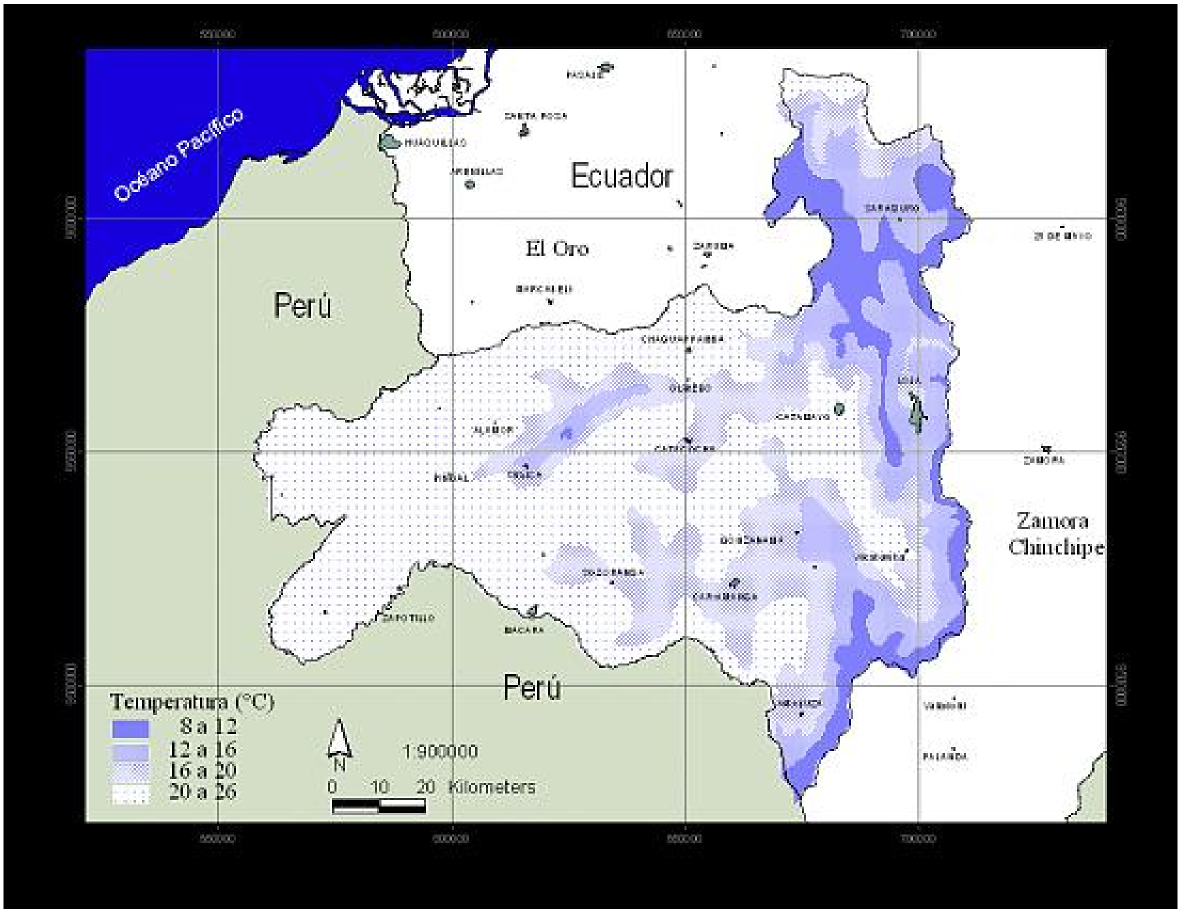

Figure 6. Mean temperatures in the Province of Loja (Source: Plan Hidraulico
Figura 6. Temperatiras promedias en la Provincia de Loja (Datos de Plan Hidraulico).

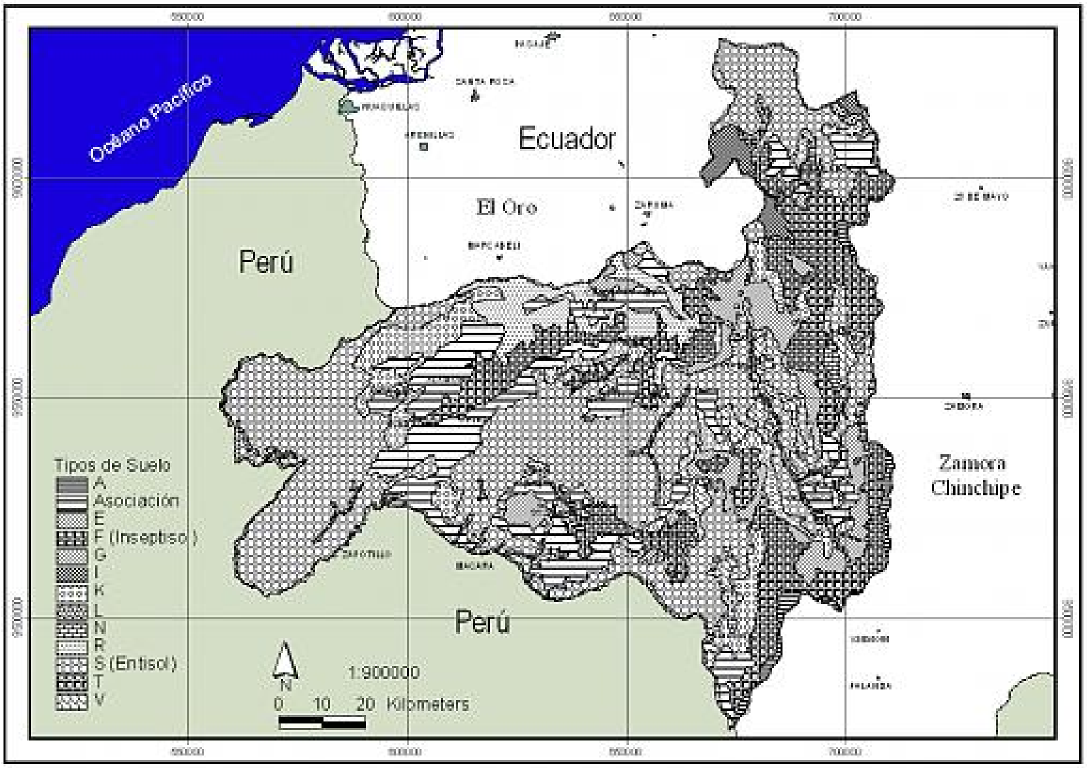

Figure 7. Distribution of soil types in the Province of Loja (Source: Plan Hidraulico)
Figura 7. Distribucion de tipos de suelo en la Provincia de Loja (Datos de Plan Hidraulico).

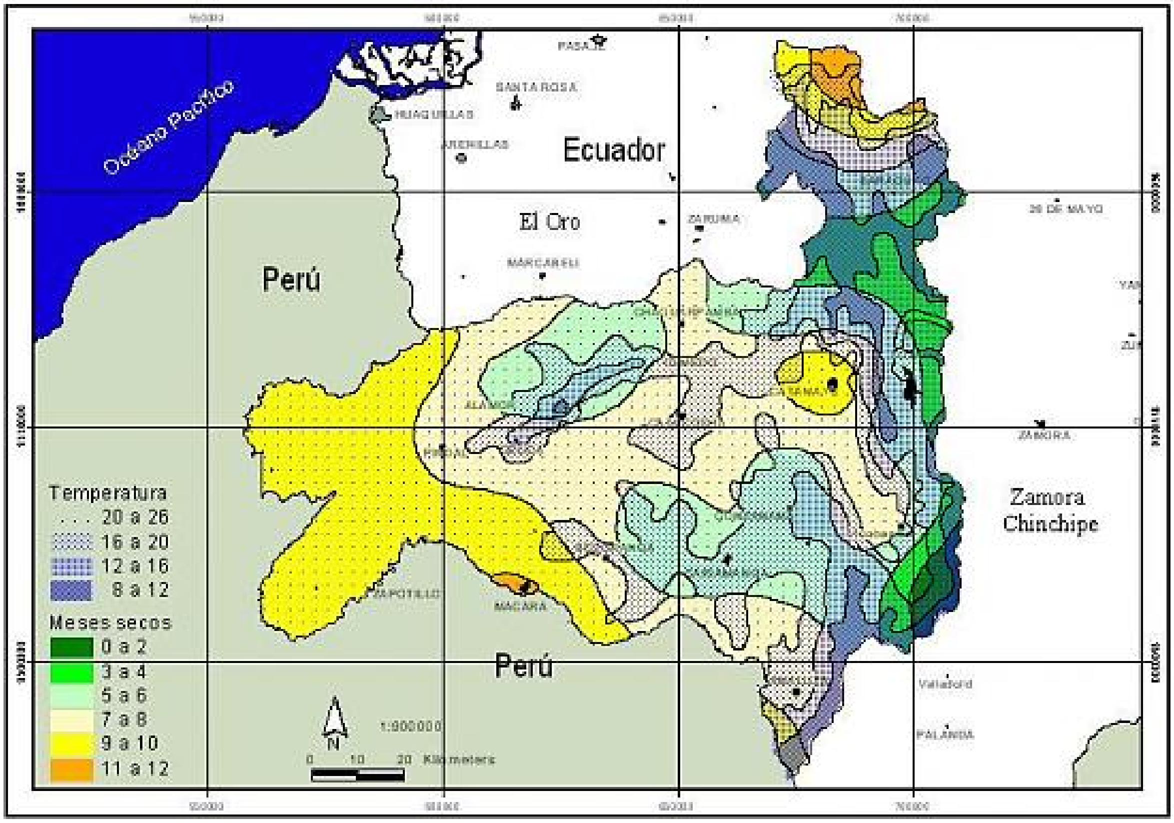

Figure 8. Climatological zonification of the Province of Loja
Figura 8. Zonacion climatologica de la Provincia de Loja.

