GRACE Summer School 2015

Ecosystems

Tropical montane forests under environmental change

- A long-term case study in Ecuador -

Prof. Dr. Wolfgang Wilcke

Institute of Geography and Geoecology, KIT

- The current environmental change is global and reaches even the most remote ecosystems.
- Dominant environmental changes include matter deposition and climate.
- A remote old-growth tropical montane ecosystem is assumed to be in stable equilibrium and well buffered against environmental changes.
- Frequently, water and element fluxes are the earliest indicators of environmental change.

Outline

Introduction

Study site – soils and hydrologic conditions

Matter deposition

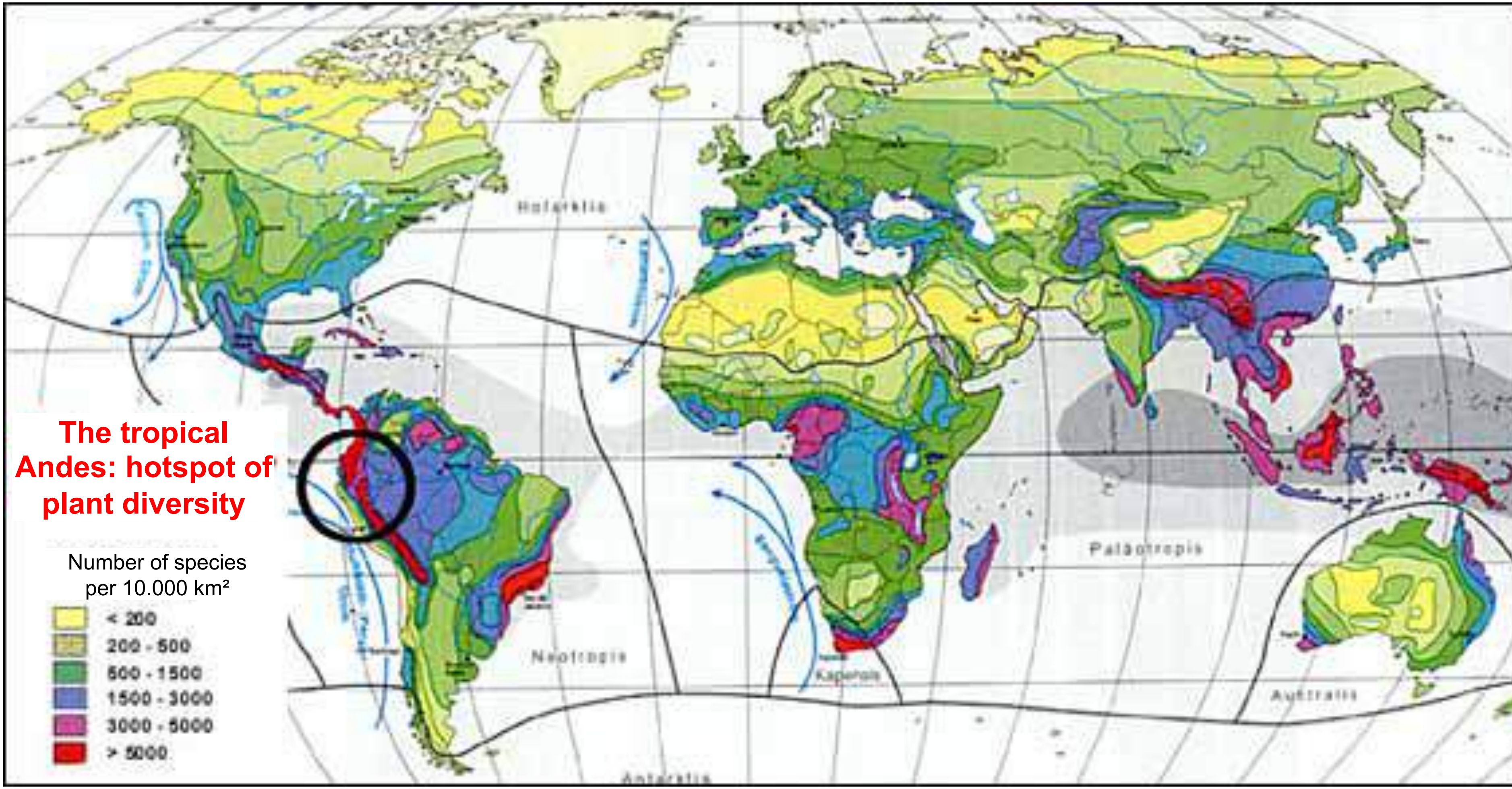
Environmental changes

Biogeochemical responses to environmental changes


Study site

Study site

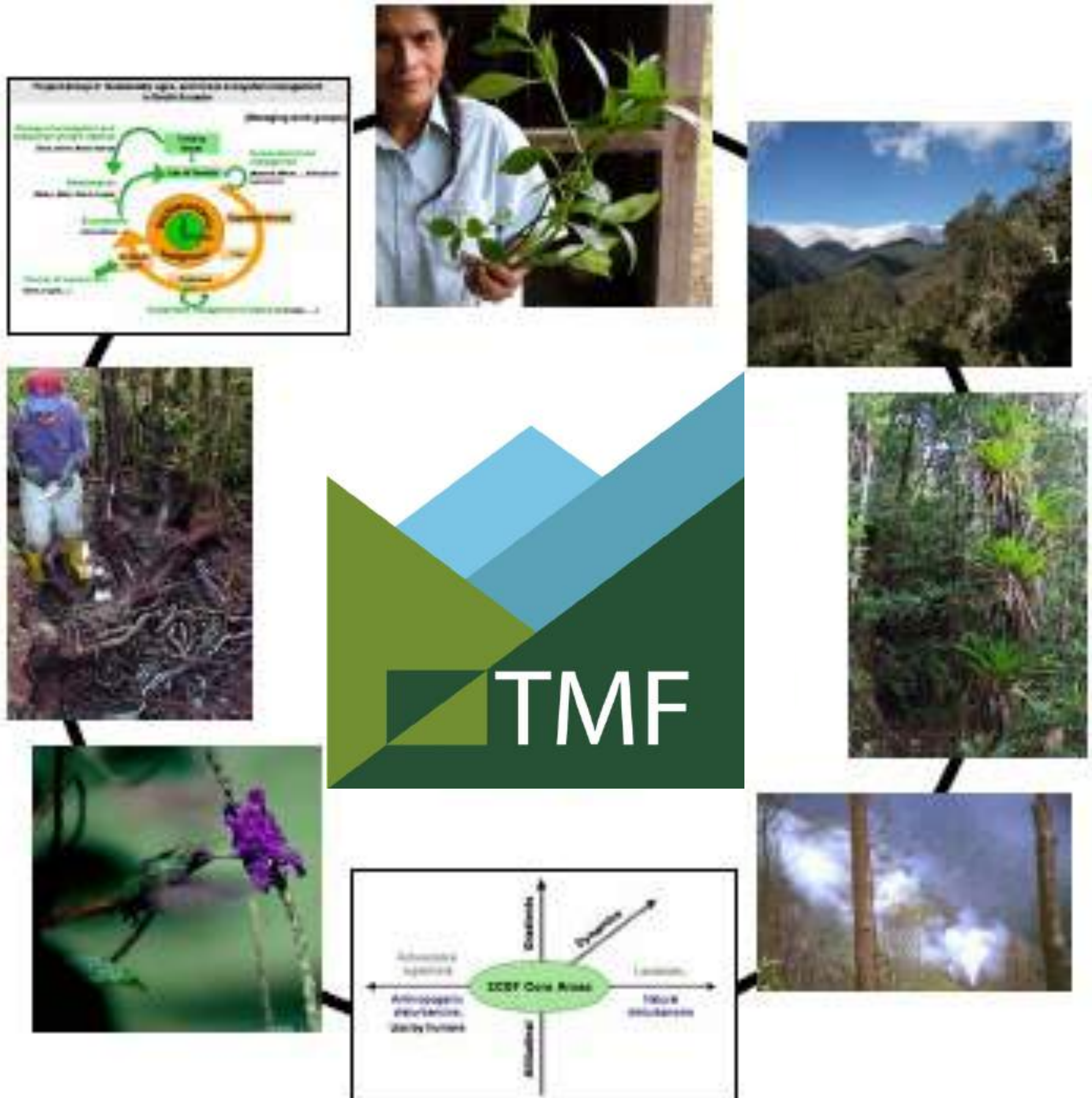
Location of the study site, research station, and view of *Long-term Ecosystem Study* site.



Barthlott et al. (1999): *Acta Bot. Fen.* **162**, 103-110.

