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Platform for Biodiversity and Ecosystem Monitoring and Research in South Ecuador

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One of the two Knowledge Transfer Workshops of the Research Consortium took the participants on the site of the project "Nuevos bosques para Ecuador" in October. Whether pine plantations are able to facilitate reforestation efforts with native species is one of the questions the scientists from several disciplines address in this project to create sustainable land use options for the people in Ecuador. Photo: Baltazar Calvas

In this Issue

Coordinators' Corner

News since May 2015

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The time since the last issue of Tabebuia Bulletin was busy with the preparation of the annual Status Symposium in Loja and the two flanking Knowledge Transfer Workshops, the latter with the intention to bring researchers and target stakeholders of the knowledge transfer projects together. Another main topic was the still ongoing discussion for a new DFG Research Unit for the time beyond 2016.

Cooperation with the National Biodiversity Institute

On 27th August, the coordinator met the director of the newly established National Institute of Biodiversity (INB) of Ecuador, Dr. Fernando Rodriguez, in the Ecuadorian embassy in Berlin (**Figure 1**, next page). The new institute based in Quito is planned as a research institute but is also an important player in the science-policy interface regarding biodiversity research in Ecuador. Dr. Rodriguez, who has conducted his PhD in the RU816 in the group of Herman Behling (University of Göttingen), expressed great interest in a collaboration regarding the platform's knowledge transfer activities, but also in a future collaboration with a new Ecuadorian-German research program beyond 2016. As a first implementation of the collaboration with the INB, it was agreed to jointly organize the Knowledge Transfer Workshops in October 2015 in Loja.

Future Research Activities

Based on intensive discussions on a draft of a new Research Unit in Ecuador in the scientific advisory board of the PAK program, a group of interested PIs met in Marburg on 21 September and presented potential contributions to a new program with the working title "Environmental changes as drivers and results of changing biotic-atmospheric interactions in natural and anthropogenic ecosystems in southern Ecuador". Based on this information, the preparation of a pre-proposal for a new DFG Research Unit is currently under work. Dr. Teschke (DFG) thankfully attended the meeting, giving important suggestions for the two-step application procedure.

Conference

On October 5th the cheerful busy week in Loja started with the conference about con-

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servation and sustainable management of ecosystems organized by our non-university partner Nature and Culture International (NCI) at the Technical University of Loja (UTPL). The main aim was to inform the scientists and the public on the great work related to ecosystem conservation and rehabilitation done by NCI in many parts of southern Ecuador and beyond, activities which are also related to the knowledge transfer subprograms of the Research Platform (see **Figure 2**).

First Knowledge Transfer Workshop

On the following day (6 October), subprogram C of the platform, together with the INB and the UTPL, organized a Knowledge Transfer Workshop at the UTPL campus in Loja. The main aim of the workshop was to discuss the potential of developed basic and functional indicators for an implementation by the stakeholders, in a group of interested people. The second aim was to synchronize the science-directed developments in the scope of our program with the need for monitoring technologies required by the national, regional and local administrations arising from political programs such as the new national biodiversity strategy of Ecuador.

Around 50 participants from the Ecuadorian and German members of the platform, other Ecuadorian scientists and the target stakeholders (INB, National Environmental Ministry MAE Loja and Quito, ETAPA Cuenca, Prefectura Loja, NCI etc.) for knowledge transfer were invited and attended the workshop. After presentations about indicator development and operational/planned monitoring systems by both parties in the morning session, two round table discussions for basic and functional indicators summarized the next steps towards an implementation of selected priority indicators (**Figure 3**). All parties underpinned the importance of continuing joint collaboration in indicator development and its implementation.

Figure 2: Pedro Paladines from Nature and Culture International informs the audience on the management of research stations. Photo: Jörg Bendix

460 Participants at the Annual Status Symposium

On 7 and 8 October, the annual Status Symposium of the platform took place in the main auditorium of the UTPL, with English talks on the first day followed by Spanish overview talks on the second day. It was the biggest Symposium ever with

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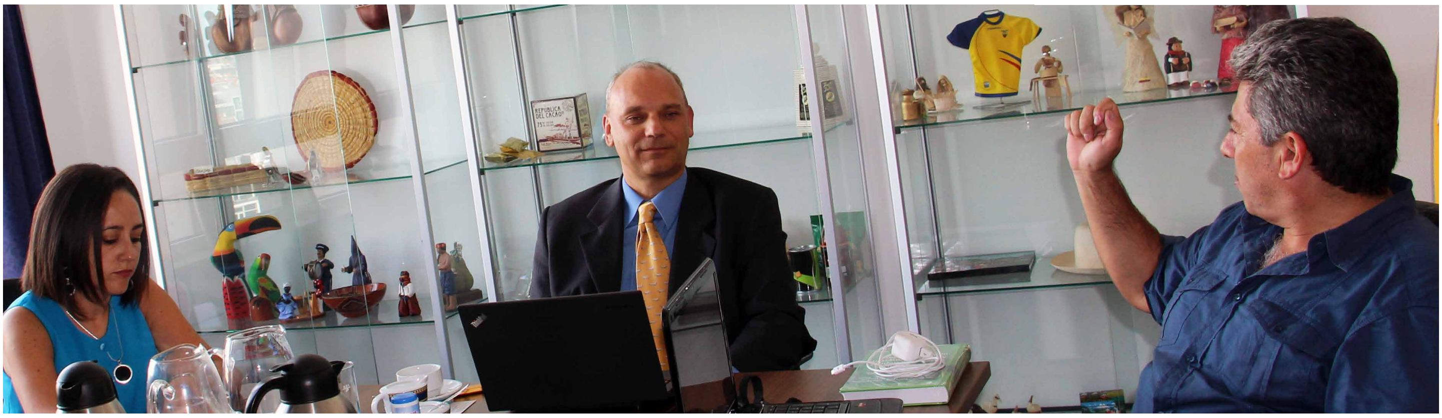

Figure 1: Discussing knowledge transfer and future cooperation in the Ecuadorian embassy in Berlin. Right: The director of the newly established National Institute of Biodiversity (INB), Dr. Fernando Rodriguez; left: Ivonne Noboa, Encargada de Cooperación Académica, Embajada del Ecuador, and Speaker of the Research Consortium, Professor Jörg Bendix. Photo: courtesy of Tobias Baumann, Departamento de Prensa, Embajada de Ecuador en Alemania

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Figure 4: This years annual Status Symposium was the biggest so far and took place in the Centro de Convenciones of the UTPL. Photo: Felix Matt

more than 460 participants which shows the great importance and high visibility of our research in southern Ecuador (**Figure 4**). Besides numerous scientists and students from the participating universities UTPL, National University of Loja (UNL), University of Cuenca (UC) and Azuay (UDA) and our non-university partners (NCI, ETAPA, FORAGUA, Zamora), representatives of various other institutions were also attending the event. Among others, these were the Ecuadorian Planning Ministry SENPLADES, the Ecuadorian Science and Education Ministry (SENESCYT), the Secretaría Nacional de Gestión de Riesgos (SNGR), the Ecuadorian Weather Service (INAMHI), the National Agricultural and Environmental Ministry (MAGAP, MAE) and the Gobierno Municipal de Gualaquiza (GADM). The oral presentations were accompanied by a comprehensive and scientifically impressive poster session.

A current setback of the platform is the yet pending start of the Ecuadorian part of the program due to the legal problem of transferring public funds from the Ecuadorian agency SENESCYT to the private universities of the consortium (UTPL and UDA). In the meantime, the formerly selected mediator agency, ETAPA, could fortunately transfer the funds to the newly selected lead agency, the public University of Cuenca. During the symposium, the three rectors of the universities signed an agreement on the willingness to instantaneously transfer the respective shares from UC to the two private universities (UTPL, UDA) in order to immediately start the Ecuadorian part of the platform (**Figure 5**). We now have to discuss with the German Research Foundation DFG, how to successfully finish the joint program particularly in the knowledge transfer domain in view of the severe delay of the Ecuadorian contribution, because there is only a single year left for overlapping joint developments. This point was intensively discussed during the joint member assembly following the symposium on 7th October. The event-rich week was rounded off by a joint dinner of the platform members.

Visit from the German Embassy

After the symposium, the German Deputy Head of Mission and commercial counsellor, Martin Langer, took the opportunity to visit the ECSF research station to get in-

Figure 3: Two round tables discussed the development and implementation of functional and basic indicators of global change effects on biodiversity and ecosystem services (left). The participants received a certificate (right). Photos: Felix Matt

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Figure 5: Signature of the agreement presented by the coordinator of the Ecuadorian part of the platform (Dr. Suarez) under attendance of (f.l.t.r.): Martin Langer (German Deputy Head of Mission, Quito), Fabián Carrasco (rector UC), José Barbosa (rector UTPL), Carlos Cordero (rector UDA) and Jörg Bendix (German coordinator) in the Centro de Convenciones of the UTPL. Photo: Felix Matt

Figure 6: The German Deputy Head of Mission, Martin Langer, from the German Embassy inspected the infrastructure of the research program: the radar site LOXX of the RadarNet Sur knowledge transfer program at El Tiro (left) and the canopy tower for research on top of the rainforest (right). Photos: Jörg Bendix

formed on the infrastructure of and the work conducted in the platform project (**Figure 6**).

Second Knowledge Transfer Workshop

A week later, subprogram B conducted the second Knowledge Transfer Workshop on "Sustainable Land Use" on 13th October. After the opening of the workshop by Thomas Knoke two instructive lectures on the successful "Ecuadorian Reforestation Program MAGAP with pine, alder, caoutchouc, Eucalyptus and other species" by Guido Mosquera, and on the "National Plan of Forest Restoration" by Georgiana Braulete from MAE impressively showed the Ecuadorian endeavours for an economically paying land restoration. Thereafter Thomas Knoke introduced our system of valuating ecosystem services, followed by Julia Adams' presentation of the efforts in, and suggestions for pasture regeneration on bracken-invaded abandoned areas. Patrick Hildebrandt completed the lecture session with a lecture on afforestation of abandoned areas. The subsequent discussion brought up many interesting and important questions, especially on the costs of the introduced programs. The workshop was completed by a visit of an afforestation site of the associated forest transfer project "Nuevos Bosques para Ecuador" (**Figure 7**). More than 70 participants from the universities and the target stakeholder groups (e.g. including the National Ministry of the Environment MAE and the German GIZ) attended the very successful event.

Tabebuia Bulletin Expands

Finally, a note to our readers: Browsing through the Science News in this issue of Tabebuia Bulletin you will find one communication in the form of a full-length paper. As the contributions to our Bulletin like those to its predecessor, MRp|SE Newsletter have a digital object identifier (DOI) and are citeable, the Scientific Advisory Board of the German Research Consortium eased the regulations, allowing one full-length paper per issue, while retaining the length of the Science News with 2,000 characters. This smooth change will strengthen the scientific perception of our Bulletin. We hope that the new regulation will be attractive to our members and that we will regularly have a full-length paper in each issue of the Tabebuia Bulletin. When planning an extended manuscript, please consult our editor Dr. Esther Schwarz-Weig (esw@sci-stories.com) for a slot in one of the upcoming issues.

Figure 7: Participants visited the demonstration plots for afforestation during the workshop on sustainable land use. Photo: Felix Matt

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Science News - Short Communications

Effects of Experimental Nutrient Addition on the Root Systems of Tropical Montane Tree Species

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We evaluated the the response of tree root systems to continued addition of nitrogen and phosphorus.

Previous studies in tropical forests indicate that nutrient inputs could affect tree carbon storage and allocation, and alter the species' composition and diversity of forests. Existing studies on nutrient addition effects on tropical forest are mostly from lowland forests and had their focus on aboveground parameters. Since tropical montane forests are important carbon stores and a future increase of nutrient deposition could be expected for most tropical regions, the aim of our study in **project A1** is to contribute to a better understanding of root growth and root architecture under increasing nutrient availability.

Material and Methods

To evaluate the response of coarse roots after six years of continued nutrient addition, we selected two dominant trees species per elevation level (1000 m, 2000 m and 3000 m a.s.l.) in the ongoing Ecuadorian **NU**trient **M**anipulation **EX**periment (NUMEX). Diameter growth of stems and selected coarse roots was monitored from April 2014 to September 2015. In the same tree species we sampled fine root sections in March 2015 to analyze the root architecture (**Figure 1**). Here we present first data from the study site at 1000 m a.s.l.. The selected tree species were *Clarisia racemosa* and *Pouteria torta*. We analyzed the relative increment in coarse root diameter and several parameters related to fine root architecture (e.g. root diameter, tip density, specific root length, specific root area) for each of the species.

Results

Our preliminary analyses for the two species show no significant differences between fertilization treatments in relative coarse root increment over the study period (**Figure 2a**, next page). Both species responded with decreases in fine root diameter after additions of nitrogen (N), phosphoros (P) and a combination of N+P (**Figure 2b**). The decrease in root diameter was marginally significant in *Clarisia* after additions of P and in *Pouteria* after addition of N. Tip density in *Clarisia* increased with P and N+P additions but decreased with N addition different to *Pouteria* that showed an increase in tip density with N and N+P additions while P addition resulted in a decrease (**Figure 2c**).

Conclusion

From our first results on tree species responses to increased nutrient availability we conclude, that

- responses are species-specific
- there are no general response patterns with elevation
- P addition seems to have stronger effects than N addition.

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Figure 1: Fine root sections of *Clarisia racemosa* (left) and *Pouteria torta* (right) collected in the NUMEX plots at 1000 m a.s.l. Images: German Lopez

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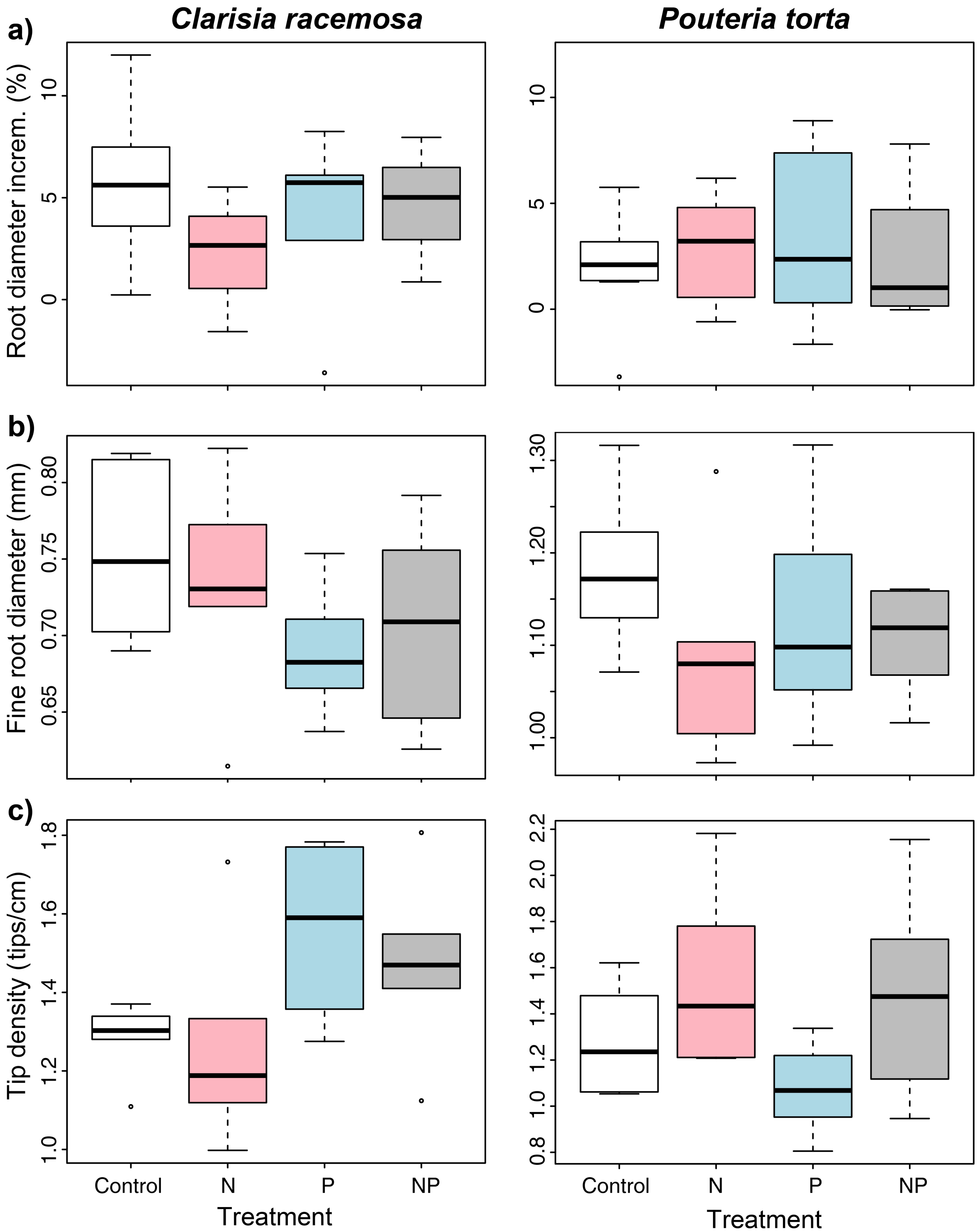