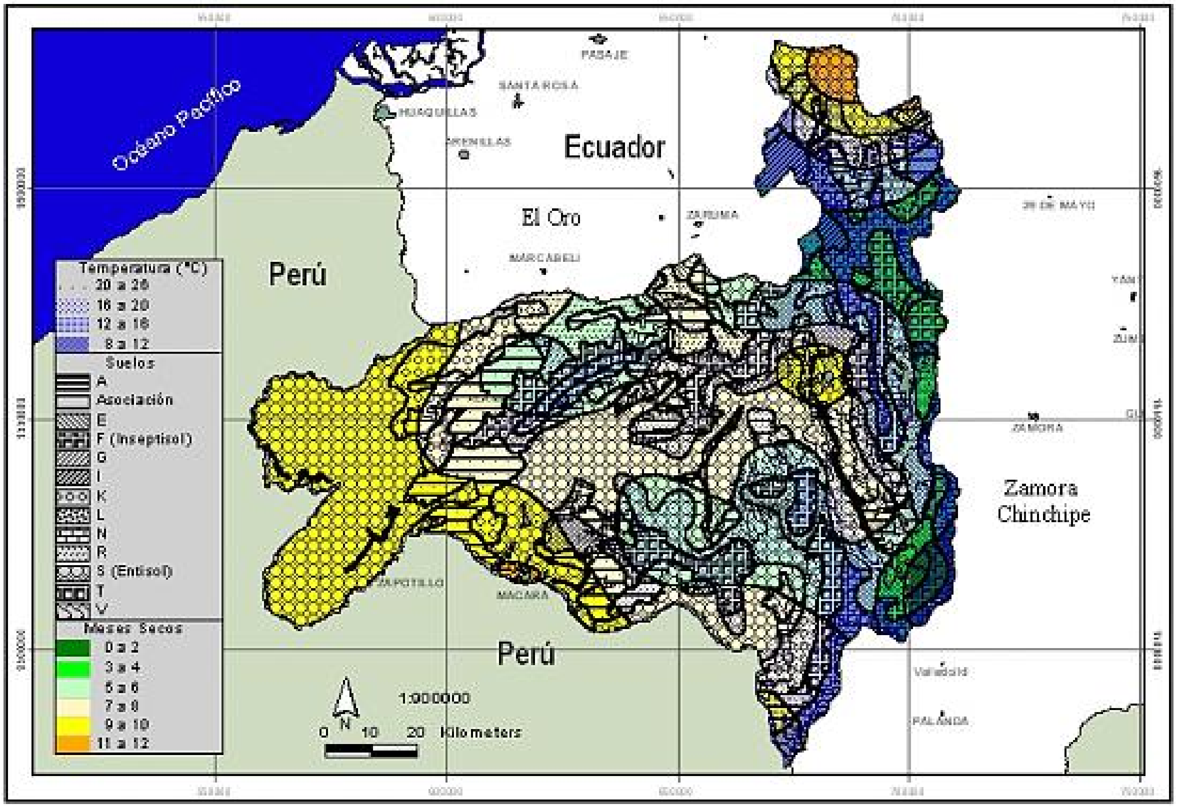

Figure 9. Potential genecological zones for the Province of Loja
Figura 9. Zonas genecologicas potenciales para la Provincia de Loja.

Temperature (°C)	Number of dry months						Sum	Area (km^2)
	0 - 2	3 - 4	5 - 6	7 - 8	9- 10	11 – 12		
8 – 12	2	7	7	7	5	0	28	1754
12 – 16	4	8	9	6	6	1	34	2659
16 – 20	3	8	10	10	7	3	41	5508
20 – 26	0	1	9	10	8	3	31	928
Sum	9	24	35	33	26	7	134	10849
Area (km^2)	137	900	3121	4027	2637	132		

Table 3. Number and area of genecological zones in the Province of Loja
Table 3. Numero y area de zonas genecologicas de la Provincia de Loja.

From [[Table 3]] we can deduce that especially the areas with relatively extreme environmental conditions are heterogeneous in genecological zones, nevertheless that they are relatively small. The perhumid (0-2 dry months) and the very dry zones (11-12 dry months) have promedium sizes of 15 to 19 km respectively, the cool (8-12 °C) and hot (20-26 °C) zones have sizes between 63 and 30 km. Maldonado (2002) remarks that the high heterogeneity of climatic conditions is related to the orograficaly variability.

Area (km^2)	Number	Percentage
0-10	46	34,3
10-20	23	17,2
20-50	21	15,7
50-100	16	11,9
100-250	15	11,2
250-500	11	8,2
> 500	2	1,5

Table 4. Size frequency of genecological zones.
Tabla 4. Frequencia y tamaño de zonas genecologicas.

Many of the potential genecological zones in the Province of Loja are very small [[Table 5]]. There are more than 90 zones smaller than La Reserva La Ceiba, which corresponds to a 67,2 % of all. Many of Loja's forests are of a similar or even higher tree diversity than La Reserva La Ceiba so that pollination distances between conspecifics are commonly high and human pressure, especially selective logging, exploitation or silvipasture of goats and cows counteract dynamic conservation by their detrimental effects, namely through reproductive isolation of subpopulations and individuals and prevention of gene flow. Management of seeds in those areas could become very difficult because high efforts are necessary to identify the potential seed trees. Therefore it is necessary to delineate major seed zones on basis of a further map that includes vegetation cover, distribution of target species and barriers for gene flow.

Protection status	Total number	Percentage
SNAP (National Parks):	17	12,7
Other categories of protection	67	50
Without any protection	50	37,3
Sum	134	100

Table 5. Number of genecological zones within certain protection categories in the Province of Loja.
Tabla 5. Numero d ezonas genecologicas con categories de proteccion en la Provincia de Loja.

[[Table 5]] shows that only a very low percentage of all potential genecological zones in Loja are represented in the SNAP-system of conservation areas (12,7%). Lower protection categories cannot provide the effectiveness of National Parks and sometimes-even National Parks suffer from human pressure. Hence it must be concluded that the variety of genecological zones in the Province of Loja are highly endangered.

It is notable that especially in the very dry areas of Loja only a very low percentage of genecological zones is represented in any category of protection. Also in the cool parts (corresponding to high altitudes) only 50 % of all genecological zones are protected, although this ecozone is relatively well covered by the Podocarpus National Park.

Temp.(°C)	Number of dry months						Sum (% of all categories)
	0 - 2	3 - 4	5 - 6	7 – 8	9- 10	11 – 12	
8 – 12		3	3	6	2		14 (50%)
12 – 16		3	1	2	4	1	11 (32%)
16 – 20	2	4	0	4	5	3	18 (44%)
20 – 26		1	2	2	2		7 (23%)
Sum (% of all)	2 (22%)	11 (46%)	6 (17%)	14 (42%)	13 (50%)	4 (57%)	50 (37%)

Table 6. Number of genecological zones without any protection status in the Province of Loja.
Tabla 6. Numero de zones genecologicas sin ningun estado de proteccion en la Provincia de Loja.

Conclusions

The continuous supply of high quality tree seed for planting activities (reforestation, plantation establishment) requires the establishment of normative and production standards.
After formulating national policies and standards, the national and provincial governments provide legal standards and regulations for good practice (e.g. mechanisms to influence and monitor the use of reproductive material). A first attempt could be the proposal "ley para la conservación y uso sustentable de la biodiversidad", but further more detailed regulations are needed.
Within these regulations, the approval and monitoring of seed sources of priority species, but also the revision of seed sources, is one of the basic steps, which will be accomplished by seed certification and control/monitoring of seed procurement.
Target groups for tree seed programmes are farmers and communities in rural areas using and planting trees for a multitude of purposes, but are also enterprises or agencies often undertaking afforestation on a larger scale (Graudal 1998).
The build-up of a network of seed production stands is seen as a prerequisite of the professionalisation of seed production. This includes the establishment and management of conservation stands.
During the initial years the establishment of a working system (including research and development in seed procurement) and infrastructure as well as the marketing of seeds may require subsidizing by the government.
Types of tree seed suppliers can be either public sector (e.g. government directed) or private (NGOs, communities, farmers etc.).
Ways of non-commercial distribution, dissemination and diffusion of seed should be found and encouraged to promote the programme. Herein the private sector will act as a seed supplier as well as a seed user, e.g. through the domestication of trees on farms.
From the organisational point of view the establishment of tree seed centres (governmental or private) is of utmost importance. These centres are in charge of the implementation of tree seed programmes through the development of long term and annual plans for seed supply and the development of additional seed sources.
We are hopeful that a well established and organized tree seed programme can counteract and minimize the uncontrolled and undocumented movement of forest germplasm, including exotic species, for plantation establishment, which is leading to the loss of locally well adapted populations of native species.

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Regeneration and succession patterns in African, Andean and Pacific Tropical Mountain Forests: The role of natural and anthropogenic disturbance.

Procesos de regeneración y sucesion en los bosques montanos de Africa, Andes y del Pacifico: El rol de perturbacion natural y antropica.

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Regeneration and succession patterns in African, Andean and Pacific Tropical Mountain Forests: The role of natural and anthropogenic disturbance.