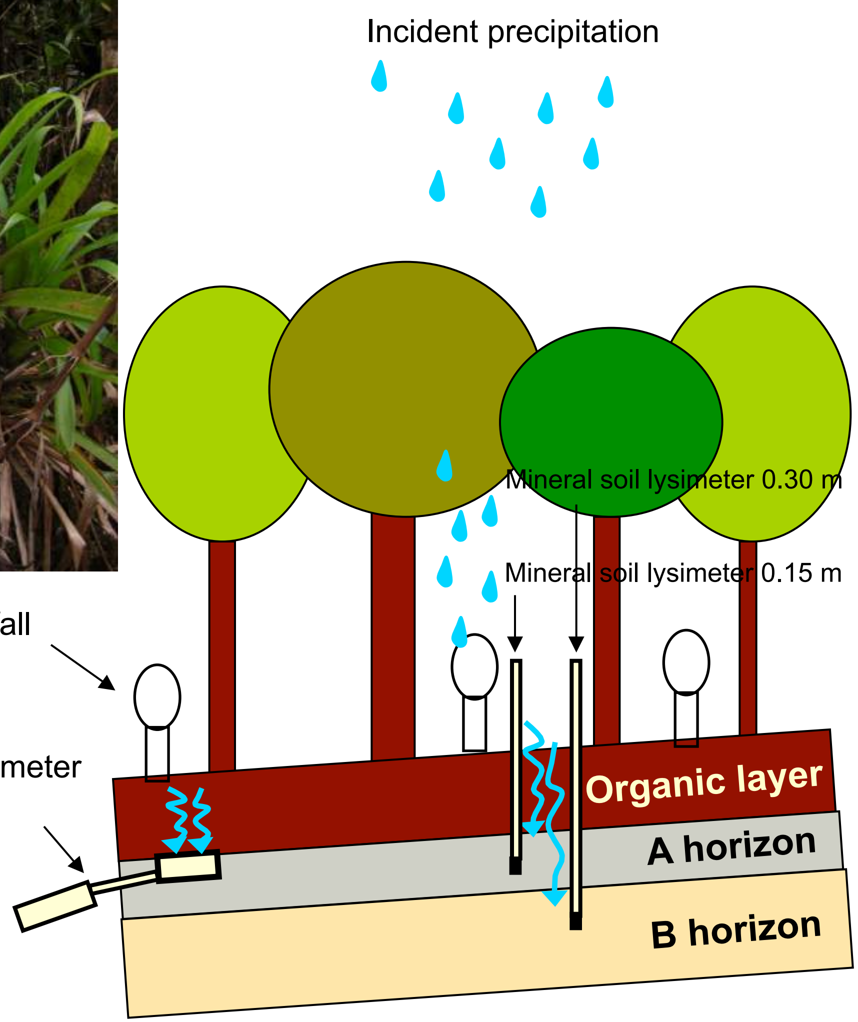
Study site

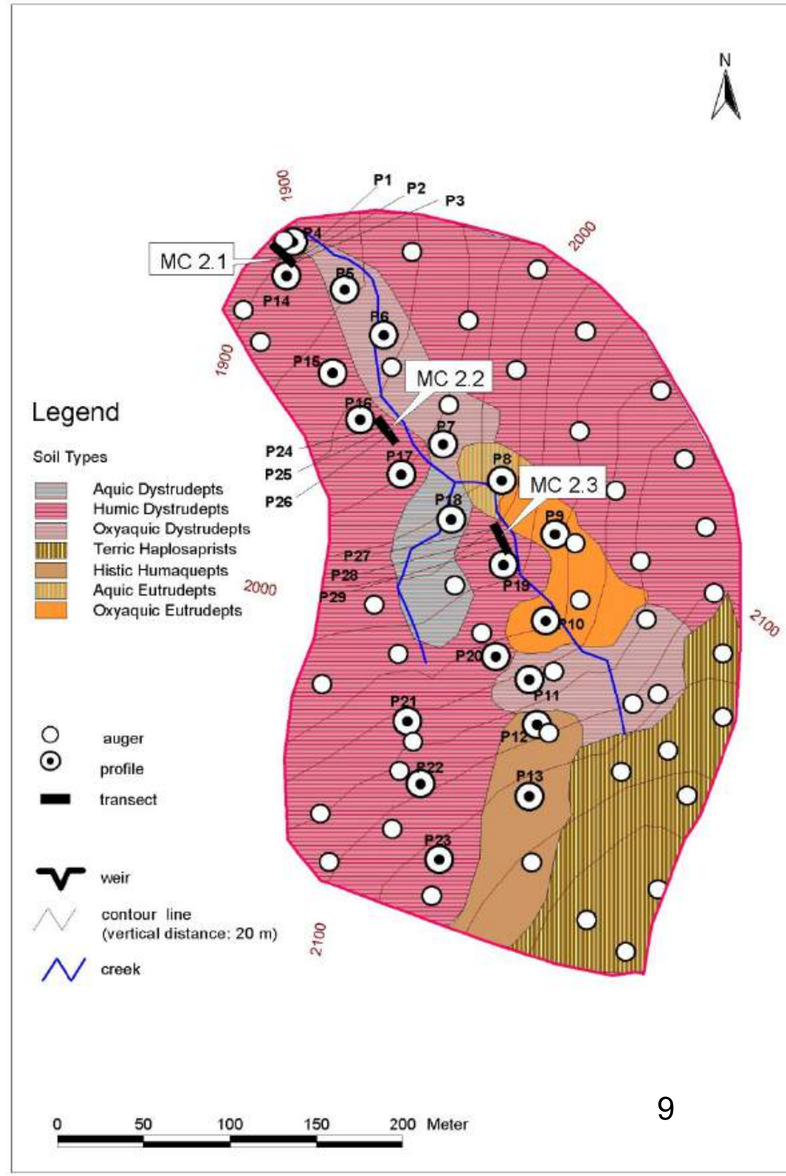
DFG Research Units 402 & 816



Tropical montane forest under environmental change

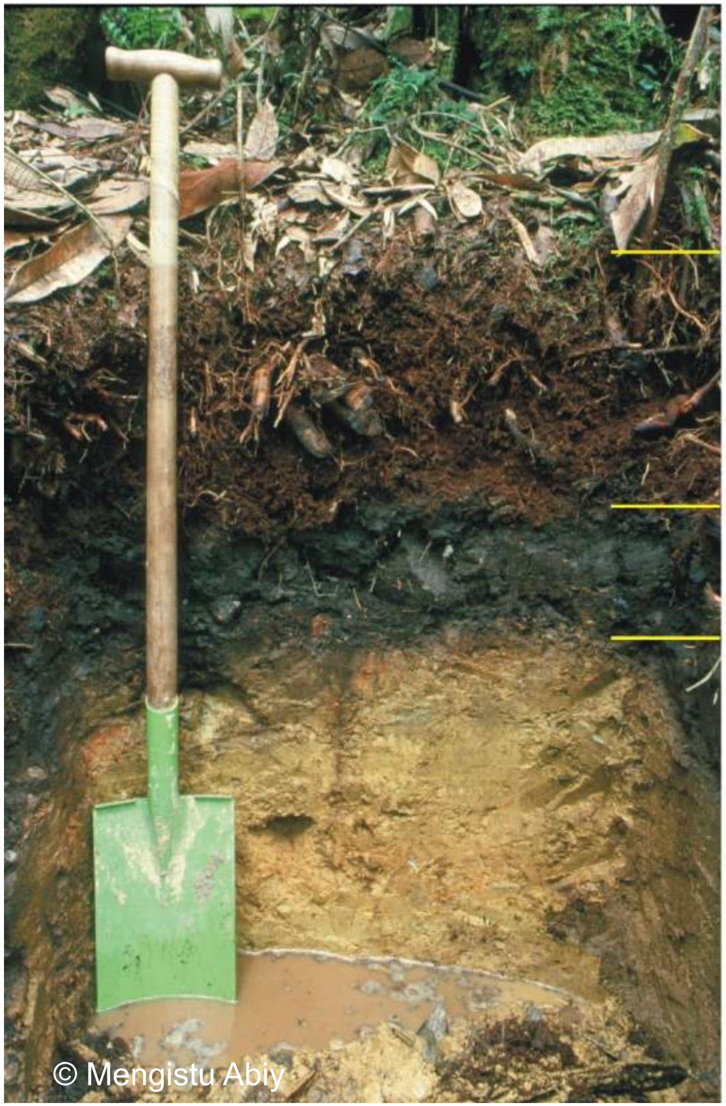
Study site





Soil map of the *Long-term Ecosystem Study* site (according to Soil Taxonomy).

Typical soil on the slopes of the lower part of the study area.

