Newsletter

DFG Research Unit 816:
Biodiversity and Sustainable Management of a Megadiverse Mountain Ecosystem in Southern Ecuador

Issue 19
March 2013

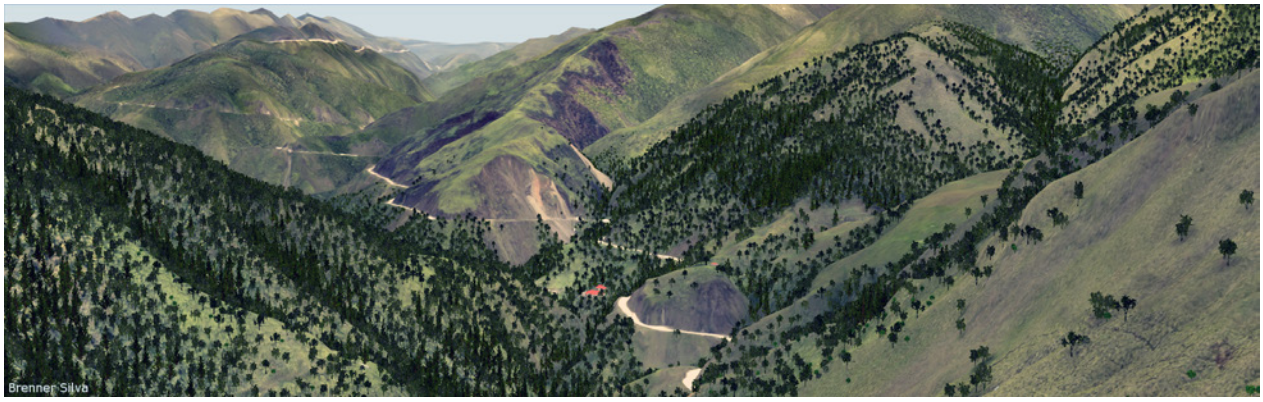


Figure 1: Reconstruction of the Rio San Francisco valley based on LiDAR (Light Detection and Ranging) flight data and aerial photography. The aerial photography covers the digital elevation model of the terrain, which is overlaid by automatically detected trees and buildings (red roof in the centre of the image is the Estación Científica San Francisco, ECSF). The visualization of detected trees is constrained to a distance of two kilometers. The figure, however, clearly shows the higher density of trees in the protected area on the south slopes (left valley side) in comparison with sparse trees and pastures on the north slopes (right valley side). The tridimensional models will enable scientists to understand the influence of microclimate and terrain on the water, carbon and nutrient cycles, which are essential in developing methods of sustainable management of natural resources. Image: Brenner Silva

Speakers' Corner

Science-Directed and Sustainable Land-Use System

The Research Unit (RU) draws to its close and the current issue is therefore the last official TMF Newsletter. After six years of exciting research activities resulting in an ample gain of knowledge we can proudly state that we have accomplished our mission towards the development of a science-directed and sustainable land-use system which is not only relevant for the investigated biodiversity hotspot of the Ecuadorian Andes, but also for other comparable regions. This newsletter finally presents the essentials of the novel results achieved in the individual subprojects.

The speakers are looking back to a very successful period of collaborative research, which had not been possible without the support of many persons and institutions which effectively promoted this endeavour.

We are primarily indebted to the German Research Foundation (DFG) for the generous funding of the exceptionally large RU. This was only possible through the relentless support and encouragement by Dr. Roswitha Schönwitz, programme director for life sciences at DFG.

We enjoyed the successful collaboration with so many motivated scientists at various levels of their career in a very trustful and constructive atmosphere. This particularly holds for our Ecuadorian colleagues from the cooperating local universities

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(Technical University of Loja, UTPL; National University of Loja, UNL, University of Cuenca, UC; Universidad del Azuay, UDA) and non-university institutions (Foundation Nature and Culture International, NCI; the company ETAPA) who contributed a lot on the way to a successful conclusion of RU816, and who became friends over the time. We are grateful also to the Ecuadorian Ministry of Environment (MAE) for supporting us by granting research permissions. Last but not least, we wish to thank many people for administrative and technical assistance who formed kind of a backbone of our successful RU. We cannot quote all of them by name but we would like to personally thank the RU office (Mrs. Birgit Kühne-Bialozyt, Mrs. Sonja Häse and Mrs. Eva-Maria Schreiner), Dr. Felix Matt and Dipl.-Geoökl. Jörg Zeilinger, the station managers, Dipl.-Ing. (FH) Maik Dobbermann and Thomas Lotz for programming the FOR816 data warehouse, and Dr. Esther Schwarz-Weig for editing this and all others TMFNewsletters – an always inspirational and internationally most visible showcase of the RU – as well as other publications of the RU.

Contents TMF Newsletter

Speakers' Corner....1
Science-Directed and Sustainable Land-Use System....1
News from the ECSF and Ecuador....4
News from NCI....5
Protection of One of the Most Threatened Areas....5
Numbala: Last Refuge of the Giant Podocarpus Trees..5
Science News....6
Effects of Nutrient Addition on Tree Growth....6
AM Extraradical Mycelium Adapted to Organic Layer....7
Soil Fauna: Indicators, Parthenogenesis and Diversity..8
Insect Herbivores on Trees and Shrubs....10
Increased Nitrogen Availability and Litterfall....11
N Addition Affects N Cycling not N_2O Surface Fluxes..12
Land Use in the San Francisco Valley....13
Changes Affect Vascular Plant Diversity....16
Acid Phosphatase indicates Phosphorus-Limitation....17
Mycorrhizal Fungi Shape Performance in Tree Nursery..18
Seeds and Forests: Sustainable Management....19
New Findings on Mycorrhizae in the TMF....21
Human Dimensions in Utilization / Conservation....22
Landscape History of the PNP Region....26
Dendroecological Analyses of Tree Growth....29
Impacts of Environ. Change on Climate and Ecosystem 31
Hydro-Biogeochemical Fluxes and Aquatic Diversity...33
Soil-Landscape and Landslide Susceptibility....35
Forest and Landslide Dynamics, and their Interactions..36
Transfer Project....38
"New Trees for Ecuador" Expands to the North....38
Data Warehouse....39
Development Successfully Accomplished....39
Cooperations....40
EDIT: Species Richness of Long-legged Flies....40
EDIT: Arthropod Diversity and Compostion on Barks...41
People and Staff....42
Event Calendar....43
Credits and Contact....44

Joint Publications

While the final TMF Newsletter can only present the essentials of our results, there are other joint publications in the pipe-line, summarizing all details of the research. Our *Ecological Studies* book "Ecosystem Services, Biodiversity and Environmental Change in a Tropical Mountain Ecosystem of South Ecuador" has been reviewed and the revised version has recently been accepted by the series editors which is a great success! Also a joint paper initiative "Trees or grass" is in the finalizing state for submission to the journal *PNAS*.

Final RU Assemblage

The final meeting of the RU members will culminate in the concluding session entitled "*Impacts of environmental change on biodiversity and ecosystem functioning / services in Tropical High Mountains*", convened by the speakers at the Annual Conference of the Society for Tropical Ecology (gtö) "*Tropical organisms and ecosystems in a changing world*" held in Vienna (Austria) on April 3rd - 5th, 2013 (www.gtoe-conference.de). This will be the largest session of the whole conference, distributed over two days (April 4th and 5th) and covering 22 oral and 6 poster presentations from our RU. Finally, we will convene for a last member assembly on April 6th (starting 9:00 LT) in the lecture hall of the Faculty Centre of Biodiversity, Rennweg 14, University of Vienna (www.botanik.univie.ac.at/index.php?nav=h72).

Heading for the Follow-Up Project

As we have stressed in the foregoing issue (TMF Newsletter no. 18, doi: 10.5678/lcrs/for816.cit.1229) parts of the follow-up programme "*Platform for Biodiversity and Ecosystem Monitoring and Research in South Ecuador*" (DFG PAK 823, 824, 825) are conditionally approved but funding is suspended until the cooperation contracts with our Ecuadorian non-university partners are signed and the German projects have joined the consortial agreement. Unexpectedly, this has proven a very tedious and complicated procedure. At the moment it cannot be foreseen when it will come to a successful end.

As a consequence, our research in southern Ecuador will be interrupted after the end of RU816 in February 2013. Because the central funds of

RU816 are nearly consumed, the research will stop until the new program can start. To warrant a minimum maintenance of the NCI stations, the instruments and the long-term field experiments we have agreed with NCI to keep the station open with the very rest of the Z2 funds so that the station managers and 2-3 persons can live there for the mentioned tasks. The salaries of the station managers are bypassed by limited funds (for a maximum of five month each) from the University of Marburg.



Figure 2: Joint research at the Estación Científica San Francisco (ECSF) will be briefly interrupted. Therefore the station can be visited only on the researchers' own accounts. See text for details. Photo: Felix Matt.

Stays in the Research Area

Nevertheless, any researcher can of course visit the station in the transition phase, however **totally on his or her own account!** Such stays should be individually arranged with Renzo Paladines from NCI via the station managers Dr. Felix Matt and Jörg Zeilinger.

Ecuadorian Partner Program

Meanwhile, also our Ecuadorian partner program was evaluated by the Ecuadorian National Secretariat for Higher Education, Science and Technology (SENESCYT) and six projects have been approved for funding (**Table 1**).

Summarizing the currently approved German and Ecuadorian projects, the German scientific advisory board of the platform suggests a contracted structure of our Ecuadorian-German platform program as presented in **Figure 3** (next page), recently under discussion with our Ecuadorian cooperation partners.

Jörg Bendix & Erwin Beck
Speaker and Deputy Speaker of the RU
(Philipps University Marburg,
University of Bayreuth)

Table 1: Six projects were approved in the SENESCYT bundle, two further projects are allowed to resubmit an improved proposal ("Nueva revisión")

Working package 1: Monitoreo de la Biodiversidad y Funciones del Ecosistema	**Aprobación**
EC 1.2 Utilizar la Ecología Acústica para desarrollar indicadores novedosos de diversidad en comunidades de anfibios y murciélagos a través gradientes de altitud y disturbio.	Si
EC 1.4 Identificar la topología de la red de interacción de orquídeas epífitas-micobiontes y orquídeas epífitas-forófitos.	Si
EC 1.5 Definir las respuestas espacio-temporales de las comunidades de aves y murciélagos a gradientes altitudinales y de perturbación en tres ecosistemas al sur del Ecuador.	Si
EC 1.6 Determinar las adaptaciones morfo-funcionales frente al estrés ambiental y su control sobre el ensamble de comunidades del sur del Ecuador.	Si
EC 1.3 Evaluar la respuesta de las comunidades de plantas vasculares y no vasculares al estrés climático, de alteración y variaciones espaciales a lo largo de un gradiente altitudinal.	Nueva revisión
Working package 2: Agua y Flujo de Elementos	**Aprobación**
EC 2.1 Desarrollo de indicadores hidrológicos funcionales para la evaluación del impacto del cambio global en ecosistemas Andinos.	Si
EC 2.3 Desarrollo de índices biológicos para diferentes ecosistemas acuáticos en el sur del Ecuador.	Si
EC 2.2 Evaluación de la erosión y pérdida de nutrientes en tres ecosistemas de la región sur del ecuador: aplicación de técnicasradioisotópicas y modelización.	Nueva revisión

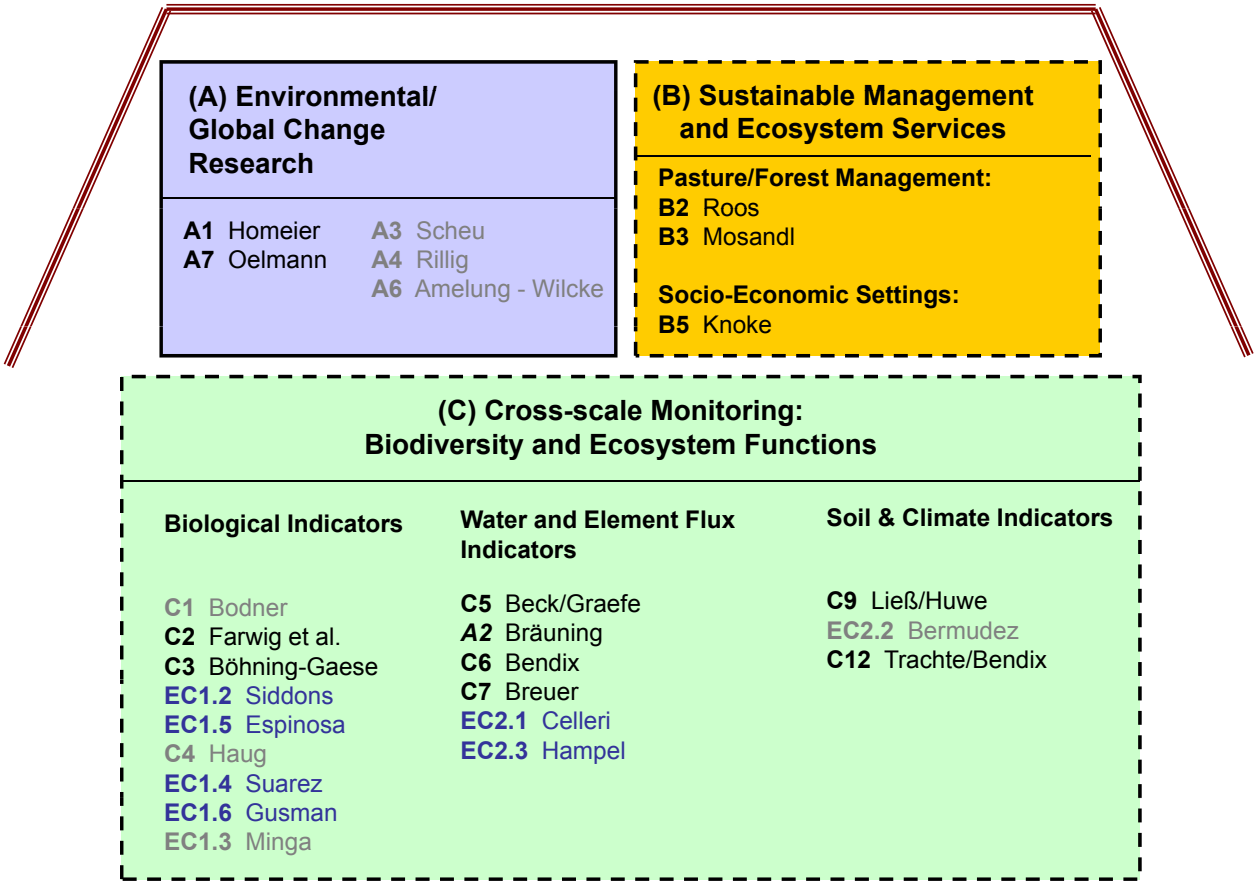


Figure 3: The suggested new structure of the German–Ecuadorian Platform for Biodiversity and Ecosystem Monitoring and Research in South Ecuador: black and blue projects numbers and principal investigators' names are the approved German and Ecuadorian projects; grey shaded projects are allowed to re-submit a revised and improved proposal to DFG and SENESCYT, respectively.
Please note, that different from the previous Research Units (FOR402 and FOR816), this house is not supported by a common financial fundament. Its base is solely scientific, namely the results and infrastructure of 15 years of research in the Reserva Biológica San Francisco (RBSF). We hope that we will be able to generate a modest financial common pool by shares from the successful German projects as a kind of fundament. Graph: J. Bendix

News from the ECSF Research Station and Ecuador

Transportation and Travel

Loja Airport

The airport of Loja in Catamay, La Toma, was re-opened in mid of December 2012. Flights operate normally but the rest is still operating on provisional arrangements. The airport terminal building is planned to be completed in May this year.

Quito Airport

The airport of Quito moved in the night from the 19th to the 20th of February to its new location in the outskirts of Quito. Transfer to or from Quito takes between 1 to 2 hours depending on the traffic and transport media which are public buses, airport shuttle buses between the new and the former airport and of course taxis.

Elections

The elections for the president, the national assembly, and the Andean parliament were held on 17th February. The actual president Rafael Correa was reelected in the first round and his party now has a comfortable majority in the national assembly.

Jörg Zeilinger (station manager)

News from NCI

Recognition for Protection of One of the Most Threatened Areas in Ecuador

"We have never been recognized for maintaining the forest in our territories. Now it is the time to get some support" said one of the around 100 Shuar present in the General Assembly of the Shuar Tayunts Centers Association of Alto Nangaritza. The association, which consists of ten Shuar communities, passed a number of resolutions including one approving the entry of 20,000 hectares of their tropical forests (**Figure 4**) into the national program SocioBosque for conservation purposes. Nature and Culture International (NCI) will assist the association to file all the technical documents required to apply to SocioBosque. The SocioBosque program will provide the communities $70,000 annually to ensure the long term protection of these rich areas, while improving the lives of 1,000 indigenous Shuar through sustainable development projects. This Shuar territory will be the first to be preserved through this program in Zamora. NCI is the main technical partner of this Governmental program in this region. The goal until the end of 2013 is to help private individuals, peasant and indigenous communities to protect more than 40,000 hectares.



Figure 4: Tropical Nangaritza forest. Photo and ©: Martina Avilés

Numbala: Last Refuge of the Giant Podocarpus Trees

The protected area for environmental conservation called the Numbala Reserve, located in the Palanda County in Zamora Chinchipe and owned by NCI, harbors a real forest of giants. The forest is dominated by two species of the Podocarpus family (**Figure 5**): *Retrophyllum rospigliosii* and *Prumnopitys harmsiana*. It is also one of the last forests of its kind within the Andean region. These two main conclusions came from a thesis research of the National University of Loja (UNL) supported by the Missouri Botanical Garden, USA.

The investigation will be released in the next days in an article entitled "Floristic Diversity and Structure of the Numbala River´s Cloud Forest: Zamora Chinchipe, Ecuador: the 'giant forest' of Podocarpus adjacent to Podocarpus National Park" which will be published in the Amazon Journal (Science and Technology of the Amazon State University, UEA of Puyo). Dr. David Neill, director of research at the university and board member of Nature and Culture International (NCI), and the researcher, Mercedes Asanza, coauthored the article.



Figure 5: Giant Podocarpus tree. Photo and ©: Eduardo Cueva, NCI

According to Dr. Neill biomass in the foot of the Numbala Reserve forest is much higher than that of any other recognized forest remnant known in any other part of the 200 plots of trees in the lowlands of the Amazon. Neill added, specifically for biomass, that the Podocarpus forest (commonly called Romerillo) in Numbala was compared with the Giant Sequoia forests in Northern California. The results are noteworthy: despite that the Redwood forest´s biomass is much greater than that of the Numbala forest, the latter remains the largest tropical forest in South America, in terms of the biomass recorded in an inventory of one hectare of natural forest. Despite the dominance of the two species of Podocarpus trees Numbala forest is diverse with 171 species of trees in only one hectare.

Formerly these giant Podocarpus forests were much more spread in the tropical Andes according to Dr. Neill. However, several reports indicate that currently these giant forests no longer exist in the other Andean countries due to logging. Numbala is one of the last refuges for this type of forest even though this reality could have been different since Numbala Valley should have been included within the limits of Podocarpus National Park (PNP), formed in 1982. Due to timber interests and problems of land titling the giant Podocarpus forests were left out of PNP ironically.

A few decades had to pass until these great trees were protected thanks to the Numbala Reserve of 1013 hectares established by NCI. In 2011 the Reserve doubled its area thanks to financial contributions from private donors.

In this section Nature and Culture International (NCI, www.natureandculture.org) introduces its activities and reports recent progress. NCI is a non-governmental organization whose mission is to assist in the conservation of biological and cultural diversity.

Science News

Effects of Nutrient Addition on Tree Growth

Within the Ecuadorian **NU**trient **M**anipulation **EX**periment (NUMEX, project **A1**) we studied the effects of nutrient addition on stem diameter increment with dendrometer tapes (**Figure 6**) at all three existing NUMEX sites (1000, 2000 and 3000 m a.s.l.).

After 4 years of nutrient addition, cumulative stem diameter increments were around 50% increased by combined nitrogen (N) and phosphorus (P) addition at 2000 m and also at 3000 m (**Figure 7A**). At 1000 m all treatments showed a 20% growth increase on average compared to controls. However, trees responsed rather species-specific to the addition of nutrients. At 2000 m, both *Graffenrieda emarginata* (the most common species) and the pooled non-common species (**Figure 7B**: "other species", comprising more than 50 different species) responded with higher diameter increments to combined N+P addition. But only the non-common species showed higher increments after P addition (**Figure 7B**) whereas three out of four common species reacted with reduced diameter growth. Only in the latter treatment the non-common species reached growth rates similar to those of *Graffenrieda*, whereas *Graffenrieda* has grown significantly faster in all other treatments. This indicates that the non-common species will probably gain in aboveground biomass with higher P availability.



Figure 6: Dendrometer tapes measure the stem diameter increments at breast heights (dbh). Photo: J. Homeier

Increased Nutrients Alter Forest Structure

The observed effects on tree growth further indicate − in addition to the earlier reported effects on tree recruitment (TMF Newsletter no. 13, doi: 10.5678/lcrs/for816.cit.993) and leaf herbivory (Newsletter no. 17, doi: 10.5678/lcrs/for816.cit.1132) − that increased nutrient availability could rapidly result in changes in forest structure and tree species composition of the studied Andean montane forests (see also [1]).