Figure 2: Effects of continued nutrient addition on relative coarse root increment monitored from April 2014 to September 2015 **(a)**, and on average fine root diameter in **(b)** and fine root tip density **(c)** in *Clarisia racemosa* (Moraceae) and *Pouteria torta* (Sapotaceae), two common tree species in the NUMEX plots at 1000 m a.s.l., fine roots were sampled in March 2015 after six years of continued nutrient addition. We found no difference in coarse root increment between the treatments, but marginally significant negative effects ($p < 0.10$) of N addition (in *Pouteria*) and P addition (in *Clarisia*) on fine root diameter and significant positive effects ($p < 0.05$) of N addition (in *Pouteria*) and P addition (in *Clarisia*) on fine root tip density (results from linear mixed effects models, boxplots show interquartile ranges and medians). Graph: German Lopez and Jhenny Salgado

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Responses of Arbuscular Mycorrhizal Abundance in Roots to Nutrient Additions Depend on Tree Species Identity

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We measured root colonization by arbuscular mycorrhizal fungi (AMF) in response to nutrient additions not only at the community-scale, but also using seedlings of different tree species. AMF abundance showed significant decreases with species- and site-specific variations.

AMF represent a group of obligate biotrophic plant symbionts, which are associated with more than 80% of land plants. In tropical forests they clearly represent the dominant mycorrhizal type, as is the case in the study area of the Podocarpus National Park.

As part of the **Nu**trient **M**anipulation **Ex**periment (NUMEX) we analyzed the responses of AMF abundance and community composition to nitrogen (N) and phosphorus (P) additions in detail for the last five years. In our **project A4** we were able to show that AMF species richness as well as community composition was significantly affected by N and P additions [1]. Furthermore, N additions reduced AMF abundance, whereas P additions had an increasing effect [2].

All of these AMF analyses have been conducted at the plant community-scale, covering AMF properties of the plant community in its entirety. Here, we aimed to characterize AMF responses at the species-scale (**Figure 1**). In collaboration with project A1 we analyzed AMF abundance in the roots of different tree seedlings, which were sampled in February 2013 in the NUMEX plots. Roots were stained with Trypan Blue and the percentage of AMF root colonization was determined. We found varying results depending on tree species identity, but also among species sampled at different elevational sites (**Figure 2**).

As previously found at the community-scale, strongest effects were observed at 2000 m. Likewise, these analyses confirmed the negative effect of N additions on AMF abundance, whereas the positive effect of P additions was not observed in these tree seedlings, which (at 2000 m) even showed a reduction in AMF root colonization under P treatment. Interestingly, responses in root biomass allocation did not correspond to the direction of effects described here, also varying among species [3].

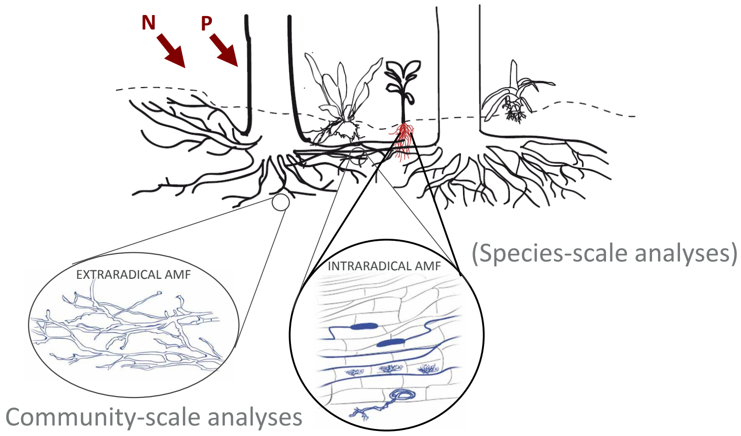

Figure 1: Sketch of the conducted analyses on AMF abundance in NUMEX. Graph: Tessa Camenzind

In conclusion, responses in intraradical AMF abundance to N and P additions differed among tree species, which might point towards differential strategies of tree species to react to increased nutrient availability.

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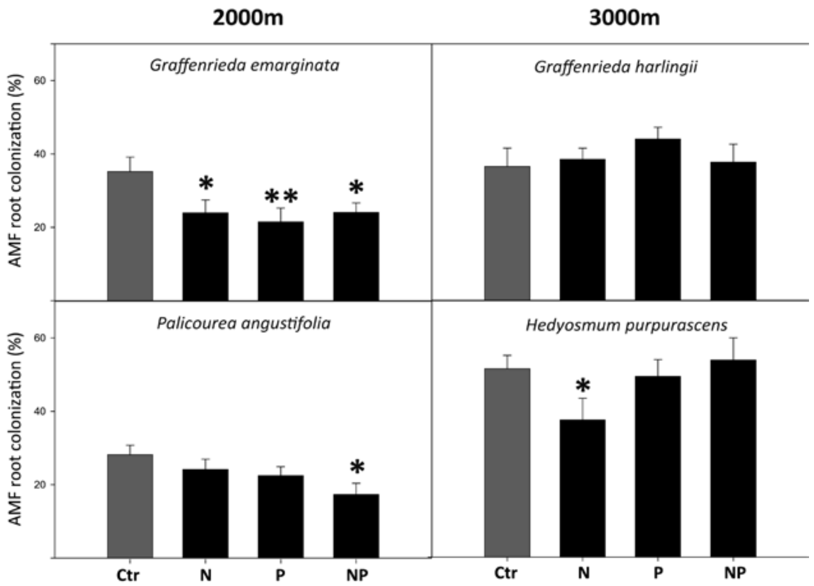

Figure 2: Responses in the percentage of AMF root colonization to N and P additions in seedlings of different tree species at two elevational sites. Bars represent mean values, error bars the respective standard error. Asterisks indicate significant differences compared to the control (linear mixed-effects model; $P < 0.05$). Graph: Tessa Camenzind

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Altitude Effects on Free and Total Enzyme Activity of the Organic Layer in a Montane Rain Forest in South Ecuador

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Our results highlight that the type of enzymes (free vs. stabilized) exuded to access sparingly available phosphorus in a tropical montane rainforest depends on climatic conditions and thus on altitude. Potential enzyme activity measures are influenced by the persistence of the enzymes particularly under lowland tropical climate calling for cautious interpretation in terms of nutrient release or availability.

The accumulation of an organic layer at higher altitudes [1, 2] might be caused by suppressed enzyme activity with enzymes being exuded to meet the organismic demand for carbon (C) and growth-limiting nutrients such as nitrogen (N) and phosphorus (P) [3]. However, potential enzyme activity measured at different points in time might be modified by the persistence of enzyme activity which in turn depends on the type of stabilization i.e. whether or not enzymes are sorbed to surfaces (cells, organic matter, clay minerals) as free enzymes are least protected against attack by protein-degrading enzymes (proteases) [3]. Our aims in **project A7** were to test the effect of altitude on i) total and free enzyme activity, and on ii) the persistence of total and free enzyme activity in the organic layer.

In October 2015, we sampled soil cores in the NUMEX experiment at 1000, 2000, and 3000 m a.s.l.. We used standard potential enzyme activity assays [5], which were conducted on bulk soil (total enzyme activity) and on solution extracted from soil containing free enzymes [6]. Enzyme activities were measured before and after incubation of the soil samples for 20 days. The effect of altitude was tested by one-way ANOVA and a post hoc Tukey test ($p < 0.05$; SPSS 21.0 IBM).

We found that potential total APase activity was significantly lower at 3000 m altitude (**Figure 1a**) which is in contrast with findings in the previous year [4] but matches well with the thick organic layer as a result of reduced decomposition at higher altitudes [2]. Potential free APase activities ranged from 51.6 to 93.1 µg Nitrophenol g^{-1} dry weight h^{-1} corresponding to 3.5 to 16.7% of total enzyme activities and representing a greater proportion as compared with [6]. Potential free APase enzyme activity was significantly lower at 1000 m altitude (**Figure 1c**), which might be linked to the low persistence of free enzymes [7]. During incubation, both total and free APase activities were reduced by 40 - 80% (**Figures 1b, d, f**). Plants, fungi, and bacteria can exude APase [3]. Based on reduction in APase activity, we infer a dominance of plant-/fungi-derived APase exuded before incubation. We found highest reduction of potential free APase activity at 3000m after incubation at 4°C (**Figures 1c, d**). Therefore, enzyme degradation is constrained by decreased stabilization of enzymes at lower altitudes and by temperature at higher altitudes rendering stabilization mechanisms negligible in the latter case. **In conclusion**, both weather conditions and the ratio between free and stabilized enzymes control altitudinal effects on APase activity.

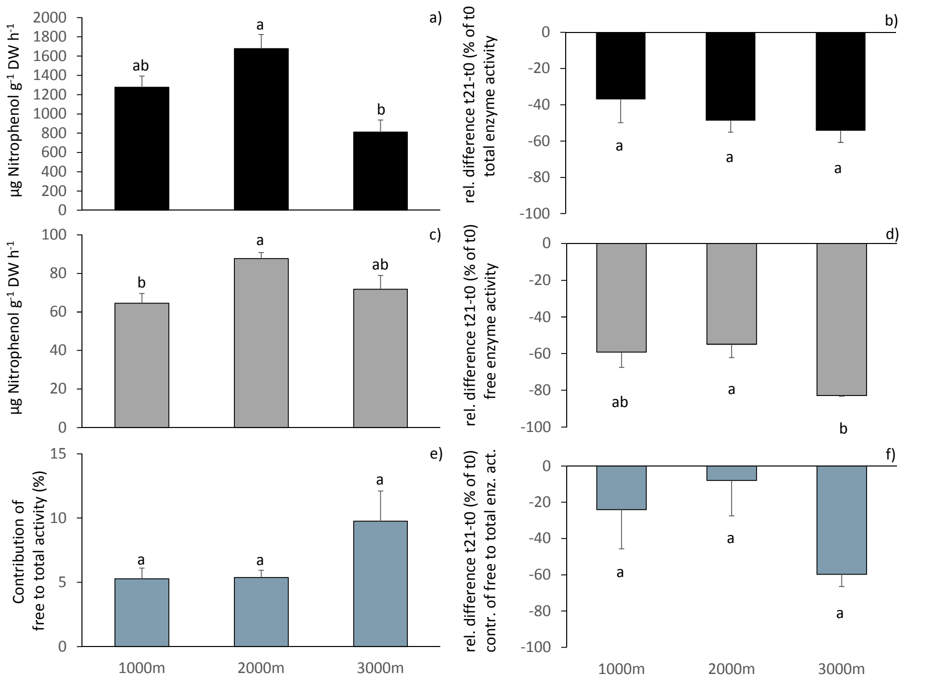

Figure 1: Potential total enzyme activities **(a)**, free enzyme activities **(c)**, and the contribution of free to total enzyme activity in the organic layer **(e)** at different altitudes. Relative differences for **a, c** and **e** after incubation are shown in plots **b, d** and **f**. All data is expressed as means. Error bars indicate one standard error. Different letters above bars refer to significant differences (Tukey test, $p < 0.05$). Graph: Yvonne Olemann

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High Elevation Tree Assemblages of the Andean Rainforests are Surprisingly Species Rich, Phylogenetically Diverse and Evolutionary Old

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We conducted a combined analysis of changes in species richness, phylodiversity and family age of tree assemblages along a mountain rainforest elevation gradient. Species rich, phylogenetically diverse tree assemblages with a high portion of species from evolutionary old families were found at high elevations.

Species richness, phylogenetic diversity and mean family age of species are known to decrease for a high number of different taxa from tropical towards temperate latitudes. The Tropical Conservatism Hypothesis (TCH) tries to explain this pattern with the old age of tropical climates, which leads to a high number of tropical lineages with traits adapted to tropical conditions [1]. Conservatism in traits thus retards the colonization of extra-tropical regions by tropical lineages. Consequently, the TCH predicts decreasing species richness, phylodiversity and clade ages towards areas with temperate climates. Numerous studies found these expected patterns along the latitudinal gradient. As elevational gradients resemble latitudinal gradients and many mountains, e.g. the Andes are geologically young, we in **project C2** tested if it is possible to translate the predictions of the TCH to the elevational scale. We expected decreasing species richness, phylodiversity and mean family age of tree assemblages with increasing elevation (1000 to 3000 m a.s.l.) in rainforests of the tropical Andes.

On 54 study plots we recorded in total 3740 tree individuals (dbh ≥ 5 cm) which belonged to 420 species from 178 genera and 72 families. We found no effect of elevation on the rarefied species richness (random sample of 17 tree individuals from each plot, **Figure 1**) but the phylodiversity increased along the elevational gradient (**Figure 2 A**). Important drivers of the phylodiversity pattern were two gymnosperm species with a distribution at mid and high elevations (**Figure 2 B**). The mean family age on our plots also increased with elevation, which was not only due to the presence of old gymnosperm families but also higher numbers of old angiosperm families at high elevations (**Figure 2 C, D**). Our findings contradict expectations derived from the TCH. The predictions of the TCH were thus not transferable to the elevational scale. This suggests that different processes influence the colonization across latitudinal and elevational gradients.