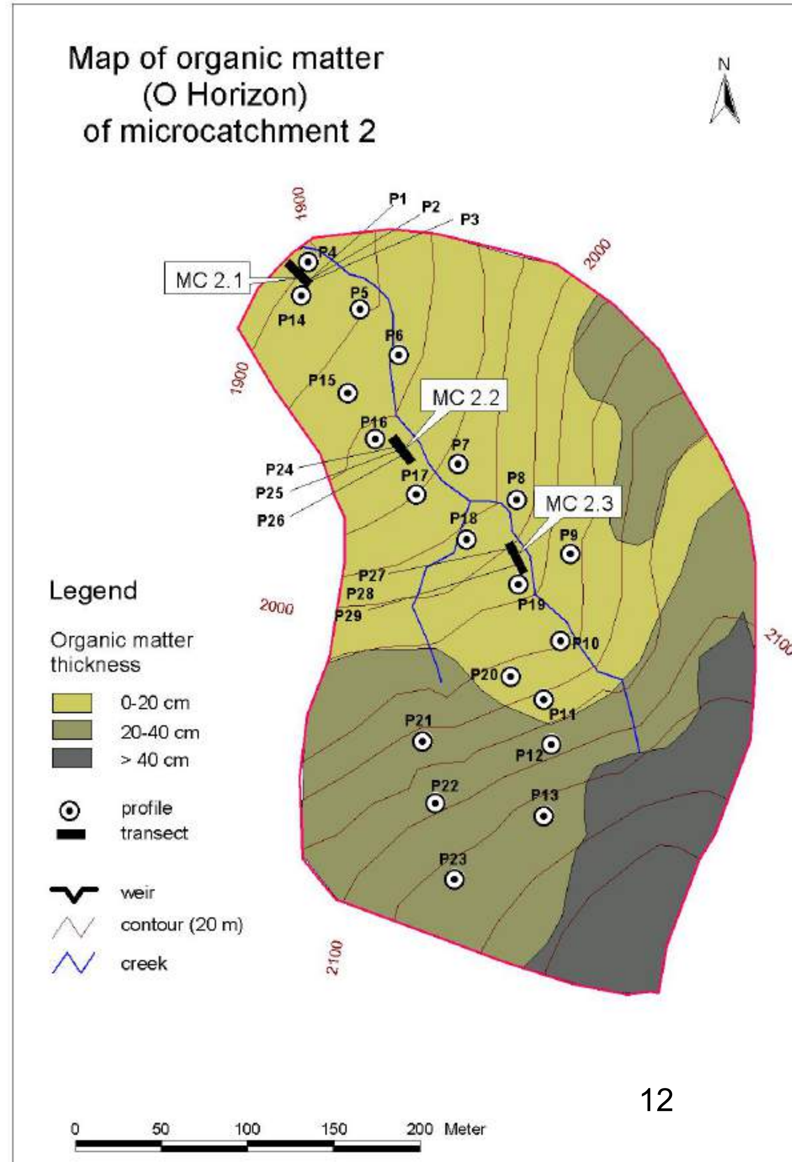


Organic layer

A horizon

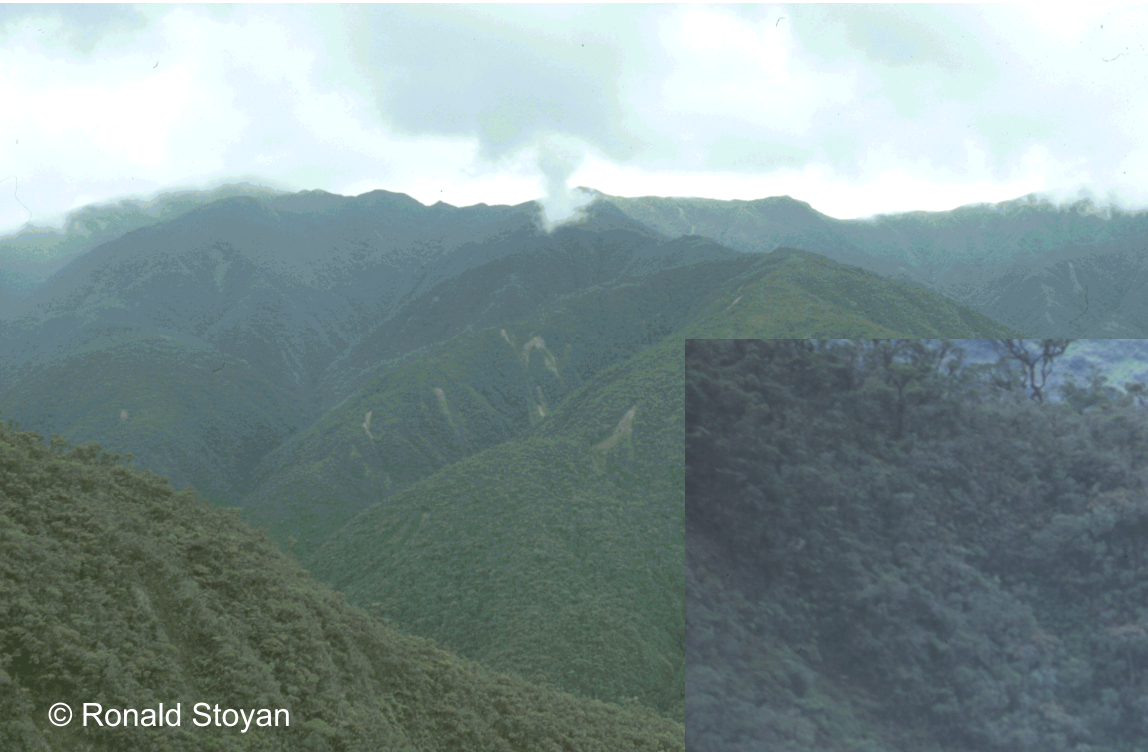
Typical soil of the ridges.

Wilcke et al. (2002): *Eur. J. Soil Sci.* **53**, 15-27.

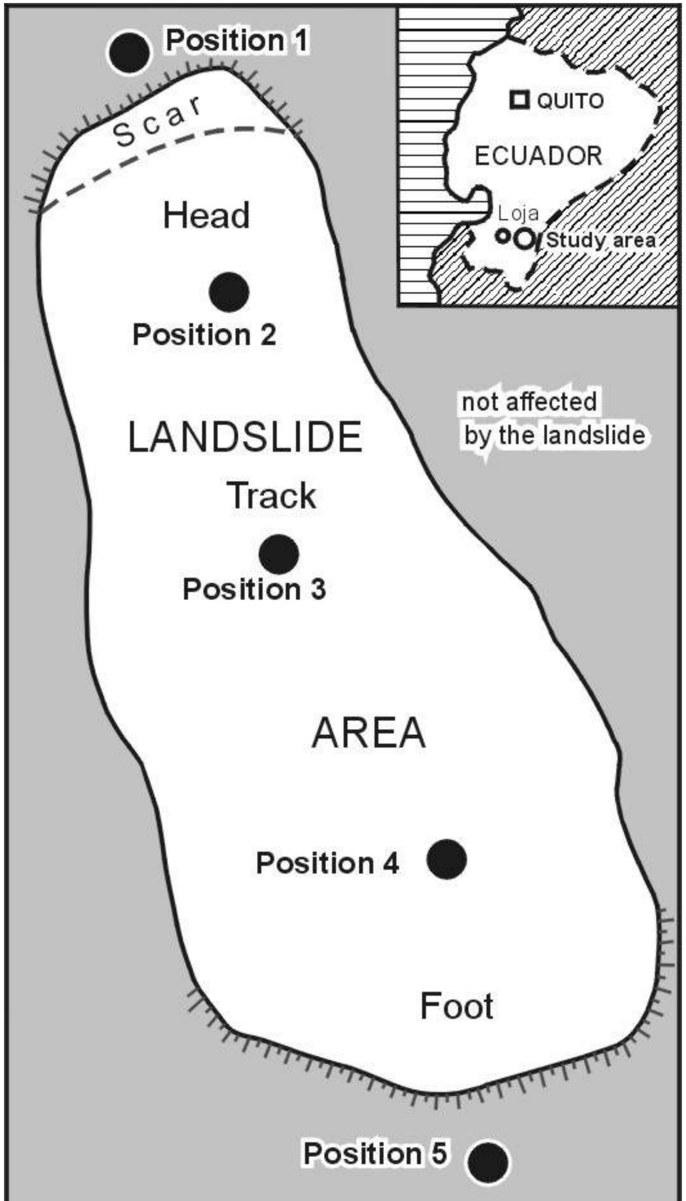


Map of organic layer thickness at the Long-term Ecosystem Study site.