Amongst the world biodiversity hotspots, Tropical Mountain Forests are one of the most important systems. Harboring larger species numbers per land area than Lowland Rainforests, they are much smaller, often highly fragmented, and have a paramount function as water catchments and erosion barriers. The presented contribution depicts the influence of natural and anthropogenic disturbances in the regeneration ecology of Andean, African and Pacific mountain forest systems by comparing examples from Southern Ecuador, Northern Peru, the Hawaiian Islands, Cameroon, and Eastern Africa. All systems show a very comparable forest zonation, with mosaic-climax formations dominating the lower montane zone, and monotypic forests taking over at higher altitudes. Neotropical mountain forests harbor much higher species diversity, mainly due to the extreme radiation of trees and epiphytes, particularly Orchids and Bromeliads. In Africa, herbs are much more abundant due to the availability of more large gaps created by large mammals, and in the Central Pacific, island bio-geographic processes have the highest influence on forest species diversity. Similar regeneration processes can be observed in all systems, although the role of natural landslides is much more important in the Andes and the Pacific region, whereas fire and big-game influence are the dominant motors for regeneration in Africa. The impact of antropogenic influences, e.g. slash and burn, timber extraction, exploitation of forest products, introduction of exotic species etc. on the regeneration and succession patterns in Tropical Mountain Forests are discussed, and possibilities for future management depicted. Entre los puntos calientes de biodiversidad mundial, los bosques montanos tropicales tienen un papel especialmente importante. Estos sistemas contienen un numero más alto de especies por area que los bosques humedos, pero estan mucho mas pequeños, seriamente fragmentados, y tienen una funcion muy importante como captaciones de agua y bareras contra la erosion. Este articulo ilumina la influencia de perturbaciones naturals y antropicas por la ecologia de regeneracion de bosques montanos Andinos, Africanos y Pacificos, comparando ejempos desde Ecuador, Peru, Hawaii, Cameroon y el Este de África. Todos estos sistemas muestran una zonacion de bosque muy comparable, con formaciones del tipo climax-mosaica en la zona baja y bosques monotipicos como unidades mas importantes en las zonas altas. La diversidad de especies en los bosques Neotropicales es mucho mas alto, especialmente por la radiacion de arboles y epifitas, en particular Orquideas y Bromelias. En África hierbas son mucho mas abundante por la disponibilidad de claros largos, causados por la actividad de la megafauna y en el Pacifico Central procesos de biogeografia insular tienen la influencia mas alta por la diversidad de especies.

Introduction

Tropical mountain forests, found mainly at altitudes between 1200 and 3500 m (LaBastille & Pool 1978, Stadtmüller 1987, FAO 1992) are amongst the species richest ecosystems worldwide. Particularly the Eastern Andean Region represents one of the hottest "biodiversity-hotspots (Myers et. al. 2000). In striking contrast to tropical lowland rainforests, these tropical montane forests have received only marginal attendance in science and society until recently, despite their ecological and economical importance as water catchments and erosion barriers. The neotropical montane region is considered one of the twelve major crop-gene centers of the world (Churchill et al. 1995). At the same time, mountain forests are especially sensitive ecosystems due to their steep relief, which allows extreme erosion under a high rainfall regime. Due to increased population pressure and resource use (firewood, mineral resources, pastures, agriculture), montane forests are more and more rapidly dwindling. FAO (1993) estimates that tropical mountain forests comprise about 11 % of the worlds tropical forest resources, and suffer an annual deforestation of about 1.1 %. Mountain forests generally occur on more humid mountains, and most frequently in Latin America and Southeast Asia, where the most widespread mountain areas occur, with outposts in tropical Africa (Stadtmüller 1987).

Most studies carried out in tropical ecosystems have focused on the lowland rainforests, and most research stations are located there (Leigh 1999). Even there, very little is known about the regeneration processes in the ecosystem (Finegan 1996), and fairly nothing about its functioning. In tropical Mountain Ecosystems, studies concentrated mainly on the alpine zone, whereas the often-inaccessible forest belt with its extreme species richness has hardly been studied. The African and Andean zone make no exception. Although particularly Andean forests host an extreme , - and - diversity (Barthlott et al. 1996; Ibisch 1996), often comparable or higher than species counts for Amazonian areas (Balslev. et al. 1998), no comprehensive studies of a tropical mountain forest ecosystem have been undertaken. Even broad-focused projects like "Ecoandes" in Colombia (Hammen et. al. 1983, 1984, 1989a, 1995) included the forest regions only marginally. First attempts to bring the frugal knowledge existing together were made only recently (Hamilton et al. 1994, Churchill et al. 1995). The deficit of scientific knowledge particularly includes all aspects of regeneration of montane forests, as well as succession processes after any kind of natural or man-made impact. The habitat requirements and the potential for rejuvenation of important tree species are almost unknown.
The present work focuses on a comparison of various Andean, African and Pacific montane forest ecosystems, as examples for tropical mountain forests in general.

Materials and Methods

Study Areas
The border region of Ecuador and Peru is one of the most biologically diverse areas worldwide, and thus a "biodiversity-hotspot" par excellence. Low passes in the Andean chain allow an easy exchange between the floras and faunas of the Amazon Basin and the pacific lowlands. Additionally, the region shows a very fast transition between the humid mountain forests of the northern Andes and the dry, deciduous forests of the northern Peruvian lowlands. Until the recent past, the Podocarpus National Park and the study area have been almost unknown scientifically. The most recent new approach for the classification of the vegetation of Ecuador (Sierra 1999) lists all montane forests between 1800 - 3000 m altitude as "bosque de neblina montano", without further distinction. In the Southern part of Ecuador and the North of Peru, a number of lower ridges with deep and dry valleys are found. The area is the lowest part of the Andes near the equator. Particularly the peak regions are covered by dense clouds or mist most time of the year. The main rainfall occurs in February-March and particularly June-September, both periods followed by a dry season, which can lead to a negative water balance especially during months from October-January.
The natural forests of Africa have been subjected to heavy tree felling for decades. Moreover, due to selective logging, they also have undergone significant changes of their species composition. Although private tree planting of exotic species has reduced the fuelwood deficit considerably, the destruction of the natural forests has increased drastically in the last decades. If current rates of forest clearing continue, no natural forest will remain by the year 2040 (Barnes 1990).
The climate of Africa shows the characteristic pattern of inner tropical regions with large diurnal temperature oscillations, known as "Tageszeitenklima" (Troll 1959), but a small amplitude of the monthly means in the course of the year. The "long rains" last from March to June, while the "short rains" occur from October to November. Due to the equatorial position, the daylight period is nearly constant all year round, which is an important factor for vegetation growth.
The results of the phytosociological fieldwork and ecological observations conducted in Kenya and Ethiopia from 1992-2004 have been presented in a wide array of publications (Bussmann 1997, 1999, 2001a,b, 2002; Bussmann & Beck 1995a,b,c; Bussmann & Lange 2000; Bytebier & Bussmann 2000; Lange et al. 1997).
Mount Cameroon is located on the coastal belt of the Gulf of Guinea in the South-West of Cameroon, rising steeply from the coast to a height of 4095 m. The summit lies only 20 km inland. It is part of a chain of volcanic mountains, covered by a tropical montane forest. This chain stretches from 100km South-West of Mount Cameroon, from the Islands of Anobon to the highlands of the Adamawa in North-Western Cameroon to Obudu in Nigeria.
Remaining natural-like forests in the Hawaiian Islands and French Polynesia were visited for comparison to the other Mountain Forest sites studied in detail.

Methodology

For the phytosociological analysis of the African mountain forests in Kenya, Ethiopia and Cameroon from 1992-2004, more than 1250 relevés were established and analyzed. In Ecuador and Peru, starting 1995, after a detailed floristic inventory based on random samples, 400 plant-sociological relevés were established in physiognomically homogenous forest areas, and 150 plots on natural, as well as 200 plots on antropogenically induced landslides were established. All Plots were selected and sampled according to the methods of Braun-Blanquet (1964) and Mueller-Dombois & Ellenberg (1974), as slightly modified by Hammen et al. (1989b). All relevés were sampled at least twice and in different seasons, for which reason the species inventory should be more or less complete in most cases.

The collection of environmental data on landslides included soil texture of the upper mineral layer, and the soil pH. The depth of the humus layer was measured as an important indicator of successional age and ongoing erosion. The inclination and position on the slide was recorded as well as the altitude above sea level, the direction aspect and the geographical position of the landslide. Space-for-time substitution (Pickett 1989) was employed to describe successional processes of initial stages. Knowledge about the history of the slides can be gained by studying the aerial pictures of the regions. However, the time since the last major sliding event for the plots could not be assessed accurately because most of the landslide material is not displaced by one big event but by several consecutive "ongoing" slides Stoyan (2000). Further on, many of the slides were invisible at the aerial pictures due to their small size and the steep relief.

During the extensive phytosociological fieldwork special attention was given to regeneration patterns and succession processes in the forests, these observations leading to the regeneration cycles presented here.

Results and Discussion

Forest vegetation units in Africa, Latin America and the Pacific

Extremely steep slopes and deeply incised riverine valleys, providing a mosaic of different microclimates, as well as frequent natural landslides, lead to a very variable mosaic of vegetation units in the Andean region. Based on the dominance-oriented floristic data the montane forests of the area have been grouped into three main formations, each covering a specific altitudinal range.

The prevalent forest formation in South Ecuador and North Peru at altitudes from 1000 - 2100 m, with an extremely diverse, 2-storeyed tree stratum, reaching 25 m, with emergent trees up to 35 m tall in riverine valleys and mean tree of 100%, is the *"***Lower Montane broad-leaved forest***" (Ocotea - Nectandra forest)* (Bussmann 2001c, 2003), extending up to 2300 m at the bottom of wind-protected riverine valleys. Species belonging to families found mainly at lower altitudes (e.g. *Cyclanthaceae, Lauraceae, Hymenophyllaceae*) are very common in this formation, whereas representatives of the flora of higher regions are very rare. Undisturbed tracts of the *Ocotea-Nectandra* forests can be mainly encountered on very steep slopes with an inclination of 30-50° or more, as well as in almost inaccessible valleys. In areas easier to reach, this formation has been almost entirely destroyed by human activities, and has been replaced by secondary forest. The epiphyte- and ground-flora contains especially ferns (particularly Lomariopsidaceae) and Orchidaceae. In contrast to higher altitudes, Bromeliaceae are less frequent. The natural regeneration of gaps in these forests leads to a typical mosaic-climax. Where the climax forest has been destroyed by natural fires the tree stratum is dominated by large palms (Arecaceae*, Dictyocaryum lamarckianum*). Characteristically, the herb stratum is dominated by different species of bamboo (*Chusquea* spp*.)*, as well as large Gleicheniaceae forming almost impenetrable thickets. The regeneration of the climax species seems to be inhibited in these areas. In areas with formerly strong human influence (slash-and-burn, clearcutting), a completely different, monotypic secondary forest develops. These forests have one tree stratum, completely dominated by the 10-12 m tall stems of *Axinea quitensis* (Melastomataceae). Species diversity is much lower. Almost no epiphyte species are encountered, and the ground flora is extremely impoverished.