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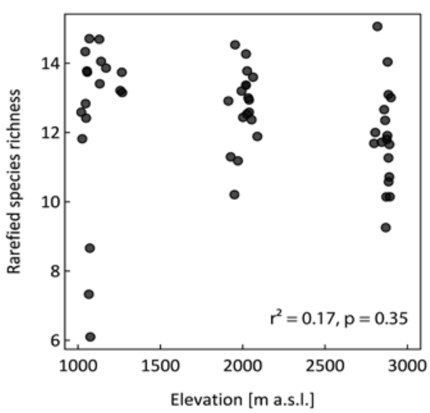

Figure 1: Linear regression model of rarefied species richness (n = 17 trees) in the study plots in relation to elevation. Graph: Yvonne Tiede

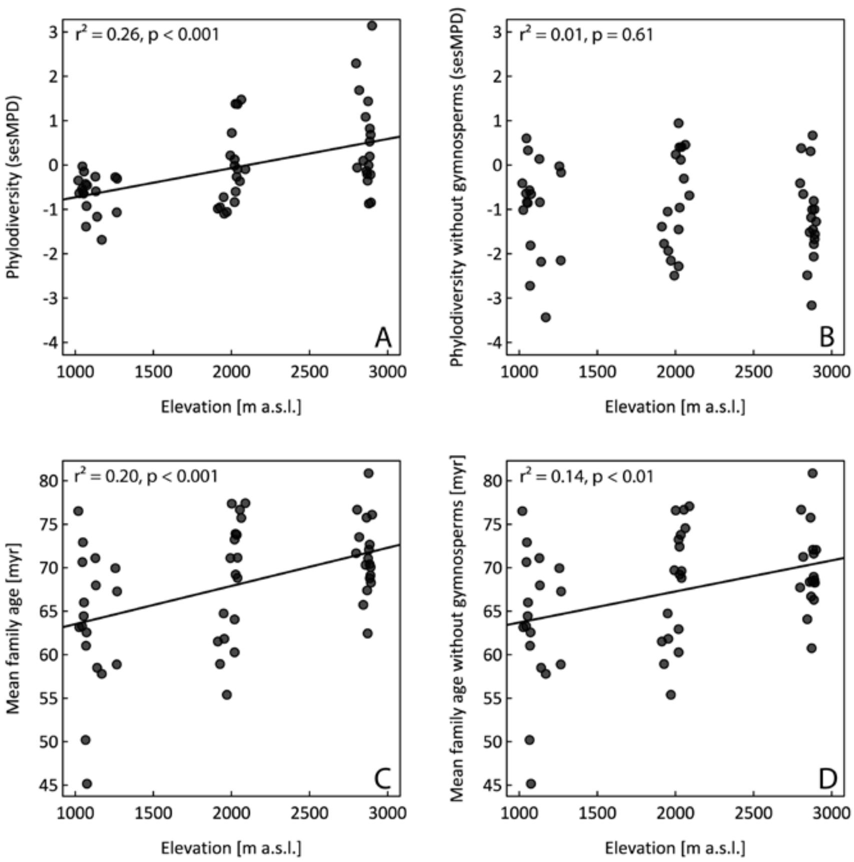

Figure 2: Linear regression models of the phylodiversity of the tree assemblages measured as standardized effect size of the mean pairwise phylogenetic distance (sesMPD) of tree individuals in relation to elevation (**A**) and of assemblages after removing gymnosperms from the dataset (**B**). Linear regression model of the relationship between mean family ages of tree individuals and elevation for the complete dataset (**C**) and after removing gymnosperms from the dataset (**D**). Lines indicate significant relationships ($p < 0.05$). Graph: Yvonne Tiede

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Tree Water Use Patterns and Forest Inventory in a Submontane Tropical Dry Forest

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During our sap flux study we found differences in the magnitude of transpirational water fluxes among three phenologically different tree species. This led us to the question of different water storage mechanisms and drought coping strategies of these trees.

In **project C5** we started our sap flux measurement campaign in the dry forst of Laipuna in March 2014. As a first step, we chose four phenologically different tree species: *Ceiba trichistandra* (stem succulent), *Eriotheca ruizii* (root succulent) and *Erythrina velutina* (typical leaf deciduous). Three plots were established at altitudes of 670, 860 and 1100 m a.s.l.. On every plot each species was studied with four replicates. Every tree was equipped with two pairs of Granier type (TDP) sap flux sensors. Sap flux was continuously monitored over a period of 14 months.

During the wet period, *Ceiba* had high values for daily water flux on the lowest and driest altitude (**Figure 1**). At the same altitude *Erythrina* and *Eriotheca* had their lowest values. This pattern changed with increasing altitude. *Ceiba* reduced water consumption by about -50% at higher elevations, whereas *Eriotheca* and *Erythrina* showed differently pronounced increases (+50% and +13%, respectively) (**Figure 1**). However, leaved periods differed among species and topographic positions. Thus, clear differences among species and topographic positions and tree water use patterns are revealed.

A forest inventory was conducted on 52 plots using a systematic sampling in the disturbed forest adjacent to reserve Laipuna (**Figure 2**), covering altitudes of 600 to 1080 m a.s.l.. This data was compared to inventory data from J. Homeier (unpublished) of the natural forest. We indicated a loss of tree species (39 vs. 22) and a reduction in number of stems (476 vs. 166 stems ha^{-1}) in the disturbed forest, but evergreen trees seemed to be reduced to a lesser extent than deciduous trees (**Table 1**).

Several species showed an increase in importance value index at the disturbed site (**Figure 3**). This was most pronounced for

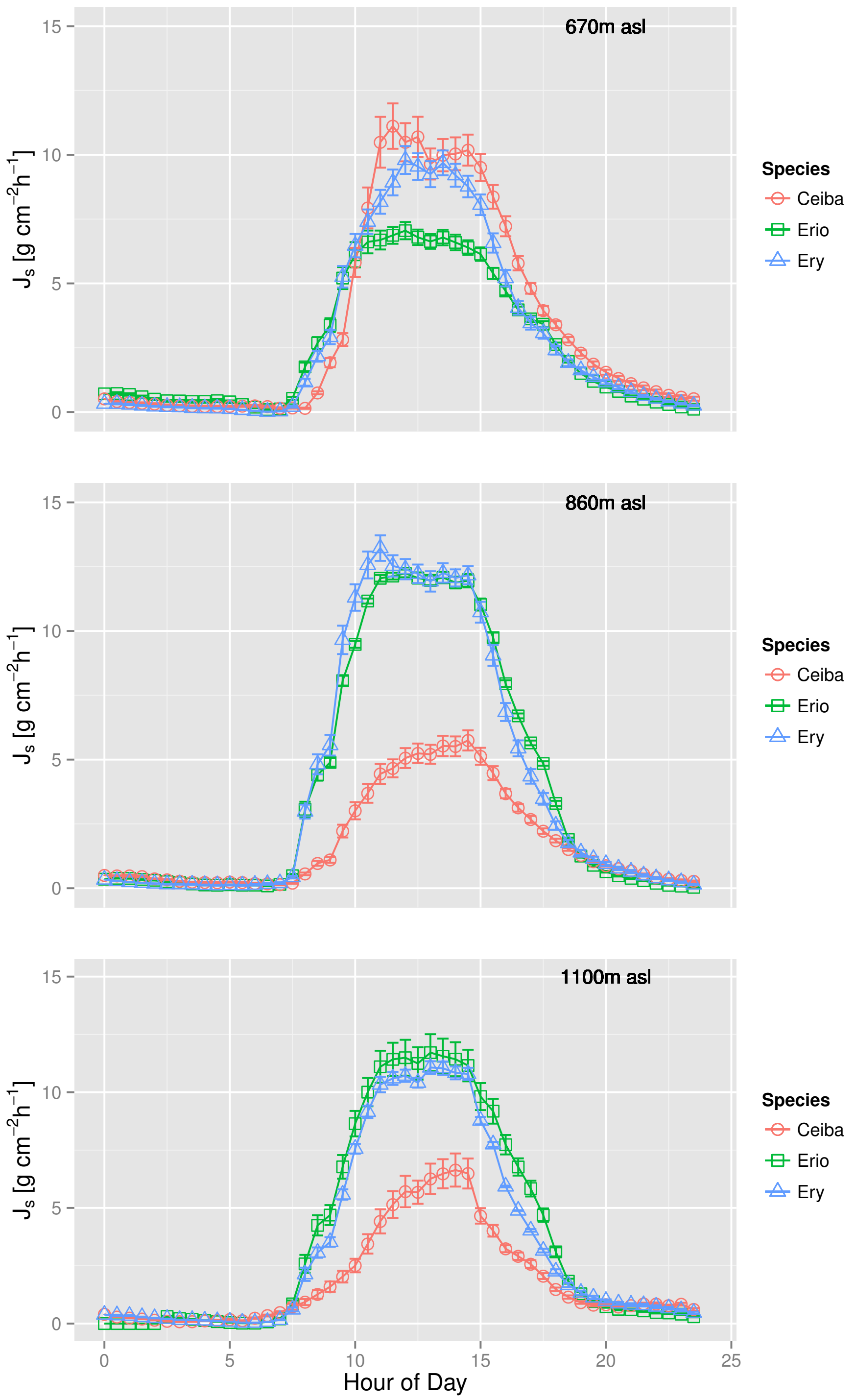

Figure 1: Mean daily sap flux density for *Ceiba trichistandra, Eriotheca ruizii* (Erio) and *Erythrina velutina* (Ery) with n = 4 repetitions at 670 m, 860 m and 1100 m a.s.l. on 10 April 2015. Graph: Philipp Butz

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Figure 2: Area of disturbed forest site close to the Laipuna forest reserve. Photo: Philipp Butz

Table 1: Number of species and stems in the natural and disturbed forest of Laipuna

Forest type	No. of species ha^{-1}	Stems ha^{-1}
Evergreen species		
Natural	7	52
Disturbed	8	30
Deciduous species		
Natural	32	452
Disturbed	14	153

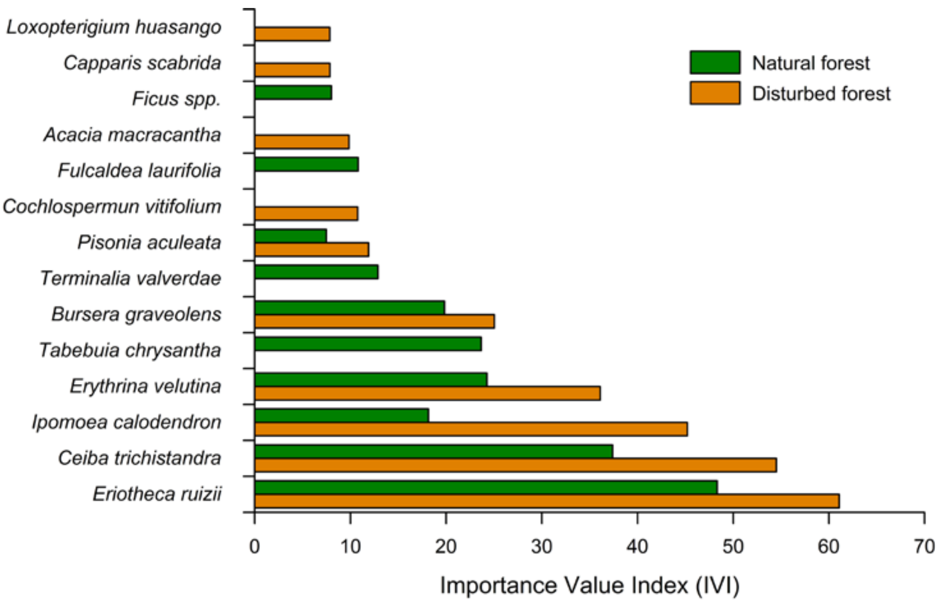

Figure 3: Importance value index (IVI) of the top ten ranked tree species in the disturbed and undisturbed forest of Laipuna (IVI = relative abundance + relative dominance + relative frequency). Graph: Ruffy Rodrigo und Sophie Graefe

Ipomoea calodendron, which is a pioneer species that gets quickly established after disturbance, especially at upper elevations.

As a next step, we are working to disentangle the effects of micro-meterological conditions (VPD, solar radiation and soil moisture) on tree sap flux, as well as to look in more detail into species specific water storage mechanisms. To better understand the findings we will use a Jarvis-type model and analyze hysteresis loops with regard to the environmental variables, water use response and water storage process. Furthermore we want to relate our sap flux data to high resolution band dendrometer data from project A2 (installed on the same trees), in order to understand relationships between tree growth and water use.

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Water Use Efficiency as a Mean for Upscaling Carbon Uptake from the Leaf to the Whole-Tree Level

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We investigated water use efficiency and its components carbon uptake and water loss of leaves of trees in the RBSF forest as a tool for upscaling carbon uptake from leaf to tree level.

Carbon relations of tropical trees and forests are important for the calculation of their potential as carbon sinks. However, measurements of carbon uptake, while easy with single leaves of a tree crown are a big challenge for whole trees. Therefore, in **projects C5 and C6** we used the relationship between net CO_2 uptake and transpiration (the so-called water use efficiency, WUE) of individual leaves on the one hand and the daily water consumption of the whole tree on the other hand, to upscale daily carbon uptake of various trees in the tropical mountain forest of the Reserva Biológica San Francisco (RBSF).

Methods

Measurements were taken on eight trees between October 2014 and November 2015 in the RBSF of which the crowns were accessible by towers (for detailed experimental setup, see [1]). A portable porometer (LI6400 XT, LI-COR Biosciences, Lincoln, NE) was used for carbon uptake and transpiration measurements. Water use efficiency was calculated as WUE = A/E where A is net carbon uptake (g C m^{-2} day^{-1}) and E is the transpiration of the same leaf (kg H_2O m^{-2} day^{-1}). The leaf water use efficiency over the daily light period multiplied by the total tree water consumption per day yields the total daily carbon uptake of the tree. The total tree water consumption was measured as sap flow (SF) with three Granier sensors per stem.

Results

The diameter at breast height (dbh) of the trees ranged between 10 and 28 cm (see legend **Figure 1**). Total water consumption of the trees increased with tree size and with vapor pressure deficit (VPD). As most of the trees do not present a completely shaded leaf layer, WUE was not significantly different between leaves of the upper and the lower part of the crown. Accordingly, we used the average WUE for calculating whole tree carbon uptake on days with simultaneous measurements on different parts of the crown (**Table 1**).

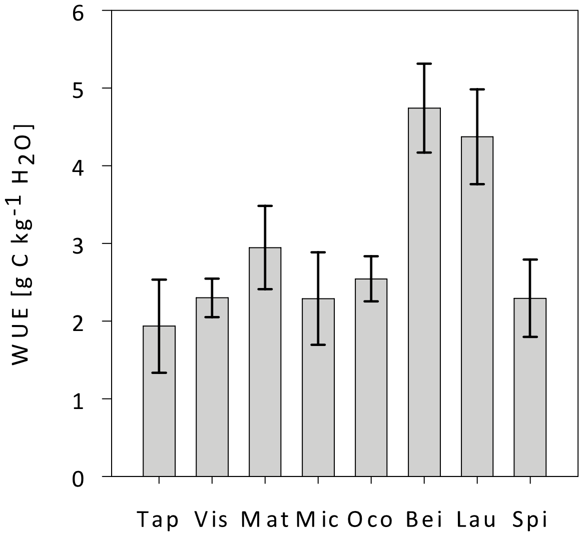

Figure 1: Average water use efficiency (WUE) of eight trees in the RBSF forest on selected days between October 2014 and November 2015. Tap: *Tapirira guianensis* (dbh 26.5 cm) (Anacardiaceae), Vis: *Vismia tomentosa* (dbh 22.2 cm) (Clusiaceae), Mat: *Matayba inelegans* (dbh 10.0 cm) (Sapindaceae), Mic: *Miconia punctata* (dbh 10.5 cm) (Melostamataceae), Oco: *Ocotea aciphylla* (21.3 cm) (Lauraceae), Bei: *Beilschmiedia tovarensis* (dbh 28.0 cm) (Lauraceae), Lau: Lauraceae sp. (dbh 12.0 cm) (Lauraceae), Spi: *Spirotheca rosea* (dbh 15.2 cm) (Bombacaceae). Graph: Simone Strobl

Average WUE of all investigated trees ranged between 1.9 and 4.7 g carbon per kg water on the respective measured days (**Figure 1**). WUE was observed to depend on the tree species and the weather conditions but it did not vary with the tree size (dbh). High irradiation during midday increased transpiration and reduced WUE (**Figure 2a**), whereas WUE was usually higher during the morning and afternoons. Under cloudy weather conditions, water

Table 1: Water use efficiency (WUE)*)

Tree	date	WUE_{LC}	WUE_{UC}	WUE_{mean}
V. tomentosa	14.10.2014	1.7 + 3.0		2.4
V. tomentosa	18.10.2014		2.4 + 1.8	2.1
V. tomentosa	20.10.2014	3.6 + 2.1	3.5 + 3.5	3.2
O. aciphylla	3.12.2014	3.7	4.1	3.9
O. aciphylla	4.12.2014	2.1	4.1	3.1
O. aciphylla	9.03.2015	3.5 + 3.9		3.7

*) WUE of leaves of the lower (WUE_{LC}) and the upper (WUE_{UC}) crown measured on the same day on up to 4 leaves per tree. Average water use efficiency (WUE_{mean}) was used to calculate the total carbon uptake of the respective day.