Jürgen Homeier
(University of Göttingen)

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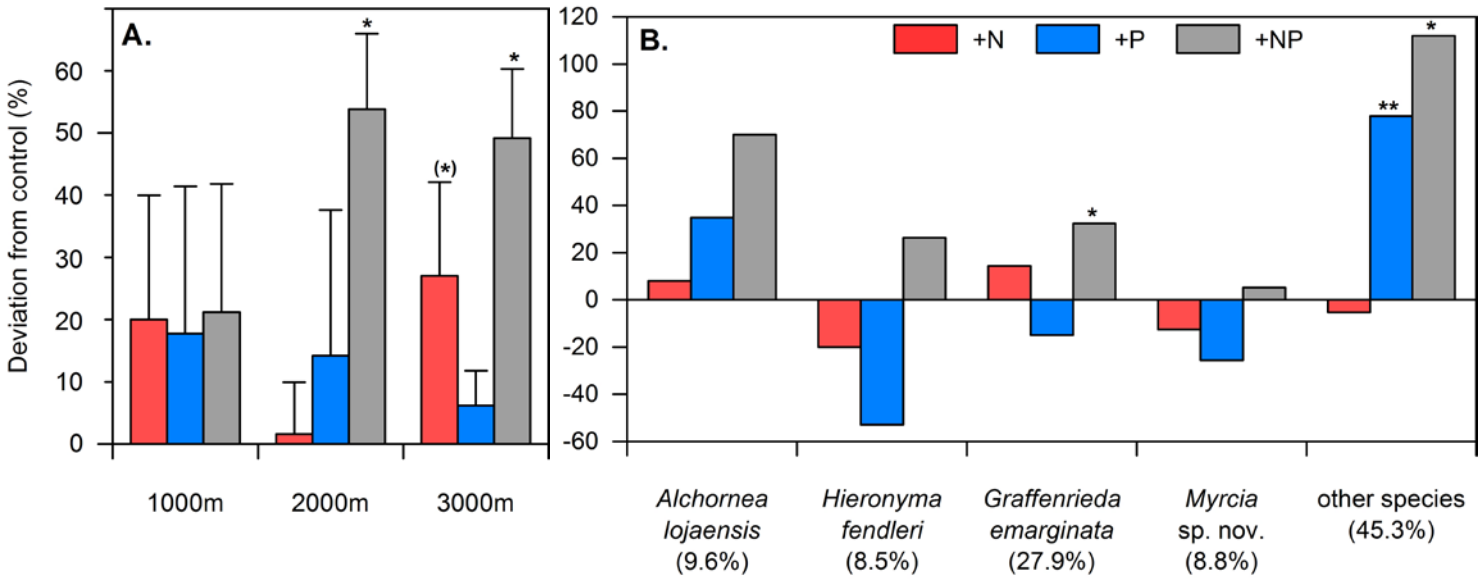


Figure 7: Effects of N or/and P addition on tree diameter growth. Bars represent cumulated deviations from the control treatment after 50 month of experiment duration (2008-2012). Given are stand means for all elevations (**A**) and means of the four most common species at 2000 m (**B**). The relative abundance of the single species at 2000 m is shown in parentheses (868 individual trees are monitored at 2000 m). Asterisks mark significant differences between fertilization treatments and control (**: $p < 0.01$, *: $p < 0.05$, (*): $p < 0.10$, two-way ANOVA). Graphs: J. Homeier

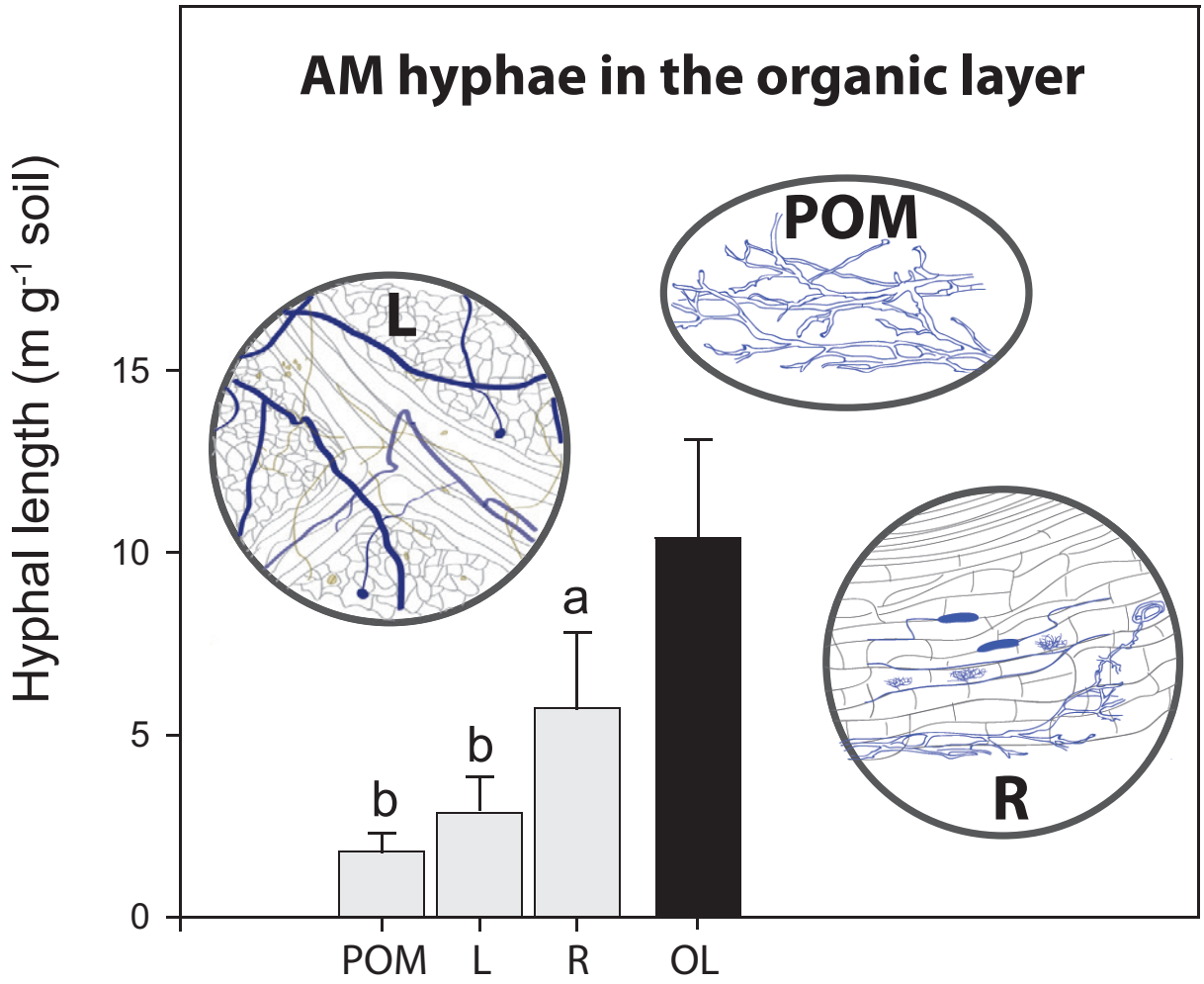


Figure 8: Distribution of the extraradical arbuscular mycorrhizal mycelium in the organic layer of a tropical montane forest soil. Bars represent the mean (± sem) of hyphal length quantified for every soil fraction (**POM**: particulate organic material, **L**: decomposing leaves, **R**: root surface) as well as total hyphal length in the organic layer (**OL**). Letters indicate significant differences between hyphal biomass in different soil fractions (Linear-mixed effect model; $p < 0.05$). Graph: T. Camenzind

Arbuscular Mycorrhizal Extraradical Mycelium Adapted to the Organic Layer

Arbuscular mycorrhizal (AM) fungi exchange nutrients as nitrogen and phosphorus for carbon via intraradical structures. Beside the fungal structures formed within the roots, AM fungi form a vast extraradical mycelium exploring the soil and thus increasing the root surface for enhanced nutrient uptake. Due to the fact that standardized hyphal extraction protocols were unable to reveal realistic amounts of AM hyphae in the thick organic layer of the tropical montane forest soil typical for the RBSF, we here aimed to quantify and localize the extraradical AM mycelium. To this end, decomposing leaves and roots in the soil were quantified and stained with Trypan Blue. Furthermore, hyphae were extracted from the remaining particulate organic material.

The analyses in subproject A2 (**Figure 8**) revealed that AM hyphae were indeed closely associated to decomposing leaves, and more than half of hyphal biomass was detected on root surfaces. The high AM hyphal biomass − on average 10.4 m g^{-1} soil − underscores the level of adaptation and predominance as mycorrhizal symbionts of AM fungi in the tropical montane forest soil. The high colonization rates of AM fungi on decomposing leaves, as reported earlier from other tropical forests [1], might point to a direct or indirect role of AM fungi in the decomposition process. We will disentangle the functional context in future studies.

Tessa Camenzind & Matthias Rillig
(Freie Universität Berlin)

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Soil Fauna: Bioindicators, Parthenogenesis and Diversity

Testate Amoeba are Sensitive Bioindicators

In tropical soils microfauna plays a pivotal role in controlling bacterial populations thereby affecting decomposition and nutrient turnover. Protists, in particular testate amoebae, are among the most important bacterial feeders in acidic tropical soils. Until today little is known about factors that drive the density and community composition of microfauna in tropical montane rainforests. The team of subproject A3 investigated the effect of soil moisture on testate amoebae communities along an altitudinal gradient in tropical montane rainforests in southern Ecuador [1]. By installing polyester roofs at three altitudes (1000, 2000, 3000 m) we excluded precipitation, thereby manipulated soil moisture. Rain exclusion strongly reduced microbial biomass but the response of testate amoebae exceeded that of microorganisms with live cells being reduced by about 90%. Further, rain exclusion significantly changed the community structure of testate amoebae with the effect being most pronounced at lower altitude (**Figure 9**). The results underline the eminent importance of precipitation for the structure and functioning of major group of soil microfauna, such as testate amoebae as main predators of bacteria and other microorganisms in the soil. Notably, testate amoebae responded more sensitive than their bacterial prey suggesting that they comprise sensitive bioindicators of tropical montane rainforest ecosystems.

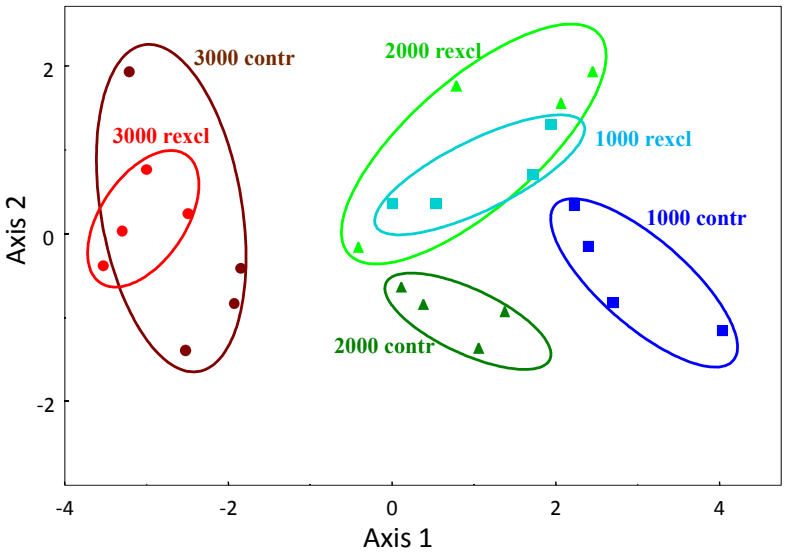


Figure 9: Discriminant function analysis (DFA) reflecting differences in testate amoeba communities of tropical montane rainforests in southern Ecuador at different altitudes (1000, 2000, 3000 m) and soil moisture treatments (**contr** = control with ambient rainfall, **rexcl** = rain exclusion). Modified after [1]. Graph: V. Krashevska

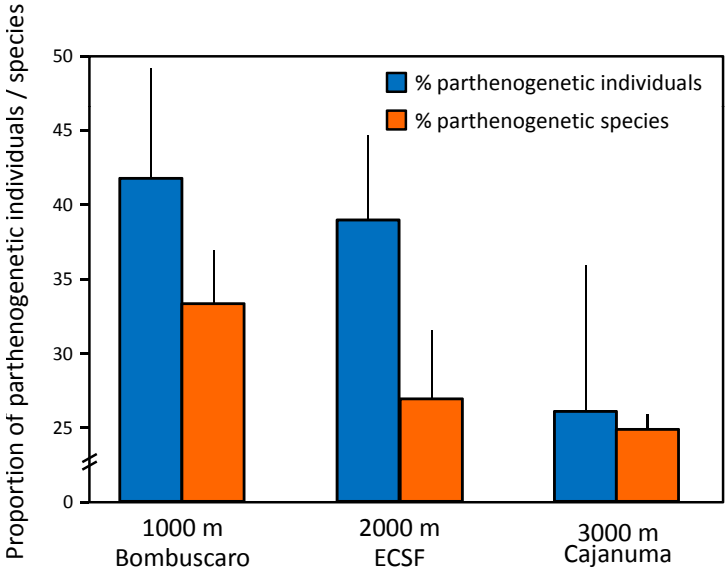


Figure 10: Proportion of parthenogenetic individuals and species/taxa of oribatid mites (Oribatida, Acari) of tropical montane rainforests along an altitudinal gradient from 1000 to 3000 m in southern Ecuador. Graph: M. Maraun

Parthenogenetic Reproduction of Ortbatid Mites is Controlled by Resources

A wide range of soil animal species abandoned sexual reproduction and live as pure female populations. We investigated the density and proportion of all female (parthenogenetic) species and individuals of oribatid mites (Oribatida, Acari) in tropical montane rainforests along an altitudinal gradient in southern Ecuador [2]. In contrast to commonly held views, the frequency of parthenogenetic species and individuals decreased with increasing altitude and this decline was paralleled by oribatid mite density (**Figure 10**). The results argue against major hypotheses explaining the prevalence of parthenogenetic reproduction in oribatid mites, i.e. difficulties in finding mating partners and harsh abiotic conditions. The results suggest that the high frequency of sexual species at high altitudes is driven by low availability of resources supporting the recently proposed Structured Resource Theory of Sexual Reproduction. Overall, the data support the view that the reproductive mode of soil animals is predominantly controlled by the availability and accessibility of resources.

Microarthropods Feeding on Fungi Aren't Very Diverse

Oribatid mites (Oribatida, Acari) are diverse soil microarthropods present in virtually any ecosystem. Comprising mainly fungal feeders they form important components of the fungal energy channel in soil. According to rarefaction analysis (**Figure 11a**) the community of oribatid mites in soil of tropical

rainforests along an altitudinal gradient from 1000 to 3000 m comprises about 200 species with moderately more to be expected [4]. Notably, this number of species resembles that of European forests covering a similar range of environmental factors. In comparison to testate amoeba species turnover at local, regional and global scales is higher; only few species at the studied tropical rainforests are also present in European forests. Most of the species of the studied rainforests comprise tropical species with an estimated number of about 40% representing new species to science.

Testate amoebae are diverse soil protists present in virtually any ecosystem. According to rarefaction analysis (**Figure 11b**) the community of testate amoebae in soil of tropical rainforests along an altitudinal gradient from 1000 to 3000 m a.s.l. comprises about 135 species with only few more to be expected [3]. This indicates that in comparison to plants the diversity of protists in the studied tropical montane rainforests is low. Notably, species turnover in space is low at local, regional and also global scales, with most of the species present in the studied rainforests being widespread and also occurring in temperate and boreal forests.

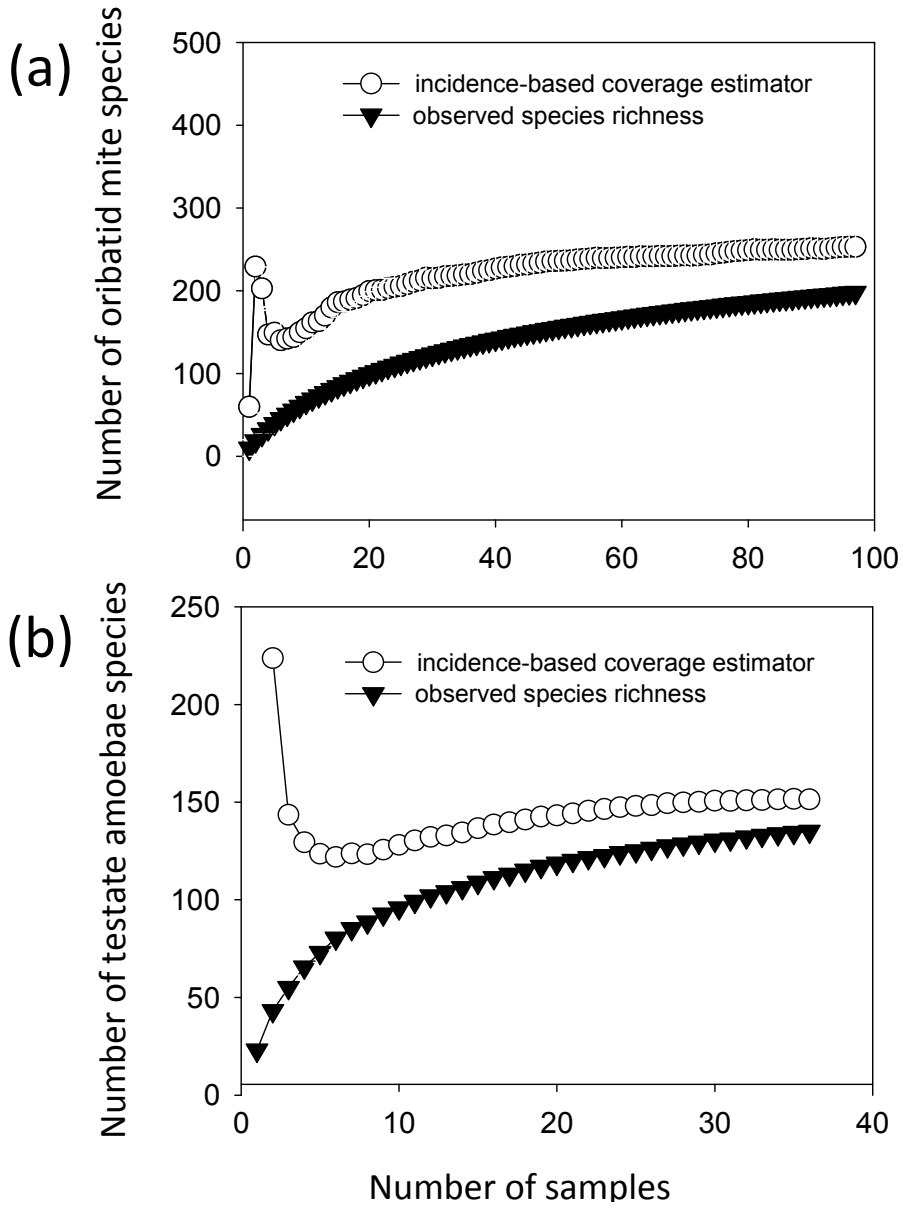


Figure 11: Rarefaction curves for (**a**) oribatid mites and (**b**) testate amoebae of the Ecuadorian tropical montane rainforests spanning an altitudinal gradient from 1000 to 3000 m. Graphs: D. Sandmann, V. Krashevska

Notably, both the diversity of testate amoebae and oribatid mites at the studied montane tropical rainforests is markedly lower than that of plants and animal species above the ground such as geometrid moths. The results therefore suggest that compared to above the ground the latitudinal gradient in belowground animal species is less pronounced.

Valentyna Krashevska, Dorothee Sandmann, Mark Maraun & Stefan Scheu (University of Göttingen)

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Insect Herbivores on Trees and Shrubs

In project A4 we addressed insect herbivores (**Figure 12**) along two contrasting ecological dimensions.

Chewing and Sucking Herbivores on Trees

In the first work package we studied insects on treelets in reforestation plots established almost 10 years ago. Over almost two years, we sampled insects every 6 weeks and sorted them to morphospecies and functional groups.

Observed herbivore abundances were unexpectedly low, even though feeding damage was considerable. Strikingly, abundance patterns were mostly governed by year-to-year variation in precipitation. In the first (dry) year densities of chewing herbivores were low and continually declined until the rainy season resumed again, with very minor differences related to tree species or habitat conditions. Only after normal precipitation levels had been reached again in the second year, herbivore densities increased. Under these less constrained conditions herbivore densities were higher and differences between tree species and habitats became obvious (**Figure 13**). Hence, our data suggest that biotic controls of herbivore communities may only unfold under favourable humid conditions. Data on species diversity and feeding damage are still being processed. Thus far at least 314 species of chewing (mostly beetles) and 192 of sucking herbivores could be recognized.



Figure 12: Caterpillar of an owlet moth (Genus: *Gonodonta*). Photo and © F. Bodner

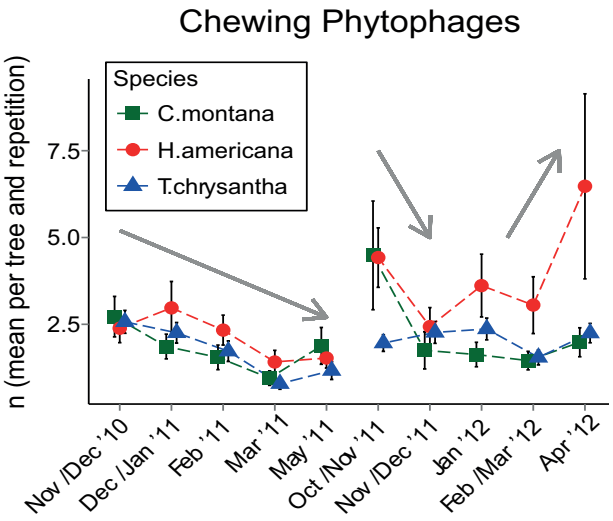


Figure 13: Mean numbers of chewing insect herbivores on treelets (*Cedrela montana, Heliocarpus americana* and *Tabebuia chrysantha*) in reforestation plots over 10 sampling rounds. Graph: M. Adams

Functional Traits of Caterpillars on Shrubs Change along the Altitudinal Gradient

In the second work package we specifically studied caterpillars at elevations of 1000, 2000 and 3000 m a.s.l.. At each elevation, shrubs from the same three plant genera were sampled in near-natural forest understorey, yielding more than 300 different lepidopteran species.

Unexpectedly, a large fraction of caterpillars at low and mid elevations turned out not to feed on foliage of their home shrubs. Rather these feed as detritivores on dead plant material, or they graze on epiphyllic lichens, fungi, mosses and algae. Those 'non-herbivore' guilds largely vanish in uppermost montane forest. Amongst truly herbivore caterpillars, large fractions build shelters or otherwise hide from enemies and adverse climate at low as well as high elevations, whereas at mid-elevations such protective devices are less prevalent. Hence, even within one single species-rich clade of plant-affiliated insects, not only species diversity, but also functional trait distributions change prominently along an altitudinal gradient within the Andean mountain forest (**Figure 14**).

Konrad Fiedler, Florian Bodner & Marc-Oliver Adams (University of Vienna)

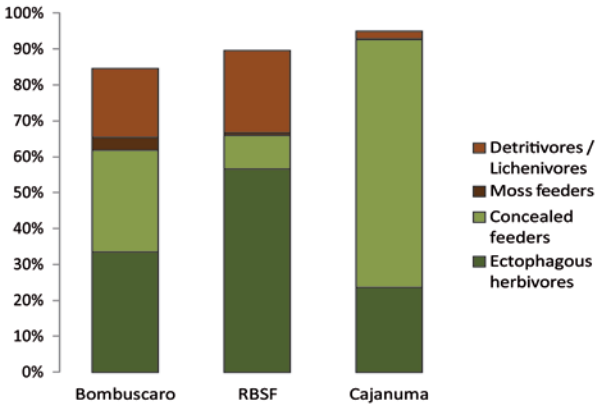


Figure 14: Proportional contribution of four different functional groups of caterpillars to samples obtained on forest understorey shrubs (*Hedyosmum, Miconia* and *Piper*; > 2,300 larvae altogether) at three elevations (Bombuscaro: about 1000, RBSF about 2000 and Cajanuma about 3000 m a.s.l.). Graph: F. Bodner

Environmental Change: Increased Nitrogen Availability and Litterfall

To assess environmental change in tropical forests modelling efforts, manipulative experiments, and comparisons of archived with recent samples were reported in the literature. However, direct observations of environmental change in tropical forests like they were realized in subproject A6 have hardly been published. In our study forest in south Ecuador, we determined in the past 15 years all relevant ecosystem fluxes at up to 15 study sites under forest between 1900 and 2200 m above sea level for various durations. Our longest record in Microcatchment 2 with its three measurement transects extends to 15 years while we ran up to 12 other measurement stations for at least 5 years.