At altitudes above 2100 m, up to about 2750 m, the "**Upper Montane Forest**" (*Purdiaea nutans - Myrica pubescens - Myrsine andina forest*) (Bussmann 2001c, 2003), a monotypic formation, with only one tree stratum, with stems between 5-10 m, sometimes up to 15 m tall, replaces the

*Ocotea-Nectandra*forest. Lowland species are completely disappearing. The canopy is completely dominated by the twisted stems of *Purdiaea nutans* (Cyrillaceae), which has its main distribution in northern Peru. A very diverse stratum of small treelets and shrubs occurs, and the undergrowth is often completely dominated by large Bromeliads. Above 2450 m, particularly on wind-exposed ridges, a transition to the *"subalpine elfin forest"* can be observed. Frequent landslides foster the dynamics in the upper montane forest, and are inevitable for the maintenance of its high floristic diversity. In overaged forests, species diversity declines drastically. On natural clearings, in flat ridgetop areas, which are most probably the effect of fires, the tree stratum almost disappears, making way for a dense layer of grasses, suppressing almost all other species in the ground layer. In extremely dry years, fires occur also on steeper, wetter slopes.

The uppermost forest belt is formed by the *"***Subalpine-Elfin Forest***"* (Bussmann 2001c, 2003), which closely resembles the Bolivian "Yalca". This formation - more like an impenetrable bushland than a forest, is closely dovetailed with the adjacent Páramo region. The "timberline" in the area is mainly induced by strong winds. Wind-protected areas are densely covered with Yalca vegetation, whereas more open, wind-exposed regions at the same altitude are covered with grassy Páramo vegetation. A real timberline thus does not exist in the study area. The only 1-2 m wide crowns of the dominant species - particularly *Cunoniaceae*, *Clusiaceae*, *Clethraceae* and many small *Melastomataceae*, form a very dense canopy, allowing only little light to reach the ground. The stems of these "trees" protrude thus from a literally meter-deep carpet of mosses, whereas in contrast to the rich woody flora almost no herbal species are found in the ground layer.

In East Africa, the montane forest vegetation has been studied intensively in the last decade (Bussmann 1997, 1999, 2001a,b2002; Bussmann & Beck 1995a,b,c; Bussmann & Lange 2000; Bytebier & Bussmann 2000; Lange et al. 1997). The **Evergreen Submontane Forest** with its two storied tree layer are found mainly on the very wet south-eastern and southern slopes of Mount Kenya on altitudes between 1550-2550 m, growing on humic Niti- and Acrisols and receiving an annual rainfall of 1500-2500 mm.

In contrast to Latin America, a wider array of montane forest communities can be found. The **Evergreen and Evergreen Xeromorphic Montane Forests** growing on humic Acrisols (Speck 1986) with rainfall between 700 and 1500 mm, represent the typical vegetation of the altitudinal range between 2500 and 2950 m. In these forests, the pencil Cedar (*Juniperus procera)* grows about 50 m tall under favorable conditions. Other important tree species, mainly of the lower canopy, are the African Olive (*Olea europaea* ssp*. africana*) and *Podocarpus latifolius*. **Evergreen Montane Bamboo Forests,** dominated by the African Bamboo, *Sinarundinaria alpina*, are found on various East African mountains. Bamboo forests are restricted to a relatively narrow ecological range, mainly depending on a soil temperature of 10-15 °C and the presence of very deep volcanic soils, namely humic Andosols. The cyclic changes of the bamboo vegetation lead to regular changes of the floristic composition. One single growth cycle of *Sinarundinaria alpina* is supposed to take 15 to about 40 years (Wimbush 1945; Agnew 1985, and own observations give indications for even longer periods).

Finally, the timberline is formed by the **Evergreen Subalpine Forests,**extending from 2900 to 3300 m a.s.l., where low clouds and mist are frequent. The dominant tree is the "Kosso"-tree, *Hagenia abyssinica* (Bruce) J.G. Gmel., of the Rose family.

The vegetation of Mt Cameroon is continuous and largely unbroken from sea level to the summit. Zonation falls in lowland evergreen forest (0 - 800 m), sub-montane forest (800 - 1700 m), montane forest (1600 - 1800 m), montane shrubs (above 1800 m) and sub-alpine grassland (2000 - 3000 m).

Regeneration Ecology of Tropical Montane Forests

Typical Mosaic Climax Regeneration in Tropical Montane Broadleaved Forests

Only few natural remnants of lower montane forests remain after centuries of logging. Under natural conditions these forests show a typical mosaic-regeneration cycle, where the gaps resulting from natural treefall or larger natural clearings are randomly closed by the species arriving first. In most cases however, a typical set of fast growing pioneer species acts as shade trees, under which the typical, shade tolerant climax species develop [[(Figure 1)]]. In **Southern Ecuadorian Lower Montane Forests**, gaps are rapidly colonized by Cecropiaceae (particularly *Cecropia montana* with its shiny silvery leaves), *Piptocoma discolor (*Asteraceae*), Isertia laevis (*Rubiaceae*)* and *Heliocarpus americanus (*Tiliaceae*).* Rapidly the canopy is being closed again, and climax species are developing.

Regeneration processes in Africa are less simple. The **East African Lower Montane Forests** are characterized by huge Camphor trees (*Ocotea usambarensis)*. This most characteristic tree of this vegetation type, is widespread on East African mountains (White 1978, 1983; Friis 1992), where it inhabits an altitudinal range between 1300-2600 m. The species is heavily logged for its valuable hardwood, but natural regeneration is problematic. Willan (1965) described the difficulties to regenerate *Ocotea* on the southern slopes of Kilimanjaro and in the West Usambara Mountains. According to his reports, *Macaranga* is dominant in gaps where *Ocotea* is absent, i.e. has died naturally or has been logged out. Saplings of *Ocotea* are successfully competed by *Macaranga*, a fastly growing pioneer species, so Willan proposed a removal of all *Macaranga* trees before replanting *Ocotea*.

Surveys on Mt. Kenya (Bussmann 2001b) revealed, that the remaining stands are almost exclusively composed of very old *Ocotea* trees of approximately 300-600 years of age (stem diameter 1.2-2.5 m, estimated according to Bussmann 1999). Very few young trees (less than 100 years old) and seedlings were encountered. In that region, the main flowering of the dioecious *Ocotea usambarensis* occurs between early March and late April, at the beginning of the long rains. A second flowering can be observed after the start of the short rains in November. In most years, however, only few trees flower, whereas every five to seven years mass-flowering occurs. Data for *O. kenyensis* in Ethiopia suggest, that the number of seeds and seedlings is relatively large in such years, and seedling density might reach up to >700/ ha (Getachew et al. 2002). A large fraction of seeds are attacked by gall-insects and birds, while seedlings suffer heavily from herbivory. Germination rates are high in the shady conditions indicating the late successional character of the species. The seeds are only viable for a few days, even under the most favorable conditions like high humidity and radiation (Katende et al. 1995; Bussmann & Lange 2000). Under natural conditions, few seeds manage to establish (Bussmann & Beck 1995a,b). This explains the often found uniform age structure, although continuous regeneration was also described (Getachew et al. 2002). *Ocotea* effectively regenerates with suckers growing from stem bases and old roots. This contrasts with the other characteristic tree species of these forests, that mostly depend on sexual regeneration. Even-aged stands of old *Ocotea usambarensis* trees die over an extended period of time, creating a mosaic of gaps in which the Euphorbiaceae *Macaranga kilimandscharica* start growth as a secondary species. This leads to patches of monotonous vegetation, but only on small scale, and does not change the structure of the forest to a significant extent. Sexual regeneration of *Ocotea* from seedlings depends on the coincidence of mast years with suitable conditions for seedling establishment, and on the level of herbivory, but usually numerous suckers from the roots of a fallen tree, not longer suppressed by the mother tree, start growing. *Macaranga kilimandscharica* hereby plays an important role as a shade tree, as *Ocotea* seeds and saplings do not tolerate full sun. After the break down of the relatively short-lived *Macaranga* trees, the meanwhile well established young *Ocotea* trees close the gaps, and effectively prevent further germination or establishment of *M. kilimandscharica* by shading. Thus, *Ocotea* stands of a more or less uniform age structure result.

On many mountains, *Ocotea usambarensis* is the most heavily exploited species (Lambrechts et al. 2002). The typical practice of clear-cutting by means of large scale uprooting of the trees hampers vegetative regeneration of Camphor. The big gaps are fastly closed by *Macaranga kilimandscharica* and at higher altitudes by *Neoboutonia macrocalyx*. As Camphor does not regenerate in these man-made "gaps" after breakdown of the secondary trees due to the lack of diaspores, these forests regenerate in a cycle of their own. The possibilities for a regeneration to primary forest are unknown, and presumably require very long time spans. In any case, a complete logging stop around the gaps seems crucial to allow colonization.

As pointed out, seeds, seedlings and suckers suffer from herbivory. Unfortunately, the influence of megaherbivores on vegetation has mainly been studied in savannah ecosystems (Buechner & Dawkins 1961, Kortland 1984), and only few data exist on forest habitats (Holloway 1965, Schmitt 1991, Schmitt & Beck 1992, Plumptre 1993; Reed 1997). However, logging certainly is more important that herbivory.