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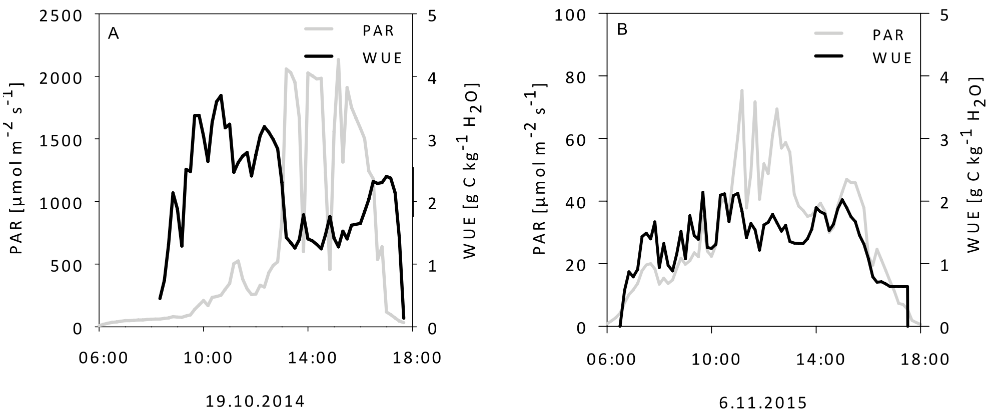

Figure 2: Daily courses of water use efficiency (WUE) and photosynthetic active radiation (PAR). **A**: *Vismia tomentosa* on a sunny day (19th Oct. 2014, **B**: *Tapirira guianensis* on a cloudy day (6th Nov. 2015). Mean water use efficiencies were 2.1 and 1.4 g C kg^{-1} H_2O for *V. tomentosa* and *T. guianensis*, respectively. Graph: Simone Strobl

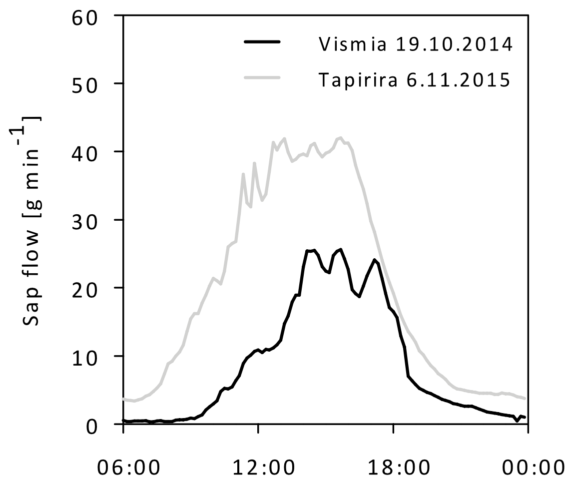

Figure 3: Daily courses of sap flow of *Vismia tomentosa* (19th Oct. 2014) and *Tapirira guianensis* (6th Nov. 2015). Total daily tree water consumption were 10.4 and 23.0 kg for *V. tomentosa* and *T. guianensis*, respectively. Graph: Simone Strobl

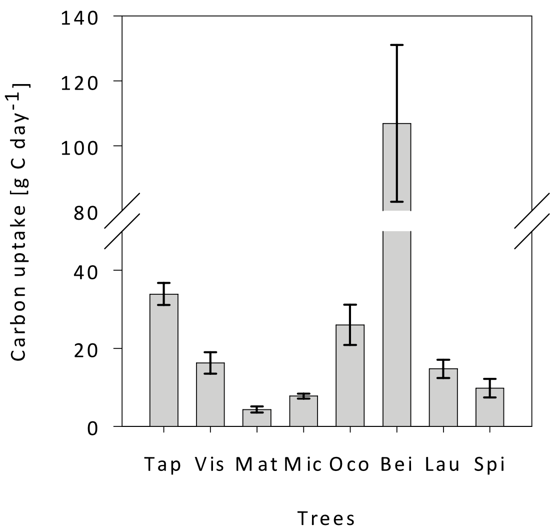

Figure 4: Mean daily carbon uptake of eight trees on selected days between October 2014 and November 2015 in the RBSF forest. Tap: *Tapirira guianensis*, Vis: *Vismia tomentosa*, Mat: *Matayba inelegans*, Mic: *Miconia punctata*, Oco: *Ocotea aciphylla*, Bei: *Beilschmiedia tovarensis*, Lau: Lauraceae sp., Spi: *Spirotheca rosea*. Graph: Simone Strobl

use efficiency was more or less constant during the day (**Figure 2b**).

In **Figure 3**, the corresponding daily courses of sap flow of *V. tomentosa* and *T. guianensis* are shown, accumulating to 10.4 and 23 kg of total water uptake. For calculating the total carbon uptake of the two trees on these days, we multiplied the daily WUE, i.e. the sum of carbon taken up per m^2 leaf area divided by the total amount of transpired water by the same leaf area (2.1 and 1.4 g C sequestration per kg water loss, respectively) with the total water consumption of *V. tomentosa* and *T. guianensis*. This calculation results in a total carbon gain of 22 g for *V. tomentosa* and 32 g for *T. guianensis* on the two days.

So far, our data allow us to calculate whole tree carbon gain for eight trees of different species on 46 days (**Figure 4**). The ongoing measurements in the dry season 2015 will provide more data to calculate whole tree carbon uptake under different weather conditions. For upscaling from the tree to the plot level, we will compare the data with the eddy covariance measurements of project C6.

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Canopy Organisms Retain Sodium in the Tropical Montane Forest

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We have measured sodium (Na) fluxes in a microcatchment in the Reserva San Francisco and observed decreasing Na deposition since 1998. Na was retained in the canopy and to a lesser extent in the organic layer. Furthermore, Na leaching from the organic layer substantially decreased from 1998 to 2012. Na retention may be attributable to Na limitation of phyllosphere organisms, which we tested in a laboratory experiment.

Recent studies raise the hypothesis that Na shortage restricts decomposition and affects the carbon cycle in tropical forests [1]. While Na is an essential element for animals and bacteria [2], the need of Na of terrestrial plants is usually low and hence Na is not considered an essential nutrient. Yet, in contrast to plants and animals, little is known of Na demands of soil fungi and phyllosphere microorganisms.

We present results from a study on Na limitation in the 9 ha-large Microcatchment 2 situated in the Reserva San Francisco in South Ecuador under an undisturbed lower montane rainforest at 2000 m a.s.l., where **project A6** has measured element fluxes in rainfall, throughfall, stemflow, litter leachate, litterfall, organic layer and stream water since 1998. We tested the hypotheses that (1) the study area is characterized by low Na concentrations because of low deposition rates with incident precipitation and (2) Na is retained in the canopy, possibly because of Na limitation of microorganisms in the phyllosphere.

Our results reveal that Na concentrations and stocks in the organic layer, which represents the main rooting zone, are low (**Figure 1**). Mean annual Na fluxes with litterfall decreased from an already low value of 0.9 kg^{-1} ha^{-1} in 1998 to less than 0.1 kg^{-1} ha^{-1} in 2012. The stands are remote from the sea and because of dominant wind directions from the Amazon Basin, Na deposition rates are low and thus the ecosystem does not receive substantial Na inputs from the atmosphere. Total Na deposition decreased within the past 15 years from ca. 40 kg ha^{-1} a^{-1} in 1998 to less than 10 kg ha^{-1} a^{-1} in 2012 (**Figure 2**). However, the reason for the decreasing Na deposition is unknown. Additionally, we found comparatively low Na concentrations in the ecosystem solutions, similar Na concentrations in throughfall and stemflow, as well as

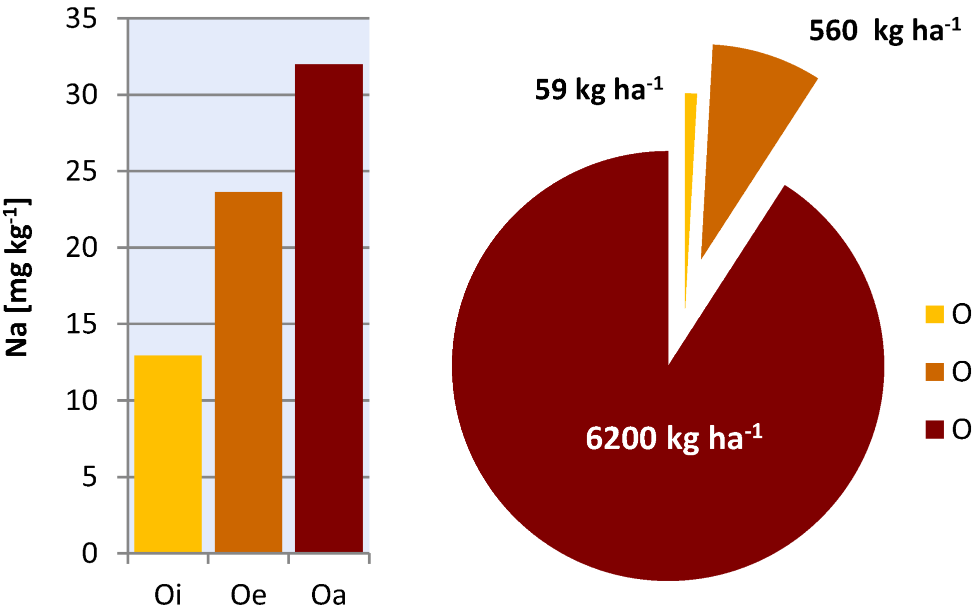

Figure 1: Mean Na concentrations and stocks in the organic layer horizons (Oi, Oe, Oa) of the study area (n = 12). Graph: Andre Velescu

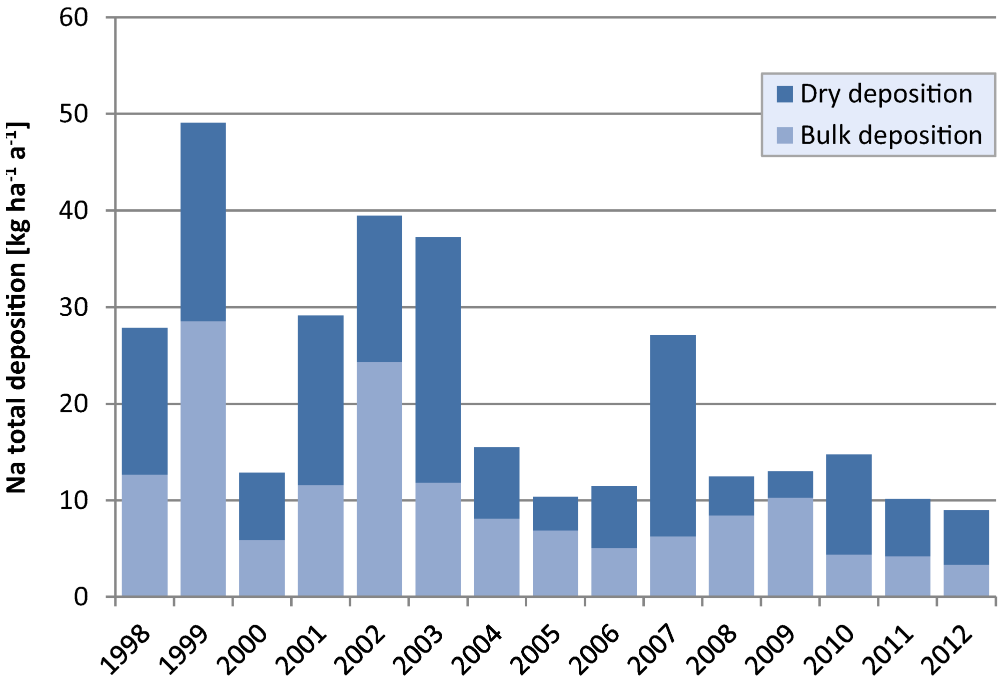

Figure 2: Total annual deposition of Na from the atmosphere in the study area from 1998 to 2012. Graph: Andre Velescu

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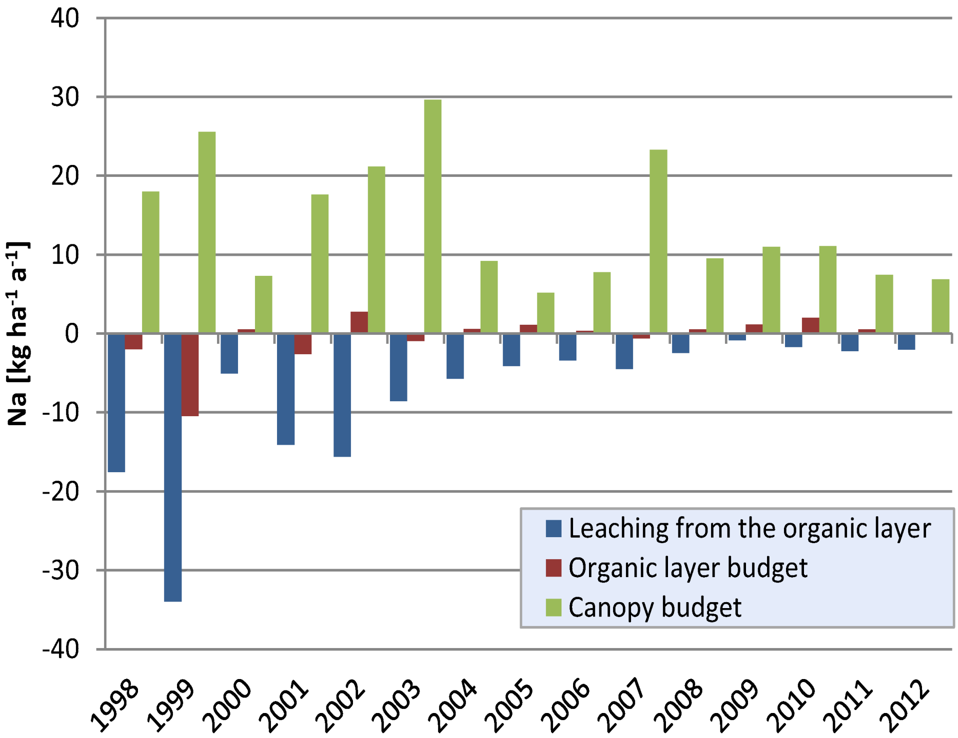

Figure 3: Annual Na leaching from the organic layer, Na budget of the organic layer and of the canopy from 1998 to 2013. Negative budget values indicate net loss, positive values indicate net retention. Graph: Andre Velescu

substantially decreasing Na leaching from the organic layer between 1998 and 2012. Since Na fluxes are lower with throughfall than with incident rainfall, which leads to a positive canopy budget, we conclude that Na is retained in the canopy (**Figure 3**).

Figure 4: Na spraying of similar leaves without phyllosphere cover (left side) and with phyllosphere cover (right side). Leave details are highlighted as overlay (blue contour). Photo: Tobias Fabian

The phyllosphere provides the vastest biological surface on Earth [3]. Especially in rainy areas with dense vegetation, the surfaces of leaves often have thick covers and contain even higher plants. To explore the role of the phyllosphere in Na retention, we investigated the absorption of Na on the surface of leaves, which is an important habitat for bacteria, yeasts, lichens, algae and mosses. We sampled leaves with similar areas covered by phyllosphere microorganisms at two different stages (ca. 20–30 and 80–90 percent cover) and leaves without phyllosphere cover. We chose leaves from the five tree species *Guarea kunthiana* A. Juss., *Piper arboretum* Aubl., *Meriania franciscana* C. Ulloa & Homeier, *Graffenrieda emarginata* Triana and *Psychotria tinctoria* Ruiz & Pav., which we have sprayed for two hours with 100 ml of a NaCl solution equivalent to a rain event of ca. 10 mm and containing 1 mg L^{-1} Na, which equals the Na concentration in incident rainfall in our study area during La Niña events (**Figure 4**). Pending chemical analyses of the leaves and of the NaCl solution collected after the treatment should reveal if and to which extent Na is retained by phyllosphere organisms, thus eventually finding a way into the animal food chain.