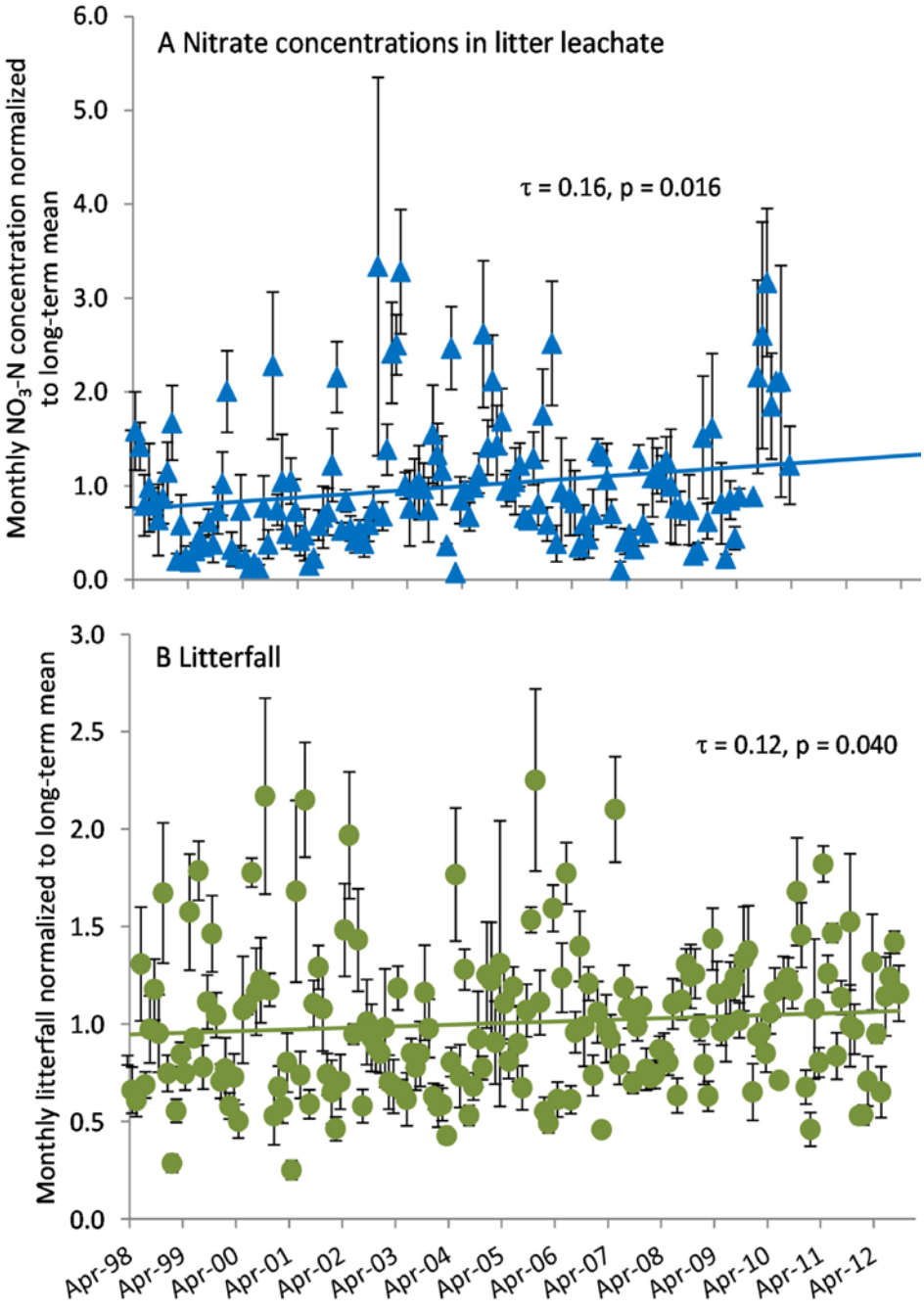


Figure 15: Course of mean (**A**) monthly NO_3-N concentrations in litter leachate and (**B**) litterfall of up to 15 study sites. Each monthly value was normalized to the long-term mean of the whole time series of a given study site prior to calculating the means shown in the graphs. Error bars indicate the standard error of the mean normalized values of all included study sites. The time series was statistically evaluated with the non-parametric Seasonal Mann-Kendall test. Regression lines are only shown to illustrate the detected trends. Graph: W. Wilcke

Here we show – based on the compiled data of all our measurements – that in the past 15 years the availability of nitrate in soil solution below the organic layer where most plant roots are located increased significantly in the whole study area (**Figure 15a**). One major reason is the rising nitrogen deposition. Furthermore, waterlogging periods in soil which slow down organic matter mineralization shortened from 1998-2012 because of increasingly drier conditions. Simultaneously to rising nitrogen availability we observed increasing fine litterfall production (**Figure 15b**) suggesting that the improved availability of the quantitatively most important plant nutrient increased aboveground biomass production. It remains to be determined, how long a positive effect of increasing nitrogen availability on aboveground biomass production will last, i.e. when nitrogen saturation will be reached and which consequences the increasing soil fertility has for the plant species composition of this extraordinarily biodiverse ecosystem.

Wolfgang Wilcke, Sophia Leimer & Carlos Valarezo (University of Berne, National University of Loja)

Nitrogen Addition Affects N Cycling but not N_2O Surface Fluxes

Nitrogen (N) exists in soils in many forms and is being constantly transformed from one to another within the N cycle. Rates of change depend on environmental factors i.e. soil nutrient status. One form of N produced within soils during the process of nitrification and denitrification is nitrous oxide (N_2O), a potent greenhouse gas contributing to global warming.

In the framework of the Nutrient Manipulation Experiment (NUMEX, introduced in TMF Newsletter no. 1, doi: 10.5678/lcrs/for816.cit.1010), the scientists of project A7 aimed to investigate the effects of nutrient addition on gross rates of N cycling and associated N_2O fluxes along an elevation gradient. Gross rates of N cycling were measured by ^{15}N pool dilution (**Figure 16**) and N_2O fluxes by static vented chambers.



Figure 16: Angelica Baldos prepares an injection of labelled nitrogen to measure gross rates of nitrogen cycling at Bombuscaro. Photo: P. Salas.

We hypothesized that with nutrient addition, gross nitrification would increase and nitrate (NO_{3-}) immobilization would decrease, resulting in increased N_2O emissions. At 2000 m a.s.l. increases in gross nitrification and decreases in NO_{3-} immobilization in both N and NP plots were observed (**Figure 17**). This supported our hypothesis of decoupled rates.

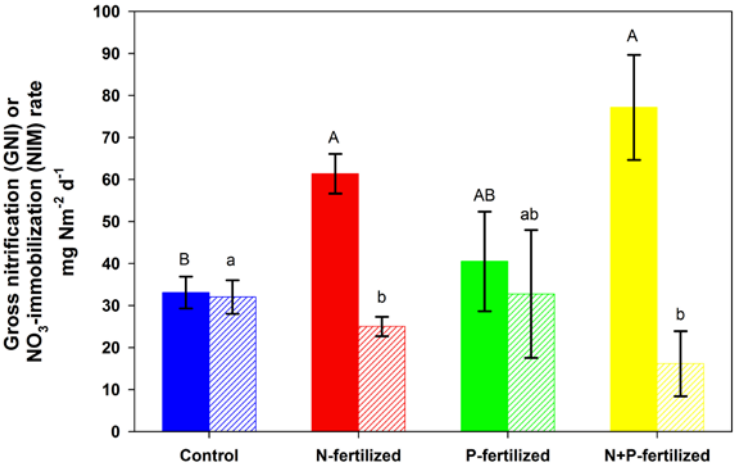


Figure 17: Mean (± SE, *n*=4) gross nitrification (GNI) and NO_{3-} immobilization (NIM) rates at 2000 m elevation. Bars with solid fills are GNI rates and bars with dot fills are NIM rates. Means with different capital letters indicate significant differences for GNI, and means with different small letters indicate significant differences for NIM among treatments (one-way ANOVA with Tukey HSD at $p \leq 0.05$). Graph: A. Baldos

However, no effects of this decoupling were visible in N_2O fluxes (**Figure 18**), possibly due to buffering by other processes. These results are contrary to our expectations and further work is required to understand the effects of increased nutrients on the N cycle in these forest soils.

Angelica Baldos & Anke Müller
(University of Göttingen)

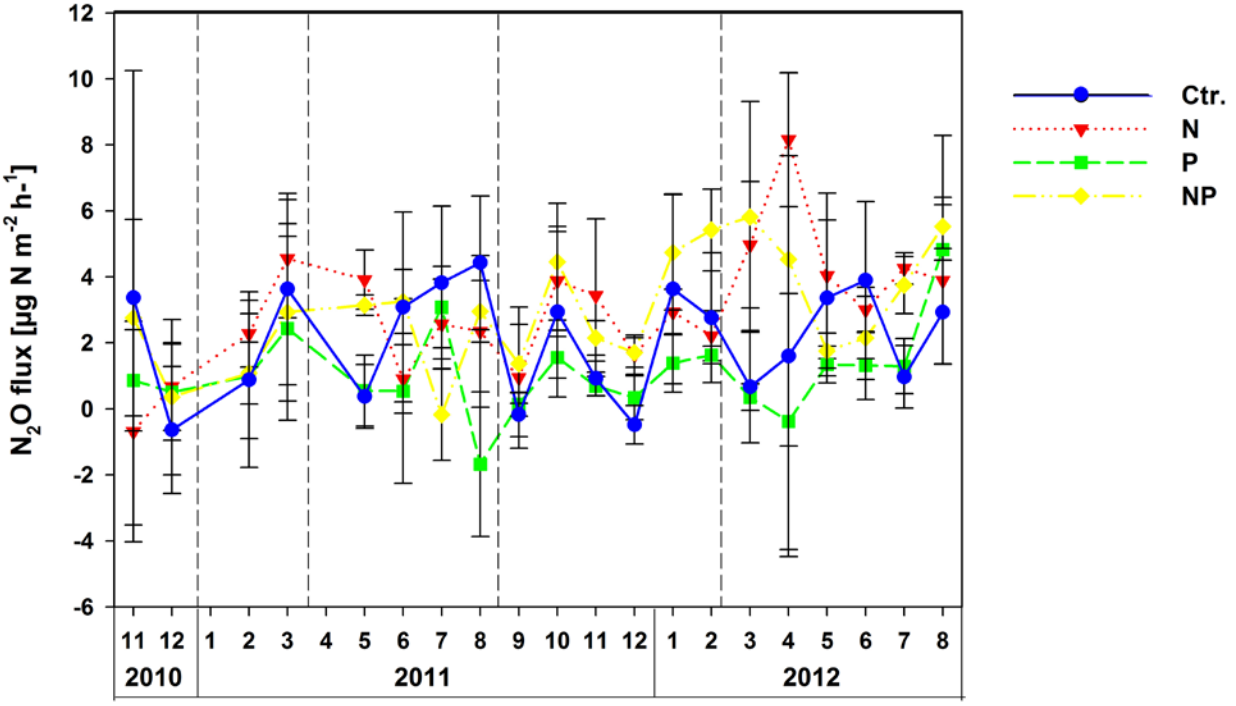


Figure 18: Average (± SE, *n* = 3) N_2O fluxes at 2000 m elevation from November 2011 to August 2012 measured in control plots (Ctr.), and plots with addition of nitrogen (N) phosphorus (P) or a combination of both (NP). Dotted lines indicate nutrient application. Graph: A. Baldos

Land Use in the San Francisco Valley

Temporal Land-Use Change and Distribution Patterns of Bracken

In the research area, pasture farming is the prevalent form of agriculture. Large areas of primary forest were and still are converted, mainly by slash-and-burn [1]. Satellite scenes (Landsat TM/ETM+) of the Rio San Francisco valley show that 4.1% of the primary mountain forest have been cleared and converted to (mainly) pastures between 1987 and 2001 (**Figure 19**).

Today, in total 14.3% of the valley composes of pastures. A detailed analysis of pasture types conducted in subproject B1 shows that 5.3% of the areas are represented by *Holcus*-, 0.5% by *Melinis*- and 8.5% by *Setaria* pastures. Due to weed infestation (mainly bracken) 10.7% is classified as waste

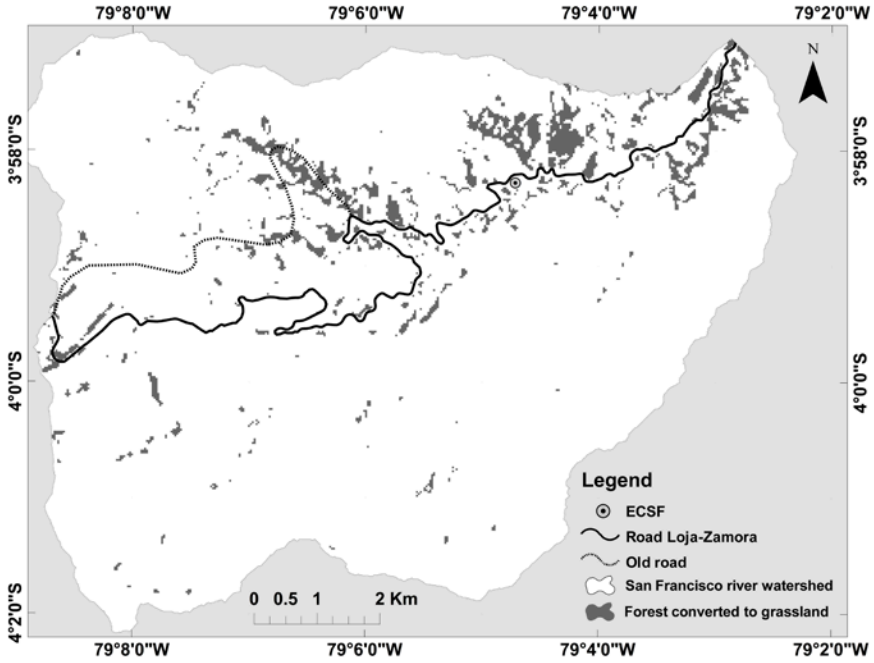


Figure 19: Land-use change in the catchment area of the Rio San Francisco from 1987 to 2001. ECSF: Estación Científica San Francisco. Figure will be published in [2] with kind permission from Springer. Graph: G. Curatola

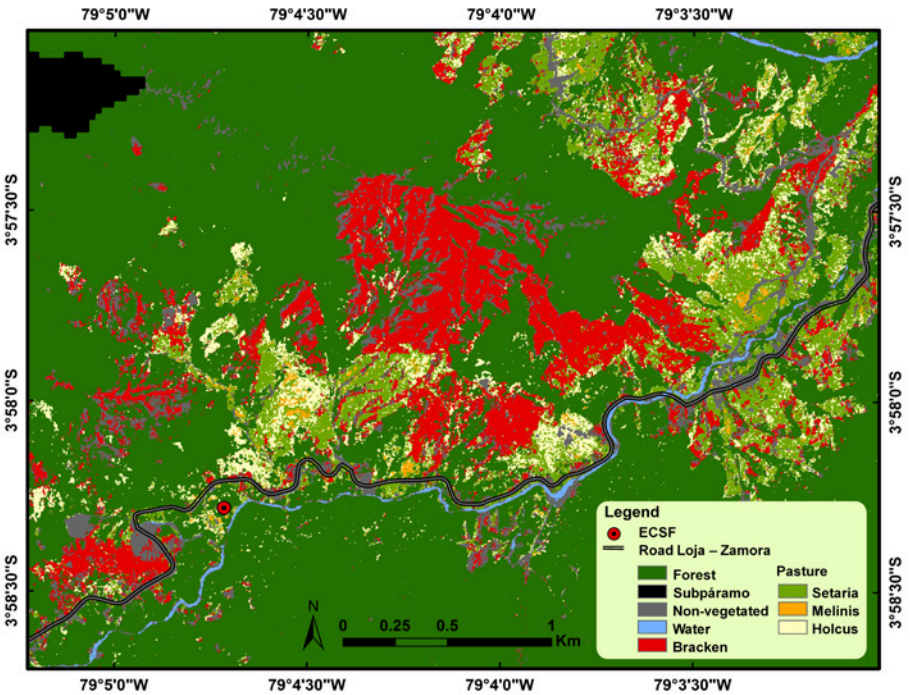


Figure 20: Land use in the Rio San Francisco valley (October 2010) based on a QuickBird satellite image. Spectral signatures were used for classification. ECSF: Estación Científica San Francisco. Figure will be published in [2] with kind permission from Springer. Graph: G. Curatola

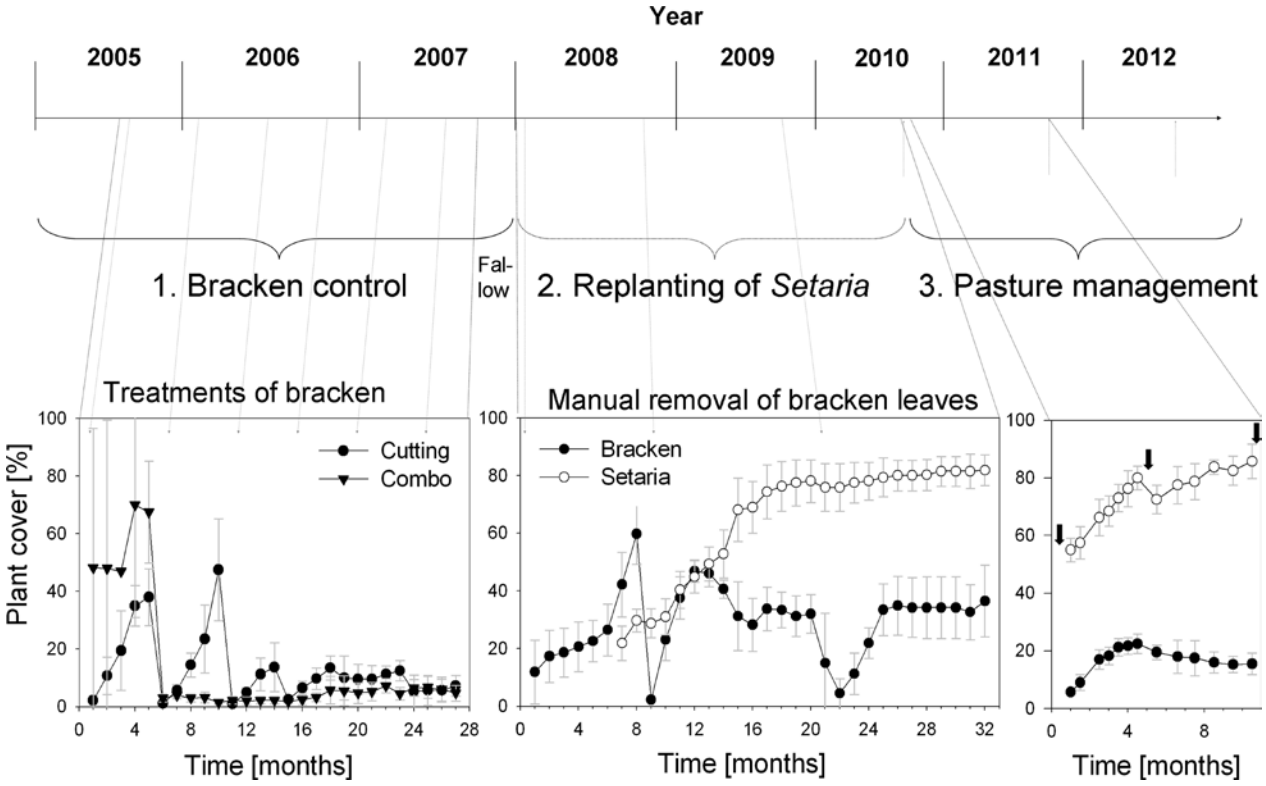


Figure 21: Setup of the pasture rehabilitation experiment consisting of 3 consecutive steps, (Combo = application of the herbicide combination picloram and metsulfuron methyl), grey arrows: bracken treatment, black arrows: grazing simulation. Figure modified after [6] with kind permission from Springer. Graph: K. Roos

land (**Figure 20**). In this respect, a strong relation of the classical burning practices by farmers, i.e. for pasture rejuvenation, and bracken occurrence has been proven (see TMF Newsletter no. 17 doi: 10.5678/lcrs/for816.cit.1132 and [3]).

Re-Conversion of Bracken-Infested Land into Active Pastures (Repasturisation)

To rehabilitate weed-ridden (mainly bracken) pastures, a three-step experiment was performed in an experimental area at an altitude around 2000 m (**Figure 21**) [4]: **step 1**: Bracken control (periodic cutting or herbicide application), **step 2**: Planting of the common pasture grass *Setaria sphacelata*, **step 3**: Probing different variants of pasture management (without further input or 2 intensities of fertilization & grazing simulation).

On the nutrient-depleted soil of the abandoned pastures, *Setaria* could not fully make use of its growth potential as C4 grass which uses an efficient metabolic way to transform the gaseous CO_2 into high energy sugars. For better growth it requires sufficient nitrogen at a developmental stage when the tufts are still small [5]. Best results were achieved with NPK-fertilizer and 3 extended grazing rounds per year (see TMF Newsletter no. 17, doi: 10.5678/lcrs/for816.cit.1132). What remains to be determined are the optimal time-points for fertilization and grazing.

The Southern Bracken Competition Model (SoBraCo-Model)

The potential growth of the two competing species (Southern Bracken and *Setaria sphacelata*) has been simulated with the *SoBraCo-Model*, which is a mechanistic vegetation model [7, 8]. Using realistic forcing and field data for parameterization, the model delivers the climate response of the two species in high temporal resolution (**Figure 22a**). The grass shows growth advantage under dry and warmer periods, while the bracken fern is favoured by humid and low radiation conditions. This information is essential to develop precise management strategies in environments like the Rio San Francisco basin. The *SoBraCo-Model* has been also run using a future climate scenario [9] adapted to the local mountain environment (**Figure 22b**). Model results point to an increasing competitive advantage of the *Setaria* pasture in the future (**Figure 22c**). Bracken will be favoured by temperature and CO_2-fertilization, but *Setarias*' growth potential under a future climate will still be slightly higher [5].

Species Distribution and Genetic Diversity of Bracken

Two co-occuring species (*Pteridium arachnoideum, Pt. caudatum*) of Southern Bracken with different ploidy levels are present in the research area. We analysed the distribution of both in 2 adjacent river

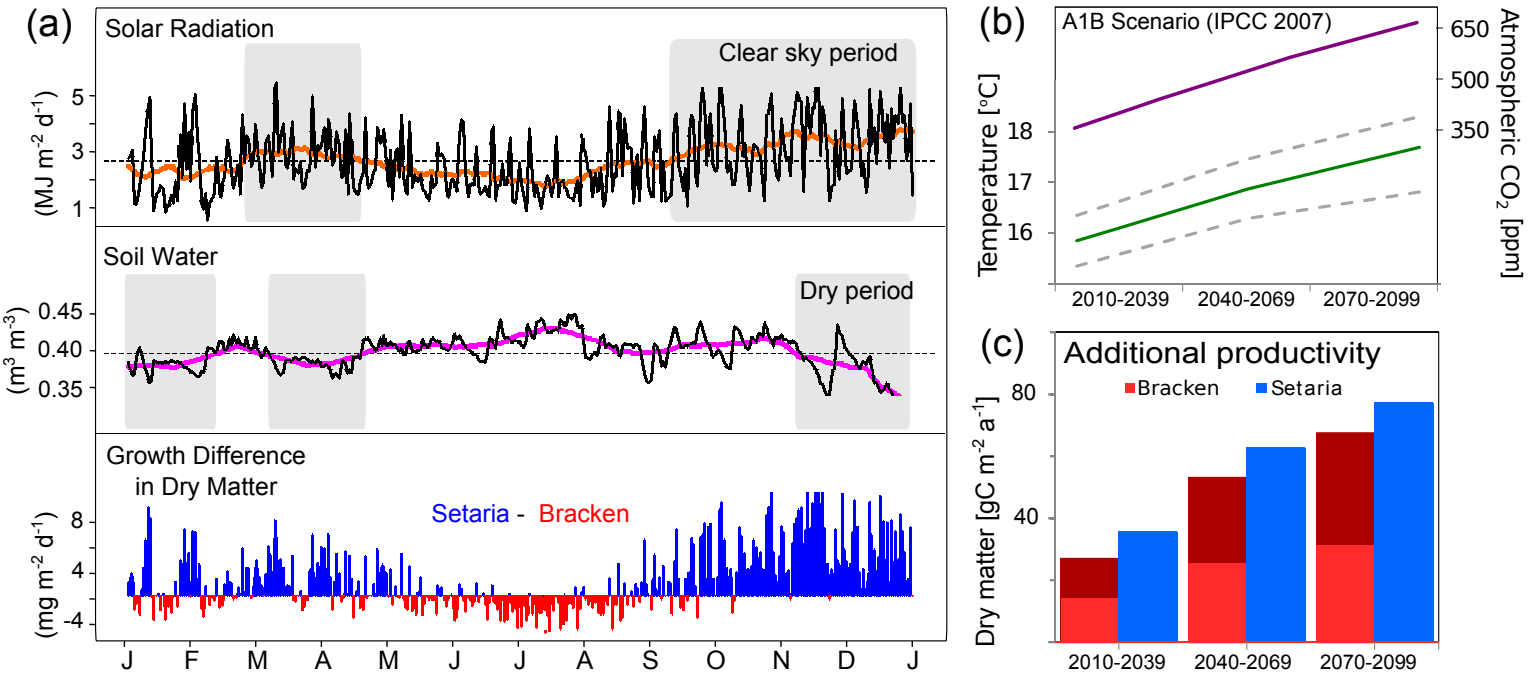


Figure 22: Meteorological forcing and model results of the potential growth of *Setaria* and bracken for current (**a**) and future climate conditions (**b** and **c**) in the Rio San Francisco valley. Graph: B. Silva

valleys (San Francisco and Malacatos) and found an interesting effect of the moisture regimes on the occurrence of the bracken species. Additionally, an extensive study of the genetic composition of the found bracken population was performed. The observed high genetic diversity suggests a predominance of sexual over vegetative propagation. This might be attributed to the above mentioned use of fires as an agricultural tool in pasture farming. Its heat wave could stimulate sexual reproduction of bracken (more results are provided in TMF Newsletter no 17 doi: 10.5678/lcrs/for816.cit.1132).