The lower montane forest in the Hawaiian Islands have been almost entirely destroyed. Originally, *Metrosideros polymorpha* (Myrtaceae) and *Acacia koa* (Mimosaceae) formed a monotypic canopy. This monotypic climax, a very special case for a lower montane forests shows a regeneration cycle very comparable to higher altitude formations, and is thus treated in the following section.

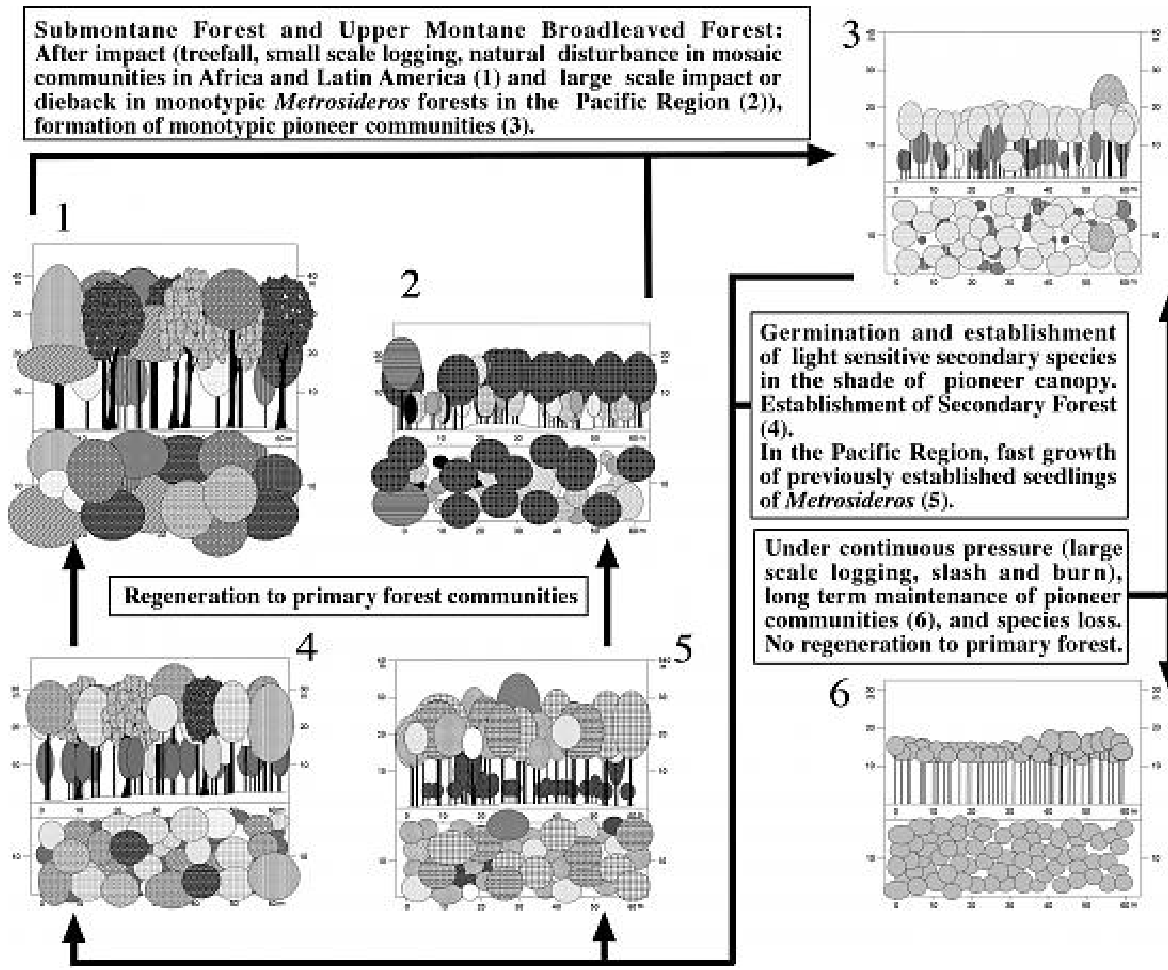

Figure 1: Regeneration Processes in Tropical Lower Montane Forests.
Figura 1: Procesos de regeneración en el Bosque Montano Bajo.

Regeneration of monotypic climax forests

Fire apparently plays an important role in the regeneration cycle of **Upper Montane Forests [[**(Figure 2)]].

The **Montane Xeromorphic and Breadleaved Forests** in East Africa are an excellent example for the regeneration strategies of Tropical Clound Forests. Montane broadleaved forests with *Cassipourea malosana* are locally common at drier afromontane sites. Regeneration generally seems to be continuous, since trees of all age classes were found. All important species lack characteristics of pioneer species, like the capability to build a seed bank, and most of them preferably germinate in the shade (*Olea capensis*, *Popocarpus gracilior*; Getachew et al. 2002). Due to the environmental conditions, especially the high rainfall, fires are rare, and, whenever occurring, they are limited in extent. In unburned forest, *Juniperus procera* occurs only sporadically, as its germination and regeneration is suppressed by heavy shade and dense vegetation covering the forest. Regenerating Cedar was only found in gaps where seedlings compete with those of the broad-leaved species.

Thus, fires play an important role in the regeneration cycle of the Montane Xeromorphic Forest. *Juniperus procera*, the African Pencil Cedar, typically grows in the drier montane, submontane and subalpine areas of the East African mountains between 1000 and 3000 m (Kerfoot 1961). Temperature as well as rainfall apparently control its distribution (Winiger 1979). In his study of the southern Aberdare Range, Wimbush (1937) suggested that in the absence of fire *Juniperus* forest is only a serial stage in the succession to a broad-leaved forest. After fire, herbaceous pioneer species and *Juniperus procera* seedlings invade the gap, leading to a regenerating forest, where broad-leaved species as

Olea capensis ssp. hochstetteri, *Olea europaea ssp. africana* and *Olinia rochetiana* become also established. Cedar is well adopted to the conditions on forest clearings in the montane belt, since its seeds germinate best in full light and under comparatively low temperatures (15 - 20°C, Demel & Granström 1997a; Bussmann & Lange 2000; Eshetu & Leinonen 2002). Seeds were shown to survive for several years in the soil (Demel & Granström 1997b), but showed no apparent dormancy. In contrast, *Olea europaea* has as strong dormancy, which is broken by scarification of the seed. Germination rates will be almost zero unless the seed coat is is removed. (Legesse 1993). The Olive builds a transitory seed bank, too, and seedlings are abundant under full insolation, although they are heavily browsed (Kebrom & Tesfaye 2000; Getachew et al. 2002). Another important member of this cycle, *Nuxia congesta*, also develops a transitory seed bank (Demel & Granström 1995).

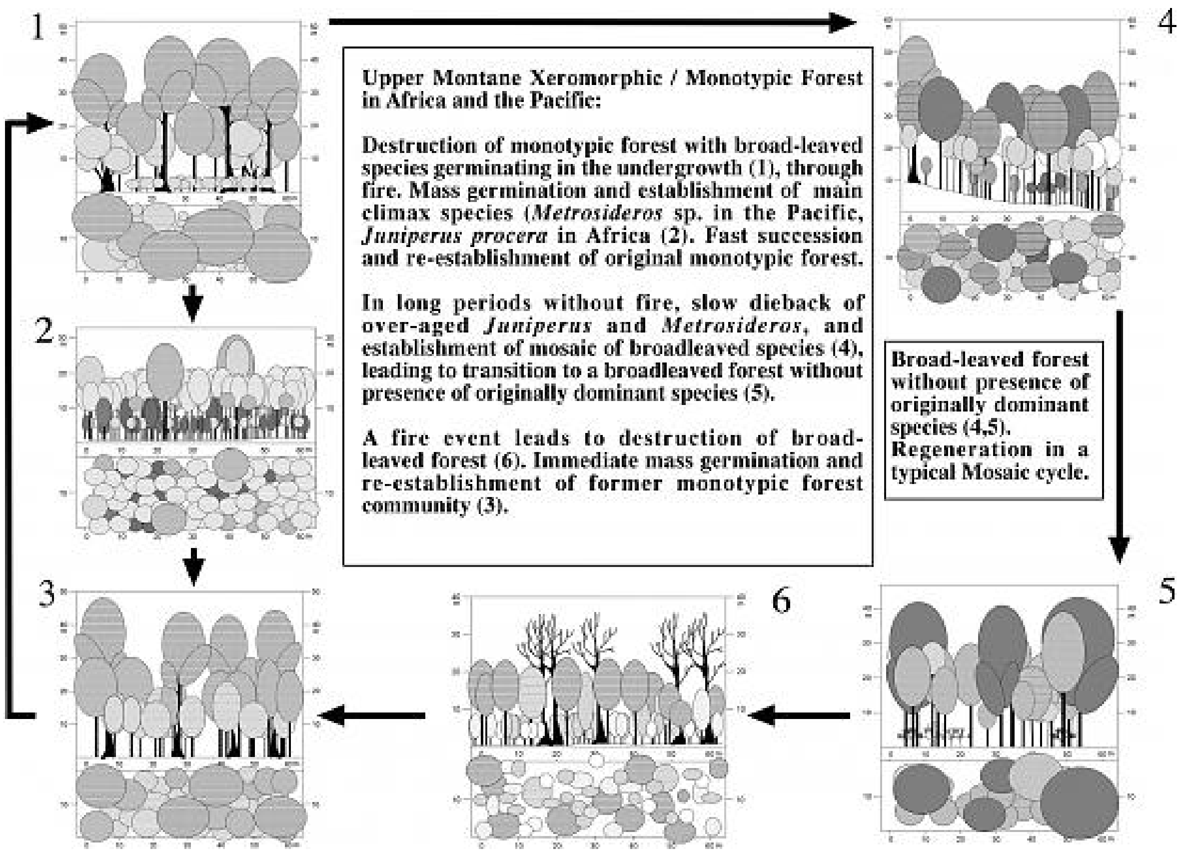

Figure 2: Regeneration Processes in Tropical Upper Montane Forests.
Figura 2: Procesos de regeneración en el Bosque Montano Alto

After about 20 years, the *Juniperus* trees have grown about 9 m high. When a closed canopy is established, the Cedar trees start to outgrow the other species, reaching about 30 m after 80-90 years. If the number of *Juniperus* trees established after a fire was high, a pure Cedar forest results by suppression of other trees. After about 200 years, the maximum height of about 40-46 m is reached. Although frequently infected by the fungus *Fomes juniperinus* thinning the crowns, the *Juniperus* trees may live for another 300-700 years. In case a burnt area is mainly invaded by broad-leaved species, these constitute the canopy and only scattered *Juniperus* specimens emerge. As Cedar cannot regenerate in closed vegetation, small natural gaps are filled with broad-leaved species. Therefore, pure broad-leaved forests built the climax community after some time. These broad-leaved forests represent a stable climax, if not destroyed by fire (Bussmann & Beck 1995c, Bussmann & Lange 1999, Bussmann 2001a).