Conclusion

Our results suggest that Na availability possibly plays a regulating role in the study ecosystem which might even grow in importance if Na deposition from the atmosphere continues to decrease or stabilizes at the current low level.

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Science News

Modeling the Competition Between the Pasture Grass *Setaria sphacelata* and Bracken: Comparison of Photosynthetic Capacities at Different Altitudes

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Valuable mountain rain forest can be preserved when usage of pasture land would be more sustained. The invasive nature of bracken in high-altitudes frequently leads to a loss of pasture areas with *Setaria* **as forage grass. In order to analyze this competition, results from field measurements and modeling approaches were combined to compare the photosynthetic capacities of both species at different altitudes. The simulated rates of CO_2 assimilation exhibit a clear advantage of photosynthetic performance for the C3 plant bracken at higher altitudes as opposed to lower locations. Since C4 photosynthesis of** *Setaria* **appears to be limited by lower temperatures in the upper pasture sites, a C3 forage grass would be preferable for more efficient usage of high-altitude pastures.**

Introduction

The tropical mountain forests in southern Ecuador are among the most threatened ecosystems in the world. The non-sustainable management of agricultural land, mainly pastures, leads to massive destruction of this unique ecosystem which is considered a biodiversity hotspot [1,2]. Large areas of mountain rain forests have been and still are cleared by slash and burn to gain new areas for pasture farming. Commonly the C4-pasture grass *Setaria sphacelata var. splendida* is planted on freshly cleared areas. However, *Setaria* frequently gets under strong competitive pressure by the extremely invasive C3 species *Pteridium arachnoideum* and *P. caudatum* (bracken) [3] (see **Photo**). Especially on steeper slopes bracken soon dominates and finally overgrows the grass after a few years, whereupon the pastures are abandoned and more mountain forest is cleared for the same purpose [4]. To counteract the ongoing clearing of the forest, methods for the efficient and sustainable management of the pastures need to be developed [3, 5]. Long-term use of the existing pastures would slow down or even prevent further deforestation. To this end, it is essential to understand the competition between the pasture grasses, in particular *S. sphacelata*, and the invading bracken.

Photo: Bracken (*P. arachnoideum*) invads a pasture planted with *Setaria*. The picture demonstrates the typical situation in a high-altitude pasture when bracken outcompetes the forage grass after a few years of grazing. Photo: Johannes Knüsting

In this communication, we focus on the ecophysiology of photosynthesis as the basis of biomass production, growth and competition between the competing plant species. Using meteorological variables as forcing data, we simulated photosynthetic CO_2 net uptake (henceforth referred to as A) during the entire light period of the day employing the already published Southern Bracken Competition Model (SoBraCoMo, [6]). This model has been developed to assess the photosynthetic performance of bracken and *Setaria* when growing at the same location on the northern slopes of the San Francisco valley. There, the competition of both species appears more or less balanced, responding immediately to the respective weather conditions [6]. However, at other elevations, the relations in cover abundance change at lower altitudes in favor of *Setaria*, and at higher altitudes in favor of bracken. Radiation intensity and temperature are environmental fac-

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tors which change considerably with the altitude of the site. Therefore, we improved the SoBraCo-model by including species-specific photosynthetic parameters derived from field measurements at different altitudes. In previous modeling attempts the photosynthetic parameters were derived from plants grown in greenhouses. Therefore, it is likely that long-term adaptations or photoinhibition of the modeled plants are not reflected in such attempts. Especially at the higher altitudes, the photosynthesis could be limited by several abiotic factors, e.g. temperature or radiation. To support our hypothesis that temperature is a crucial environmental factor for A, we chose two sites of different elevation (1850 m a.s.l.; latitude: 3° 58’ 18” S, longitude: 79° 4’ 44” W and 2110 m a.s.l.; latitude: 3° 57’ 50” S, longitude: 79° 4’ 37” W) in the study area in the proximity of the Reserva Biologica San Francisco, on which both plant species coexist. For parameterization of the model photosynthesis-related variables were determined for *Setaria* and bracken at both sites based on their (i) light-response curves of A at ambient CO_2 partial pressure, (ii) the response of A to the internal CO_2 concentration (the so-called A/Ci curves), and (iii) the maximum rates of A. The maximum rate of CO_2 net uptake was considered as the photosynthetic capacity that reflects the adaptation of a plant to the environment of its habitat.

To validate the amended model, daily courses of A of *Setaria* and bracken at one site (the upper site) were measured simultaneously with the forcing variables of the climate.

Methods

Photosynthetic CO_2 net uptake was measured with a portable porometer (LI6400 XT, LiCOR Biosciences GmbH, Bad Homburg, Germany) equipped with a 6400-40 leaf chamber fluorometer. When changing the light (PAR) intensity, an intermittent interval of 2 min was allowed for adaptation of the leaves to the new condition. The light-response curve started with the highest intensity which was stepwise decreased, and the similar principle was used for the A/Ci curves. The internal CO_2 concentration in the leaf (Ci) was directly obtained from the porometer after applying the chosen CO_2 concentrations to the air stream. The derived photosynthetic parameters were integrated into a model which includes meteorological data recorded at the two sites for simulating photosynthetic performance. The model is based on earlier attempts as the SoBraCo model [6] and the accepted photosynthetic models of Farquhar et al. [7] and Collatz et al. [8, 9].

Results and Discussion

The light response of A at two elevations

At the lower site, the measured maximum of photosynthetic CO_2 net uptake was 18.6 µmol m^{-2} s^{-1} for *S. sphacelata*, whereas it was according to the students t-test significantly lower ($p = 0.01$) for *P. arachnoideum* (12.5 µmol m^{-2} s^{-1}, **Figure 1A**). On the higher-up pastures, for *P. arachnoideum* the maximum rate was only slightly lower (11.2 versus 12.5 µmol m^{-2} s^{-1}), while that of *S. sphacelata* was decreased by 40% (11.4 versus 18.6 µmol m^{-2} s^{-1}, **Figure 1B**).

Light saturation of A of bracken is at around 1000 µmol quanta m^{-2} s^{-1}, and there is no significant difference between bracken at the two sites. In contrast, light saturation of photosynthesis of *Setaria* showed strong

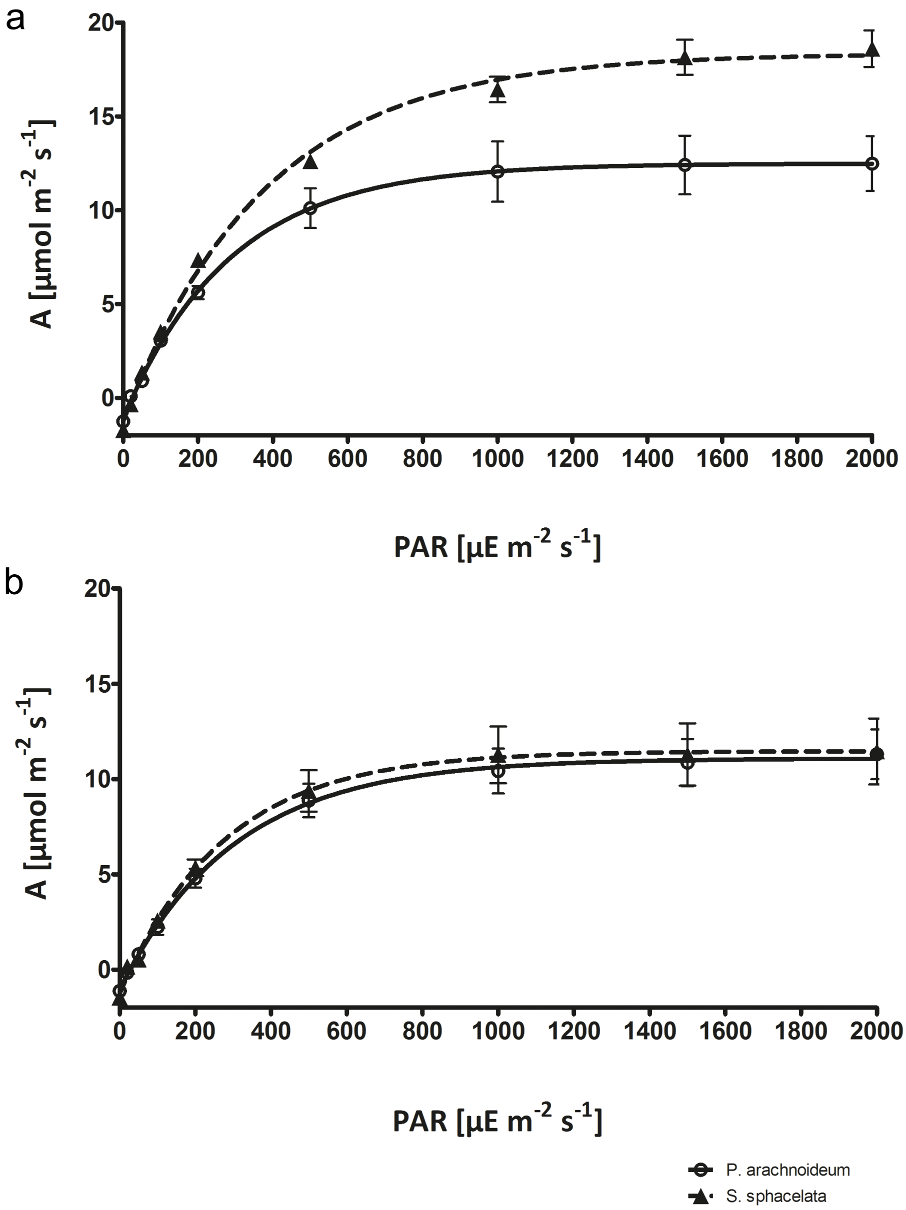

Figure 1: Light-saturation curves of *S. sphacelata* and *P. arachnoideum*. Photosynthesis rates **(A)** of *S. sphacelata* (triangles) and *P. arachnoideum* (circles) were determined as dependent on the light intensity (PAR). The light-saturation curves were taken at two different altitudes: at 1850 m **(a)** and at 2110 m **(b)**. The measurements were performed at 400 ppm CO_2 and ambient temperatures. n = >3
Graph: Johannes Knüsting and Michael Schorsch

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dependence on the elevation. At 2110 m the light-saturation curve equaled that of bracken, but at 1850 m the rate of photosynthetic CO_2 uptake at 1000 µmol quanta m^{-2} s^{-1} was only 90% of the maximum rate which was achieved at around 1600 µmol quanta m^{-2} s^{-1}. Since in the open pastures light intensities are mainly between 600 and 1000 µmol quanta m^{-2} s^{-1}, light as such does not appear as the major limiting factor of photosynthesis for most hours of the daylight period. Nevertheless, if mutual shading takes place, competition for light may indeed occur.

Response of A to varying CO_2 concentrations

Considerable differences of photosynthetic CO_2 net uptake between bracken and *Setaria* on the one hand and between the same species growing at different elevations on the other were observed in the photosynthetic response to the CO_2 concentration, as indicated by the A/Ci curves (**Figure 2**) at saturating light intensities. Saturation of the C4 photosynthesis of *Setaria* was expected at lower CO_2 concentrations than that of the C3 photosynthesis of bracken. However, this expectation was only met at the lower site where photosynthetic CO_2 net uptake of bracken was not fully saturated at a Ci of 1600 ppm. Likewise expected were the higher photosynthetic rates of the C3 plant bracken at high CO_2 concentrations and the lower rates at concentrations below 500 ppm (**Figure 2A**). At the higher elevation, photosynthesis of both species was not yet fully saturated at 1600 ppm internal CO_2 concentration and the photosynthetic performance of *Setaria* was much poorer than that of its competitor (**Figure 2B**). Only at a Ci below 100 ppm the C4 plant *Setaria*

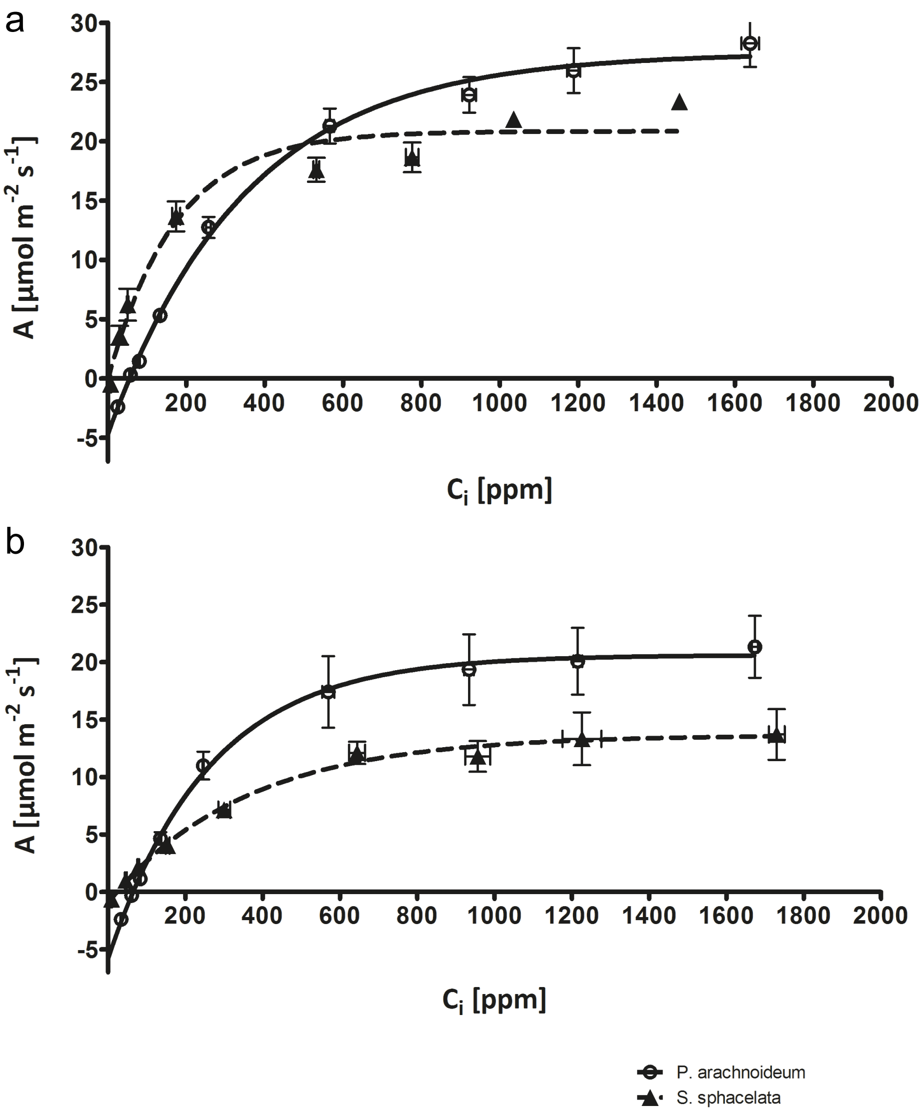

Figure 2: A/Ci curves of *S. sphacelata* and *P. arachnoideum*. Photosynthesis rates **(A)** of *S. sphacelata* (triangles) and *P. arachnoideum* (circles) were determined as dependent on CO_2 partial pressure (Ci). A/Ci curves were taken at two different altitudes: at 1850 m **(a)** and at 2110 m **(b)**. The measurements were performed at 1200 µmol quanta m^{-2} s^{-1} and ambient temperatures. n = >3. Graph: Johannes Knüsting and Michael Schorsch

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photosynthesized more efficiently than the C3 plant bracken.

In summary, the photosynthetic capacity of bracken was more or less independent of the elevation, while that of *Setaria* decreased significantly at higher altitudes (**Figures 1 and 2**).