Study site



Study site

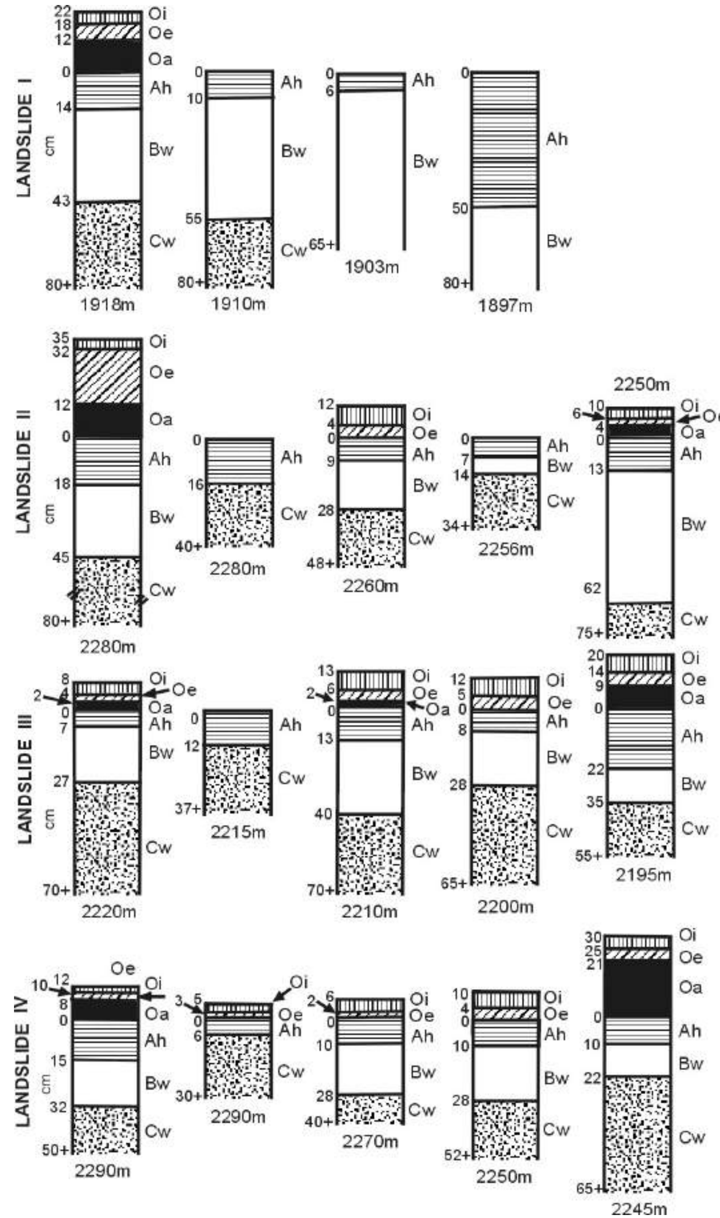


0.5 yr

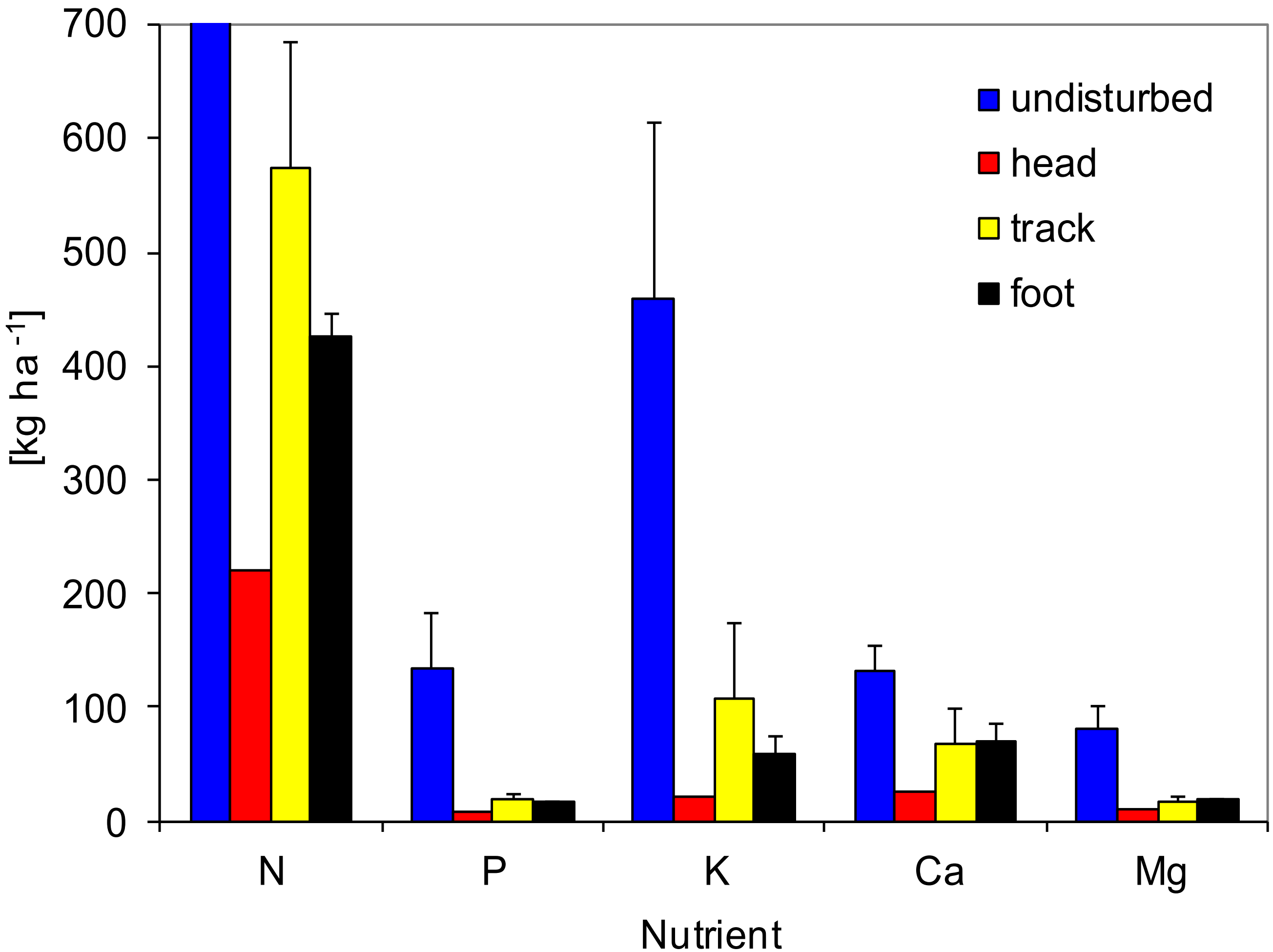
2-3 yr

8-10 yr

20 yr



Wilcke et al. (2003): *Catena* **53**, 79-95.

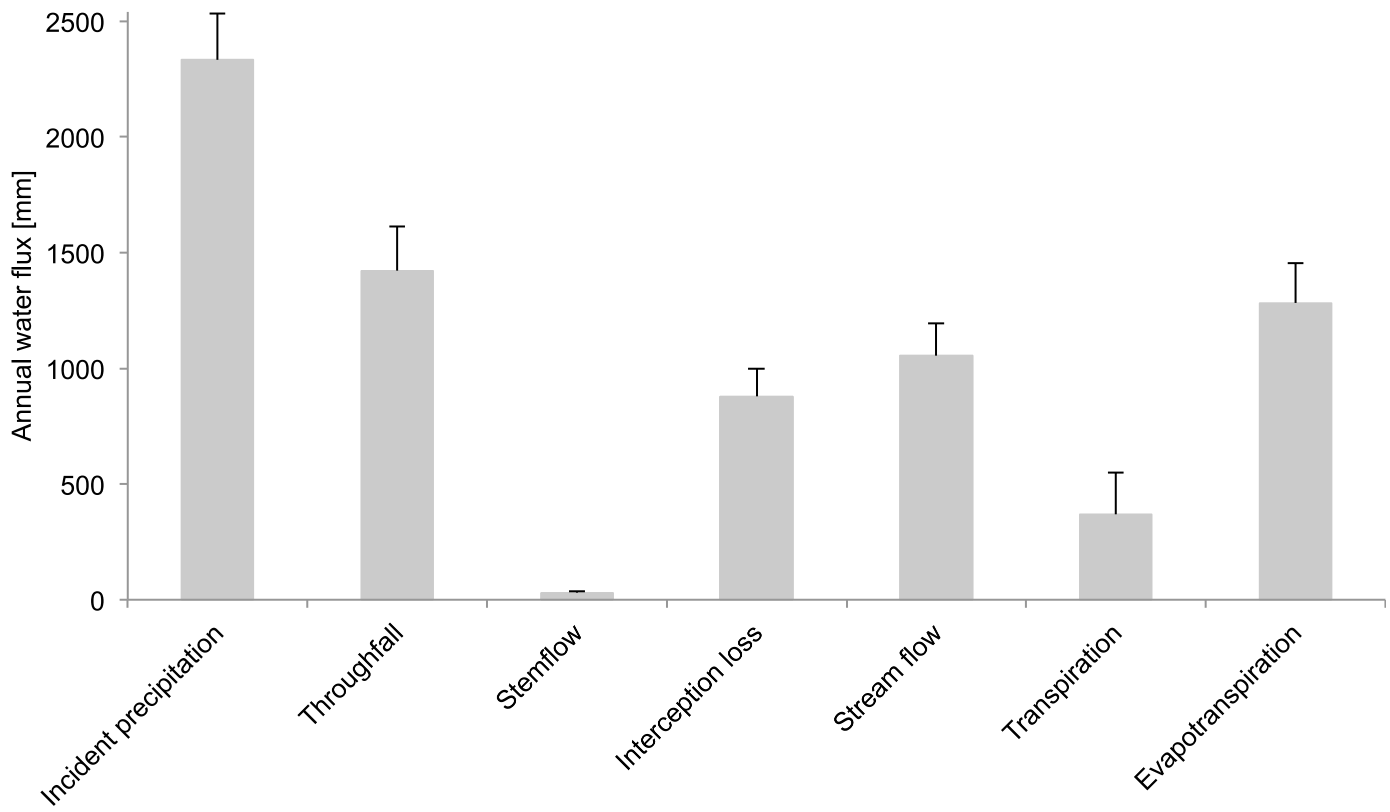


Wilcke et al. (2003): *Catena* **53**, 79-95.

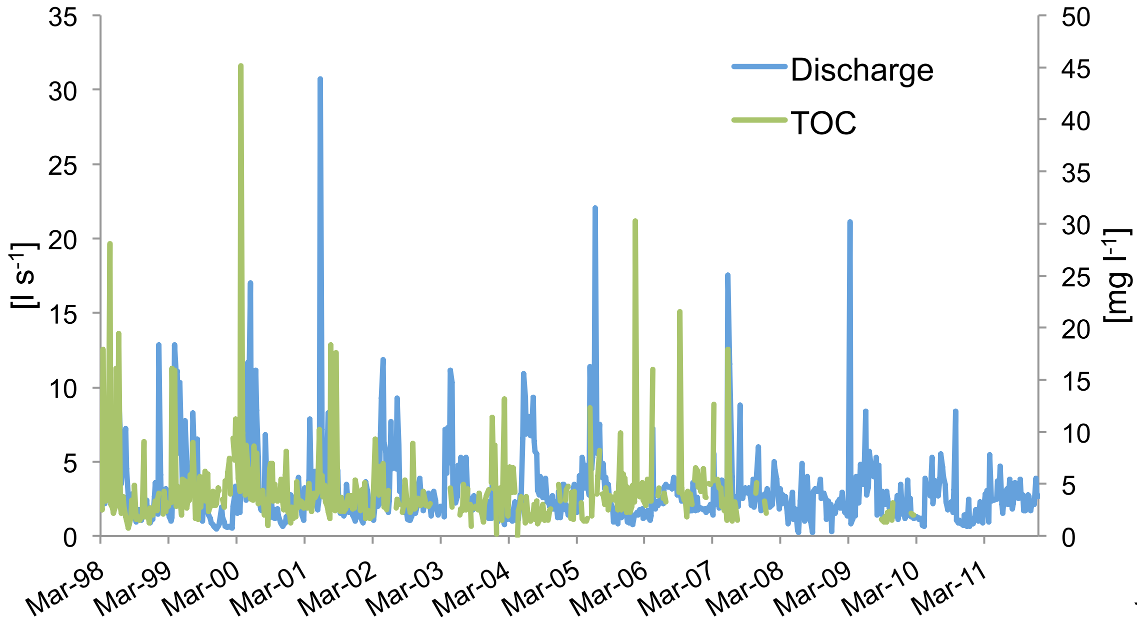
Mean nutrient storage in the organic layers at different positions next to and on the landslide. Error bars indicate standard deviations.

Study site

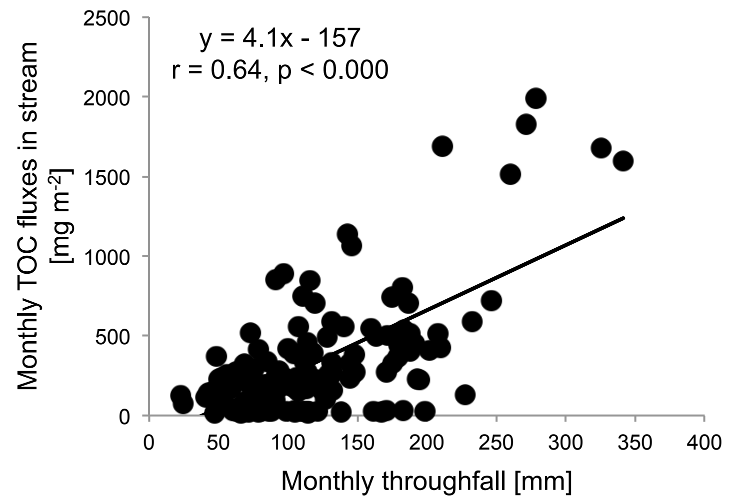
Fleischbein et al. (2005): *Hydrol. Proc.* **19**, 1355-1371,
Fleischbein et al. (2006): *Hydrol. Proc.* **20**, 2491-2507.



Mean annual water fluxes 1999-2010. Direct evaporation from the forest floor was neglected. Error bars indicate standard deviations.