In over-aged climax communities of the **Ecuadorian Upper Montane Forests**, the ground layer is almost entirely dominated by large grasses, particularly *Neurolepis elata* (Bambusoideae), the canopy gets very depleted and open, with canopy cover as low as 5%. After mass flowering events of *Neurolepis*, as well as during extremely dry conditions, as occurring during El Niño / La Niña years, a large amount of dry organic matter is being accumulated, and provides ideal conditions for fires. After burning, the resulting open spaces are rapidly invaded by fern species, without a pronounced cryptogamic stage. Within a short time, woody species belonging to the surrounding primary forests start growing. After a few years, the characteristically dominating Bromeliads occur. Due to the very low annual growth of most tree species in this region, a very dense shrub stratum develops and is being maintained for many years. Slowly *Purdiaea nutans* starts outgrowing all other species, to form the typical monotypic climax. After about 4-500 years this dense tree layer starts dying back, and the dense shrub and bromeliad layer is replaced by the more light-tolerant grass species again.

Cyclic processes in the Bamboo forests

The African Bamboo, *Sinarundinaria alpina*, inhabits the highland and mountain areas of East and Central Africa at altitudes between 1800 and 3400 m (Hedberg 1951; Dale & Greenway 1961). Bamboo forests prefer deep volcanic soils, especially Andosols (Speck 1986 and own observations). According to Wimbush (1945), Bamboo shoots can reach a height of up to 18 m and a stem diameter of up to 10 cm. New shoots are sprouting from old rhizomes every two to three years. The main growing period starts some weeks after the long rains and lasts for about one to two months. New shoots are to be encountered after each long rainy season. However, maximum rates of biomass production with most of the 4500-7000 culms being replaced per hectare require longer periods of favorable climatic conditions. When old culms die and fall over, young sprouts from the dense network of old rhizomes will replace them, thus giving rise to a homogenous Bamboo forests. In undisturbed areas, where the lifespan of a culm is estimated at about fourteen years, the numbers of dying culms roughly equal the new ones. Flowering, after which the culms die, occurs in areas of about one to several hundred acres in more or less regular intervals (Wimbush 1945). On Mt. Elgon a flowering cycle of fifteen years was observed for a given stand, but reported figures differ among authors. At a given flowering event, only part of the stands in an area will flower, but occasionally there are mass flowering events with large-scale synchronization. In most years, only small areas of flowering or postflowering Bamboo are found, and populations of different mountain ranges are not synchronized. Thus, mass flowering events appear to be rare, and this is in clear contrast to many Asian and South American Bamboo species.

Seeds are said to exist (Greenway in Agnew 1985; Katende et al. 1995), but have not been described in the available literature. Thus, we can not rule out that sexual propagation plays some role, but vegetative regeneration is the principal and overwhelmingly important mechanism. Agnew (1985), based on extensive knowledge of the vegetation of the Aberdare Range and after the analysis of ten 1x1 m quadrates, distinguished a Bamboo cycle with five stages :

1. Pioneer - Regeneration from sections of old rhizomes and rhizome fragments and occasionally from fallen culms, lasting about three to five years, during which dense, 1-3 m tall thickets *invade* the still present *Sambucus africana* stands of the previous cycle.

2. Building - During this period, the growing Bamboo exceeds the average plant height in the stand, and the vegetation becomes floristically depleted as the bright light requiring species of the pioneer stage disappear and more shade tolerant species of the following stage, which might be survivors of a previous cycle, get momentum. The pH of the soil starts decreasing.

3. Mature - No further increase in culm height takes place during this stage. The culms show even age classes, and the soil pH is decreasing further.

4. Flowering and 5. *Sambucus* Stage - Within two or three years after mass-flowering the culms die and fall, so light-demanding species invade, above all *Sambucus africana*. The soil pH increases again during this stage. This situation offers opportunities for the establishment of several montane tree species such as *Podocarpus latifolius*, *Nuxia congesta* and *Dombeya goetzii*. Later, these often form an upper canopy storey above the mature Bamboo stands.

The Bamboo cycle is an important source of autogenic dynamics, and many species specialize on the distinct site conditions of the various stages. Biomass productivity is generally high, and many, especially large herbivores travel the Bamboo belt regularly. Often, their large trails are the only opportunity to pass through the otherwise almost impenetrable forest. The high production of durable and relatively easy to handle "wood", made Bamboo one the preferred building materials for the local population. Moreover, in some places shoots are collected and form an important source of carbohydrates at the end of the rainy season, when crops are planted but not yet ripe. Not surprisingly, many Bamboo stands suffer from heavy exploitation (Scott 1994; Banana & Tweheyo 2001).

On Mt. Kenya, the neighboring Aberdare Range, and on Mt. Elgon, Bamboo stands grow mainly on the wetter western, southern and southeastern slopes and are largely absent in the Northern areas. *Sinarundinaria alpina* appears to require annual precipitation totals of about 800-1000 mm per year, although arid periods are tolerated. On Mt. Kilimanjaro Bamboo is strangely absent (Grimshaw 1999). Of special interest is the occurrence of large areas of Bamboo forests in Ethiopia. They occur at several sites, albeit with limited extent (Central Ethiopia and Harenna Forest: Tamrat 1993; Bussmann 1997, Illubabor: Friis, pers. comm.). The large Bamboo populations of South and Central Kenya (Mt. Kenya, Aberdares, Mau, about 1000 km South of Harenna) are linked to Harenna only by a small population occurring on top of Mt. Nyiro at the southern end of Lake Turkana, which is also at least 500 km away from the Bale mountains (Bytebier & Bussmann 2000). Because the importance of sexual propagation is doubtful for this species, means of dispersal over such long distances are even less clear than for other vascular plants. Therefore the large gaps between the main population and these outposts pose some interesting questions regarding the ecology and former distribution of *Sinarundinaria*, as influenced by the palaeoclimate of the region. This requires further fieldwork, especially since some of the much more easily dispersed companions of Bamboo forest are apparently absent from Ethiopia (*Sambucus africana*; Friis, pers. comm.)

Regeneration in the subalpine forests

The importance of fires for the cyclic regeneration processes in subalpine forests is again high [["Figure 3"]]. Fire cycles can be found in *Hagenia abyssinica* dominated forests in Africa, *Polylepis* and other subalpine forests in Latin America, and *Metrosideros polymorpha* forests in Hawaii. The regeneration processes in *Hagenia abyssinica* forests have been described more than a decade ago (Schmitt 1991; Bussmann & Beck 1995). This seems surprising, since forests of *Hagenia abyssinica* are predominately located in the misty regions of the East African mountains, where high precipitation, as well as frequent cloud formations, should prevent plant material from becoming sufficiently dry to burn. Martin (1982), however, stressed that fires tend to be most frequent in areas with a combination of comparatively high rates of primary production, slow decomposition rates, and occasional droughts. Houston (1995) stated, that the alternation of wet and dry seasons produces ideal conditions for fires in semi-humid regions. East Africa is notorious for its unreliable precipitation (Nieuwolt 1978), and the occasional presence of drought conditions triggers large-scale wildlife fires in the East African mountains (Wesche in press). Long-term measurements are rare, but the few records available suggest intervals of droughts of 2-10 years for a given mountain range.

Thus, in sufficiently wet years, the relatively high plant productivity, the large litter production of an adult *Hagenia*, with its continuously shed leaves (Miehe & Miehe 1994a), and the low decomposition rates in the cold climate of the subalpine forests, result in massive accumulation of fuel. This facilitates extensive fires in drought years, although the frequency a given patch gets burnt certainly is lower then the drought year intervals. The presence of former fires is indicated by charcoal layers, which have been found in soil profiles from *Hagenia* forests. Field observations revealed, that regeneration stages of *Hagenia abyssinica* are always growing together with either young seedlings of *Juniperus procera* and other fire-tolerant plants. Moreover, the even-aged character of many *Hagenia* forest stands suggest, that the Kosso is not regenerating successively, but all of a sudden after a disturbing event like fire. Germination tests yielded, that *Hagenia* seeds do not germinate, unless open conditions are available (Lange et al. 1997). Fire is the only natural factor that is able to destroy the undergrowth of larger areas, and to provide an environment with reduced competition, suitable for germination of the seeds. Since germination was promoted by direct light and by temporary heating equivalent to short fires, regeneration of Kosso clearly depends on a fire event.

The climax forest shows adult Kosso trees of uniform size and age, and *Juniperus procera* as a co--dominant tree species. The canopy of these forests is often closed to nearly 100 %, and the undergrowth consists of a dense herb and grass layer, whereas higher shrubs are rarely found. The conditions of high competition and intensive shading of the ground are not suitable for the germination of *Hagenia abyssinica*. A fire event disturbs the climax community by destroying herbs and leaf litter in the undergrowth, as well as all roots in the upper soil layers, whereas the adult Kosso trees survive although more or less severely damaged. Miehe & Miehe (1994a) regarded adult *Hagenia* trees as largely fire-resistant, as their bark is peeling off in large pieces, preventing a fire from reaching the essential vascular strands of the tree. Supporting this assumption, Kosso trees sometimes show heavy signs of former burning, but are still green and even flower. After a fire, the heated ground, now bare of vegetation and only covered with black ash, provides ideal conditions for the germination of the Kosso seeds.