Testing of the model

The refined model was tested by comparison of the daily courses of A measured at the upper plot with the simulated complements (**Figure 3**). The improved SoBraCoMo exhibited a better fit of the simulated with the measured A in particular for the C3 plant bracken (r^2 = 0.86). The simulated and the measured daily courses of A of *Setaria* match less well, but agreement of both curves is acceptable (r^2 = 0.65). Differences appear mostly in the morning hours, when the modeled photosynthetic CO_2 net uptake is too high, presumably due to a still insufficient temperature correction.

Modeling the daily courses of A at the lower site corroborate the weak temperature dependence of A of bracken, and the strong one of the C4-grass *Setaria* (**Figure 4**). C4 photosynthesis shows temperature optima above 20°C [10], a temperature range that is not regularly met even at the lower study site (mean temperature during the daily light period = 19.0°C), but not at all at the higher-up site. This explains the competitive advantage of bracken at higher elevations. At elevations lower than 1850 m an according advantage of Setaria could be expected. Thus the observation of a change of the balance of the competition between *Setaria* and bracken with the elevation may be traced back to the effect of the strong altitudinal temperature gradient in the San Francisco valley.

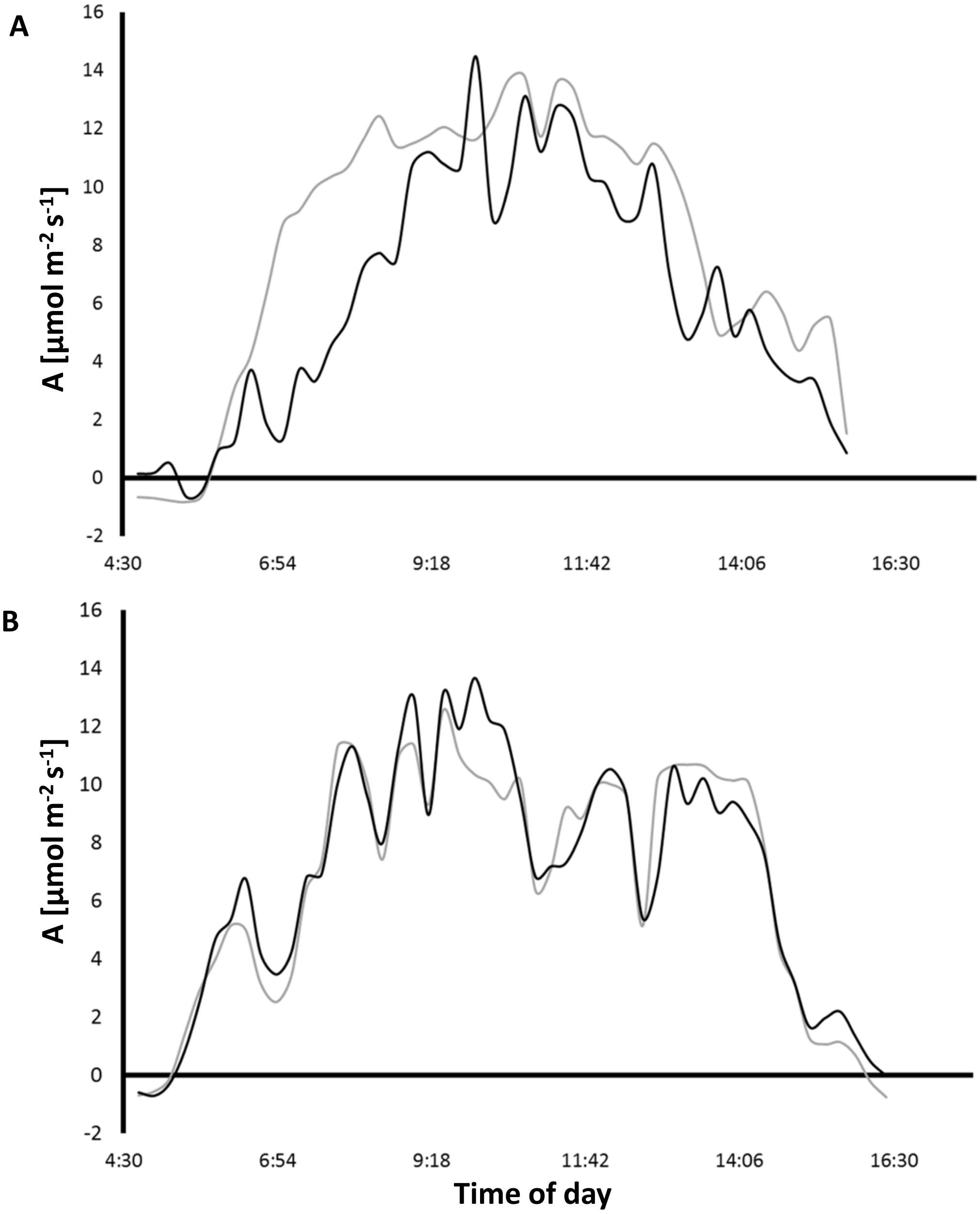

Figure 3: Figure 3: Comparison of modeled and measured CO_2 assimilation rates of *S. sphacelata* and *P. arachnoideum*. Measured photosynthesis rates (black lines) versus modeled photosynthesis rates of (grey lines) of a representative leaves of *S. sphacelata* **(A)** and of *P. arachnoideum* **(B)** at the upper site is shown for a representative daily course. Graph: Johannes Knüsting and Michael Schorsch

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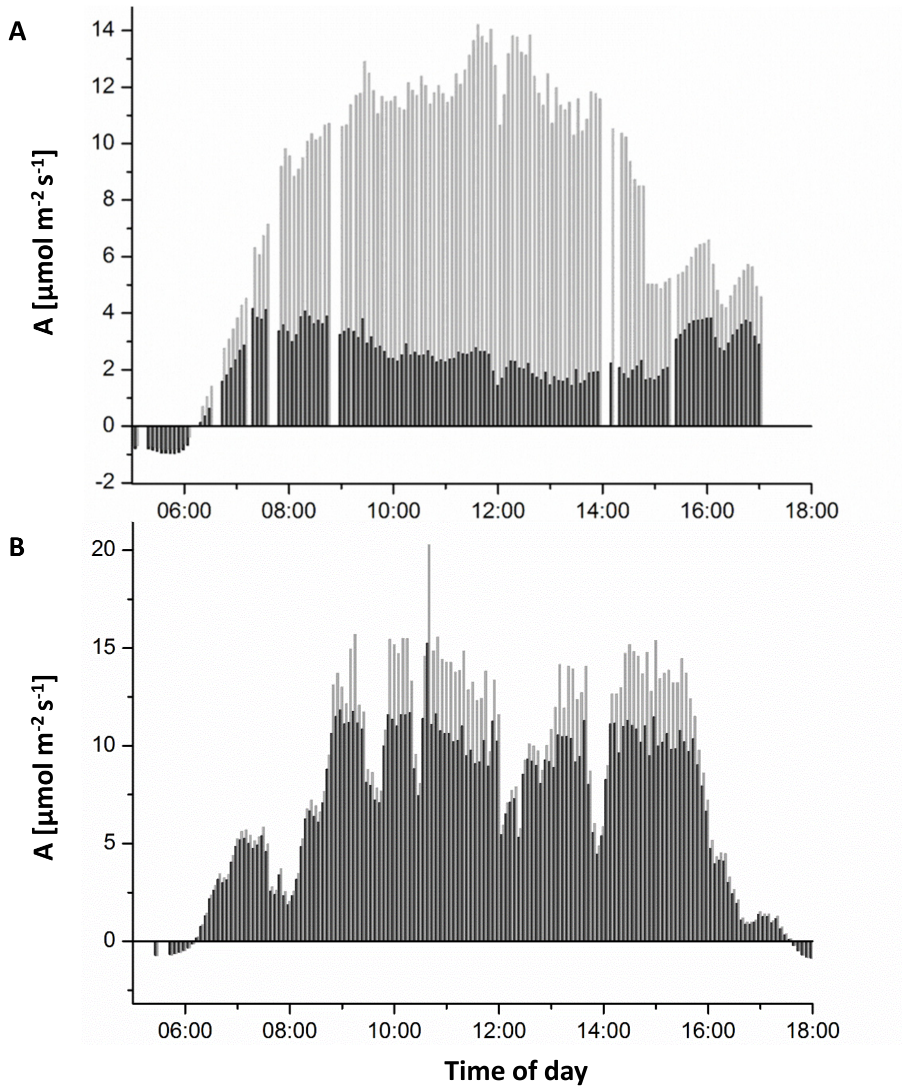

Figure 4: Comparison of modeled CO_2 assimilation rates of *S. sphacelata* and *P. arachnoideum.* Photosynthesis rates at the 1850 m (grey) and at the 2110 m (black) were modeled for representative leaves of *S. sphacelata* **(A)** and of bracken **(B)** throughout the day. Graph: Johannes Knüsting and Michael Schorsch

Conclusion

Our study allows assessing the usefulness of planting *Setaria* as pasture grass along an elevation gradient of more than 2000 m in the tropical Andes of Ecuador. Up to around 2000 m a.s.l., the competitive strength of bracken is lower or at most equal to that of *Setaria*, while higher up bracken grows more vigorously and finally outcompetes the C4 grass. Applying microclimate data over an entire year, the improved model will allow a quantitative assessment of the productivities of both competitors and of the upper limit of using *Setaria* as the major pasture grass.

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Transfer News

Sampling, Upscaling and Modelling in Tropical Mountain Areas

Mareike Ließ
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In ecological research we are often confronted with the need to think about a reasonable sampling design. Often we later want to do regression analysis or apply statistical tests to our data. But what is a statistically sound but applicable sampling design for spatial prediction (upscaling) of our data while we are working in the hardly accessible tropical mountain landscapes of Ecuador?

Representativeness of the sample concerning the population to be sampled needs to be guaranteed in any regression-based modelling approach. In sampling for regression-based spatial prediction, the above all aim is to ensure that the spatial variability of the variable is well-captured without introducing any bias, while the design remains feasible according to operational constraints such as accessibility, man power and cost. The here presented approach from **project C9** solves the problem of many statistically-based sampling designs which select unreachable points. And instead of sampling a previously unsampled area with limited accessibility, the presented sampling designs may also be used to subsample an existing dataset. So we may use our existing data without starting to sample all over again.

Four random sampling schemes were adapted to guarantee suitability for any investigation area, while limited accessibility is taken into account [1]. The tropical mountain landscapes of Quinuas and Laipuna serve as examples (**Figure 1**). The variability of each area is captured by a number of parameters representing the vegetation and topography. While selecting sampling positions with a good representation of the spatial variability of these parameters and hence the predictors for regression modelling, the spatial variability of the ecological variable itself is well-captured.

The four selected approaches include two point sampling approaches and two approaches, which sample landscape units. The former two approaches are termed accessible random point sampling (arPS), the latter two are termed accessible random landscape unit sampling (arLUS).

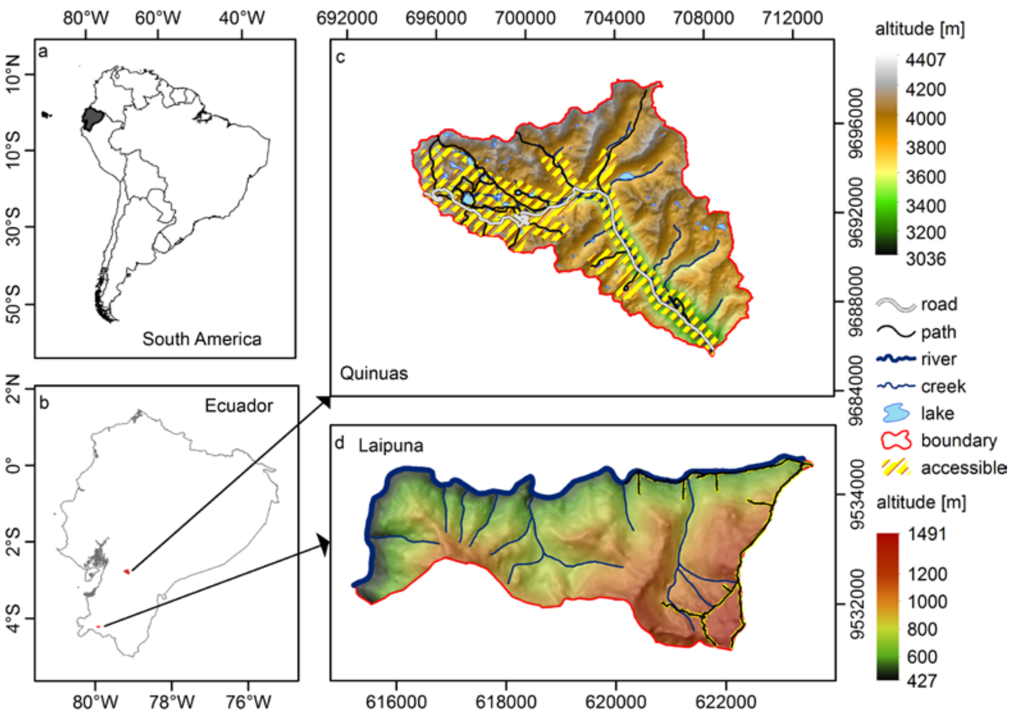

Figure 1: Position of investigation areas. **(a)** Ecuador in South America, **(b)** Quinuas and Laipuna within Ecuador, **(c)** Quinuas, **(d)** Laipuna (overlaid hill shading with light source from north). Topographical data use with permission from the Ecuadorian Geographical Institute (2013, national base, scale 1:50.000), further GIS data provided by NCI and ETAPA. Graph: Mareike Ließ reprinted from [1] with permission from Elsevier.

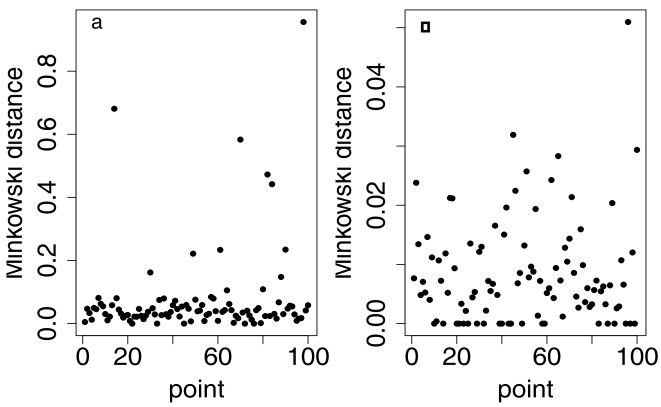

Figure 2: Manhattan distance between random point and accessible alternative point in S-arPS. **(a)** Laipuna, and **(b)** Quinuas. Graph: Mareike Ließ adapted from [1] and reprinted with permission from Elsevier.

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Simple – arPS (S-arPS)

Randomly selected points are replaced by accessible points which are close to the selected points within the n-dimensional predictor space (smallest Manhattan distance, **Figure 2**).

Latin Hypercube based – arPS (LH-arPS)

With little changes to the clhs algorithm [2] quantile strata are calculated based on the complete investigation area, but selectable points to optimise the latin hypercube may only be chosen from the accessible subarea. **Figure 3** shows the development of the objective function.

Cluster Analysis based – arLUS (CA-arLUS)

Random sampling of landscape units formed by cluster analysis (**Figure 4**) according to their spatial coverage. Selectable samples are restricted to the accessible subarea (**Figure1**).

Quantile Combination based – arLUS (QC-arLUS)

Landscape units are formed by combinations of predictor quantiles (**Figure 5**). The detail of parameter space representation is chosen through the number of parameters (n) and quantiles (k) each of these parameters is divided into. k^n determines the number of landscape units. The so formed strata are sampled as in CA-arLUS.