Kristin Roos, Brenner Silva, Giulia Curatola, Ingo Voss, Nicolas König, Jörg Bendix, Renate Scheibe & Erwin Beck (Universities of Bayreuth and Osnabrueck, and Philipps University Marburg)

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Climate and Land-Use Changes Affect Vascular Plant Diversity

Since the announcement of the Millennium Ecosystem Assessment [1] it is undeniable that land-use and climate change are threatening biodiversity.

Temperature Changes

Concerning air temperature, own measurements in the research area show partially different trends since 1998. On the one hand temperature measurements at the meteorological climate station at the ECSF (Estación Científica San Francisco, 1950 m a.s.l.) indicate a significant cooling (τ = -0.314, p = 0.0000, n = 136, Seasonal Mann-Kendall test used for monthly temperature series). On the other hand the two higher located meteorological stations at Cajanuma Páramo (approx. 3400 m a.s.l., τ = 0.054, p = 0.30697, n = 160) and at El Tiro (2820 m a.s.l., τ = 0.045, p = 0.27084, n = 134) show positive temperature trends.

Precipitation Changes

As we analysed in subproject B2 changes in rainfall are even more complex: Areas west of the main Cordillera might be affected by a slight increase of rainfall and vice versa. Both, the ECSF station (τ = -0.125, p = 0.0309, n = 135) and the Cajanuma Páramo station (τ = -0.138, p = 0.0082, n = 149) reveal a significantly accelerated decrease in precipitation. These negative trends can be mainly traced back to an increase of the number of dry days at the ECSF (τ = 0.0898, p = 0.1284, n = 135) and Cajanuma Páramo station (τ = 0.0589, p = 0.3536, n = 149).

Plant Biodiversity

Another, even faster processing threat to biodiversity is caused by land-use change. Our investigation focused on the loss of vascular plant diversity caused by transformation processes from natural forest to pastures and burned fallows (**Figure 23**). Species richness in the tropical mountain forest was more than twice as high as on anthropogenically influenced sites combined (pasture, fallow, pine plantation, and silvipastures). The conversion into anthropogenically manipulated landscapes caused an average loss of about 95% of the natural forest plant species and an alpha diversity loss of 77% (**Table 2**).



Figure 23: Mountain forest (front), pine plantations and pastures close to the research station ECSF. Photo: T. Peters

Thorsten Peters & Julia Gawlik
(Friedrich-Alexander Universität Erlangen-Nürnberg)

Reference

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Table 2: Changes in total plant species richness, forest species, and diversity (eff. = effective Shannon diversity) , by type of land-use transition: Tropical Mountain Forest (TMF), pasture, fallow *n* = 16; pine plantation, sivlipasture *n* = 6; plot size: 100 m²

Land-use transition	Δ total species richness	Δ forest species	Δ eff. Shannon diversity
		[%]	
TMF to pasture	-72*	-98*	-84*
TMF to burned fallow	-76*	-96*	-78*
TMF to pine plantation	-62*	-94*	-76*
TMF to silvipasture	-49*	-92*	-69*

* p < 0.001. Significance of each transition was determined using Mann-Whitney-U tests

Acid Phosphatase as Indicator for Microbial Phosphorus-Limitation

In the mountain rainforest region of southern Ecuador, Homeier et al. [1] recently pointed out that ecosystem processes such as primary production of the mountain rainforest, are limited in phosphorus (P). This coincides with the low to medium P-status of the soils [2, 3]. Since up to 56% of total P is stored as organic P [3], the enzymatic release of P in forms available for plants and microbes is of importance. Phosphomonoesterases are enzymes that catalyze the hydrolysis of such monophosphates, releasing phosphate for plant and microbial uptake [4]. Along a natural forest-pasture-secondary succession-sequence we investigated in subproject B3 the extracellular enzyme activity of acid phosphatase (AP) (by MUF-substrate, method described in [5]) in mineral topsoil (0-5 cm) samples. Specific enzyme activities (extracellular enzyme activity normalized to a per µM microbial biomass carbon basis) are useful to characterize the microbial demand [6].

Microbial extracellular AP production was not similar in undisturbed and disturbed ecosystems (**Figure 24**). We found the highest specific activity of AP at the natural forest site (**Figure 24**), indicating a high microbial demand for P. This emphasized the relevance of the mineralization of organically bound P for ecosystem processes in the tropical mountain rainforest. The application of a multivariate linear regression model for AP indicated significant relationships to total soil nitrogen and dissolved organic carbon (DOC, $ra^2 = 0.84^{***}$). It can be concluded that microbial demand for P regulated the production of AP, provided that N and carbon (C) were available for enzyme production. The last-mentioned fact is important, since nutrient depletions (nitrogen, and DOC) due to land-use change, constrain the production of AP (total activity; data not shown) at the abandoned pasture and the shrubland site. In addition, these results highlight the susceptibility of ecosystem processes of the natural forest and the abandoned sites to nutrient inputs (particularly to nitrogen).

Alexander Tischer, Evgenia Blagodatskaya, Ute Hamer (Dresden University of Technology, Russian Academy of Sciences)
Hamer's new address: see rubric "People & Staff")

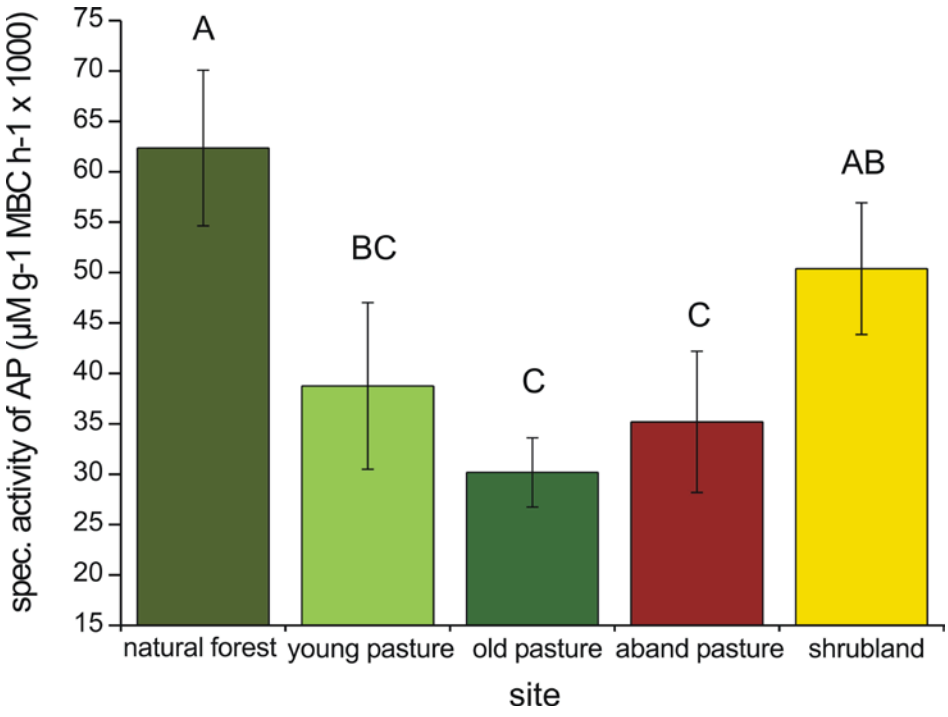


Figure 24: Specific enzyme activity of acid phosphatase (AP) of the mineral topsoil (0–5 cm). Letters indicate significant differences between means ($p < 0.05$; Tukey's-HSD test, $n = 6$). Graph: U. Hamer

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Figure 25: *Tabebuja chrysantha* grown for 6 month in the nursery after the different treatments described in the text. Photo: N. Urgiles & A. Schüßler

Mycorrhizal Fungi Shape Tree Performances in Nursery

Defined arbuscular mycorrhiza (AM) forming fungi native to Ecuador, isolated either from nursery grown tree seedlings used in Urgiles et al. [1] or from *Cedrela montana* rhizosphere soil from afforestation sites, and a well characterised model arbuscular mycorrhizal fungus (AMF) were used as individual inocula to study their impact on plant performance in the tree nursery. Eight AMF were produced and harvested in subproject B4 at the Ludwig-Maximilians-University Munich (Germany) to inoculated tree seedlings in the greenhouse at the Universidad Nacional Loja (Ecuador). Individual inocula consisted of *Diversispora* sp. Att1449-5, *Claroideoglomus etunicatum*-like Att1449-10, *Ambispora* sp. Att1449-12, *Acaulospora* sp. nov. Att1450-1, *Rhizophagus* sp. Att1451-8, *Archaeospora* sp. Att1456-7, *Scutellospora savannicola* Att1455-2 and *Rhizophagus irregularis* DAOM197198.

Five different treatments were applied to potential crop tree seedlings of *C. montana, Heliocarpus americanus and Tabebuia chrysantha* (**Figure 25**):

- CTRL (control, no inoculation with AMF or fertilization)
- +HF (high-fertilization)
- -AMF+LF (inoculation with heat-killed AMF, low fertilization)
- +AMF (inoculation with living AMF)
- +AMF+LF (inoculation with living AMF, low fertilization).

Sterilized standard nursery substrate (soil-sand mixture) was used. Seedlings were inoculated with 10 g individual inocula and/or fertilized with 0.25 g (low fertilization) or 0.75 g (high fertilization) Osmocote slow-release fertilizer.

After 6 months in the nursery height, root collar diameter (RCD), total leaf area, aboveground and belowgrond biomass and mycorrhization rates of the tree seedlings were measured. Statistical analysis of the growth data showed significantly different plant performances of the seedlings dependent of inocula, with up to >300% increased biomass production for plants inoculated with AM fungi.

Arthur Schüßler, Claudia Krüger & Narcisa Urgiles
(Ludwig-Maximilians-Universität München)

Reference

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From Seeds to Forests: Silvicultural Knowledge for Sustainable Management

The project of working group C1 was building-up silvicultural and ecological knowledge for sustainable management of different forest resources: natural and managed forests, as well as abandoned land. The activities considered three complementary research sections:

- management of forest reproductive material of native species;
- reforestation of different types of abandoned pastures with native species;
- management of natural forests and potential seed sources.

Optimum Time for Harvests - Reproductive Material of Native Species

Among other topics, the first section included the continuation and consolidation of perennial reproductive phenological studies of nine native tree species. **Figure 26** (next page) shows time series of flowering and fruiting for nine native species from January 2004 until August 2012 and the resulting monthly means, which provide valuable information for seed harvests. In addition, investigations on propagation of *Podocarpus* sp. by seeds, exploration of seed storage potentials and propagation of selected woody non timber forest product (NTFP)crops have been realized. Rhizotron experiments (see TMF Newsletter no. 17; doi: 10.5678/lcrs/for816.cit.1132) have been conducted to promote the understanding of biomass allocation, root development and competition between tree seedlings and grass.

Direct Reforestations - Restoration and Reforestation of Abandoned Areas

Moreover, initial pathways of natural succession and limiting factors for restoration of abandoned sites with native species have been defined. Pretreatments by fertilization or inoculation with mycorrhiza and the effects on seedling establishment and field performance were evaluated. The results have been published in the dissertation of Palomeque. The possibilities of direct seeding for reforestation of burned areas have been tested and seem to be species specific (see TMF Newsletter no. 17; doi: 10.5678/lcrs/for816.cit.1132 and dissertation of Ximena Palomeque [1]). The analysis of enrichment planting with native species in Pine stands showed promising results for nine native species and provide a valuable basis for the DFG-funded transfer project “Nuevos Bosques para Ecuador” (see “Transfer Projects” this Newsletter).

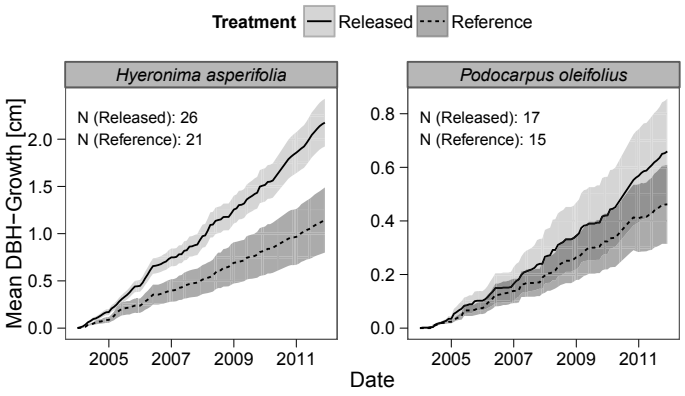


Figure 27: Growth reactions (diameter at breast hight, DBH) of individuals of the valuable tree species *H. asperifolia* and *P. oleifolius* to an improvement thinning experiment at the Reserva Biológica San Francisco (RBSF). Figure will be published in [2] with kind permission from Springer. Graphs: D. Kübler

Improvement Fellings - Natural Forest Management

The section of natural forest management also included several topics: the effects of improvement felling on the growth performance of selected trees have been observed for nine valuable tree species. Exemplary results for *Hyeronima asperifolia* and *Podocarpus oleifolius* are shown in **Figure 27**: both species gain diameter growth after the release from competitors. Nevertheless, other tree species reacted negatively upon the silvicultural treatment. The comprehensive repeated inventory of permanent plots allows for evaluation of stand dynamics. Moreover, this information has been used for species distribution modeling in order to provide more insight on relevant environmental factors for the spatial distribution of several species (see TMF Newsletter no. 16; doi: 10.5678/lcrs/for816.cit.1081).
Finally, the modeling of land-use scenarios for reforestation will be used for the assessment of alternatives for recovering abandoned areas in close cooperation with several other working groups.

Patrick Hildebrandt, Sven Günter, Ximena Palomeque, Daniel Kübler, Julio Mora, Johana Munoz, Omar Cabrera, Nikolay Aguirre, Michael Weber, Bernd Stimm & Reinhard Mosandl (Technische Universität München-Freising, CATIE, Costa Rica, Technical University of Loja, National University of Loja)

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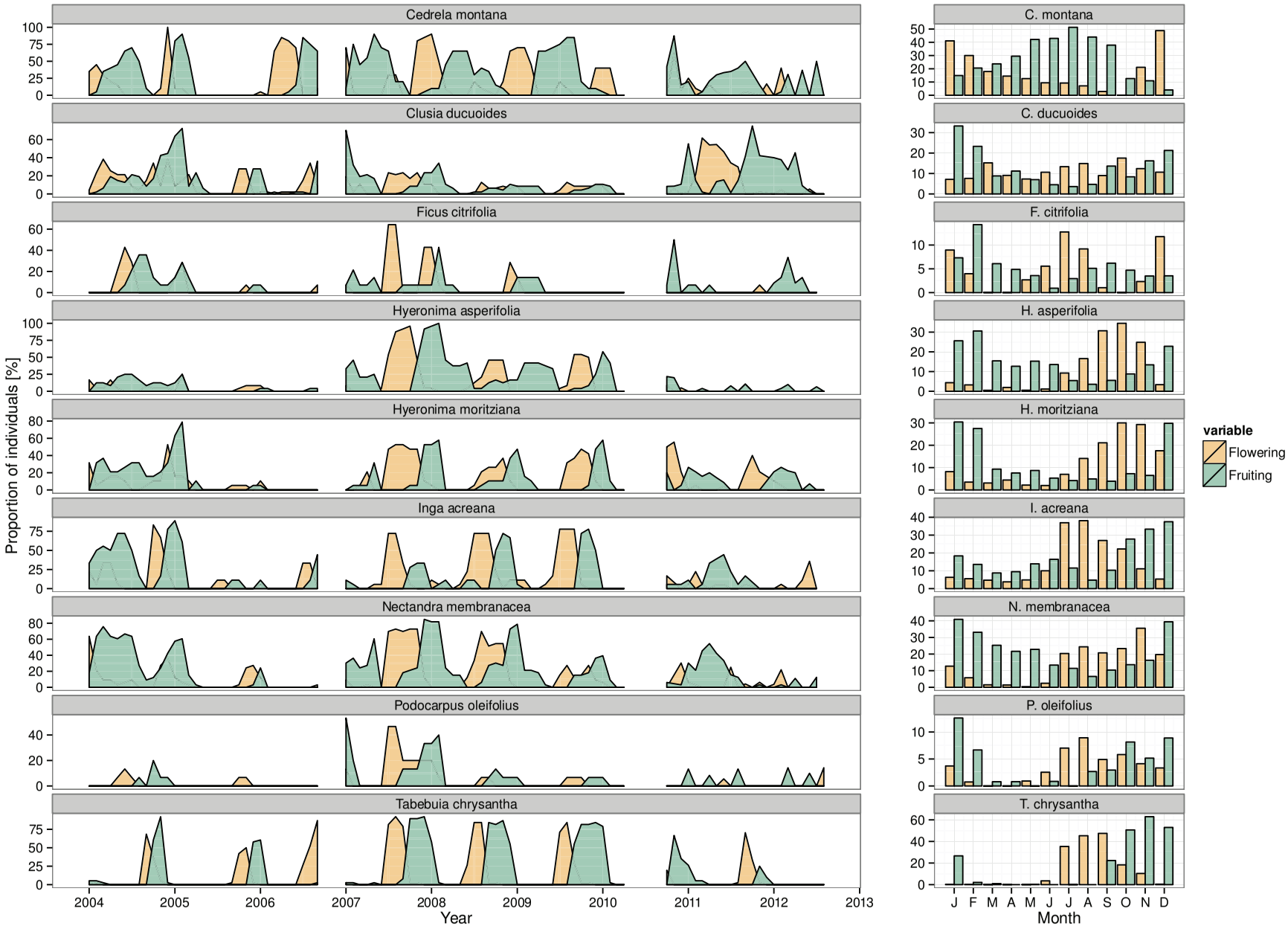


Figure 26: Time series of flowering and fruiting for the trees *C. montana, C. ducuoides, F. citrifolia, H. asperifolia, H. moritziana, I. acreana, N. membranacea, P. oleifolius, T. chrysantha* recorded from January 2004 until August 2012 (left) and shown as monthly means (right). Graphs: P. Hildebrandt

New Findings on Mycorrhizae in the Tropical Mountain Rain Forest

Mycorrhizae of trees, orchids and ericads were sampled from pristine forest and open habitats and studied by use of microscopy and molecular tools. Results (summarized in **Table 3**) show the omnipresence of mycorrhizal fungi associated in high numbers of operational taxonomic units (OTUs), most of them new to science. New mycorrhizal associations differing structurally and/or by their mycobionts from the known types were found for the Andean Clade of Ericaceae (cavendishioid mycorrhiza), in orchid mycorrhizae (association with Atractiellomycetes, Pucciniomycotina), on Nyctaginaceae (special ECM structures), *Graffenrieda emarginata* (Melastomataceae, arbuscular mycorrhiza (AM) and ECM simultaneously), and new AM fungi structures described for *Alzatea verticillata* (Alzateaceae, **Figure 28**).

Mycobiont communities of Glomeromycota shared many OTUs among forest and abandoned pastures and the mycobiont communities of orchids were found quite similar among forest and landslide area and among epiphytic and terrestrial habitats.

However, Sebacinales were not shared among Orchidaceae and Ericaceae. Links among plants and fungi were found to be organized in non random bipartite networks. These results make clear that mycorrhizae are an important stabilizing component of the tropical mountain rain forest ecosystem. The results of your work in subproject C2 were summarized in 22 publications (see below).

Ingrid Kottke, Ingeborg Haug, Juan Pablo Suarez & Sabrina Setaro (University of Tübingen, Technical University of Loja, Forest University in Winston-Salem)

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19 of the 22 publications resulting from our research can be retrieved via: http://www.tropicalmountainforest.org/publications.do?search=Kottke or http://www.mycorrhiza-research.de/Pages/02Publications.html.