In case the time intervals between two fire events are sufficiently high, the young *Hagenia* trees are found scattered between a dense pioneer vegetation of about 5 to 6 m height. On Mt. Kenya, *Clutia abyssinica* (Euphorbiaceae), *Dombeya torrida*(Sterculiaceae), *Helichrysum schimperi* (Asteraceae) and *Leonotis mollissima* (Lamiaceae) are characteristic species in the impenetrable thicket of this successional stage after fire. In contrast, more frequent burning results in a shift to a less high and dense vegetation dominated by *Gnidia glauca* (Thymeleaceae).The high altitude forests in Latin America and the Pacific follow very much this pattern (Drake et al. 1993; Kessler 2002; Kitayama et al. 1997).

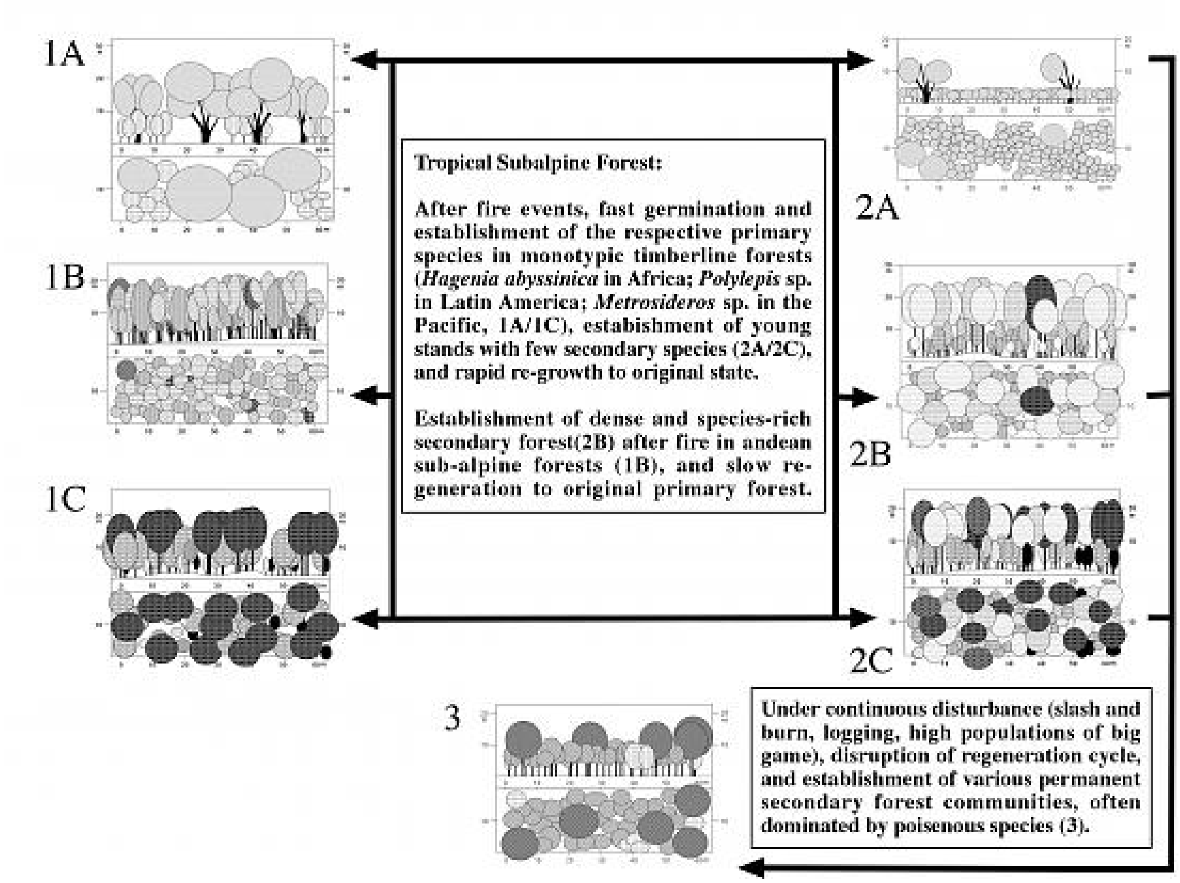

Figure 3: Regeneration Processes in Tropical Subalpine Forests.
Figura 3: Procesos de regeneración en el Bosque Tropical Subalpino

Tree heather forests

On most of the east African mountains, the uppermost forests are constituted by tree heathers rather than by *Hagenia* forest. They show a surprising similarity among mountain ranges and would form the treeline at 3600-3900 m, if disturbance levels were lower (Wesche 2002b). *Erica* species burn exceedingly intense due to their small leaves, and fires often reach the rather low crowns. Most adult individuals survive, but vegetative regeneration takes years (Wesche 2002a). Given that the most widespread tree heathers *Erica excelsa* (southern Ethiopia *E. trimera* sl.) are capable to survive fire, whereas many other afromontane tree species are not, heather forests benefit from a moderate fire frequency (Hemp & Beck 2001). Thus they often form secondary replacement communities in the montane belt.

However, no other African tree species climbs as high as *Erica excelsa* and its relatives, so stands at the timberline cannot be regarded as replacement communities. This is nicely exemplified in the Rwenzori, where the most extensive heather forests are found, and where fires are certainly rare due to the almost permanently wet conditions.

In semi-humid mountain ranges, afroalpine vegetation dries out quickly in drought conditions, while the upper montane *Hagenia* forests retain some moisture in all but the most extreme years. Fires most commonly originate in the open vegetation, and not surprisingly, afroalpine vegetation and the bordering heather forests are much more frequently affected than Kosso forests. If fire intervals become short, time is not sufficient for regenerative recovery of adult *Erica* trees, nor can saplings grow big enough to develop a fire resistant bark. Thus, in the long run, *Erica excelsa* forests are replaced by more shrubby vegetation types or even afroalpine grasslands (Wesche et al. 2000). At present, timberlines have been depressed by 500 to 800 m due to burning.

Several succession schemes have been proposed (Schmitt 1991; Miehe & Miehe 1994b; Hemp & Beck 2001; Wesche 2002a), which all nicely demonstrate how *Erica* forests degenerate under frequent fires. However, a major shortcoming is the lack of information about the seedling stage, and about regeneration in the absence of disturbance. Except for the mostly shrubby *E. arborea*, no information on seed ecology is available, and sound data on re-sprouting are only available for Mt. Elgon (Wesche 2002a). At present, it is largely unclear, if *E. excelsa*, *E. trimera* and its relatives should be classified as re-seeders like the South African heathers or as re-sprouters like most of the Mediterranean species (Ojeda 1998; Pausas 2001). Thus, the available data are not sufficient to infer complete succession cycles, as they are available for other montane vegetation types.

Forest regeneration on tropical landslides

Naturally occurring, often earthquake-triggered landslides are a crucial factor for the dynamics and stability of tropical montane forest systems, and are crucial for the maintenance of high species diversity. In over-aged forest communities, particularly so in the Tropical Upper Montane Forest, species diversity declines drastically (Ohl & Bussmann 2004).

In East Africa, most montane forests are growing on relatively gentle slopes, and landslides are restricted to the steep flanks of river valleys, and are comparatively rare. After a slide event, the bare ground is rapidly colonized by the same pioneer species as in the Mosaic Climax regeneration cycle already described above.

In contrast, extremely steep slopes are the normal feature in the Andean and Pacific regions, and many other tropical mountains. Here, natural landslides are very common, and the main motor of forest regeneration. **Lower Montane** as well as **Upper Montane Forests** regenerate in a landslide induced succession cycle [[(Figure 4)]].

Landslides are extremely frequent in the tropical mountain regions. Destruction of roads and catastrophic events burying houses or even villages are common. Such slides, however, are usually initiated by human impact; most often by construction projects weakening the underground and by deforestation accelerating erosion. At some distance from roadsides and settlements, dense forests still exist. Even in these untouched areas, landslides are a very common phenomenon. Such natural slides are usually of smaller size than the anthropogenic slides. Investigations on landslide regeneration are scarce. Stern (1995) carried out research on the regeneration of a single landslide in Northern Ecuador (1995). Kessler (1999) studied succession on landslides in Bolivia, and Erickson et al. (1989) in the central and southern Andes. In other tropical mountain areas species colonization on landslides was analyzed by Garwood (1981 in Panama), Garwood et al. (1979), and Guariguata (1990 in Puerto Rico) and geomorphological processes by Batarya & Valdivia (1989 in the Lesser Himalaya in India), Restrepo & Vitousek (2001, Hawaii), Ohl & Bussmann (2004). Keefer (1984) studied earthquake triggered landslides all over the world.