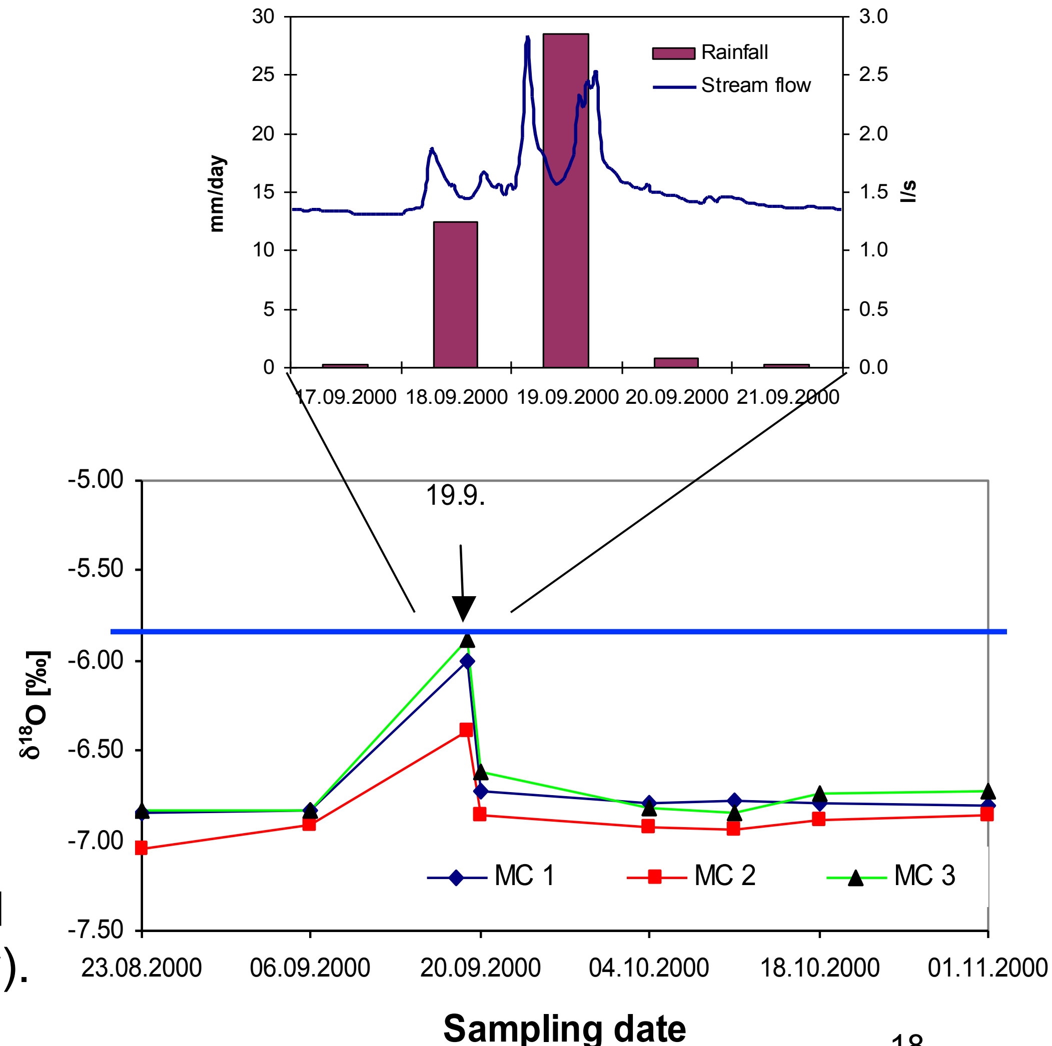


Temporal course of stream discharge and TOC concentrations 1998-2011.



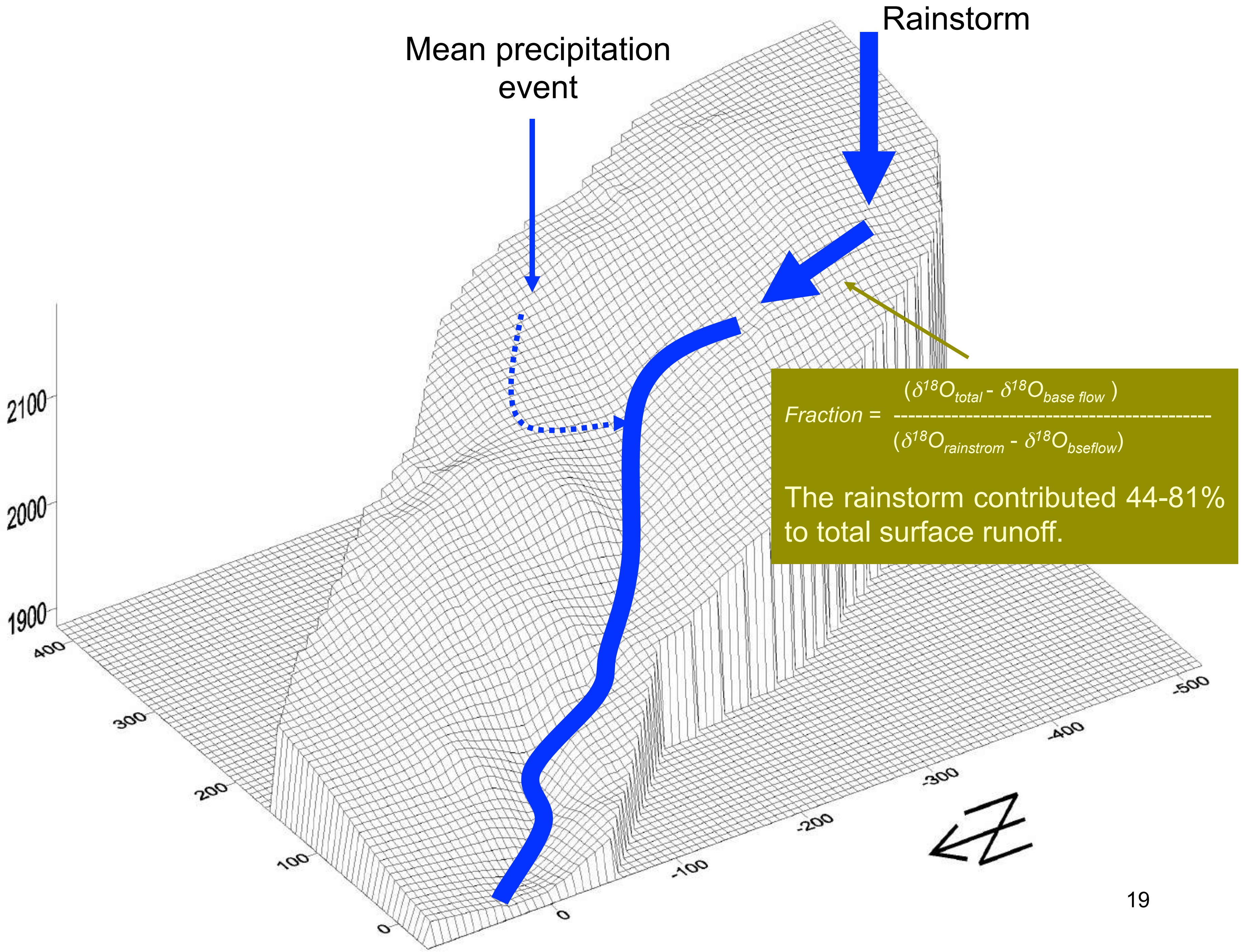
Goller et al. (2005): *J. Hydrol.* **308**, 67-80.

^{16}O: 99.76%
^{17}O: 0.04%
^{18}O: 0.20 %



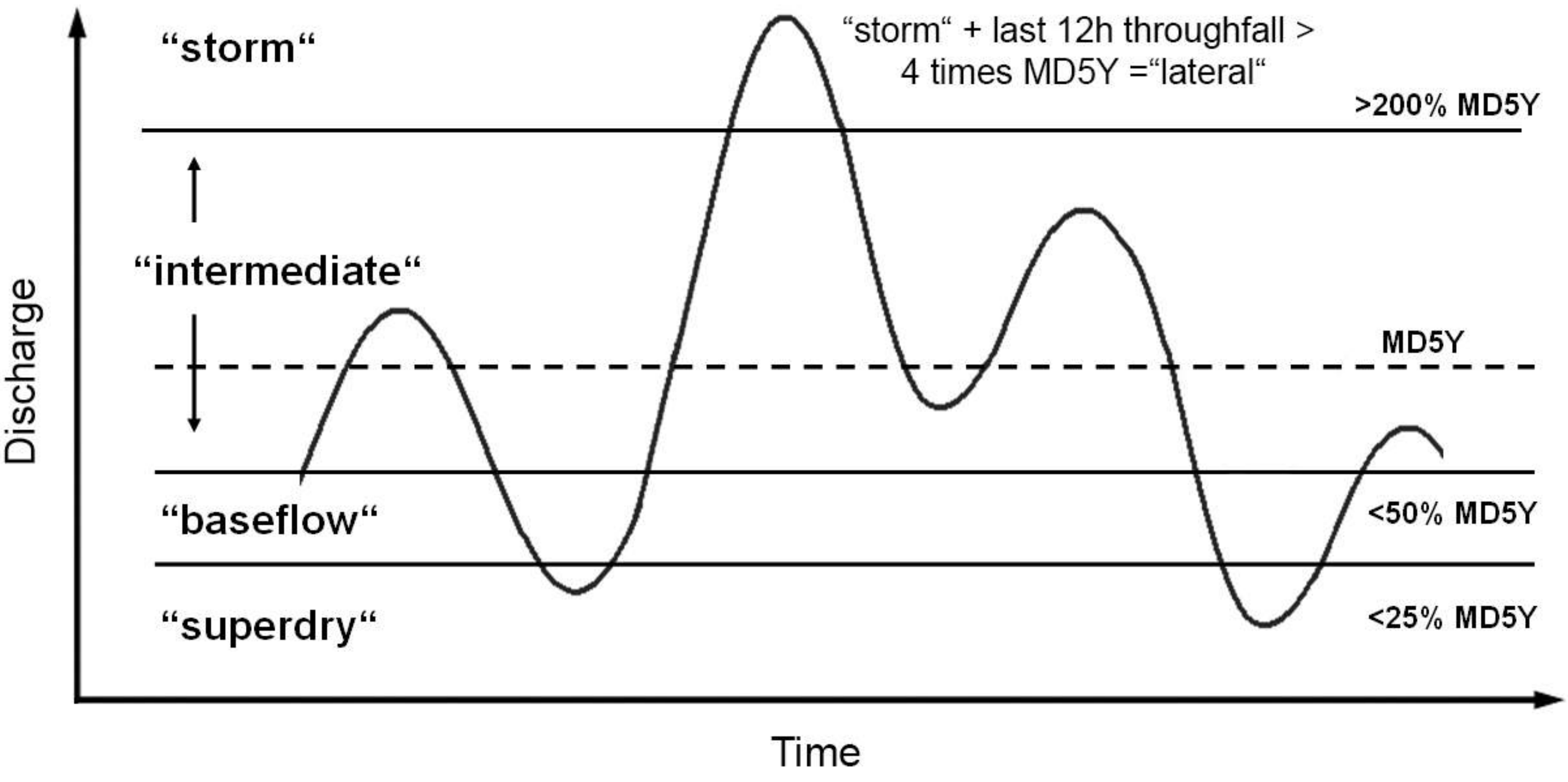
Stream flow, rainfall (above), and $\delta^{18}O$ value of stream water (below).