The three other papers not listed in the sources above are:

Kottke I, Setaro S, Haug I, Herrera P, Cruz D, Fries A, Gawlik J, Homeier J, Werner F, Gerique A, Suárez JP (accepted for publication) Mycorrhiza Networks Promote Biodiversity and Stabilize the Tropical Mountain Rain Forest Ecosystem – Perspectives for Understanding Complex Communities. In: Bendix J, Beck E, Bräuning A, Makeschin F, Mosandl R, Scheu S and Wilcke W (eds): *Ecosystem Services, Biodiversity and Environmental Change in a Tropical Mountain Ecosystem of South Ecuador,* Ecological Studies, Chapter 14, Springer, Heidelberg

Setaro S, Kron K (2011) Neotropical and North American Vaccinioideae (Ericaceae) share their mycorrhizal Sebacinales - an indication for concerted migration? *PLoS Currents*: Tree of Life. 2011 Available at: http://currents.plos.org/treeoflife/article/neotropical-and-north-american-2cqluq6cch6gh-5/

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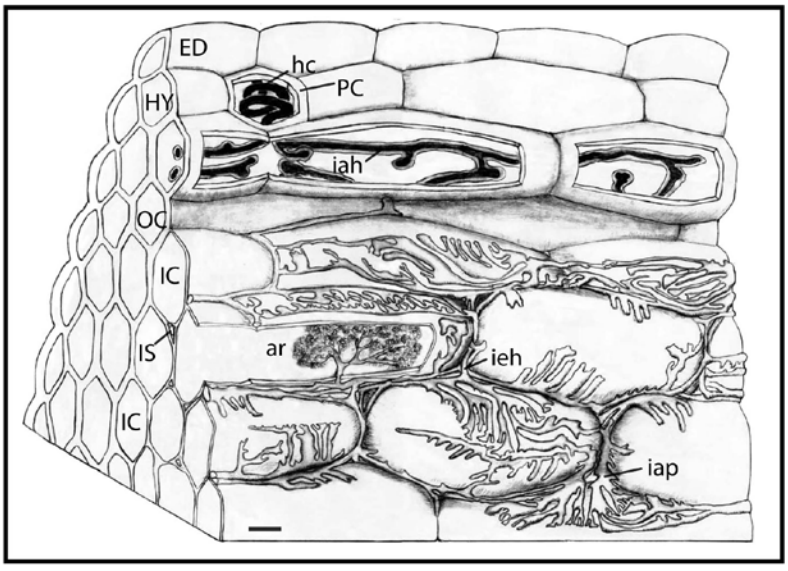
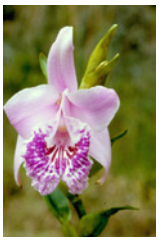
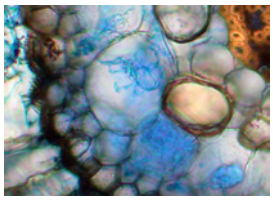
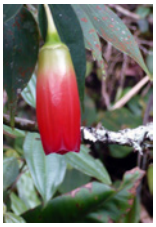


Figure 28: One of the decribed mycorrhiza forms discovered in the tropical mountain rainforest of Southern Ecuador: The block diagram shows an arbuscular mycorrhiza with intercellular appressoria (iap), reminiscent of Hartig net structures of ectomycorhizas, arbuscules (ar) in inner cortical cells, intercellular hyphae (ieh) in intercellular space (IC), intracellular hyphae (iah) in the outer cortical cells (OC), hyphal coils (hc) in passage cells (PC) of hypodermis (HY), (ED) epidermis of root, formed on *Alzatea verticillata* by unidentified Glomeromycota in the cloud forest (redrawn from [1] with kind permission from Springer). Image: Adela Beck

Table 3 Plant groups and identified mycorrhizas in subproject C2

Investigated plant groups	Type of mycorrhiza	Plants investigated	Fungi involved, () number of OTUs or species
Trees 	Arbuscular mycorrhiza 	*115 tree species, about 600 individuals surveyed; *fungal OTUs from 31 tree species	Glomeromycota (120 OTUs at 99% similarity of SSU)
Nyctaginaceae 	Ectomycorrhiza 	Nyctaginaceae (1 *Guapira* sp.,2 *Neea* sp.), rare South America forest trees *Graffenrieda emarginata* (Melastomataceae)	*Russula* (1), *Lactarius* (1), *Thelephora* (4), Ascomycete (1) *Graffenrieda emarginata*: **Rhizoscyphus* (1)
Orchidaceae 	Orchid mycorrhiza 	Orchidaceae, subfamily Epidendroideae (63 species, 194 individuals), epiphytic and terrestrial	Tulasnellales (33 OTUs at 3% similarity of ITS), Sebacinales (12 OTUs at 3% similarity of ITS) *Atractiellomycetes (3 clades)
Ericaceae 	Cavendishioid mycorrhiza 	Terrestrial and hemiepiphytic Ericaceae, mostly from Andean Clade, 12 species, 39 individuals	*Sebacinales (31 OTUs at 3% similarity of ITS)

* indicates new to science

Human Ecological Dimensions in Sustainable Utilization and Conservation Tropical Mountain Forests

In previous projects of the DFG Research Units (RU) 402 and 816 the human ecological approach towards sustainability of eco- and livelihood systems (**Figure 29**) has been developed and applied in tropical mountain forest areas of southern Ecuador [1]. For the development of sustainable land use, rural livelihoods and conservation options of biodiversity hot spot areas, the analysis of four human ecological parameters (topics) has proved to be indispensable. Selected results of these research topics of subproject C4 explored in indigenous Shuar and Saraguro as well as local *mestizo* communities of southern Ecuador are summarized as follows:

To analyse the landscape transformation process, land-use change detection was undertaken in sample communities of El Tibio and Los Guabos (Saraguros and *mestizos*, 1969-2001, cf. [2]), the watershed area of Tambo Blanco (Saraguros and *mestizos*, 1976-2001, cf. [3]) and the Alto Nangaritza valley (Shuar, Saraguros and *mestizos*, 1986-2010, cf. [4, 5]. In all study sites (**Table 4**, next

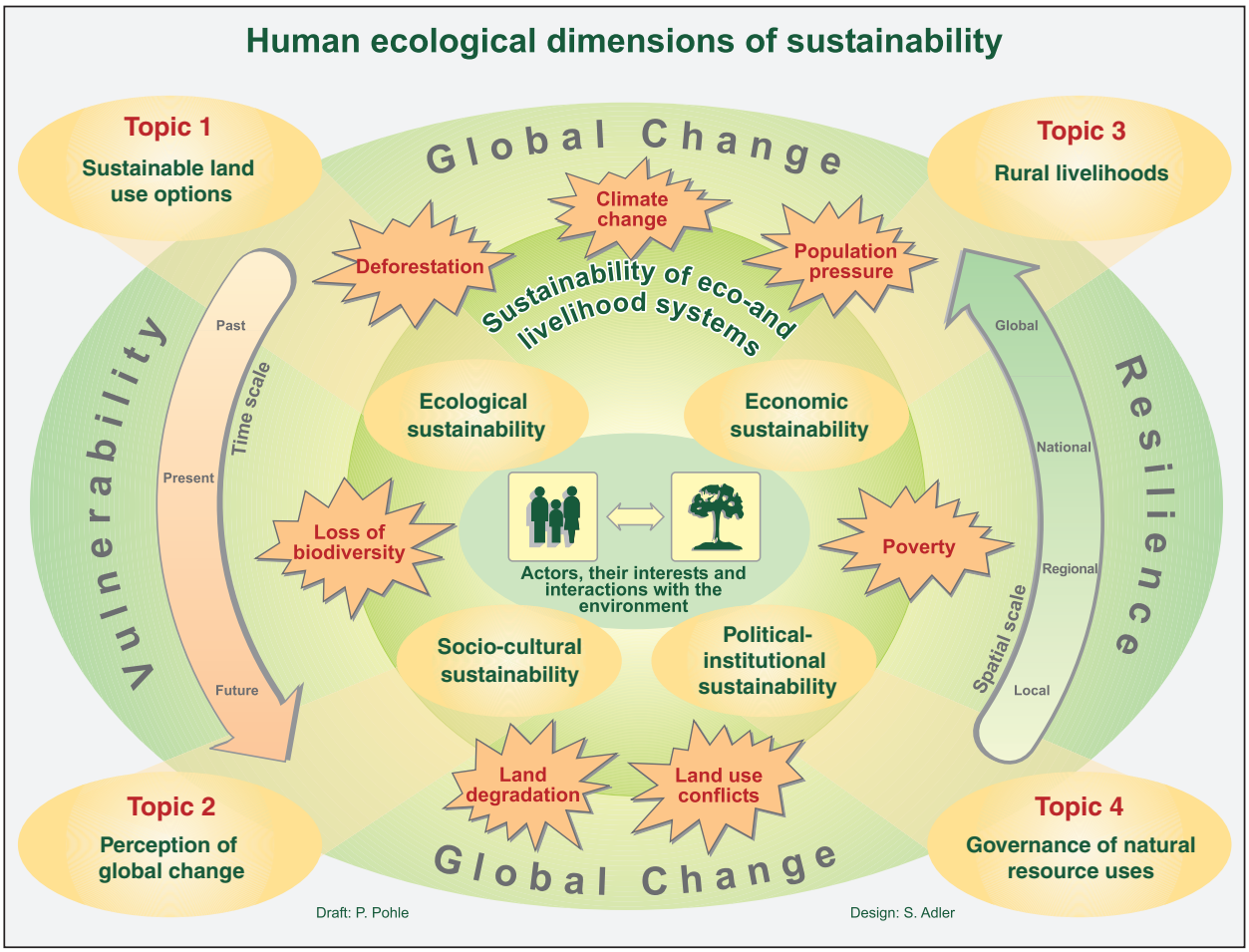


Figure 29: The human ecological approach towards sustainability of eco- and livelihood systems. Image: P. Pohle

page) a substantial loss of forest in favor of pasture has taken place reducing the forest coverage even below 40% (Alto Nangaritza). Today, the frontier of agrarian colonization is moving in both directions, from low to high altitude towards the Páramo (Tambo Blanco) as well as in the reverse direction towards the Oriente (Alto Nangaritza), which is currently most pronounced (**Table 4**). In areas, which are in a more advanced stage of the landscape transformation process (Los Guabos), forest clearing occurs side by side with land abandonment, the latter may give new possibilities for reforestation and rehabilitation measures [6].

In the research area cattle ranching represents the main threat to forests and biodiversity. Thus, alternative activities for securing rural livelihoods are needed in order to reduce the pressure on the forests. To identify more sustainable land use options the use of non-timber forest products (NTFPs) and local agrobiodiversity of home gardens was investigated for additional income generation (cf. [1, 7]). Small in size, high in productivity and biodiversity, the home gardens of the three ethnic groups can be seen as an optimal form of exploitation in the region of tropical mountain forests. As the ethnobotanical and agrogeographical surveys indicate, there is a

Table 4: Change detection of tropical mountain forest cover in research areas of South Ecuador

Research area	Forest cover change (in %)		
El Tibio (1770 m a.s.l.)[1]	1969: forest cover 68%	2001: forest cover 42%	- 26%
Los Guabos (1900 m a.s.l.)[1]	1969: forest cover 58%	2001: forest cover 49%	- 9%
Tambo Blanco (1800-3200 m a.s.l.)[2]	1976: forest cover 67%	2001: forest cover 52%	- 15%
Alto Nangaritza (900-1200 m a.s.l.)[3]	1986: forest cover 87%	2010: forest cover 38%	- 49%

Sources: [1][2]; [2][3]; [3][4, 5]

Table 5: Potential plant species for market-oriented production in home gardens (after [1], modified)

Family	Species	Use (plant parts used)
Amaranthaceae	*Alternanthera porrigens*	Medicine, tea (leaves)
Araceae	*Zantedeschia aethiopica*	Ornamental
Buddlejaceae	*Buddleja americana*	Medicine (leaves)
Cannaceae	*Canna indica*	Food (leaves, tubers)
Hydrangeaceae	*Hydrangea macrophylla*	Ornamental
Iridaceae	*Gladiolus sp.*	Ornamental
Juglandaceae	*Juglans neotropica*	Food (seeds), medicine (leaves)
Liliaceae	*Lilium cf. longiflorum*	Ornamental
Mimosaceae	*Inga spp.*	Food (fruits)
Musaceae	*Musa spp.*	Food (fruits)
Passifloraceae	*Passiflora spp.*	Food, juices (fruits)
Piperaceae	*Piper aduncum*	Teas (leaves)
Rosaceae	*Fragaria spp. , Rubus spp.*	Food (fruits)
Sapotaceae	*Pouteria lucuma*	Food (fruits)
Solanaceae	*Physalis cf. Peruviana*	Food (fruits)

potential for the production of plant species in demand (e.g. medicinal herbs, fruits, vegetables, and ornamental flowers) for regional markets in home gardens (**Table 5**).

From a conservation perspective, the challenge is to stop deforestation and to reduce the amount of cleared land going to pasture, while preserving or increasing farm incomes. **Figure 30** delineates a draft of an alternative agroforestry system that could be implemented in the *mestizo* or Saraguro land-use system in order to achieve a more diversified production.

Research also showed that land use among Saraguros and *mestizos* differ clearly from those of the Shuar [1, 7, 8]. As typical forest dwellers the Shuar



Figure 30: Actual land use and draft of an alternative agroforestry system. **Left**: Actual land use in the upper Zamora valley: Pasture land (a), including abandoned or over-exploited paddocks (b), and forest patches (c) dominate the landscape. Around the housings home gardens (d) and corn fields (e) are cultivated for subsistence. **Right**: A proposal for a more sustainable land use: The existing system is completed with plantations of (exotic and native) trees (f, g), improved pasture management including leguminous trees and living fences (h), the use of NTFPs from restored forest areas (i), and the cultivation of new agricultural products (j) at the expense of pasture and/or fallowed land [7]. Graph: A. Gerique

Table 6: Proposed alternative plant use in Shuar communities in the Alto Nangaritza Valley

Use	Plant species
Reforestation with commercial species within the community forests	*Terminalia amazonia, Platymiscium pinnatum, Cedrelinga cateniformes*
Reforestation of pastures	*Trema micrantha, Inga* spp. [9], *Oenocarpus bataua, Bactris gasipaes* [10], *Cordia alliodora, Cedrela odorata* [11, 12]
Improved production in forest gardens, diversification of the production	*Theobroma cacao, Coffea arabica, Solanum quitoense*
Commercialization of non-timber forest products (previous market survey and external aid for certification needed)	*Caryodendron orinocense, Carludovica palmata, Croton* sp., *Uncaria tomentosa, Pouroma* sp.

practice subsistence slash and burn agriculture, besides gathering, fishing and hunting. Due to recent agrarian *mestizo* and Saraguro colonization in the Alto Nangaritza high stress is put on the Shuar's traditional forest and biodiversity conserving resource use system, especially by reducing available land for shifting cultivation, by overexploitation of river food resources and game but also by the contamination of rivers due to increasing mining activities [4]. Therefore, a main goal in terms of conservation of lower tropical mountain forests should be the protection of traditional Shuar territory and the recognition of the environmental services forest-dependent peoples provide. Besides, the following alternative plant uses may be proposed for Shuar communities (**Table 6**).

In any case, alternative land use options should incorporate existing sustainable practices, should be based on local knowledge and experience and should take ethno-cultural preferences into account.

Perdita Pohle, Andrés Gerique & María Fernanda López
(Friedrich-Alexander Universität Erlangen-Nürnberg)

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Landscape History of the Podocarpus National Park Region

To elucidate the landscape history of the Podocarpus National Park (PNP) and the surrounding areas, we analyzed several records of peat bogs, lakes and soil deposits using palynological methods, during the last eight years (**Figure 31**). We also installed several pollen traps to collect the modern pollen rain on an altitudinal gradient to analyse the relationship between modern pollen rain and Andean montane forest vegetation. Our palaeoecological studies focused on environmental changes including vegetation, biodiversity, fire, climate and human impact of the mountain rainforest and páramo ecosystems since the late Pleistocene during the last about 20,000 years.

Modern Pollen Rain and Present Vegetation/ Plant Diversity Patterns

A main task of our research in subproject D1 was to enhance the knowledge about the relationship between modern pollen rain and Andean montane forest vegetation. This information is essential for a more quantitative view on pollen diversity and distribution patterns that can be used for accurate palaeoecological reconstructions. We collected data of annual pollen rain in the forests of Bombuscaro (premontane forest), San Francisco (lower montane forest) and Cajanuma (upper montane forest) by the means of pollen traps for a period of three years, using an extended sampling design (TMF Newsletter no. 12; doi: 10.5678/lcrs/for816.cit.999).

Generally, the modern pollen rain reflects vegetation patterns well, and all three vegetation types have distinguishable and characterizing pollen spectra that can be used for a differentiation of the forest types when analyzing a palynological record.

With respect to diversity and contrasting to tree species richness (which was highest at lower montane forest and premontane forest-sites) pollen type richness is highest on sites of the upper montane forest. This is mostly due to the fact that single pollen taxa, such as Moraceae/Urticaceae and Melastomataceae, produce large quantities of pollen which mask the samples at the premontane and lower montane forest sites. This leads to high over-representation of these taxa in the pollen record and to the under-representation of less productive plant taxa, such as Licania and Sapotaceae in the premontane forest, *Alzatea, Gordonia* and *Tabebuia* in the lower montane forest and - to a lesser extent - Celastraceae, Lauraceae and *Symplocos* in the upper montane forest.



Figure 31: To explore former vegetation in the research area lake sediments were extracted with a Livingstone piston-corer. Photo: Corinna Brunschön

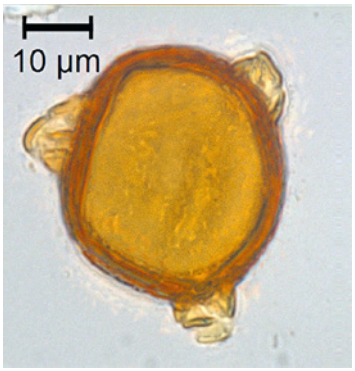


Figure 32: *Polylepis* pollen grain under the light microscope. Image: N. Jantz

Interannual variation in pollen rain spectra is evident, but not higher than spatial variation within one forest type. We recommend that in species-diverse tropical forest ecosystems, modern pollen rain data should not rely on single samples but include a wider spatial and temporal frame to account for the variability of pollen spectra within one forest type.

Reconstruction of Past Vegetation, Climate and Fire Dynamics since the late Pleistocene

Over longer time periods, observed vegetation changes are not always solely caused by human impact and disturbance regimes. Especially during times with less or without human activity, climatic conditions controlled vegetation development. In the Andean depression region, including the PNP, precipitation and temperature may be much more important for the vegetation development.

During the late Pleistocene (20,000−11,500 cal yr BP) páramo vegetation with high occurrence of *Plantago rigida* dominated the pollen assemblages of Cerro Toledo and El Tiro records reflecting cold and wet conditions. Andean montane forest likely occupied markedly lower elevations than today [1, 2]. However, the pollen record of Cocha Caranga, at 2710 m a.s.l. suggests that between ca. 14,500 to 9700 cal yr BP the upper montane forest vegetation expanded; indicating increased temperatures [3]. Due to rising temperatures since late glacial times, deglaciation concluded with the beginning of the Holocene, and Andean montane forest shifted gradually upslope, thus repressing páramo vegetation. A clear directional change towards sub-páramo and upper montane forest communities is visible at the end of the Pleistocene after about 11,800 cal yr BP at the El Tiro record [2].

Also, the El Tiro record shows that, from ca. 11,200 to 8900 cal yr BP, Andean montane forest taxa, as well as ferns became frequent, indicating moist conditions [2]. However, the Laguna Rabadilla de Vaca site (central PNP) was still covered with herb páramo during the beginning of the Holocene, thus suggesting relatively cold and wet conditions [4]. At the El Tiro site, between ca. 8900 to 3300 cal yr BP, upper montane forest was predominant with *Hedyosmum* and Podocarpaceae; and occurred at slightly higher elevations than at present, reflecting warmer climatic conditions [2]. Moreover, results from Tres Lagunas (Quimsacocha páramo, located 30 km west of Cuenca) indicate that climate was relatively dry and possibly warmer than at present during the period from 7600 to ca. 2500 cal yr BP, since taxa of dry páramo vegetation (e.g. Fabaceae, Lamiaceae, Poaceae) prevail. The sediment itself also points to a relatively dry environment [5]. The dry phase lasted from ca. 8000 o ca 3900 cal. yr BP.

During the late Holocene the Cocha Caranga record shows that after ca. 1300 cal yr BP the vegetation is characterised by open grassy areas with forest patches of mainly *Weinmannia*, Melastomataceae, *Myrsine, Clethra* and Moraceae/Urticaceae [3]. The El Tiro record shows a decrease of upper montane rainforest and an increase of Melastomataceae, thus suggesting relatively stable subpáramo vegetation from ca. 3300 cal yr BP [2]. From the Quimsacocha páramo is shown that after ca. 2240 cal yr BP, vegetation changes suggest a moister and cooler environment, as *Plantago rigida* as well as R*anunculus* and *Hypericum* become very abundant [5].

Fires, most likely of anthropogenic origin, were recorded from early to late Holocene times. They occurred at the study sites during different times and with various intensities. Past fires influenced local vegetation composition as well as páramo expansion. However, past fires were rarely responsible for extensive forest destruction. Nevertheless, certain taxa, e.g. *Weinmannia* or *Myrica*, were seriously affected by fire.

Drivers of Past Changes in *Polylepis* Populations from Southern Ecuador

Ecuador is considered a centre of diversification of *Polylepis* (**Figure32**) after Peru and Bolivia. The genus *Polylepis* is represented by eight species distributed throughout the Ecuadorian Andes, but is missing in the PNP region of the Andean Depression. The Lagunas Natosas forest (LNB) record (located at Jimbura region) south of the PNP provides the first evidence of the development of *Polylepis* forest in the southern part of the Andean Depression, reflecting warmer and drier climatic conditions during the early and mid-Holocene. Moreover, during the late Holocene humid and cooler conditions and frequent fires could be considered the factors that most likely influenced the almost total absence of *Polylepis*. Record from the LNB reveals high fire frequencies for late Holocene, which limited the *Polylepis* expansion [6]. The not yet published record from El Cristal, located ca. 30 km north of the PNP at 2026 m a.s.l., also reveals the evidence of *Polylepis* forest at low elevations in the northern part of the Andean Depression. Nevertheless, af-

ter ca. 3500 cal. yr BP *Polylepis* forest decreased; probably due to higher fire frequency as it is a fire sensitive tree (**Figure 33**).

Andrea Villota, Nele Jantz & Hermann Behling (University of Göttingen)

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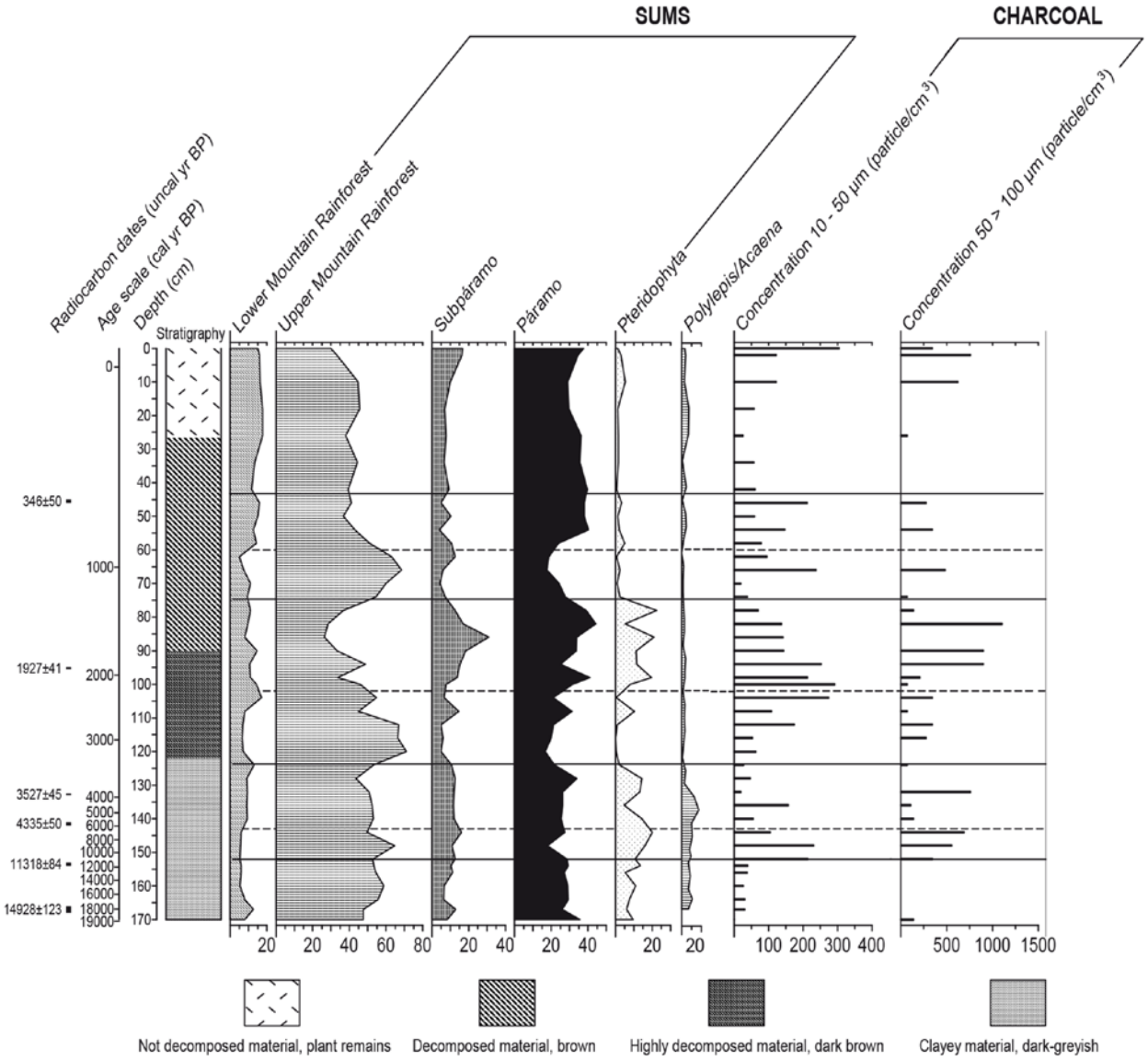


Figure 33: Summary pollen percentage diagram of the El Cristal (EC) core showing radiocarbon dates (uncal yr BP), age scale (cal yr BP), vegetation groups, Polylepis and charcoal concentration. Image: A, Villota

Dendroecological Analyses of Tree Growth

Wood Anatomical Evidence of Annual Growth Rings

Dendrometer measurements and wood anatomical investigations in subproject D2 have revealed that the dynamics of cambial wood formation and the formation of annual growth ring boundaries in the tropical mountain rainforest of RBSF is strongly species specific. Deciduous tree species like e.g. *Tabebuia* spp. [1] often form clear ring boundaries during the leafless period. Detailed wood anatomical investigation, however, reveal that even some evergreen broadleaved and coniferous species are forming annual ring boundaries, enabling the application of standard dendrochronological techniques. **Figure 34** shows macroscopic and microscopic images of *Alchornea lojaensis* and *Podocarpus oleifolius* depicting tangential bands of flattened and thickened libriform fibres or tracheids marking the growth ring boundary.