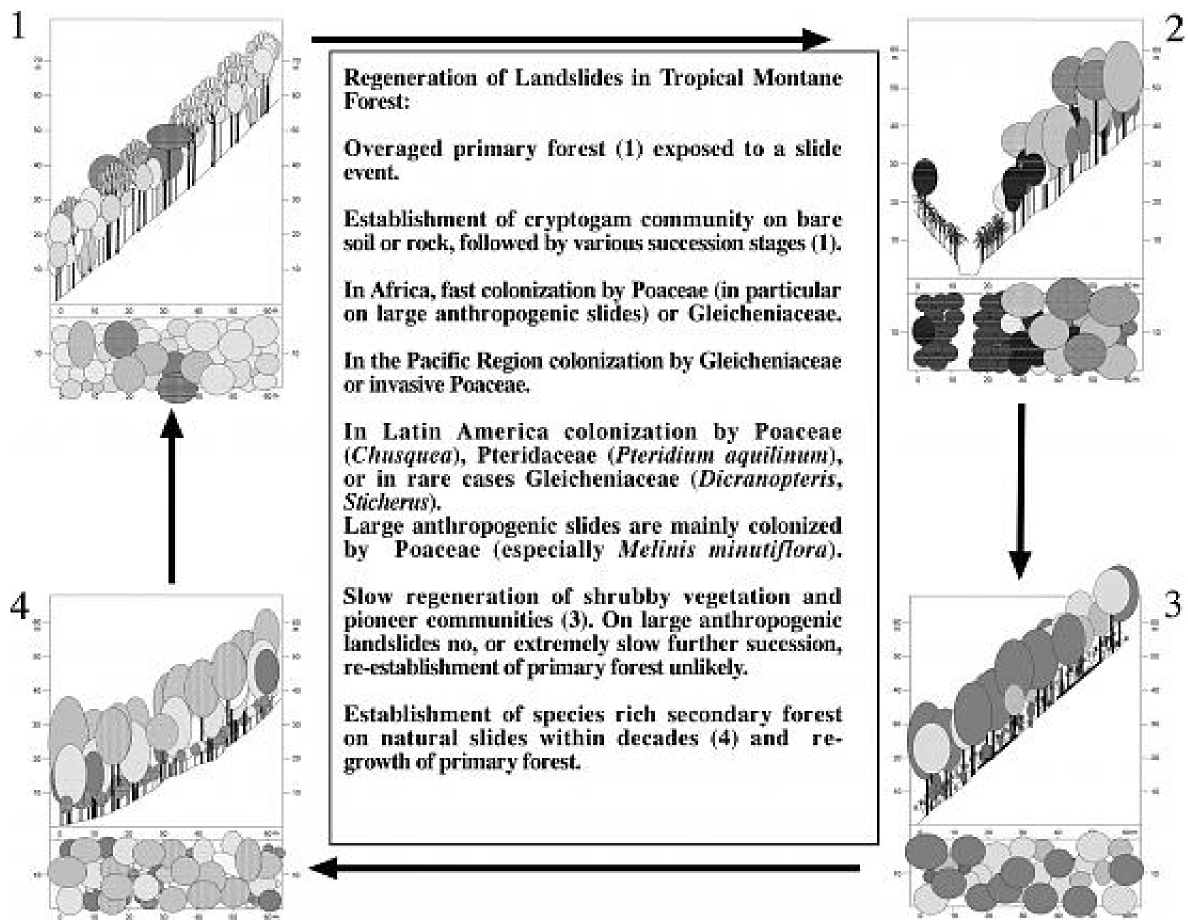

Figure 4: Regeneration of tropical forest landslides.
Figure 4: Regeneración de derumbos en bosques tropicales.

The first remarkable thing noted when climbing on landslides, is the 'patchy' distribution of vegetation. The slides are very similar in shape, being long and narrow, although they vary in size. The surface is smooth and very few rocks are present. Inclination varies between about 30° and 80°. This leads to different erosive forces at different parts of the slide. Nevertheless, a direct correlation between vegetation cover and inclination or erosive energy would only partly account for the distribution of the vegetation. The study of soil cores of the slides under more, and less, dense vegetation did not produce results with significant differences in regard to soil texture, structure, color and pH. This excludes the edaphic conditions as principal responsible factors. Landslide areas are colonized quickly either at the borders of the slide or around islands that slipped down without being overturned due to vegetative propagation from the undisturbed neighboring areas and possibly due to a favorable microclimate. Other patches of high vegetation cover are created by the clonal, looping runner-shoot building growth of most of the individual pioneers that managed to establish seedlings first (Gleicheniaceae, Lycopodiaceae, Bambusoideae and Ericaceae). The majority of abundant species is wind-dispersed and produces many seeds. Under certain conditions freshly slipped slides do not last very long in the first stage and lichens and mosses do not develop well as the colonization by higher plants starts already in the first year of succession. On landslides well protected against wind and direct sunlight, seedlings of the surrounding flora established themselves after a few months. In contrast, a landslide exposed to wind and direct sunlight was bare of any vegetation about eight months after the slide event. Differences in vegetation along the altitudinal gradient have been found. This altitude corresponds to the change in the vegetation zonation in the surrounding forests (Bussmann 2001c). On the landslides at higher altitudes some species typical for alpine vegetation are found. Other distribution patterns do not correspond to vegetation changes along the altitudinal gradient but show similar patterns to differences in soil chemistry.

Landslides are a common phenomenon in most tropical mountain systems. Stern (1995) and Kessler (1999) hypothesized that landslides maintain species diversity. Stern (1995) compares the effect of landslides to the meandering rivers of the lowland ecosystems. They create secondary forests dominated by colonizing species which are not able to survive in mature stands. Landslides are very common in some tropical areas where long and heavy rainfall and very steep slopes favor slides as well as a high number of more or less intense earthquakes. In addition, the building of roads and logging and burning weaken the substrate. The material and degree of weathering of the geological substrate is also important (Brabb & Harrold, 1989).

Species richness during the first two stages of regeneration is low due to the dominance of a few species of ferns or grasses. However, during the third stage of succession, species composition still differs somewhat completely to the surrounding forest, but diversity is high. The second stage with a dense cover of Gleicheniaceae has not been described from northern Ecuador (Stern 1995) but it was found on landslides in Bolivia (Kessler 1999) and Hawaii (Restrepo & Vitousek 2001). There, the role of Gleicheniaceae seems similar, although in Hawaii, the regeneration patterns are more and more influenced by invasive exotic species. *Diplopterygium bancroftii*and species of *Sticherus* dominate. In contrast, Stern (1995) found a dominant species of *Chusquea*, 31/2 years after the slide event at the lower zone of a landslide. She adds that the presence of the bamboo is especially noteworthy because under certain environmental conditions it can grow quickly and aggressively. Further on, she describes the great density of the bamboo, thereby having a profoundly limiting effect on the establishment of other plant species. The bamboo occurred at sites with a reasonable upper layer of organic debris. Other interesting differences in her work are that species of the genus *Equisetum* are important in the early stage and *Blechnum* dominates locally. No species of Gleicheniaceae were found. Reasons for those variations might be found in the obvious differences in geological substrate (of quaternary volcanic origin) and the lower humidity and altitude of the site (1440 m). Gleicheniaceae do not hinder the establishment of bushes, though the time period from when seedlings of bushes appear to when they manage to break through the fern layer, varies. Different types of succession models seem to correspond to the regeneration processes at the slides studies by Stern on one hand and on the other hand the slides observed by Kessler and the work on hand. Following the division of succession models according to Connell & Slayter (1977) and Pickett et al. (1987) the model of inhibition will have to be used to describe the situation in northern Ecuador as observed by Stern (1995). In contrast, the tolerance model combined with the facilitation model could be used to describe the situation in Bolivia (Kessler) and southern Ecuador. Little change in species composition but mainly a change in vegetation density or -height was observed due to local erosive energy, time elapsed since the last destruction, depth of the organic layer or the distance towards densely covered sites. Mosses and lichens are not only abundant during the first stage but also during the second and third stage and Gleicheniaceae are present in the second and third stage though they loose importance as they are overgrown by the bushes and trees of the pioneer forests. Up to this point, the model of tolerance seems to fit while the missing of species of the primary forests during the third stage follows the facilitation model. Under mature forest organic layers build up, but due to evaporation and transpiration they will not get heavily waterlogged. In contrast, comparable amounts of water do not transpire from senescent forest. A mosaic-like forest structure with younger and older forest stages is described in Kessler (1999) from the montane forest in the Bolivian Andes. He observed irregularly formed and spaced patches of senescent forest with single trees having already collapsed. This could explain the clustered occurrence of landslides as the risk of slipping in zones of senescent forest is higher than in zones of mature forest. In this case the effect of landslides in the ecosystem would be very important for the natural regeneration of the system. At altitudes above 2100 m, especially under senescent forest, very dense layers of terrestrial Bromeliads are found. Germination of other species is very difficult under these circumstances. In contrast, a landslide provides light and a high availability of minerals for successful plant growth.

What is the main difference between the studied natural landslides and the human triggered slides? Hartig (2000) carried out studies on the regeneration of the latter type of slides in Southern Ecuador. Antropogenic slides are usually very extensive. The surface is not smooth but often rocky. A heavy organic layer slipping over the mineral soil mainly creates natural slides. If thick mats of organic material become waterlogged due to long-lasting heavy rains, the weight of the material reaches a critical point when the adhesive strength gives in to gravity and a slide-event is initiated. The threshold in this area is very low as the adhesive strength is low due to the slippery mineral soil and the lack of a well developed rootsystem in the B-horizon which could help to fix the upper layers (own obs.; Stern 1995). The human triggered slides are usually initiated due to the weakened geological underground and have more in common with rock-falls. Succession differs between the two types of slides. Grasses largely replace the Gleicheniaceae and build a very dense layer often limiting the establishment of bush species. Succession seems to follow the inhibition model (Connell & Slayter 1977; Pickett et al. 1987). Especially the number of orchids is tremendous which leads to a very high diversity on man-made slides (Gross 1998). In contrast, there are not many species of orchids found at the natural slides but in the few areas with rocky relief they become more abundant.

Conclusions

The main formations of Tropical Montane Forests in Africa, Latin America and the pacific share a lot of common characteristics in their zonation and regeneration. Lower Montane Forests characteristically form a diverse mosaic climax, where tree-fall represents the main natural disturbance. Natural landslides and infrequent fires are the main motors driving diversity maintenance, at least in mid-elevation and high-altitude forests. All these forest formations tend to shift towards less diverse, and possibly less stable degenerated secondary forests under heavy human impact. Further research, especially in Southeast Asia is required, to fully understand the global picture in Tropical Mountain Forest Regeneration.

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