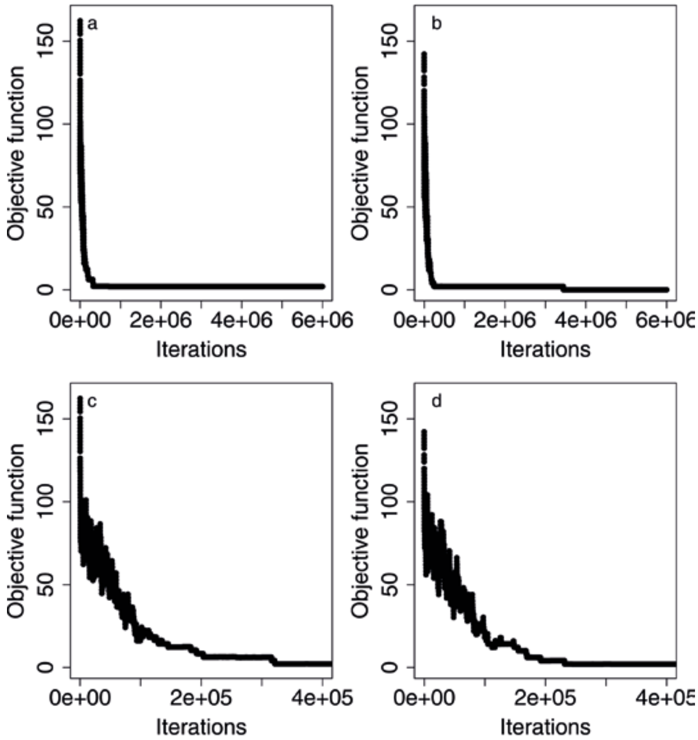

Figure 3: Development of the objective function in LH-arPS. Laipuna **(a)**, **(c)** and Quinuas **(b), (d).** Row 1 shows the complete iterative process, row 2 shows the early iteration steps in more detail Graph: Mareike Ließ reprinted from [1] with permission from Elsevier.

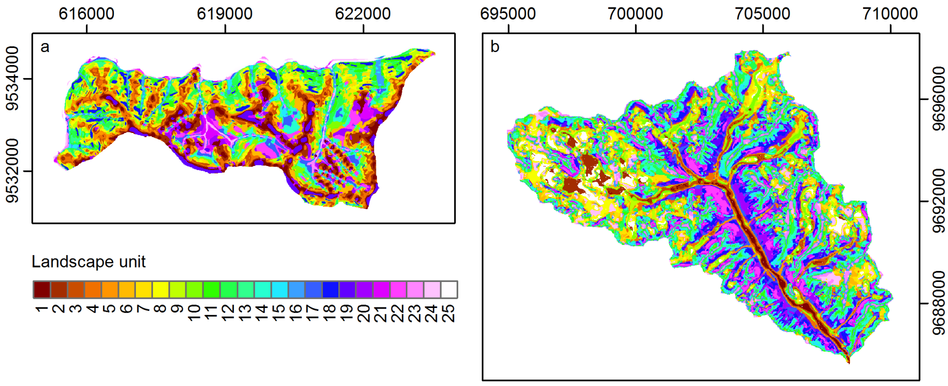

Figure 4: Landscape units from in CA-arLUS. **(a)** Laipuna, and **(b)** Quinuas. Graph: Mareike Ließ reprinted from [1] with permission from Elsevier.

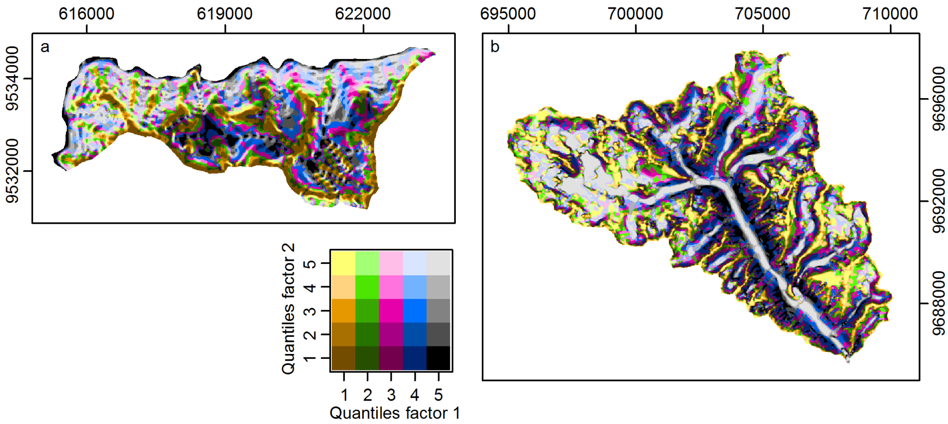

Figure 5: Landscape units formed in QC-arLUS by quantiles of the 2 factors obtained from factor analysis: **(a)** Laipuna, and **(b)** Quinuas. Graph: Mareike Ließ reprinted from [1] with permission from Elsevier.

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Recent Trends in Temperature and Precipitation Obtained by the high resolution Climate Indicator System (hrCIS) for South Ecuador

Katja Trachte and Jörg Bendix
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Accuracy and benefits of the hrCIS data set in ecological climate change studies are analyzed. We discuss examples of recent trends in air temperature and precipitation for the province of Loja in southern Ecuador.

In the framework of the **project C12** a highly resolved Climate Indicator System (hrCIS) is generated using the regional climate model Weather Research and Forecasting (WRF) [1] driven by the NCEP/NCAR Reanalysis data [2]. The aim of hrCIS is to derive spatial-explicit ecologically relevant climate indicators affecting the three ecosystems mountain rain forest (RBSF), dry forest (Laipuna) and Paramo (Cajas) of the research platform, which is difficult to obtain by the low-density measurement network. The hrCIS is a set of area wide gridded climate variables like air temperature, precipitation, wind field, radiation and humidity available in an hourly temporal resolution for a time period of 20 years (Dec 1994 – Nov 2014) at 4 km grid size. Uncertainties in the WRF model were tested in an extensive sensitivity study encompassing an ensemble of 33 different physical parametrization combinations. The reliability of hrCIS was further examined by a validation against surface measurements, e.g. precipitation and temperature, provided by the national weather service INAMHI.

In heterogeneous landscapes as the south Ecuadorian Andes mountains, precipitation is strongly affected by interactions of the atmosphere and the terrain. This behavior is mainly reflected in a high variability of the spatial distribution of precipitation and air temperature as demonstrated in **Figures 1a** and **b**. Particularly the mean annual precipitation patterns of the hrCIS describe the typical behavior with the dry western slopes, while at the eastern slopes most of the rain occurs.

With respect to the temporal profile of these climate indicators **Figure 1c** shows the bias of monthly mean hrCIS data taken at the nearest grid point corresponding to the location of La Argelia-Loja climate station. For both indicators a good agreement can be observed with a general tendency of WRF to slightly underestimate air temperature (between -2 °C and +1 °C) likely due to a higher model terrain height of 394 m compared to the actual elevation. For precipitation a dry bias and wet bias (-4 mm/d to +4 mm/d) is generated. However, the most important response of the model is a proper representation of inter-annual variability, e.g. due to the ENSO phenomenon, which is obviously very well captured as indicated by the strong temperature peak in the 1997/98 event (**Figure 1d**).

For the province of Loja (red contour in **Figure 1b**) the temporal evolution of both indicators obtained from hrCIS is displayed in **Figure 1d**. Over the considered time period, an increase of temperature of 0.4°C can be observed, while precipitation reveals no trend. Moreover, clear inter-annual variations in temperature and rain amount are evident representing warmer and colder as well as drier and wetter years, respectively, for this region.

Based on these exemplary presentations of the main climate indicators (temperature and precipitation) the utility of hrCIS for ecologically relevant climate change studies in the heterogeneous landscapes of the ecosystems of the platform in southern Ecuador is demonstrated.

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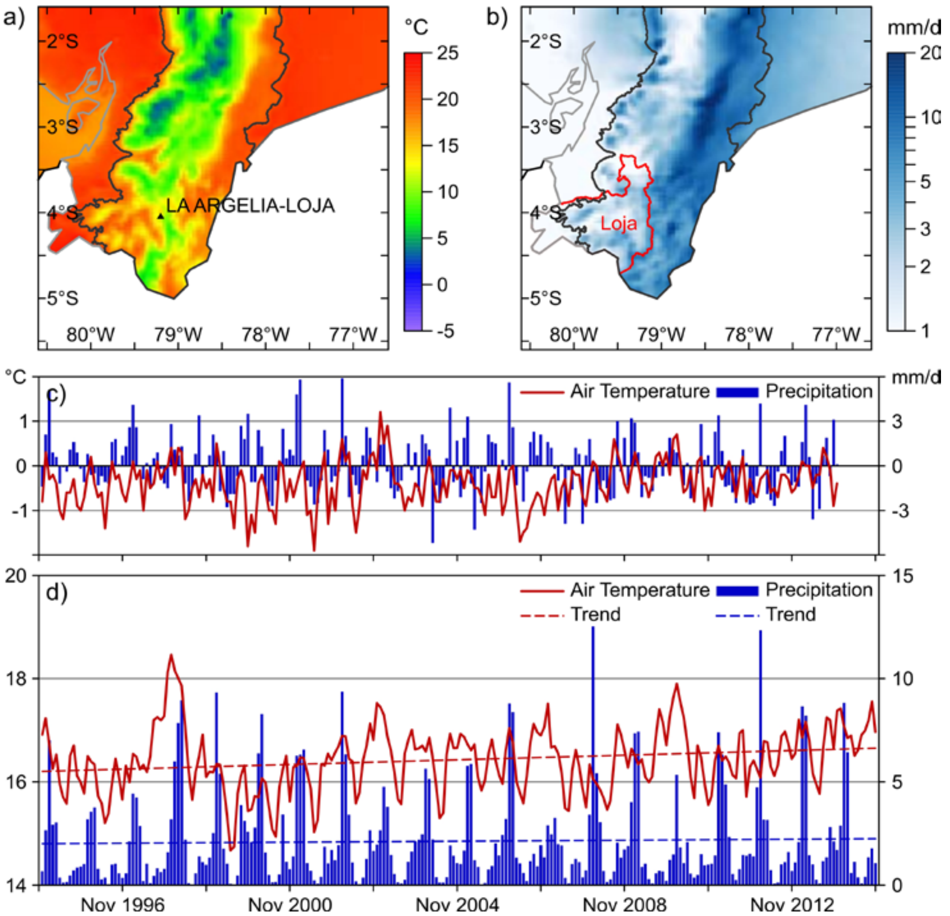

Figure 1: hrCIS annual mean (Dec 1994 - Nov 2014) **a)** air temperature (°C) and **b)** precipitation [mm/d]; monthly mean time series of **c)** biases against La Argelia-Loja climate station and **d)** hrCIS area averaged over province of Loja overlayed with the respective trend. Graph: Katja Trachte

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Transfer Workshop of Subprogram B: "Restoration of Abandoned Lands: Potentials and Limitations"

Baltazar Calvas, Carola Paul and Patrick Hildebrandt
Technische Universität München (TUM) – members of DFG-PAK research consortium

On the 13th October 2015 forest owners, farmers and representatives of universities and state organizations took part in a joint workshop on restoration strategies. The workshop, held in Loja, was organised by members of the subprogram B "Sustainable management and ecosystem services" of the DFG PAK Research Consortium in cooperation with the Universidad Técnica Particular de Loja (UTPL), Nature and Culture International (NCI) and the Instituto Nacional de Biodiversidad (Ecuadorian Ministry of Environment, MAE). It aimed to bring together science and practice to promote the rehabilitation of abandoned areas for productive and protective purposes. All participants agreed that this will be an important measure to ease pressure on natural ecosystems.

After some welcoming words by Professor Thomas Knoke (TUM) and Guido Mosquero (Ecuadorian Ministry of Agriculture and Fishery, MAGAP), representatives of MAGAP, Paulo Bustamante, and MAE, Georgiana Braulete, presented current achievements in Ecuador to incentivize active and passive, commercial and non-commercial forest restoration [1, 2] (see **Figure 1**). Both speakers expressed the urgent need for high-quality plant material and research on suitable species and management for both productive and protective rehabilitation. The lack of information on long-term ecological processes in passive restoration was also raised.

In the following scientific presentations Professor Knoke (**project B5**) outlined a model-approach which could help to decide on the quantitative allocation of different restoration options within a landscape, to provide multiple ecosystem services [3-4]. Julia Adams (**project B2**) and Patrick Hildebrandt (**project B3**) presented strategies for productive restoration of abandoned lands through rehabilitation of pastures (see [5] for more information) and reforestation [6-7].

The fruitful exchange of ideas continued during a visit to the reforestation sites of the Forestry-Transfer project "Nuevos bosques para Ecuador" (**Figure 2**). This project investigates how pine plantations could facilitate reforestation with native species [8-9].

Finally, the participants agreed on the need for and interest in establishing a network to further investigate and promote restoration strategies and identified new research topics. In his concluding remarks, Professor Knoke highlighted the need for close cooperation and the potential of Ecuador to become a leader in forest restoration.

The workshop proceedings will be available on the Monitoring and Research Platform | South Ecuador (MRp|SE) website in December 2015.

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Figure 1: Paulo Bustamante (MAGAP) presenting the current state and success of national incentives for commercial reforestation. Photo: Baltazar Calvas

Figure 2: Dario Veintimilla and Baltazar Calvas (from right) explain the research approach of the Forestry-Transfer project "*Nuevos bosques para Ecuador*". Photo: Carola Paul

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Knowledge Transfer

Learning About Birds and Seed Dispersal – Researchers Visit School and Meet Kids in the Forest

Marta Quitián, Vinicio Santillán and Eike Lena Neuschulz
Senckenberg Biodiversity and Climate Research Center (BiK-F) and Goethe University Frankfurt, Germany – members of the DFG-PAK research consortium

In collaboration with Nature and Culture International (NCI), researchers of the project C3 met students of the Unidad Educativa Fiscomisional "San Francisco" in Zamora Chinchipe to share their passion about birds and avian seed dispersal.

The National Bird Day was announced by NCI on 9th and 10th October 2015. To celebrate this event, Marta Quitián, Vinicio Santillán, Agustín Carrasco (**project C3**: Development and validation of functional indicators for avian seed dispersal) and Trotsky Riera Vite (NCI) organized a workshop to transfer their knowledge of birds and seed dispersal to the students of Zamora Chinchipe. The workshop was held end of October 2015 during one week where two events were offered to the students: a theoretical journey to the world of biodiversity, birds and seeds and a practical excursion to the forest of Bombuscaro.

The theoretical part took place in the Unidad Educativa Fiscomisional "San Francisco" on 26th October. Over two hours Marta, Vinicio and Agustín explained the concepts of ecosystems and biodiversity to 35 students of the sixth grade (**Figure 1**). The students learned about environmental gradients and how researchers assess biodiversity and the functioning of ecosys-

Figure 2: Marta Quitián (second right) and a group of students identify birds in the forest of Bombuscaro. Photo: Noemi Vites

Figure 1: Vinicio Santillán (left) and Agustín Carrasco (right) explain the principles of bird identification to the students of the Unidad Educativa Fiscomisional "San Francisco". Photos: Nina Gunselmann

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Figure 3: The coppery-chested jacamar (*Galbula pastazae*) was discovered by the students on their excursion to Bombuscaro forest. They observed the bird foraging on insects (here with a butterfly) and feeding them to its chicks. Photo: Vinicio Santillán

tems in Podocarpus National Park. The researchers illustrated their work and interest in birds by pictures and videos taken during their field work. After this general introduction, the students had some hands-on exercise, where they learned how to identify some basic bird families based on visual and acoustic cues. They also learned how to use binoculars, to be prepared for the second part of the workshop, the excursion to Bombuscaro forest.

Four days later, on 30th October the students were invited to attend the practical part of the workshop at Bombuscaro forest, Podocapus National Park. The students, accompanied by three teachers of environmental sciences, arrived early in the morning to take advantage of the first hours of the day for some birdwatching (**Figure 2**). Each student received an identification sheet with pictures of the most common and interesting birds of Bombuscaro. The aim of the morning was to fill in the names of the birds on the sheet and to check those birds that had been observed.