Goller et al. (2005): *J. Hydrol.* **308**, 67-80.



$$Fraction = \frac{(\delta^{18}O_{total} - \delta^{18}O_{base\ flow})}{(\delta^{18}O_{rainstrom} - \delta^{18}O_{bseflow})}$$

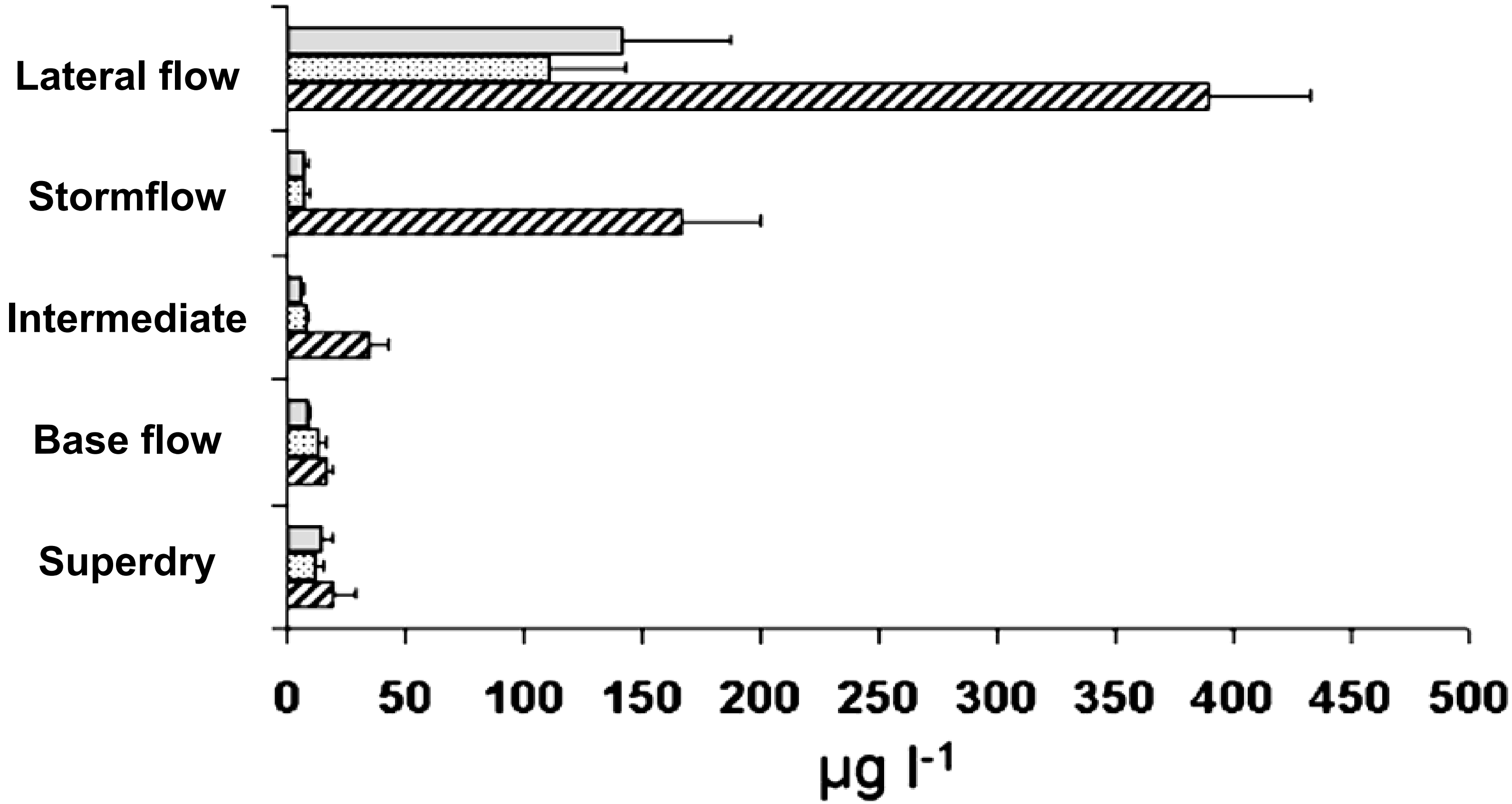
The rainstorm contributed 44-81% to total surface runoff.



Boy et al. (2008): *Eur. J. Soil Sci.* **59**, 1209-1227.

Sketch of five flow classes (MD5Y= mean discharge over five years).

Boy et al. (2008): *Eur. J. Soil Sci.* **59**, 1209-1227.



Concentrations of Al in stream water during different flow conditions.

Summary study site:

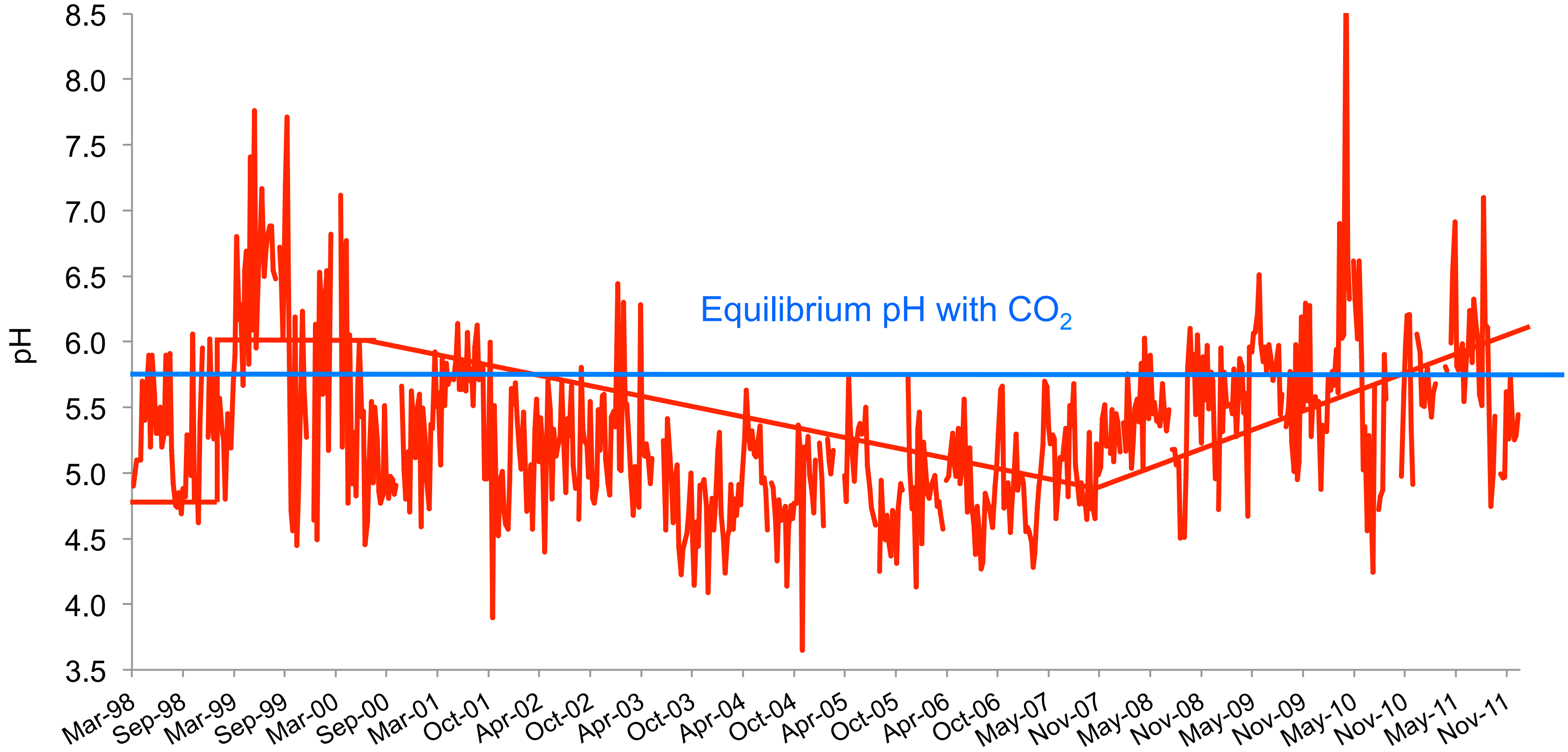
Soils:

- Shallow, acid soils with thick organic layers.
- Landslides are frequent and mainly remove the organic layers.

Hydrological conditions:

- High interception loss.
- Flow depth in soil is variable; considerable near-surface flow.