Nutrient Availability Alters Water Budget of Rainforest Trees

Dendrometer measurements have revealed species-specific growth reactions to nitrogen fertilization [2]. *Graffenrieda emarginata* is the only species showing better growth of control trees than fertilized trees. A detailed look at the daily amplitudes of stem diameter variations reveals that changes in the nutrient status influence the trees' water status (measured as daily amplitude of stem diameter variations) and their reaction to drought stress (measured as vapor pressure deficit of the atmosphere, **Figure 35**): For *Prunus* and *Alchornea*, fertilized and non-fertilized trees show statistically weakly significant or non-significant differences in term of drought reaction. In case of *Podocarpus*, the fertilized tree showed a stronger reaction to drought, whereas for

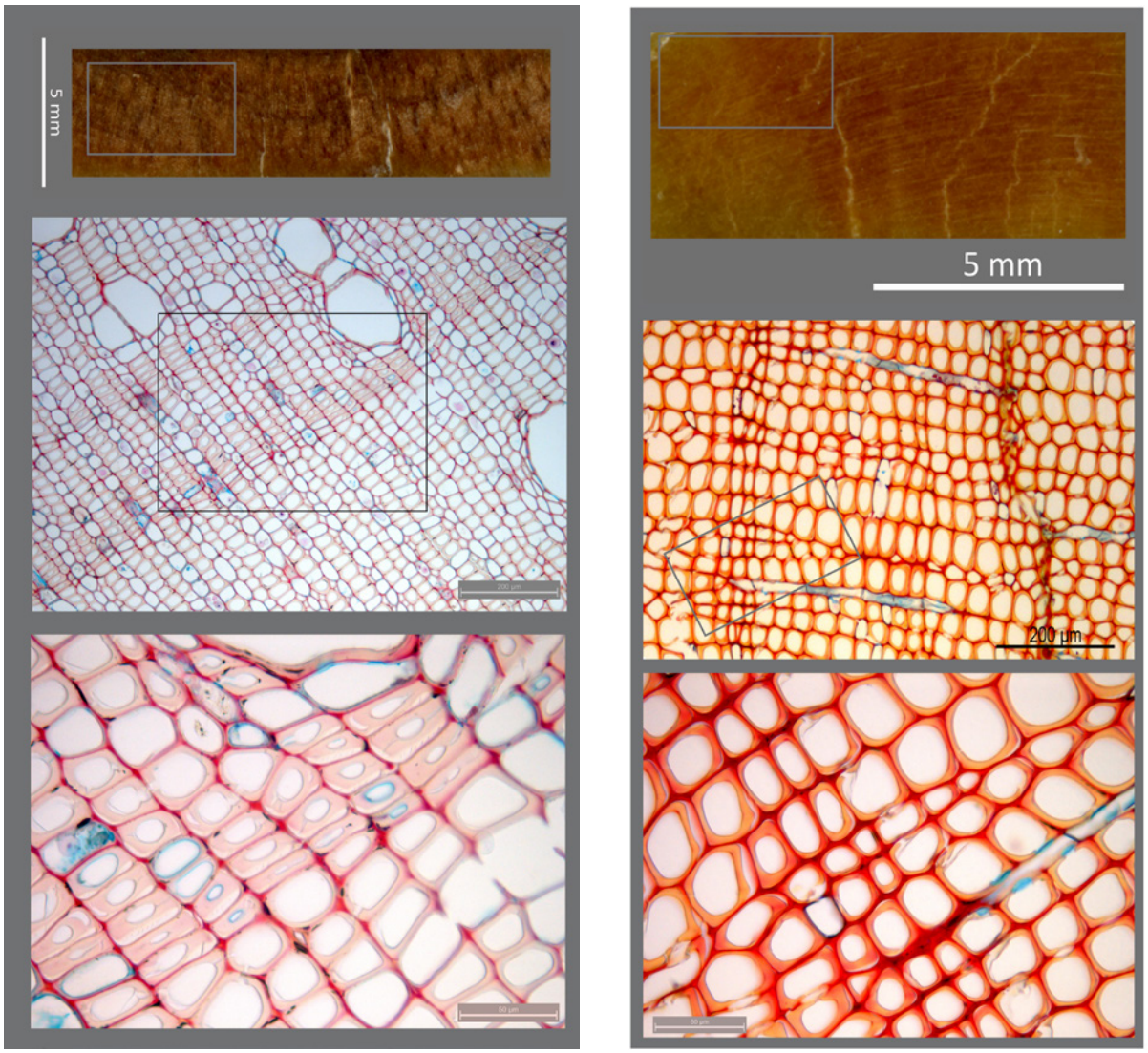


Figure 34: Wood anatomy and growth ring formation in *Alchornea lojaensis* (Euphorbiaceae, **left**) and *Podocarpus oleifolius* (Podocarpaceae, **right**). Images: S. Spannl

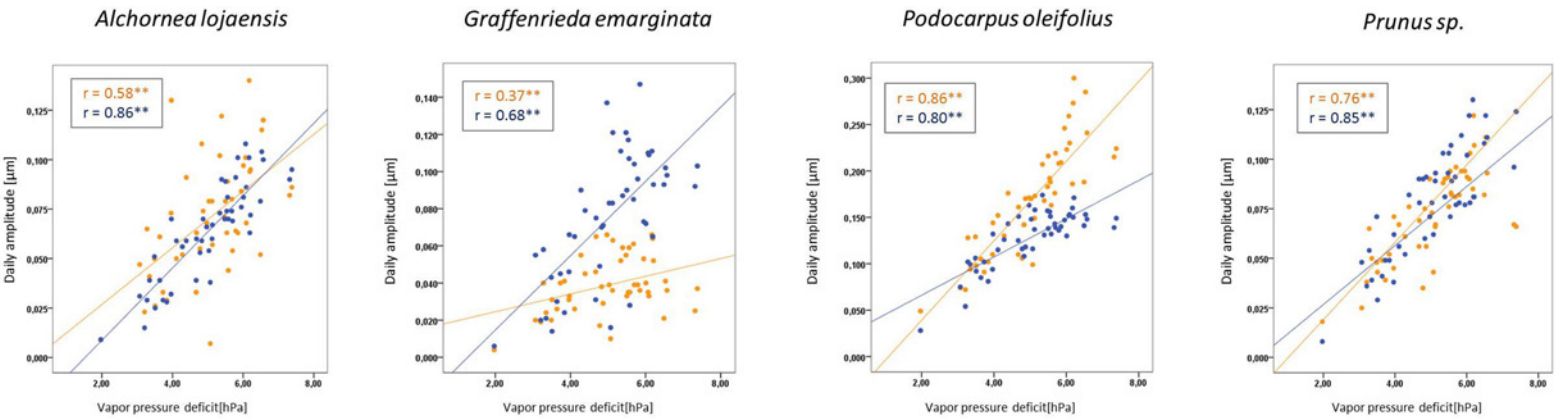


Figure 35: Correlations between daily stem diameter variations of four tree species and atmospheric vapour pressure deficit. Blue: control trees; orange: fertilized trees. Asterisks mark significant correlations ($p < 0.01$). Graph: S. Spannl

Graffenrieda, the fertilized tree was less susceptive to vapor pressure deficit. These findings indicate that a further accumulation of nutrients deposited in the tropical mountain rainforest via long-distance wind transport from the Amazone region or from local sources may alter the competitive conditions of tree species in the forest and may lead to changes in the species composition of the forest.

Stable Oxygen Isotope Variations in *Cedrela montana*

The establishment of a tree ring-width chronology of *Cedrela montana* [3] from Reserva Biológica San Francisco (RBSF) is now complemented by stable oxygen isotope measurements in wood cellulose (**Figure 36**). The inter-annual $\delta^{18}O$ variations of different trees are highly correlated and show stronger common signals between trees than ring width or $\delta^{13}C$. This offers a high potential for the reconstruction of climatic forcing factors related to the hydrological cycle. Presently, the length of the *Cedrela* isotope chronology is extended further back until A.D. 1880 which will enable the reconstruction of former moisture conditions at San Francisco. Ongoing research including other tree species shall reveal the environmental signal contained in the stable isotope signals.

Achim Bräuning, Franziska Volland, Susanne Spannl, Darwin Pucha, Oswaldo Ganzhi & Hector Maza
(Friedrich-Alexander Universität Erlangen-Nürnberg)

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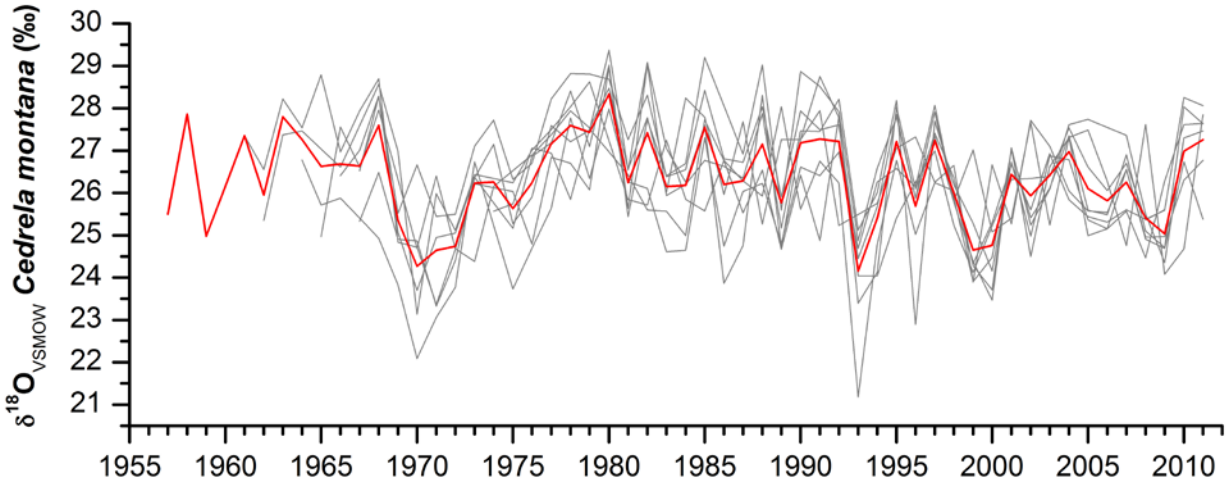


Figure 36: Interannual variations of stable oxygen ($\delta^{18}O$) isotopes in the wood cellulose of *Cedrela montana* (Meliaceae). Grey curves show isotope variations of individual trees, red curve shows the mean. Graph: F. Volland

Impacts of Environmental Change on Climate and Ecosystem

Important progress was made with respect to the overall aim of subproject D3, the observation and analysis of current dynamics and processes of climate-ecological interaction and the potential future development.

The initial phase saw the installation of new instruments and methods, which resulted in new data products and important conclusions.

The calibration method for the Local Area Weather Radar (LAWR) was implemented as a semi-automatic processing chain, enabling the generation of high-resolution precipitation maps (500 x 500 m) each 5 minutes within a range of 60 km radius [1]. By adapting this processing chain to the refined data output from the radar, local maps down to 100 m resolution can now be generated. This allows analyzing local phenomena in the San Francisco valley. An example is given in **Figure 37**, where the unknown feature of negative altitudinal gradients of rainfall can be observed under the influence of an anomalous zonal circulation.

In general, however, vertical precipitation gradients are strongly positive in the area of the Reserva Biológica San Francisco (RBSF). Interestingly, no upper limit for this gradient could be found, which is in contrast to findings from other mountain areas in the world [2].

A strong relation between local climate and land cover could be recognized, by combining interpolated station data with ancillary data from land cover classifications. Local air humidity strongly depends on the type and density of the vegetation cover, showing more extreme values above pasture sites and the buffering capabilities of the natural forest cover [3].

Furthermore, based on the application of the numerical grid box model Advanced Regional Prediction System a new nocturnal cloud formation mechanism affecting the precipitation regime in the RBSF area was identified [4, 5, 6].

The Impact of future environmental change was addressed by different means. The increasing emission of anthropogenic air pollutants certainly will affect the local deposition of atmospheric matter

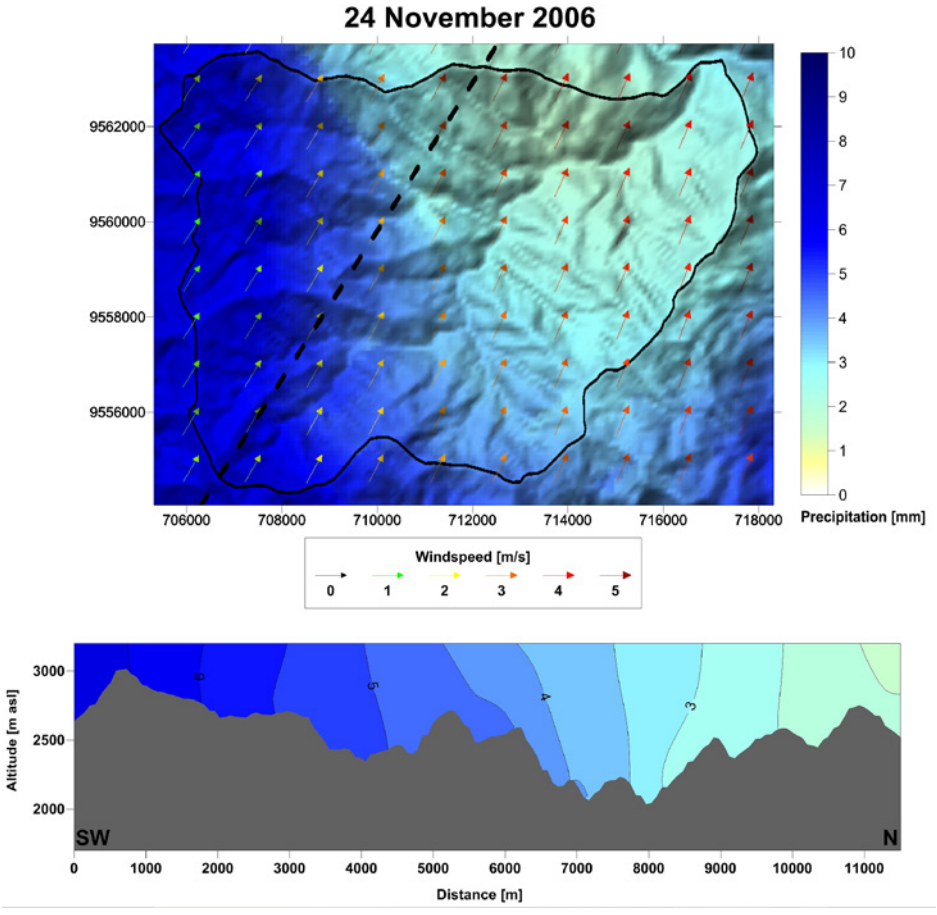


Figure 37: Precipitation and general wind vectors at the 24th November 2006 and the respective cross section of precipitation gradients. Graph: R. Rollenbeck

in the RBSF. The current situation already shows episodic peak emissions, which could be traced back to distinct sources by using new emission inventories, satellite observations and the extended analysis-software EmissTrajekt [2, 7]. By applying the known transport mechanisms to the projected development of future emissions as given by the "Special report on emission scenarios" published by the IPCC, two potential developments of the local impact on nutrient deposition were deduced (see **Figure 38**).

A precondition for regional future climate projections is a regional climate model properly adjusted to the study area. Therefore, the Weather Research and Forecasting (WRF) model was tested and evaluated for tropical South America with special focus on the highlands of southern Ecuador.

WRF was also applied within the study regarding anomalous rainfall patterns in the traditional El Niño region in South Ecuador [8]. A rapid change in sea surface temperature in the Niño 1+2 region during the La Niña event 2008 (Nino 3.4 region) resulted in devastating rainfalls and floods in the south Ecuadorian highlands. It was due to natural variability or represented a signal of climate change.

Rütger Rollenbeck, Katja Trachte & Jörg Bendix
(Philipps University Marburg)

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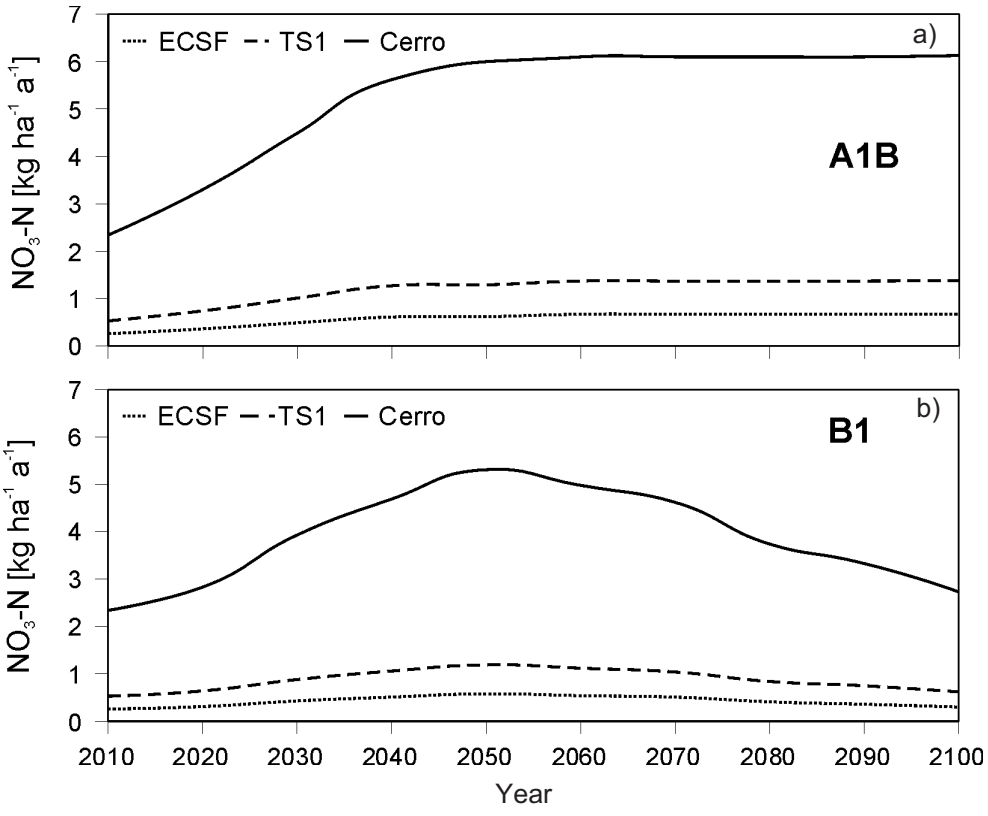


Figure 38: Local deposition scenario of NO_3-N according to IPCC special report emission scenarios (SRES) A1B (a) and B1 (b) for three different altitudes in the San Francisco valley (ECSF 1,960 m a.s.l.; TS1 2,660 m a.s.l.; Cerro del Consuelo: 3,180 m a.s.l.). Scenario A1B is the most likely one with its higher underlying consumption of fossil fuels and more intensive land-use changes which will cause quantitatively higher future nitrogen depositions. The more optimistic B1 scenario assumes an accelerated change to an energy-saving service society and consequently generates lower depositions, particularly after 2050. Both scenarios are reaching peak depositions between 2040 – 2050. Figure will be published in [9] with kind permission from Springer. Graph: R. Rollenbeck

Catchment Scale Hydro-Biogeochemical Fluxes and Aquatic Diversity

Within the past 6 years the team of subproject D4 covered many water related aspects at a catchment scale in the Rio San Francisco area. Two Ecuadorian National Secretariat for Higher Education, Science and Technology (SENESCYT) projects are currently complementing our ongoing research. As part of a SENESCYT scholarship starting in summer 2012 held by M.Sc. Alica Correa (see TMF Newsletter no. 17, page 32, doi: 10.5678/lcrs/for816.cit.1132) at the University of Cuenca we extended our research efforts towards the Yanuncay and Zhurucay catchments in the páramo areas surrounding Cuenca. The second project is located at the Technical University of Loja (UTPL) and focuses on aquatic diversity in particular on macroinvertebrate and is worked on by Ing. Carlos Iñiguez since 2011 (see TMF Newsletter no. 11, page 14, doi: 10.5678/lcrs/for816.cit.1132).

Since 2010 we intensified our previously accomplished sampling procedure and established a high frequency geochemical measurement station at the main outlet of the Rio San Francisco. This station records discharge, sediment fluxes and nitrate concentration in a 15 minutes resolution. These data will be used as validation and calibration datasets for a series of process orientated hydrological modeling approaches. To supplement these approaches we started a number of additional field campaigns to gain initial parameters sets for our models and to investigate different aspects of the hydro-geochemical system to improve our system understanding.

Stable Water Isotopes as a Process Tracer

Apart from long-term measurements at the catchment's outlet we conducted subcatchments scale snapshot type sampling of stream solutes and stream water isotopes in combination with automatic water level recording to get a better understanding of land use change impact on water quantity and quality. In field campaigns we investigated landscape specific patterns on the generation of subsurface flow using stable isotopes in soil water collected via capillary wick samplers. Stable water isotopes were also sampled in incoming precipitation and throughfall collected at various altitudes. Knowing and mimicking the processes which alter the isotopic signature of water within our models (like rainout or evaporation) allows us to gain a deeper understanding of and verify the hydrological process at hand.

The findings presented in **Figure 39** for example hind at a δ^2H elevation gradient of rainfall as well as a significant temporal dependency. The latter can be linked to prevailing weather conditions and the origin of air masses as was shown by [1].

How Long Does Water Need to Leave the Catchment?

Stable isotope measurements in stream water were directly incorporated into a lumped modeling approach to calculate the Mean Transit Time, i.e. the average time a raindrop needs from touching the ground till it leaves the catchment through the outlet. A characteristic transit time distribution can be applied depending on the expected behavior of the flow through the catchment. The more common transit time distributions are: the Exponential, the Piston Flow and the Dispersion models. The Exponential model was applied in this study and the model performance was evaluated using several goodness-of-fit criteria.