This field trip to Bombuscaro was a successfully venture. Most of the students were at Bombuscaro for the first time and had never observed or identified birds and their particular behaviors before. One highlight of the morning with the students was observing the foraging and fruit pecking behavior of a number of colorful frugivores. This was a great opportunity for Marta, Vinicio and Agustín to explain the process of seed dispersal by birds and its importance for the functioning of ecosystems. Other highlights were to observe how the Russet-backed oropendola (*Psarocolius angustifrons*) builds its sophisticated nest and how the Coppery-chested jacamar (*Galbula pastazae*, **Figure 3**) feeds insects to its chicks in one of cave nests in the mud wall. The example of the beautiful Jacamar, an endangered bird listed as vulnerable by the IUCN, helped to emphasize the importance of nature conservation.

Knowledge Transfer Event

Next Workshop: Software “SAGA-GIS” and “R”

A practical course to learn about digital soil mapping with the open source software “SAGA-GIS” and “R” was announced at the Platform Symposium on October 8th. The course will include terrain analysis with SAGA, regression modelling and spatial prediction / upscaling with R. The course will be free of cost. The exact date has not been set, but will be negotiated and announced via e-mail to all interested parties. Please contact mareike.liess@uni-bayreuth.de (**project C9**) if you want to participate. *Mareike Ließ*

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Data Warehouse News

Data Quality and Usability

Rütger Rollenbeck (Data Manager) and Maik Dobbermann (Developer and Webmaster)
Philipps University Marburg, Germany – Data Manager, Developer and Webmaster of the DFG-PAK Research Consortium

New insights into priorities and requested functionality of the Data Warehouse has been obtained. The Data Warehouse now meets the needs for most recent and high quality climate data by the implementation of new measurements and continuation of the development of quality assessments.

Data Warehouse Usage

After a high in mid-2015, the number of users accessing the Data Warehouse has returned to normal levels. Visitors from outside the Research Consortium always outnumber the internal visits by a factor of two. By this, the Data Warehouse also serves as a portal for information about our work.

A short survey of download activities within the Data Warehouse supports the assumptions, that the climate data still are the backbone of most interdisciplinary research. With 753 downloads, climate data covers almost 60% of the downloads, 25% of the requests are for maps and digital elevation models, while all the other data are accessed in 15% of the cases (see **Figure 1**).

Hence, the importance of having high quality and recent climate data is crucial for on-going interdisciplinary work. The Data Warehouse team has dedicated much time to implement new measurements, improve data transfer and develop sophisticated quality control to warrant the supply of up-to date climate data with a high degree of certainty.

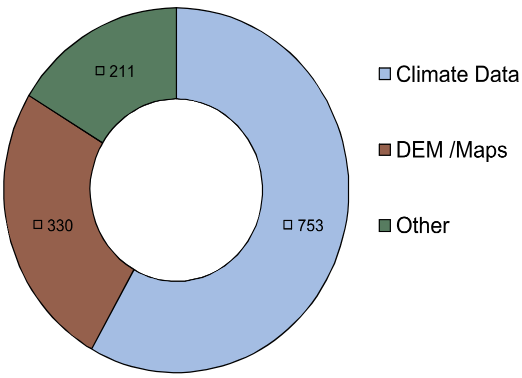

Figure 1: Download requests for data grouped by category since 2009. DEM: Digital elevation models. Graph: Rütger Rollenbeck

Figure 2: Sebastian Achilles installs and configures the new climate station ECSF. Photo: Rütger Rollenbeck

Implementation of New Climate Stations

The aging network of climate observation has been upgraded by parallel measurements at four of the most important research spots: Bombuscaro, ECSF, El Tiro and Cajanuma. While the new stations in ECSF and El Tiro are up and running since October 2015, the setup for the two other sites had to be postponed, due to delays with the remote wireless access to those sites. ECSF and El Tiro data will soon be available in real-time with a display of current weather data on the website.

Another reason for the installation of new equipment was the improved assessment of data quality. Large issues were observed with older data sets, which could be resolved by applying rigorous quality control and improved data gap filling methods. All methods are now documented in a paper to be released soon in the AMS Journal of Atmospheric and Oceanic Technology [1]. Also, the processing scheme is documented in the meta-data of the new dataset, which is updated now until September 2015.

Up- and Download Interface

The announced improvements of the upload- and download interface are now under testing in and will be made available within a few weeks. The same applies to the templates and scripts, to simplify data preparation for uploading to the Data Warehouse. Here, also feedback from the users is desired, to have a better understanding of the necessities with different data types.

Accompanying Data Warehouses

Furthermore, the associated Data Warehouse of the FACE2FACE group in Germany is now running and is starting to gather data and attributes from the respective users. The activities of the Data Warehouse team in Ecuador still need some time, due to complications with funding and responsibilities. Anyway, both associated groups can benefit from the progress in the Data Warehouse based in Marburg, Germany.

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News from Infrastructure Providers and Non-University Partners[1)]

NCI Signs Operations Agreement with SETECI

On 25th September NCI signed a Basic Operations Agreement with the Technical Secretariat of International Cooperation (SETECI) for four years. According to this NCI´s interventions will focus on environmental conservation with an emphasis on strengthening capacities, science and technology.

In detail, NCI´s programs to be executed within the aforementioned period are:

1. Conservation of water sources within the Autonomous Decentralized Governments (GADs)
2. Establishment of public and private conservation areas
3. Enrollment of new beneficiaries into the SocioBosque Program.

During this period, NCI will invest 3.4 Million US-Dollar into the programs mentioned, which will be complemented by 4.3 Million US-Dollar in additional funds from other local and foreign sources. This fact is of the utmost importance given that within SETECI´s competencies is the ability to sign this type of agreement with foreign NGOs that provide non-reimbursable funding in Ecuador.

Figure 1: Ec. Gabriela Rosero, SETECI´s Secretary, and Renzo Paladines, NCI´s Executive Director, are signing the agreement. Photo: NCI

Figure 2: Renzo Paladines summarized the achievements of NCI in the years 2014 and 2015. One of the highlights in 2015 was the joining of the E. O. Wilson – depicted in the slide – to the board of NCI's directors. Wilson is a famous myrmecologist and biodiversity scientist. He has written several books which greatly influenced the scientific community. Photo: NCI

Naturaleza y Cultura's 18 Years of Development

On its 18th anniversary, NCI began its annual accounting with a Conference on the "Conservation and Social Management of Natural Ecosystems" held at the Technical University of Loja on October 5th. In this NCI´s staff shared its experiences and achievements in four different areas:

1. Conservation of source water areas
2. Conservation and territorial management of fragile ecosystems
3. Sustainable use of biodiversity
4. Protected areas, biosphere reserves, economic incentives, and other conservation strategies.

On October 7th, the Annual Report was delivered. In this the most important achievements of 2014 – 2015 were highlighted:

- the co-organization of the "Seventh Annual Meeting of the National Network of Ecuadorian Biosphere Reserves" (Theme: Management Models)
- the expansion of the model of the regional water fund (FORAGUA)
- support for the first Water School in Ecuador (including source water protection)
- and financial and technical assistance for the creation of provincial, municipal, and private reserves in various parts of Ecuador and in Bolivia, Brazil, and Colombia.

[1)] In this section infrastructure providers and non-university partners present news around the Research Platform. This time Bruno Paladines from the NGO Nature and Culture International (NCI) reports about latest devepolments.

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People and Staff

Edison Timbe (with graduation hat) received his PhD in October. PhD student Alcia Correa, Professor Dr. Lutz Breuer, as well as Edisons parents, Blanca Castro and Manuel Timbe, and PostDoc Alejandro Chamorro congratulated him (v.l.t.r.). Photo: Lucy Timbe

On October 14, **Edison Timbe Castro** from the University of Cuenca successfully completed his doctoral studies at the Institute of Landscape Ecology and Water Resources, Justus Liebig University Giessen, Germany. The main objective of his research "Water Flow Dynamics Assessment for a Tropical Montane Forest Basin by Means of Spatially Differentiated Multi-Criteria" was to provide improved insights on the complex rainfall-runoff processes occurring in the San Francisco basin, a western headwater catchment of the Amazonian basin, located in the southeastern escarpments of the Andean mountains of Ecuador. For his research in **project C7**, Edison sampled and analyzed water from rainfall, streams, soils and seeps. A relevant source of information were stable water isotope data (Deuterium and Oxigen-18), which were utilized as tracers of water flow paths and to estimate mean transit times of the various water sources. On average, it takes surprisingly long for a molecule of water from entering the system through rainfall until leaving it through the San Francisco river: between two to four years. Edison put a large effort into uncertainty analyses to back up these observations, something new in the field of mean transit time estimation. A second emphasis was given to the study of a 15-year long discharge time series. Diverse techniques such as hydrometric and hydrochemical modelling, mixing and multivariate statistical approaches, were applied to investigate the contributions of event, deep and shallow subsurface waters that form the discharge. Despite the very reactive water level (an indicator of quickly reacting discharge), around 56% of the discharge is of groundwater origin. The methodologies that Edison developed together with David Windhorst in this project now serve as a standard in related studies of tropical hydrological systems in the Paramo of Ecuador and mountain rainforests in Kenya. For the sites of Ecuador we are particularly interested in the effects of the coming El Niño. This natural phenomenon will give insights to the likely reaction of hydrological systems in future climates, where increasing extremes are expected. Edison, who is now a lecturer at the University of Cuenca, will contribute to this research by his expertise. *Edison Timbe*

Photo: Jürgen Homeier

Daisy Cárate Tandalla (**project A1**) defended her PhD-thesis at University of Göttingen on October 29th. The topic of her dissertation thesis is "Effects of moderate nitrogen and phosphorus addition on the species composition and dynamics of the tree seedlings community in tropical montane forests in southern Ecuador". Daisy was principally funded by a DAAD PhD scholarship. By studying the tree seedlings within the plots of the ongoing **Nu**trient **M**anipulation **Ex**periment (NUMEX) in **project A1** she could demonstrate how continued experimental nutrient addition affects the current composition and performance of different montane forest tree species. *Jürgen Homeier*

Photo: Jürgen Homeier

María Fernanda Tapia Armijos (**project A1**) also defended her PhD-thesis at University of Göttingen on October 29th. The topic of her dissertation thesis is "Definition of areas with high conservation priority in southern Ecuador – an approach combining spatial and temporal patterns of deforestation and human impact with endemic plant diversity". María Fernanda was funded by a SENESCYT PhD scholarship and by the DFG bilateral cooperation project. Using remote sensing data she describes trends of deforestation and fragmentation in South Ecuador during the last three decades. The results were combined with the Human Footprint Index and patterns of endemic plant species diversity to propose areas that should be prioritized for conservation. *Jürgen Homeier*

Photo: Tessa Camenzind

Juan F. Dueñas-Serrano started beginning of November 2015 at the Freie Universität Berlin as a new doctoral student in the **project A4**. His previous experience ranges from systematics to applied ecology in diverse systems such as the Amazon or the eastern slopes of the Andes in Ecuador to the farmland and Southern Beech forests in New Zealand's South Island. In his last position he was a biology tutor at Yachay Tech University in Ecuador. We are happy to welcome him now in our group. His PhD thesis will focus on the diversity and functionality of arbuscular mycorrhizal fungi in the tropical montane forest of the Podocarpus National Park. *Tessa Camenzind*

Photo: Andre Velescu

Tobias Fabian is a Bachelor student in Geoecology at the Institute of Geography and Geoecology of the Karlsruhe Institute of Technology (KIT, Germany) and started to work in the Soil Science Group of Wolfgang Wilcke in September 2015. He conducts his field research in the Reserva Biológica San Francisco within **Project A6** and investigates sodium retention in the canopy, which may indicate sodium limitation of phyllosphere organisms. At the ECSF he is also involved in the Nutrient Manipulation Experiment (NUMEX) and in the long term ecosystem study (LTES) of Project A6, where he supports the installation of new instruments (weir, water gauge, rainfall totalizer and data logger) to replace the ones destroyed by the landslide in the micro-catchment Q2 earlier this year. *Andre Velescu*

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News from the ESCF

New Internet Connection for the ECSF

After years of struggling and trial and error, we were now able to connect the research station in the mountain rain forest Estación Científica San Francisco (ECSF) via glass fiber to the internet. This finally delivers a very fast and reliable internet access. Also the local network (both wired and WIFI) got a major upgrade with new access points, switches and some new cabling.

Car Requests

Requests for the two station cars can now be done online in the Intranet of the website of the Research Consortium under:
> "Documents + Services" > "Booking System" > "Car requests"

VOIP

To foster the communication between Germany and Ecuador the ECSF and the coordinators of the Local Adivsory Board, Felix Matt and Jörg Zeilinger, now can be reached via German landline phone numbers. The numbers can be found at the TMF-website under: > "About Us" > "Contact"
http://www.bergregenwald.de/getcontactp3.do

About Us

Monitoring and Research Platform | South Ecuador

The Platform for Biodiversity and Ecosystem Monitoring and Research in South Ecuador (MRp|SE) is a German-Ecuadorian joint venture of interdisciplinary research and knowledge transfer. Investigating three ecosystems in South Ecuador, the teams aim to understand impacts of global change (mainly atmospheric nutrient deposition related to land use changes) on processes, functions and services of the megadiverse ecosystems of the Andean mountain rainforest, the dry forest and the Páramo. Regarding knowledge transfer the program aims on implementing and further testing options for sustainable land use. At the same time, research has been started towards a novel functional monitoring system indicating impacts of environmental changes on ecosystem functions in the sense of an early warning system. The prototype indicator system under development shall be implemented on a broad scale in cooperation with non-university partners for use by relevant stakeholders in policy and development planning. In the Tabebuia Bulletin scientists and partners inform about their progress and latest research results. It is named after the Tabebuia tree which generates charismatic yellow blossoms and is home to the Neotropics.

Research and knowledge transfer is funded by two national research foundations, the Deutsche Forschungsgemeinschaft (German Research Foundation, DFG PAK 823-825) and its Ecuadorian partner organization Secretaría Nacional de Educación Superior, Ciencia, Tecnología e Innovación (SENESCYT), as well as by four Ecuadorian non-university partners (NCI, FORAGUA, ETAPA and Gestión Ambiental Zamora).

In research funding, the Platform marks a new and advanced step of co-operation as all involved organizations are funding joint German-Ecuadorian projects for the first time in parallel and on a larger scale. The MRp|SE was inaugurated in Cuenca on 16 October 2013 based on more than 16 years of intensive research into biodiversity and ecology of the South Ecuadorian Andes. In 1997, a small group of German researchers funded by the DFG began to investigate the biodiversity-rich mountain rain forests. From 2001 the first DFG Research Unit (FOR 402) operated with a significantly larger consortium. A second Research Unit (FOR 816) continued from 2007 to 2013.

Over the years, cooperation with Ecuadorian partners has gradually been intensified including the Universidad Técnica Particular de Loja, the Universidad Nacional de Loja, the Universidad del Azuay, the Universidad de Cuenca, the Pontificia Universidad Católica de Quito, the foundation Nature and Culture International (NCI), the city enterprise of Cuenca (ETAPA EP), the regional water fund FORAGUA, and the environmental department of the city of Zamora. Two more knowledge transfer projects funded by DFG are closely linked to the Platform: The program "Nuevos Bosques para Ecuador" and "Radar Net Sur" which are cooperating with the government of the province Loja (GPL) and private land owners.

Editorial Board

Deadline

The editorial deadline for the forthcoming German issue of the Tabebuia Bulletin is:
7th June 2016.
Please contact the editor Dr. Esther Schwarz-Weig: esw@sci-stories.com

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DFG PAK 823-825 Research Consortium

More information about the Research Consortium: www.tropicalmountainforest.org

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