Matter deposition



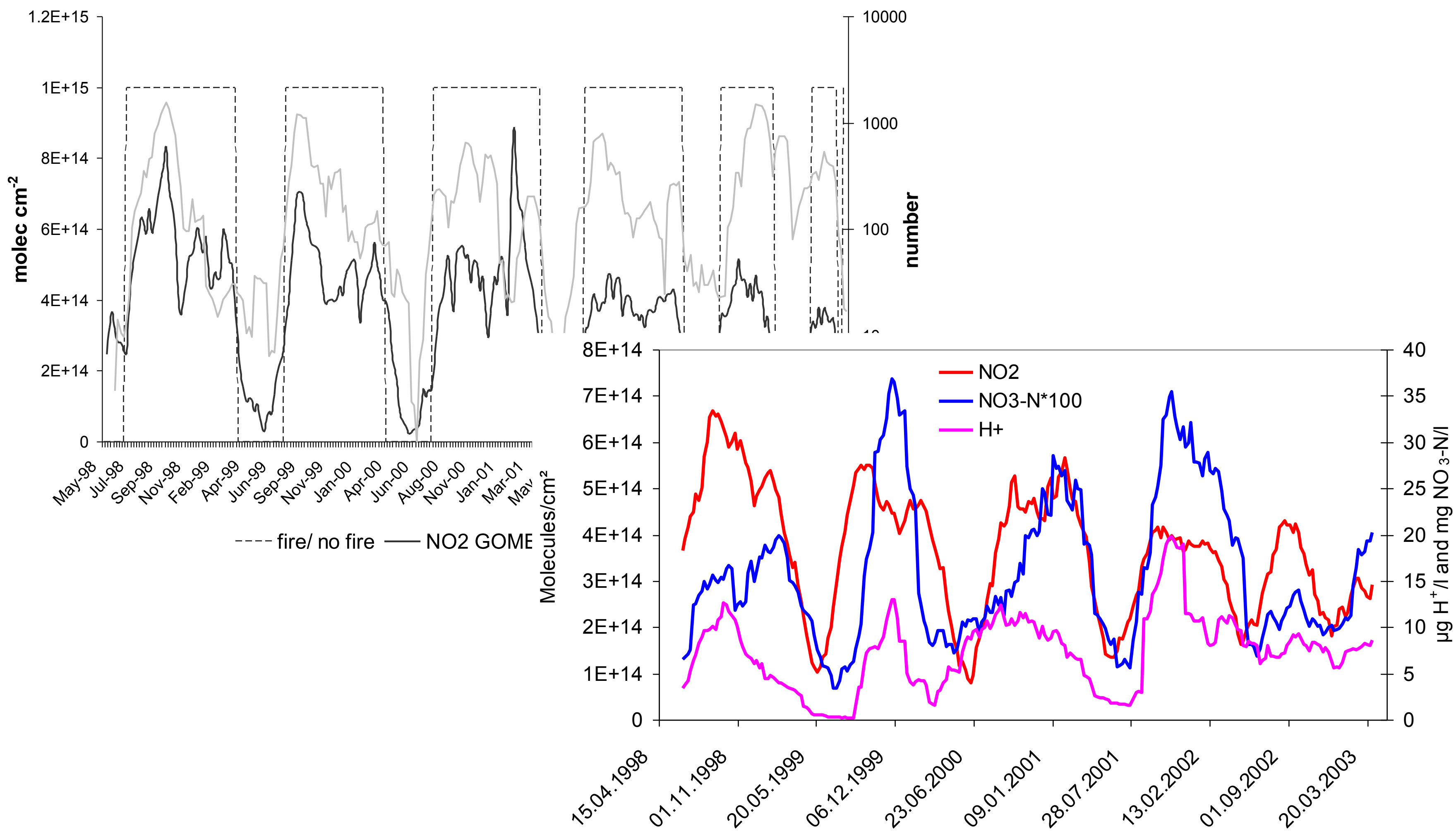
Course of the pH in in rainfall between 1999 and 2008.

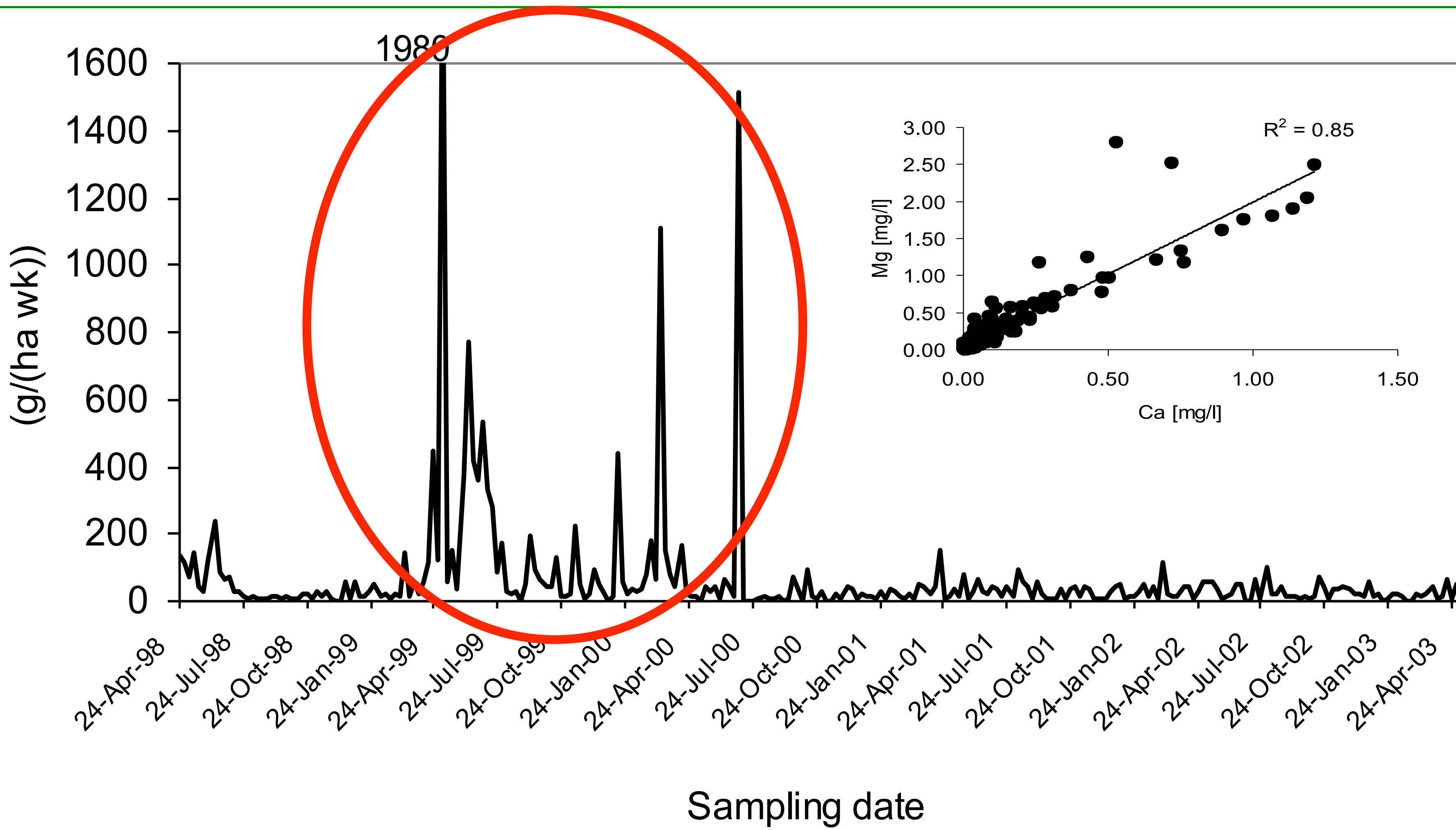
Matter deposition

Tropical montane forest under environmental change

Matter deposition

Boy et al. (2008): *Glob. Biogeochem. Cycle* **22**, GB4011.





Boy and Wilcke (2008): *Glob. Biogeochem. Cycle* **22**, GB1027.

Course of Ca concentrations in incident rainfall 1998-2003.

Desert dust

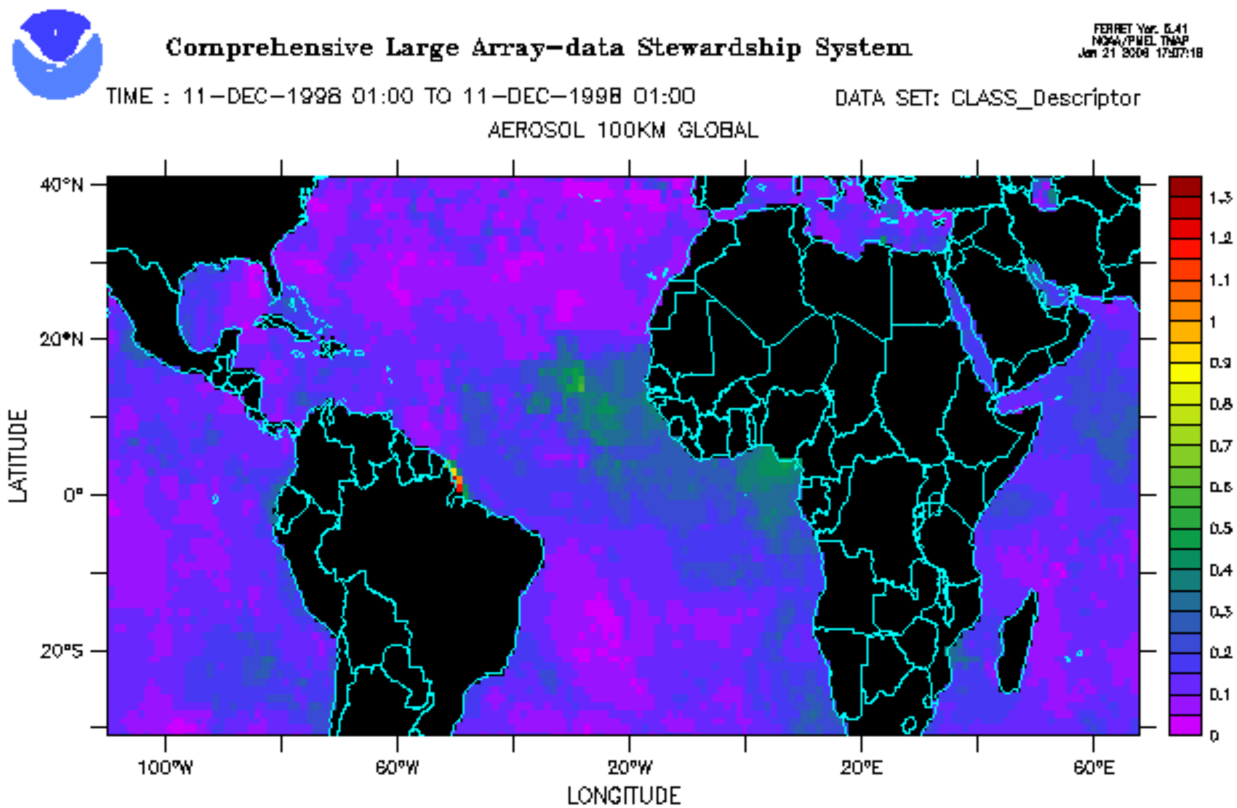
Boy and Wilcke (2008): *Glob. Biogeochem. Cycle* **22**, GB1027.