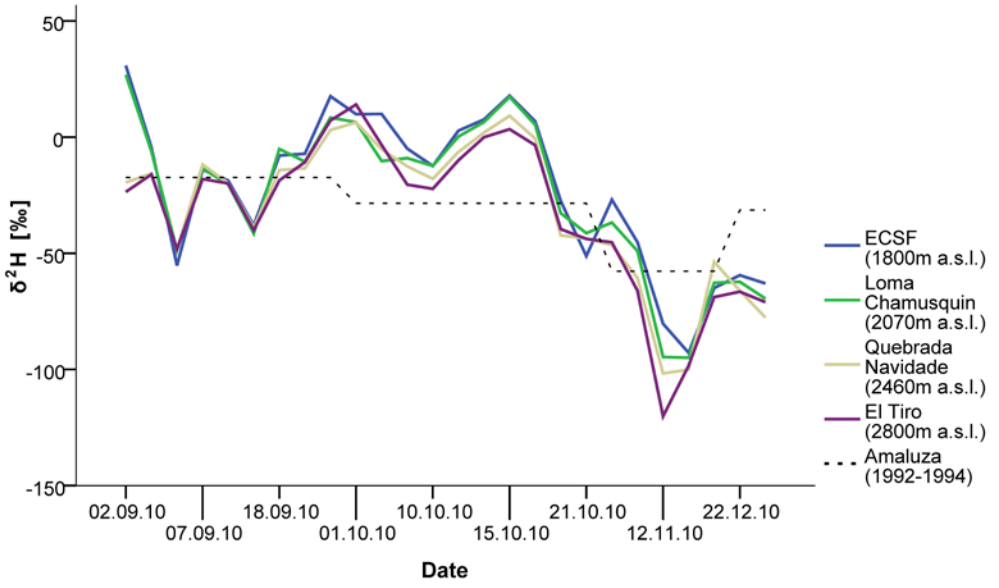


Figure 39: Temporal and altitudinal variation of the incoming deuterium (2H)-precipitation signal within the Rio San Francisco area in comparison to the isotope data recorded at the GNIP station near Cuenca [4]. Graph: D. Windhorst

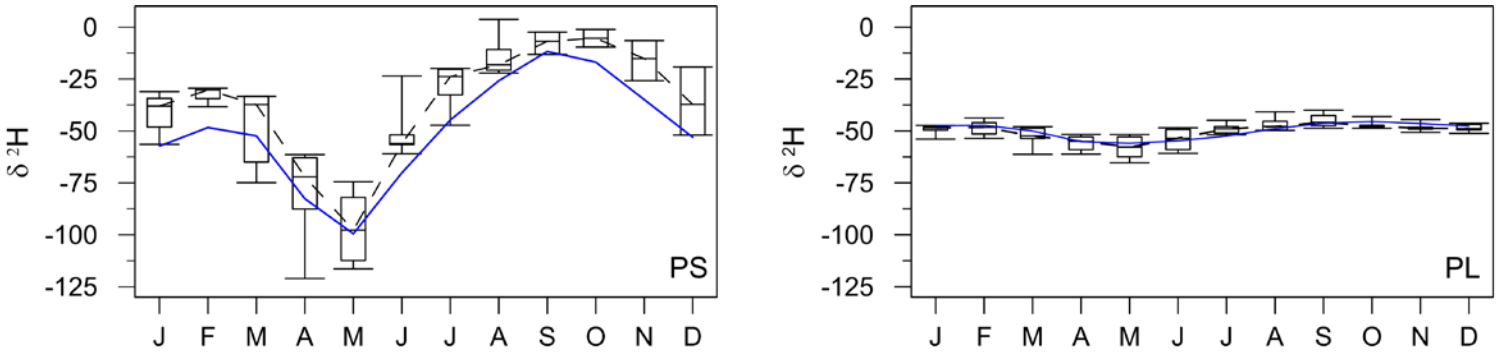


Figure 40: Modeled monthly isotopic variation (blue line, Exponential model) and observed (dashed line) of monthly Deuterium excess in pasture dominated subcatchment (**PS, left**) and at the outlet of the catchment at Planta (**PL, reight**). Boxplots show minimum, maximum, median, upper and lower quartiles of the weekly data. Graph: E. Timbe

Figure 40 shows a characteristic output signal of water originating from pasture soils and a more damped signal of stream water collected at the catchment's outlet. The modeling of the signals of the different types of waters yielded Mean Transit Times from 12 to 13 months for stream water, while springwaters show a wider range, from 8 to 38 months. As expected, the waters from soils had the shortest Mean Transit Times from 1.5 to 2 months, and there were just minor differences between the two dominant land cover types forest and pasture.

The relatively large Mean Transit Time of the stream water compared to the mobile water present in the soil horizons indicates that although the flashy response (by the order of a few hours) of the hydrograph (i.e. the water level increase after a rain event), slow flow conditions prevail in the catchment. Results of Mean Transit Times estimates are currently prepared for publication.

Uncertainty in Model Prediction

Why do we need such information? Rainfall-runoff models are sometimes highly uncertain with regard to their parameters and their model structure. In a recent model intercomparisons and ensemble forecasting experiment we were able to show, that uncertainty of model structure significantly contributes to the global model uncertainty in predicting discharge in the San Francisco. This is even the case when predictions of hydrological fluxes are made under future climate projections – itself a rather uncertain issue. Up to 50% of the global uncertainty of these future projections was attributable to the choice of the hydrological model as compared to the uncertainty in climate projection [2]. Utilizing information about Mean Transit Time or the isotopic signature of incoming precipitation allows rejecting hydrological models that do not reflect this additional information. Together with obtained time series for stream nitrate we will finally run coupled process-based hydro-biogeochemical models taking also the nitrogen cycle of the area into account.

Outlook: Cooperation with SENESCYT Projects

The scope of future research efforts with our counterparts in Cuenca is to identify the runoff generation processes in páramo ecosystems and their responses to natural and anthropogenic impacts. Alica Correa will pay special attention to the comparative prediction of discharge of páramo basins using linear and non-linear approaches for the regionalization of model parameters. Experience obtained in field studies of the San Francisco will help in her research.

Combining hydro-biogeochemical fluxes with biological indicators (e.g. aquatic diversity or abundance) is a key element of the work of Carlos Iñiguez at the Technical University of Loja (UTPL) [3]. Identifying the connection between these two will not only allow to ease the assessments and maintenance of water quality standards, it will also facilitate the possibility to launch combined modeling efforts driving empirically derived models with deterministically hydro-geochemical flux models. This for example, will allow to study the impact of future climate and land use projections on stream ecology.

David Windhorst, Edison Timbe, Carlos Iñiguez, Alicia Correa, Rolando Celleri, Jan Feyen, Hans-Georg Frede, Lutz Breuer (Giessen University, Universities of Cuenca and Loja)

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Relevance of the Soil-Landscape for the Prediction of Landslide Susceptibility

The soil-landscape under tropical mountain forest in the Reserva Biológica San Francisco (RBSF) is dominated by stagnic soils with thick organic layers. The soils are influenced by slope processes such as shallow slope parallel subsurface flow. Soil properties can be spatially predicted from point data by making use of terrain parameters as predictors. Supervised learning methods are then used to relate the soil properties to the predictors in subproject D5.

Digital soil maps (DSM) by definition have to include a map uncertainty. In order to evaluate model performance fivefold cross validation was applied. To account for random effects within the model mechanism itself, hundredfold model runs were applied based on different data subsets. The 100 predictions finally provided a distribution function for every point within the landscape. Its median and interquartile range is displayed in **Figure 41a** and **b** which present the DSM of the stagnic horizon thickness.

The DSM uncertainty has an impact on the accuracy of the spatial prediction of unstable slopes: Only where soil map uncertainty is low, a slope failure can be predicted with high accuracy (**Figure 42**, next page). It could be shown that particularly the depth of the potential failure plane which was assumed at the lower boundary of the stagnic soil layer has a high impact [1].

Mareike Ließ & Bernd Huwe
(University of Bayreuth)

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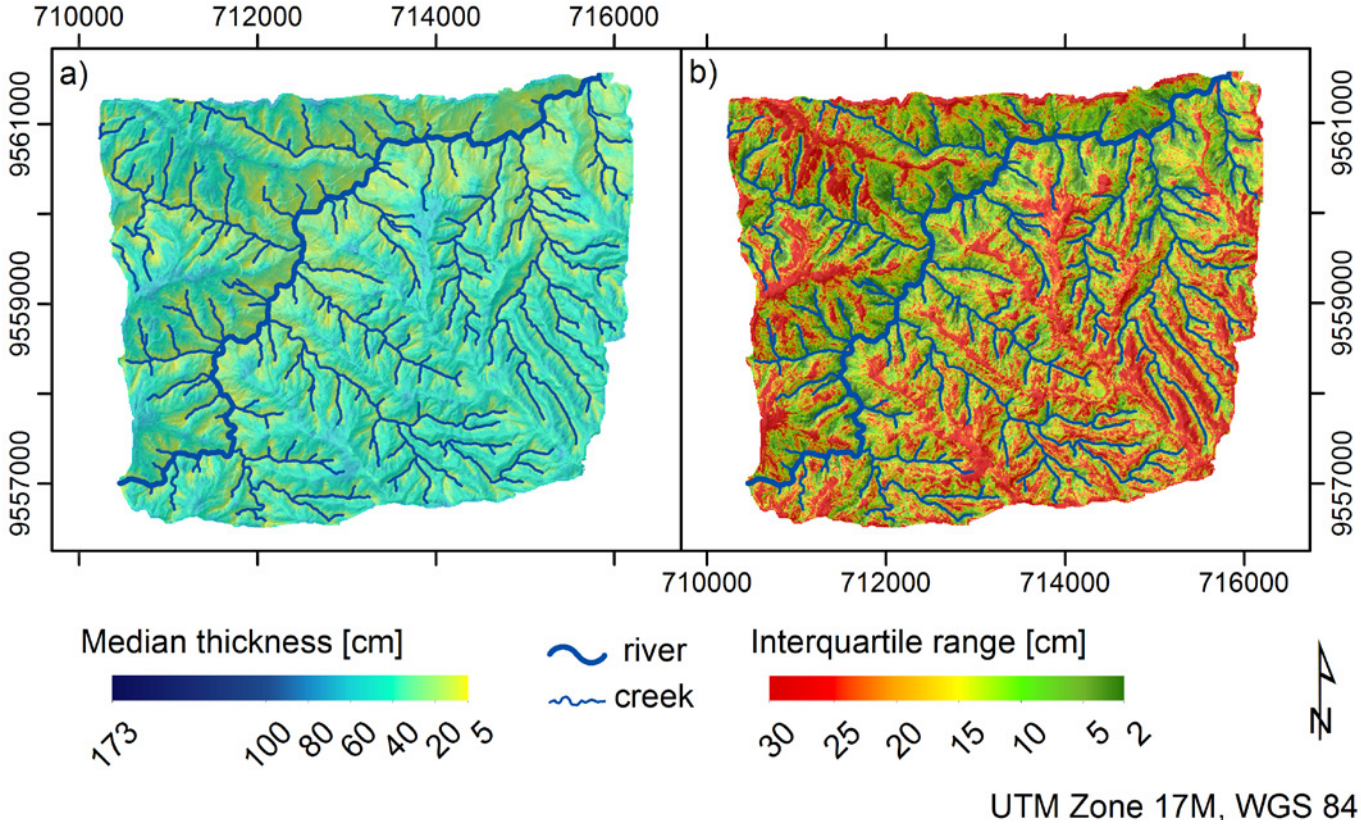


Figure 41: Median thickness of stagnic soil layer (a) and interquartile range (b) (Overlaid hillshading from North). Graph: M. Ließ

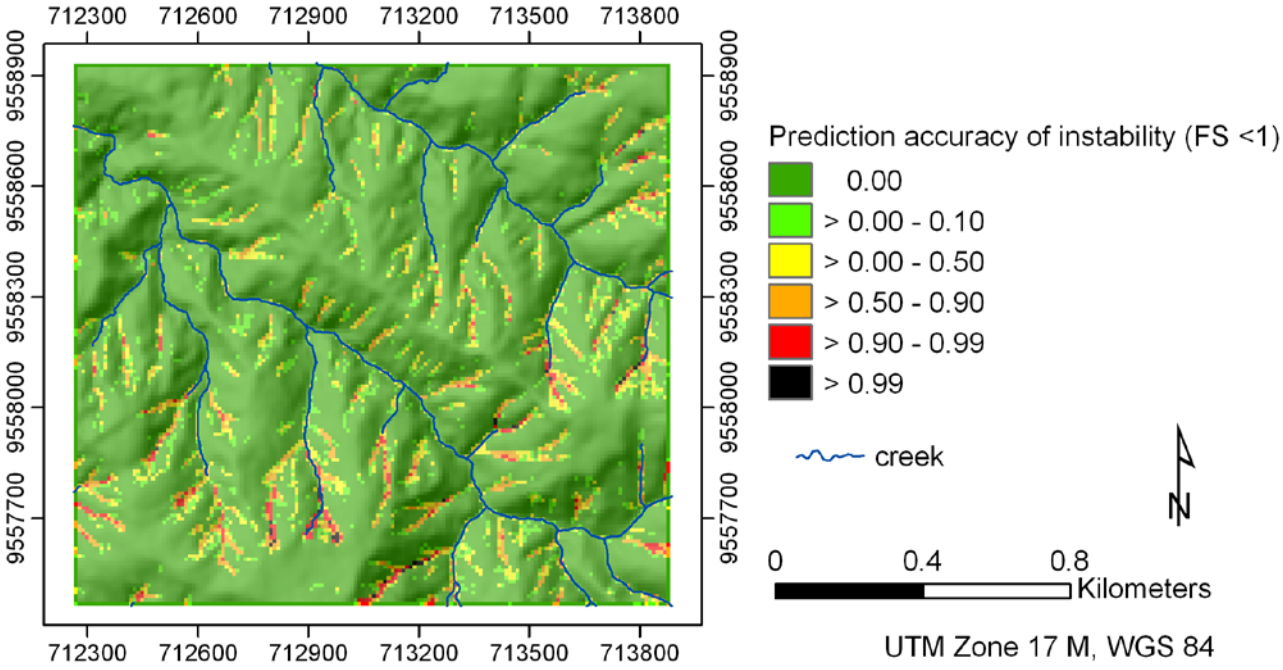


Figure 42: Prediction accuracy of unconditionally unstable slopes based on uncertainty in soil regionalization. Overlaid hill shading with light source from north-west. Figure adapted from [1]. Graph: M. Ließ

Forest Dynamics, Landslide Dynamics, and Their Interactions

Shallow landslides are one of the major natural disturbances in the forest of the Reserva Biológica San Francisco (RBSF). They create a patchy distribution of sites with different environmental conditions and successional stages of vegetation and have therefore been assumed to be a driver of high biodiversity. In our subproject D7 we thus investigated the interaction of shallow landslides and forest dynamics. We used statistical models (see **Figure 43**) to relate landslide activity to topography [1], applied a physically-based slope stability model to our own measurements on and close to eleven landslides in the RBSF to reconstruct the circumstances at the time of failure [2] and finally, we employed a landscape evolution model to assess the long term driving factors of landslides [3].

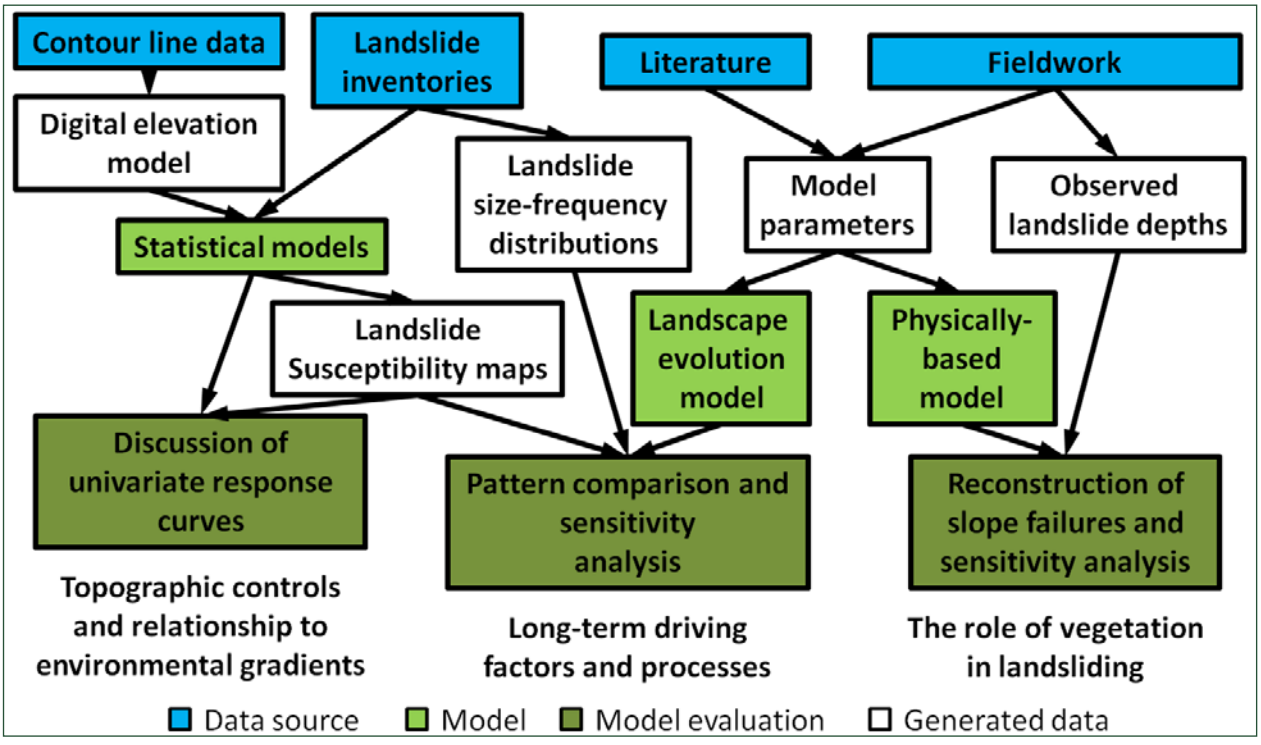


Figure 43: Model framework to assess landslide driving factors. Image: P. Vorpahl

We found the long-term landslide size and frequency to be mainly controlled by bedrock weathering and soil physical properties such as cohesion followed by erosion due to surface runoff. Considering these factors as temporally invariant soil hydrology and vegetation dynamics gain importance for landsliding. Landslides in the RBSF are mainly hydrologically triggered, while on slopes steeper than 37.9° vegetation can destabilize the slope by contributing to the mass of the organic layer. Thus, the mass of the growing forest can cause landsliding which in turn causes a new cycle of succession.

To study the impact of landslide disturbances on the forest we utilized the process-based forest model FORMIND (see TMF Newsletter no. 14, doi: 10.5678/lcrs/for816.cit.1031). On the local scale of a single landslide we developed potential scenarios of forest recovery with changes in different attributes (e.g. mortality, tree growth) due to changed environmental conditions on landside sites [4]. For most scenarios our model predicts a recovery time for aboveground tree biomass < 100 years but concomitant effects might prolong the process of biomass recovery. On the landscape scale landslides reduce aboveground tree biomass by ~13% and strongly increase spatial heterogeneity of biomass distribution (**Figure 44**).

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(University of Potsdam, Helmholtz Centre for Environmental Research, Technische Universität München-Freising)

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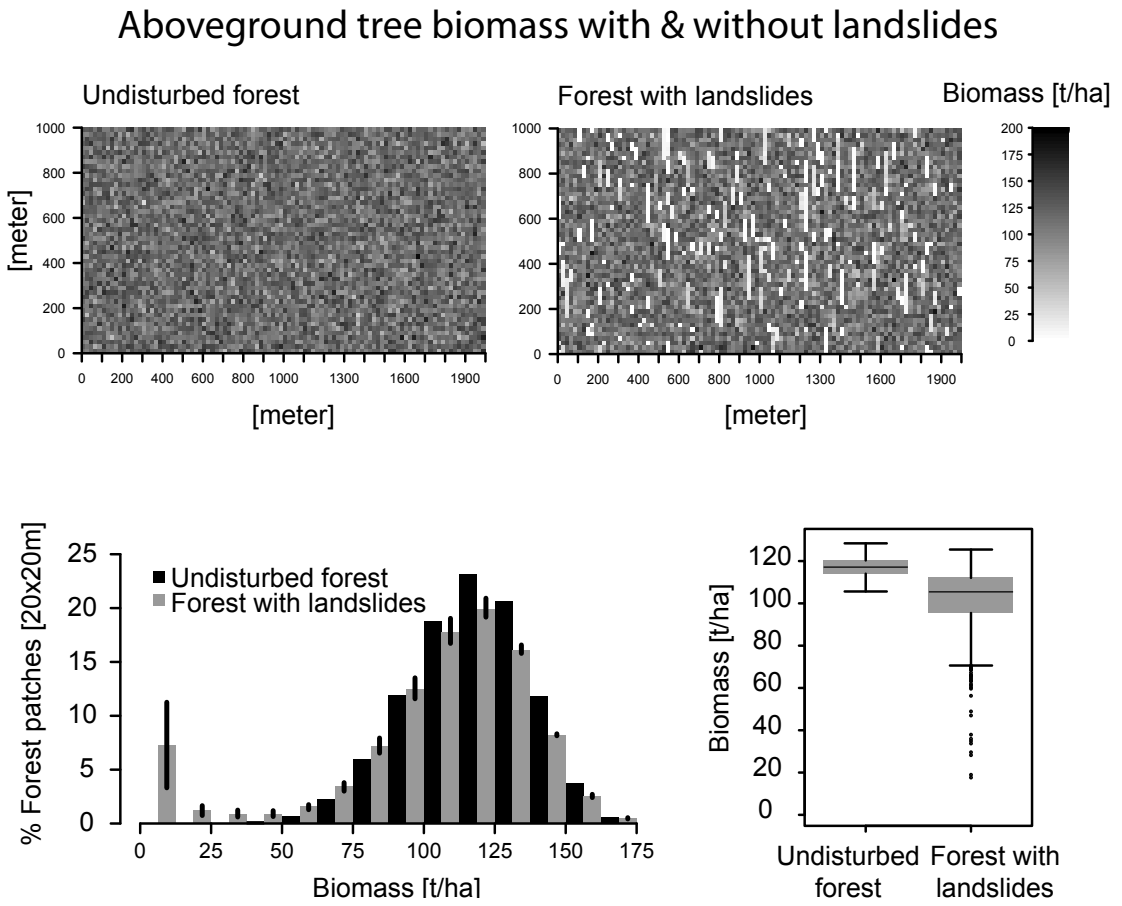


Figure 44: **Panels on top**: Simulated spatial distribution of aboveground tree biomass with and without the natural disturbance regime of landslides. **Bottom panel left**: Frequency distribution of biomass on Plots of 20x20 meter. Grey bars depict the mean frequency of different forest regrowth scenarios after landslides; error bars mark the minimum and maximum of the applied scenarios. **Bottom panel right**: Boxplots of aboveground tree biomass per hectare; medians, interquartile ranges, maximum and minimum are shown; biomasses more than 1.5 times outside of the interquartile distance are depicted as outliers. Graphs: C. Dislich

Transfer Project

"New Trees for Ecuador" Expands to the North

Acceptance of international experiences and implementation in the Ecuadorian forestry field are the main goals of our Transfer project T1 called "Nuevos Bosques para Ecuador". We aim to transfer scientific results into application. To reach this we work in a mutual cooperation of Ecuadorian institutions and German universities.

Our transfer project continues working in southern Ecuador trying to overcome institutional barriers of knowledge transfer. Our experiences were requested from people from the province of Orellana also known as "El Coca", located 684 kilometers northwest of the city of Loja in Ecuador. The main attraction of this province is a wild jungle ecosystem which encompasses most of the territory. The people in the province mainly rely on exports of crude oil and timber. Their second most important source of income is tourism.

Eduardo Cueva, a know botanist in southern Ecuador, accompanied by Jose Acaro, who is a local technician in Naturaleza y Cultura International (NCI) and trained in our transfer project previously, shared their knowledge of tree climbing techniques. They thus provided information about the selection of trees to collect fruits and seeds which meet reforestation requirements.

Local institutions such as the Municipality of Orellana, the local government, the Association of Timber Producers and NGO's, all of which are involved in natural resource conservation activities, were the main actors work in a frame of institutional cooperation. This cooperation led to 25 men and women (**Figure 45**) who were trained in tree selection for seed sources and who were taught in practical techniques in the field. They were also trained and advised in techniques for using tree climbing equipment in order to reduce the risk of accidents and to improve conditions for the selection of fruits and seeds needed for the reforestation process (**Figure 46**).

Thus our project continues to open doors for the transference of knowledge appealing especially to local technicians who are working for different local institutions. While working with these technicians our project develops new courses in different disciplines related to forestry and other topics of new interest which are all accompanied by a strong and solid base of scientific results. Our project has now scheduled additional courses which include more topics related to Nuevos Bosques para Ecuador.



Figure 46: A participant of the climbing course trains how to harvest seeds from a high tree. Photo: E. Cueva

Eduardo Cueva, Bernd Stimm, Sven Günter, Reinhard Mosandl & Baltazar Calvas (Nature and Culture International, Technische Universität München-Freising)



Figure 45: Participants of the first climbing course in the province of Orellana. Photo: E. Cueva

Data Warehouse

Development Successfully Accomplished

The data warehouse (*FOR816dw*, subproject Z1) has been successfully developed and improved over the last six years, based on the preliminary work of the FOR402 metadata base (**Figure 47**, see [1]).

Based on the developments of the *FOR816dw* in the first phase of the Research Unit (RU) which included (i) setting up a basic project- and user management, (ii) the implementation of an accounting system and the station booking tool, (iii) the creation of a basic data upload workflow to allow the researchers to upload their data as CSV files and (iv) the description with the international metadata standard EML (Ecological Metadata Language), phase RU816/2 brought a wide range of additional features which were based on user requirements defined during several data base workshops conducted by the data manager.

One of the major achievements was that the upload workflow of tabular and raster data was streamlined and the web interface was made more accessible. As of now the *FOR816dw* allows uploads of raster data in EsriASCII, Idrisi and GeoTIFF format.

To further enhance working with spatial information the web based MapViewer tool (based on OGC Web Map Service, GeoServer, OpenLayers) was developed which provides a map of the research area together with additional vector layers (roads, rivers, etc.) and the possibility to view and determine geographic coverages of datasets directly in this map.

The representation of the EML metadata of a dataset – until now just a downloadable source XML file – received a major overhaul by setting up an on-the-fly solution to “XSL-Transform” it into an easy to read html page. This is now part of every datasets download package. This also allows us to provide additional transformations to different metadata formats (eg. DataCite).

The *FOR816dw* also received several administrative and technical upgrades: We implemented online help pages covering all aspects of the data warehouse, a daily updated website and data warehouse specific statistic page, the station pass to confirm membership to the RU in the research area and the station booking subsystem received a major upgrade with new features requested by the station managers.

To build a basic ontology on top of the datasets metadata an initiative to categorize the underlying attributes as the basis of those was pursued. We build a tree like structure of categories together with the dataset creators where we would sort the attributes to. This structure is visible and useable as a search instrument on the data warehouse web page.

Two requested features to further improve dataset retrieval and editing were developed. The new and extended search option provides temporal, spatial, ontology, personnel and project specific filters; via the edit page the metadata of a dataset can be revised and its data values can be extended or corrected.

The demand for viewing and analyzing tabular data within the *FOR816dw* is high. Hence a new module was designed to display, filter and aggregate the data of tabular datasets. Complementary to the established dataset search, it is now possible to work directly on the value-level.

Currently, the release version of the data warehouse system source code under an open source license is in work, completing and rounding off the Z1 project.

Maik Dobbermann (Developer and Webmaster), Thomas Lotz (Data Manager) & Jörg Bendix (Project Leader, University of Marburg)

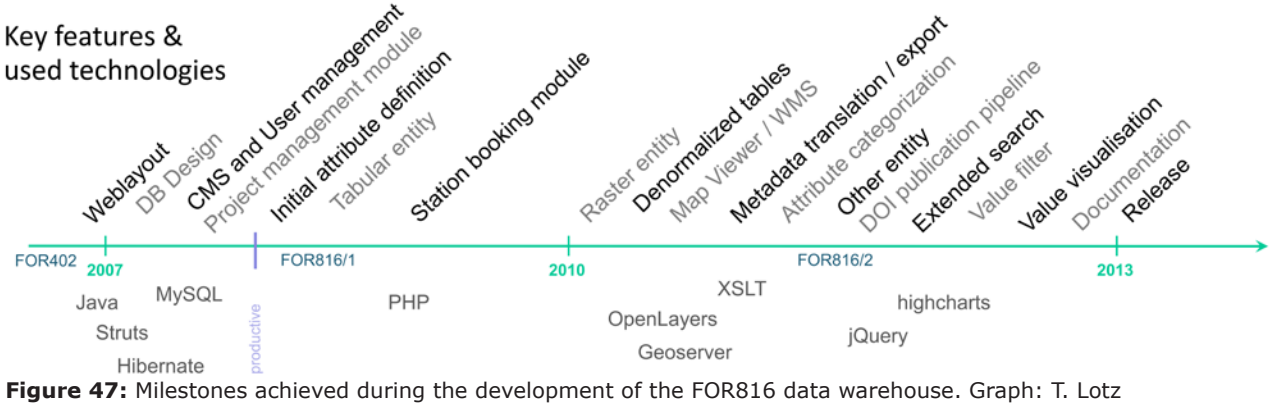


Figure 47: Milestones achieved during the development of the FOR816 data warehouse. Graph: T. Lotz

References

[1] Lotz T, Nieschulze J, Bendix J, Dobbermann M & König-Ries B (2012) Diverse or uniform? — Intercomparison of two major German project databases for interdisciplinary collaborative functional biodiversity research. *Ecol. Inform.* 8, 10–19.

Cooperations[1)]

Species Richness of Long-legged Flies

With over 7,000 species in the world long-legged flies (Diptera, Dolichopodidae) is the fourth most diverse fly family around. Males of many species feature ornaments on legs, wings and/or body that play a role in courtship behavior (**Figure 48**) and many species demonstrate very strict habitat requirements.



Figure 48: A new species in the subfamily Achalcinae only found in the Reserva Biológica San Francisco (RBSF). Photo: M. Pollet, EDIT

A first account on the results in long-legged fly diversity (Diptera, Dolichopodidae) was presented in the TMF Newsletter no. 14, doi: 10.5678/lcrs/for816.cit.1031. Samples collected with Malaise and pan traps (see Figure 9 in TMF Newsletter no. 14), and sweep nets from February to March 2009 yielded nearly 200 different species. With 66 sweep net samples taken from Bombuscaro and Cajanuma to go the total species richness will likely rise to 250 or more. Before, only 32 species were reported from Ecuador.

Moreover, the majority of the species appears new to science. This holds true entirely for representatives of the subfamily Achalcinae, a rarely collected lineage at other sites that proved both diverse (22 species) and exceptionally abundant in the samples (see **Figure 49**). This subfamily is most diverse at 3000 m a.s.l. (Cajanuma site), contrary to the bulk dolichopodid fauna with strikingly higher species richness at 1000 m and 2000 m, respectively.

Dolichopodidae made up only a minor part of the sampled invertebrate fauna, and 25 other fly families or superfamilies, and 5 other invertebrate taxa were also pulled from the samples, resulting in 1738 taxon samples. They were disseminated among 37 taxonomic experts mainly from Canada and the United States, but also from Belgium, Brazil, France, Finland, Germany, Netherlands, Spain, Switzerland, and the UK. Identification data start to come in, and the first papers are published, and all show the same pattern: most of the examined species appear new to science (**Figure 50**). The labor of separating the different taxa seems to pay off!

Marc Pollet
(Research associate RBINS, Brussels, Belgium)

More Information

www.naturalsciences.be/cb/ants/projects/andes-mountain-forests-dolicho.htm

Research Institute for Nature and Forest (INBO): www.inbo.be

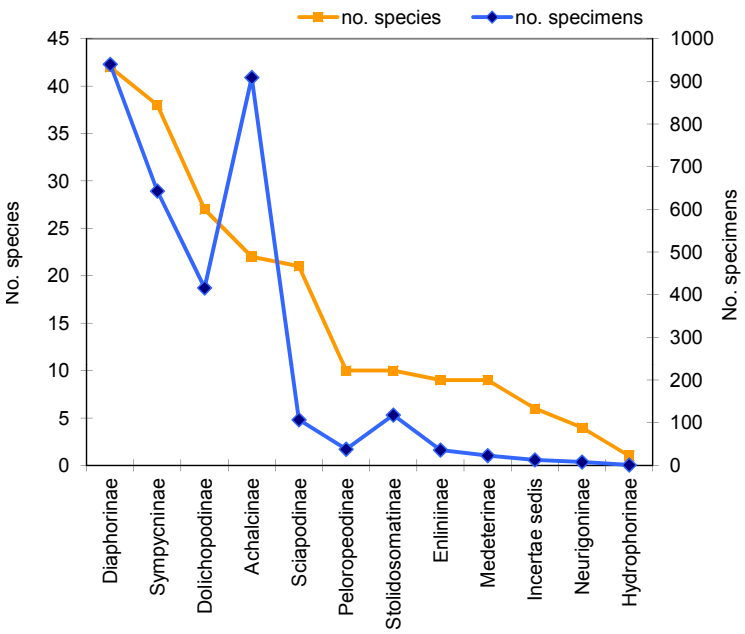


Figure 49: Distribution of examined species and specimens over dolichopodid subfamilies. Graph: M. Pollet, EDIT



Figure 50: A sample of wingless Sphaeroceridae from Cajanuma (Podocarpus National Park) containing new archiborborine species. Image: M. Pollet, EDIT

1) Scientists of the RU collaborate with several researchers and institutes outside the RU. In this issue scientists from Belgium and Germany report their findings in this section. They are two of the many institutions in the European Distributed Institute of Taxonomy (EDIT) and join forces to provide accountable tools to taxonomists, to significantly accelerate global taxonomic knowledge. The RU cooperates with researchers from EDIT since 2009.

Altitudinal Variation in Arthropod Diversity and Compostion on Tree Barks

Our MACAG-Project (Monitoring of Arthropods along Climate and Altitude Gradients) in the Podocarpus National Park (PNP) aims at a spatial and temporal quick assessment, monitoring and evaluation of climate change and altitudinal gradient driven impacts on arthropod faunas on undamaged tree barks in primeval and near-to-nature forests. PNP as a global biodiversity hotspot and the RU-projects as a logistic and informational framework offer excellent conditions to study "microarthropods" on tree barks in permanent monitoring plots along a continuous forest matrix from 1000 to 3000 m a.s.l..

Within the RU-EDIT cooperation and from 2007-2009 we sampled 339 tree bark assemblages in 29 plots at Bombuscaro, at the ECSF research station and at Cajanuma by standardized barkspray protocol. Thousands of arthropods were sorted and the focal taxa beetles, pseudoscorpions and harvestmen were analyzed regarding altitudinal turnover of composition and diversity. Progress is also made towards taxonomic diversity (see TMF Newsletter no. 17, doi: 10.5678/lcrs/for816.cit.1132).

Summary of Results

1 Beetles, harvestmen and pseudoscorpions show clear altitudinal gradients in diversity, corresponding to structural properties of the tree bark (roughness, epiphyte and climber coverage, trunk diameter at breast height, dbh) which in turn are significantly correlated to altitude.

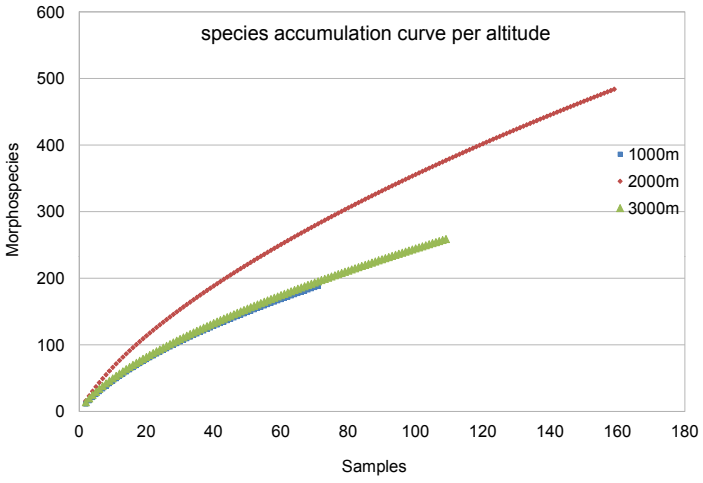


Figure 51: Species accumulation curve of beetle diversity on tree barks at altitudes of 1000, 2000 and 3000 m, based on a total of 339 samples (71/159/109). The species accumulation curve estimates the number of additional species that might be discovered with further sampling effort. Species richness estimator Chao 2 calculates 477, 1167 and 645 species, respectively, and a total of 2289 species on the tree barks at the three elevations altogether. Graph: J. Schmidl

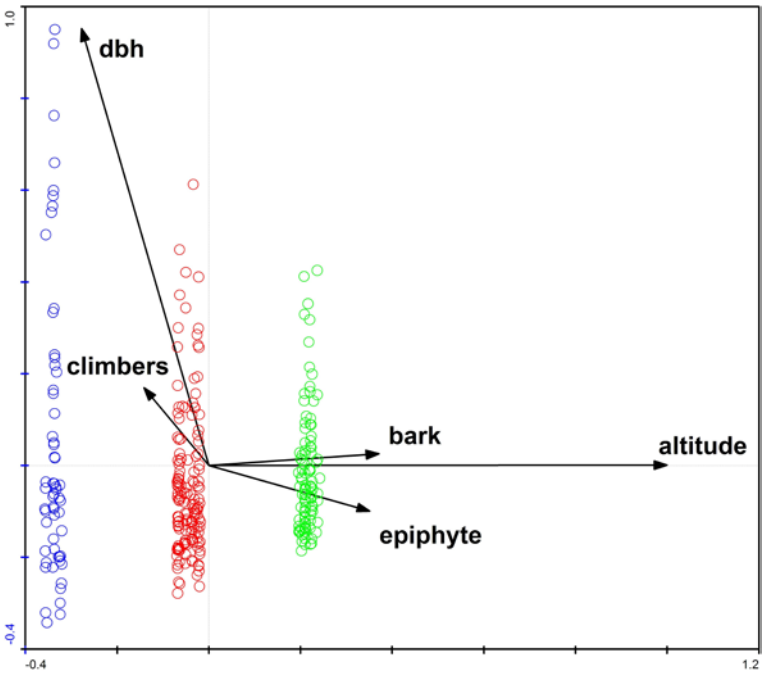


Figure 52: Canonical Correspondence Analysis (CCA) axis 1/2 of 311 tree bark beetles assemblages (with 862 morphospecies) sampled at elevations of 1000 m (blue, Bombuscaro), 2000 m (red, ECSF) and 3000 m (green, Cajanuma) and five environmental parameters: trunk diameter at breast height (dbh); climbers cover of bark (climbers); epiphyte cover of bark (epiphyte); bark roughness in intervals 1-5 (bark); elevations (altitude). Beetle assemblages are highly confined to altitudinal levels, altitude is the driving force for the tree bark (=habitat) parameter gradients. Graph: J. Schmidl

2 Diversities and degree of sampling saturation (rarefaction) are different between the beetles (high, no saturation, a total of 2289 species on tree barks from the three sampled altitudes can be calculated by Chao2 species richness estimator, see **Figure 51**) and the two arachnid taxa (low, near saturation, Chao2 harvestmen: 55 species, Chao2 pseudoscorpions: 14 species).

3 Different species ranges, altitudinal niche dimensions and altitudinal diversity peaks:

- Beetles display a mid-domain-like peak of diversity in the cloud forest at 2000 m, a tropical 'singleton' phenomenon (i.e. most species in a single specimen) in the warm rainforest formations at 1000 m, and lower but distinct species richness in the páramo transition forest at 3000 m. Species show low altitudinal species range, almost being confined to one level (see **Figures 52 and 53**)
- Harvestmen diversity correlates with structural bark properties (high roughness and epiphyte coverage at 2000 m and esp. 3000 m), and species have medium ranges.

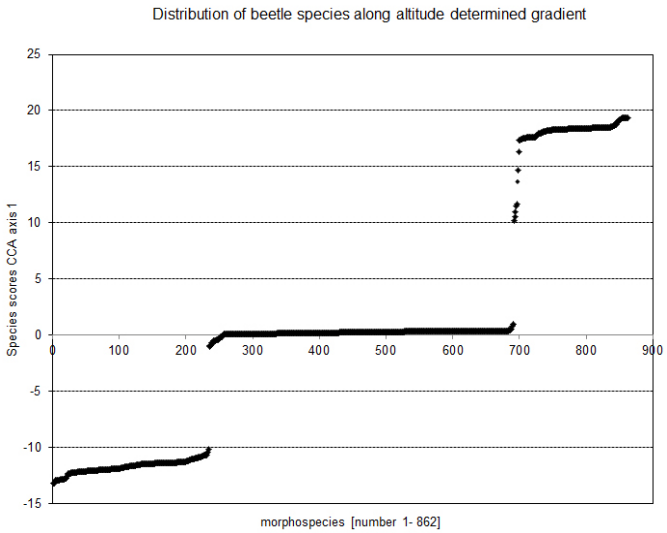


Figure 53: Position (species scores) of 862 beetle morphospecies from the 311 tree bark samples along CCA (Canonical Correspondence Analysis) axis 1 which represents the altitude determined main ecological gradient in the data set. Note again the distinct species clusters at the different elevations: at Bombuscaro 1000 m (bottom left), at the ECSF research station 2000 m (mid) and at Cajanuma 3000 m (upper right) altitudinal level; there are only a few "intermediate" species which occur both in 2000 m and 3000 m. Graph: J. Schmidl

- Pseudoscorpions are more diverse in the warm forests at 1000 m a.s.l., with generally quite low species numbers on barks, and medium to high altitudinal species ranges.

Conclusion

Due to the diverse biology of this mega-diverse insect group and the complex food-web and community relations, beetle assemblages on barks are best suited to serve as bioindicatores to monitor and calculate diversity patterns and climate change responses (re-samplings in time intervals). All investigated altitudes show distinct species sets, with only a few 'intermediate' species between adjacent levels. No between-year differences show up in multivariate ordinations, the results are reproducible. So shifts in species altitudinal ranges and assemblages within PNP forest matrix might reveal short- to medium-term climate change effects.

Jürgen Schmidl
(Research associate RBINS Brussels &
Friedrich-Alexander Universität Erlangen-Nürnberg)

Reference

Schmidl J, Prötzel D, Pfeifer T (2012) Monitoring tree-bark arthropod diversity along altitudinal and structural gradients in tropical forests. *Verhandlungen der Gesellschaft für Ökologie Band* 42, p. 209.

People and Staff

Therese Hertel (**Figure 54**) received the Audi Sustainable Resource Management Award 2012 for her Master Thesis with the title "Tree Seed Procurement and Management in the Province of Loja, Ecuador - With special reference on the development of a concept for a Regional Tree Seed Program". Hertel conducted her studies in the subprojects C1 and the "Knowledge Transfer" project T1 to convert montane ecosystems by large-scale conversion of monocultures into mixed forests. According to thesis supervisor Bernd Stimm Hertel has made an outstanding contribution for a successful restoration and sustainable management of the Ecuadorian Mountain Rain Forests as well as to the country's efforts on conservation of biodiversity and national culture. Up to now native tree species played only a minor role in reforestation and restoration, although they show great advantages in comparison to exotic ones, e.g. are adapted to environmental conditions and hence very valuable for the conservation of associated flora and fauna. Unfortunately the knowledge about reproduction, propagation and sustainable management is still very limited so that the raising of planting stock from native species is rarely practiced or often shows serious failure. Based on socio-economic surveys and comparative studies Hertel provided an important cornerstone for the sustainable supply of tree seeds and presented a regional concept for a Tree Seed Management Program for the Province of Loja, which will hopefully result in the restoration of the Andean Mountain Rain Forests. The award is endowed with 1.500 Euro and is given by the car manufacturer



Figure 54: Prof. Dr. Alfons Gierl, expert in plant genetics from the Technical University of Munich, TU München, prize winners Therese Hertel and Christina Deibl, and Dr. Dagobert Achatz, speaker of the Foundation for Environment at Audi. (f.l.t.r.) Photo: © Audi AG.

Audi since 2010 for sustainable resource management. In contrast to the previous ceremony the prize was given to two persons in 2012. Hertel's thesis is available at the RU data warehouse: http://137.248.191.82/publications.do?citid=1234.

Bernd Stimm



Photo: Hamer

Dr. habil. **Ute Hamer** left Dresden University of Technology to start working at the Westfälische Wilhelms-Universität Münster, Germany. She got a permanent position at the Institute of Landscape Ecology as Assistant Professor for Soil Science and Site Ecology. Hamer is going to continue her research activities in the transfer project "New forests for Ecuador" (see above) where she is leading the establishment of an adapted site classification. She is supervising the PhD thesis of Pablo Quichimbo (UTPL). Her new address will be: Institute of Landscape Ecology (ILÖK), Robert-Koch-Str. 26-28, D-48149 Münster, Germany, e-mail: ute.hamer@uni-muenster.de; http://www.uni-muenster.de/Landschaftsoekologie/en/index.shtml

Dr. Sabrina Setaro obtained the doctoral degree (Dr. rer. nat.) at University Tübingen in 2007, then obtained a grant from DFG for a postdoc at Wake Forest University in Winston-Salem, North Carolina (U.S.A.). Since 2010 she is employed as program coordinator and part-time assistant professor at this university. Her duties comprise development of electronic educational tools, database management and analyses of educational data as well as teaching and supervising undergraduate students in the field of mycology.

Dr. Juan Pablo Suárez Chacon obtained the doctoral degree (Dr. rer. nat.) at University Tübingen in 2008 and since then is employed as Director for research at Universidad Técnica Particular de Loja (UTPL), Ecuador. At same time he is guiding a mycorrhiza research group at the Department of Natural Science at UTPL.

Dario Javier Cruz Sarmiento, UTPL, is currently finalizing his doctoral thesis on *Tulasnella* fruiting bodies at J. W. Goethe-University Frankfurt under guidance of Prof. Meike Piepenbring, financially supported by grants from DAAD/DFG and UTPL.

Paulo Ignacio Herrera Vargas, UTPL, finished a Master on Ecology at Universidad Rey Juan Carlos in Madrid in 2012, submitting a master Thesis on "Diversidad molecular de MOTUs de Tulasnellales en orquídeas epífitas y terrestres en un bosque tropical montano lluvioso del sur de Ecuador". He will continue to obtain a doctoral degree at that university.

Event Calendar

gtö Conference



The final program of the conference of the Society for Tropical Ecology (gtö) entitled "Impacts of environmental change on biodiversity and ecosystem functioning / services in Tropical High Mountains" is available at www.gtoe-conference.de/index.php?cat=program. The speakers of the RU, Jörg Bendix and Erwin Beck, will chair the largest session, comprising more than 20 talks and 6 posters which will be distributed over two days of the conference. The conference will be held in Vienna, Austria, on 2nd – 5th April 2013. RU member and congress president Professor Dr Konrad Fiedler looks forward to see you in Vienna, Austria.

Next General Assembly of the RU

All members of the RU are invited to join the upcoming meeting which will take place at the lecture hall at Professor Fiedlers institute (Rennweg 14 in Vieanna) on 6th April 2013 from 9.00 to 11:00 am directly following the gtö conference.

Credits and Contact

DFG Research Unit 816

More information about the Research Unit (RU 816) investigating Tropical Mountain Forests (TMF) is available at:
www.tropicalmountainforest.org

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