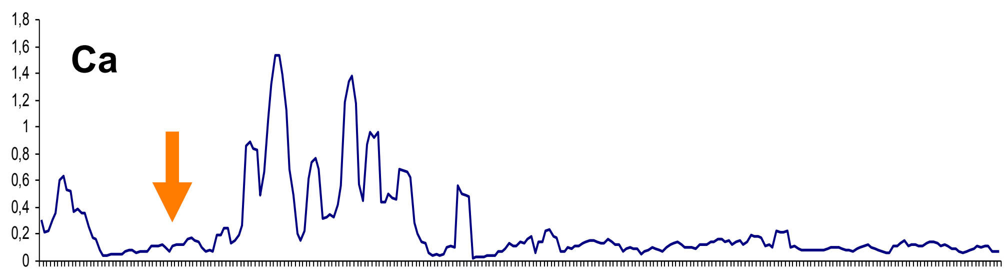
Trajectories from the Sahara to south Ecuador. (NOAA hysplit backwards, 3000, 4000, and 6000 m ü. NN) - cooperation with Rütger Rollenbeck.

Tropical montane forest under environmental change

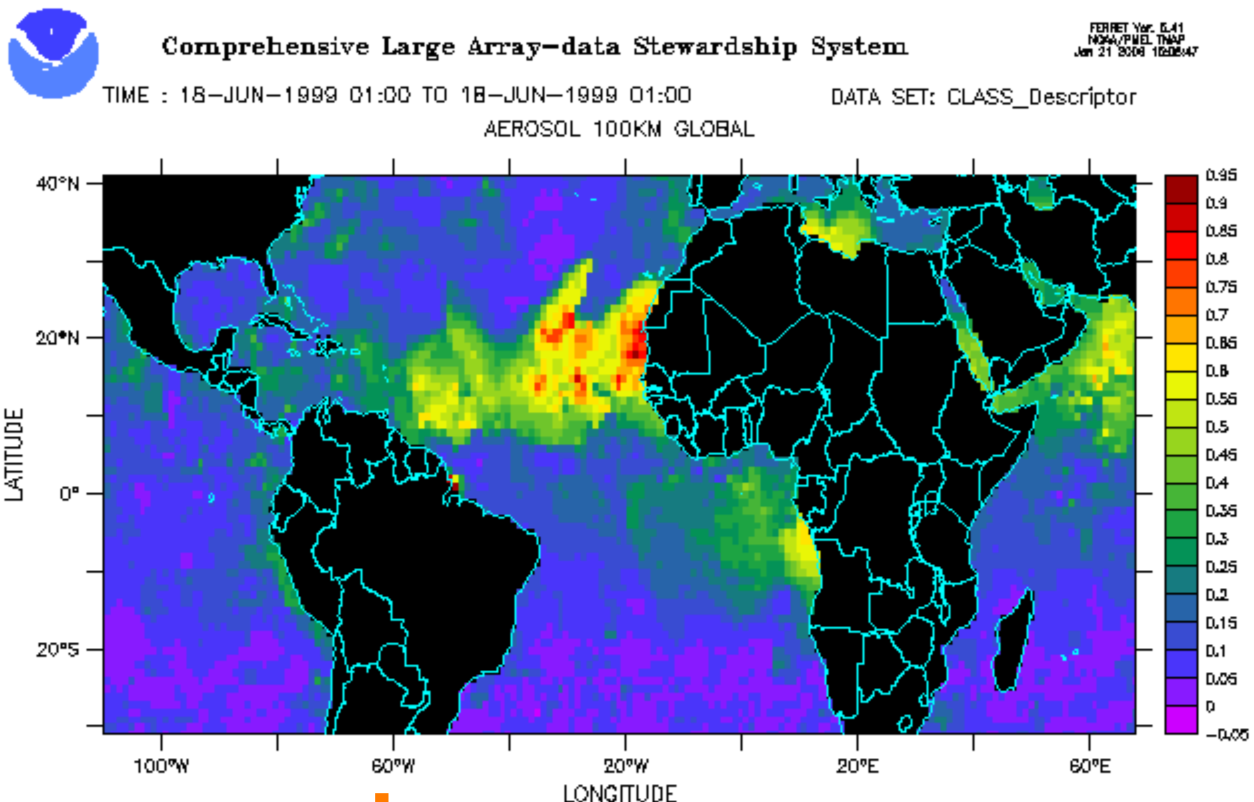
Matter deposition

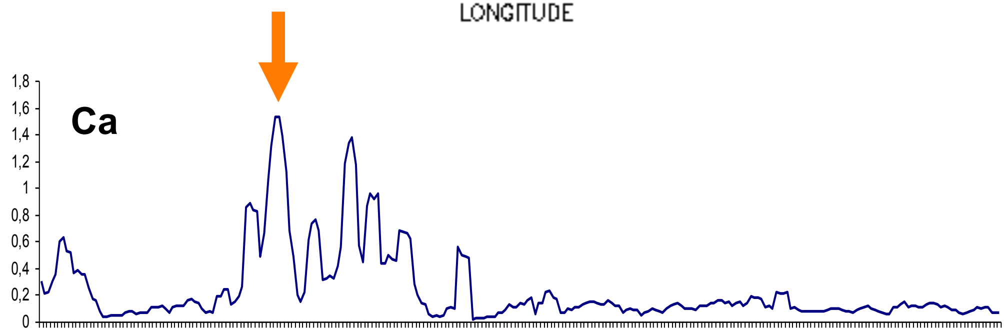
Boy and Wilcke (2008): *Glob. Biogeochem. Cycle* **22**, GB1027.





Boy and Wilcke (2008): *Glob. Biogeochem. Cycle* **22**, GB1027.

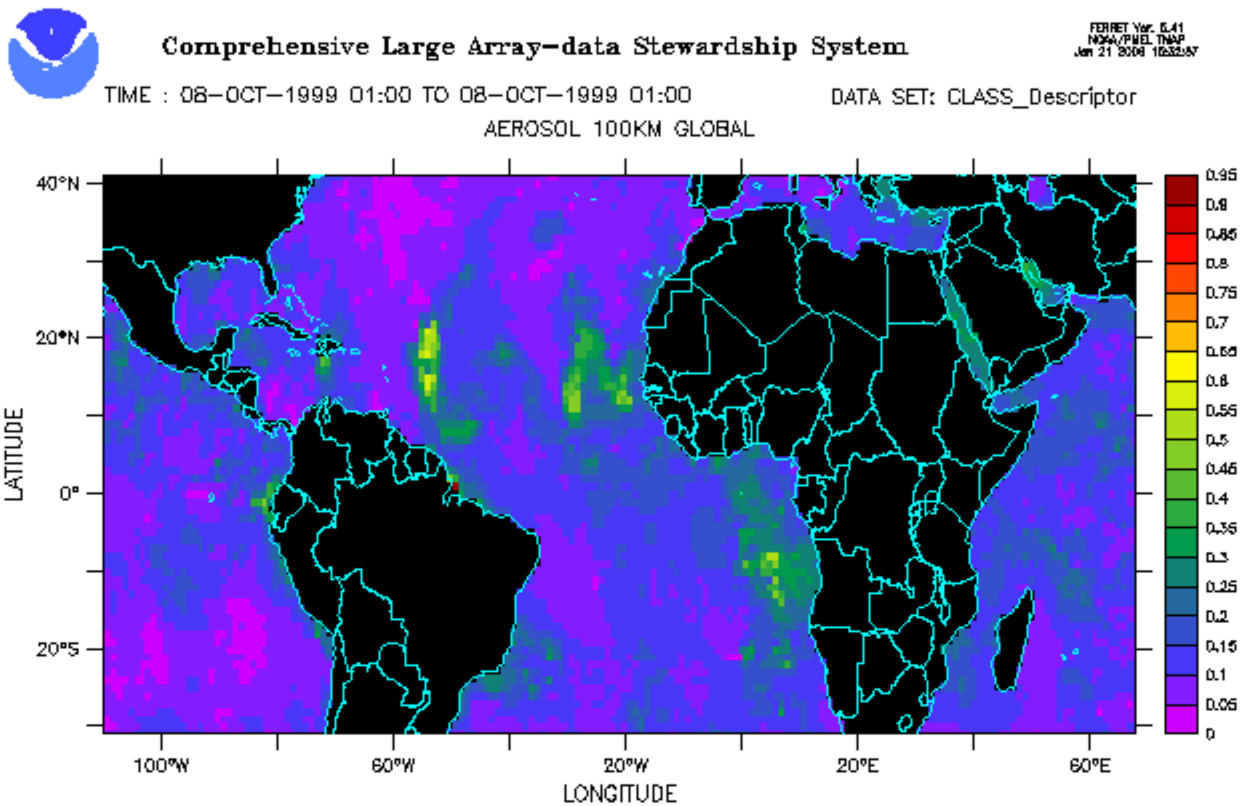


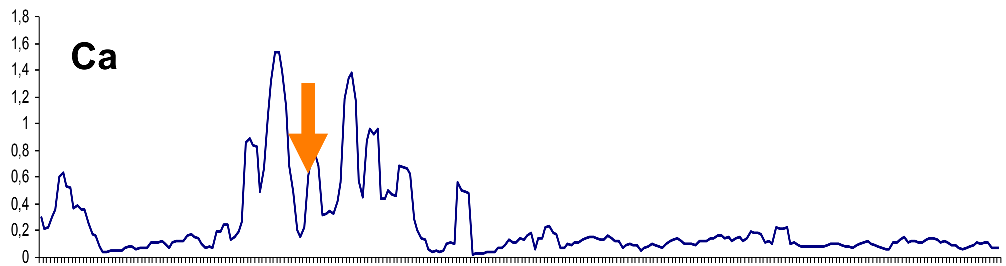


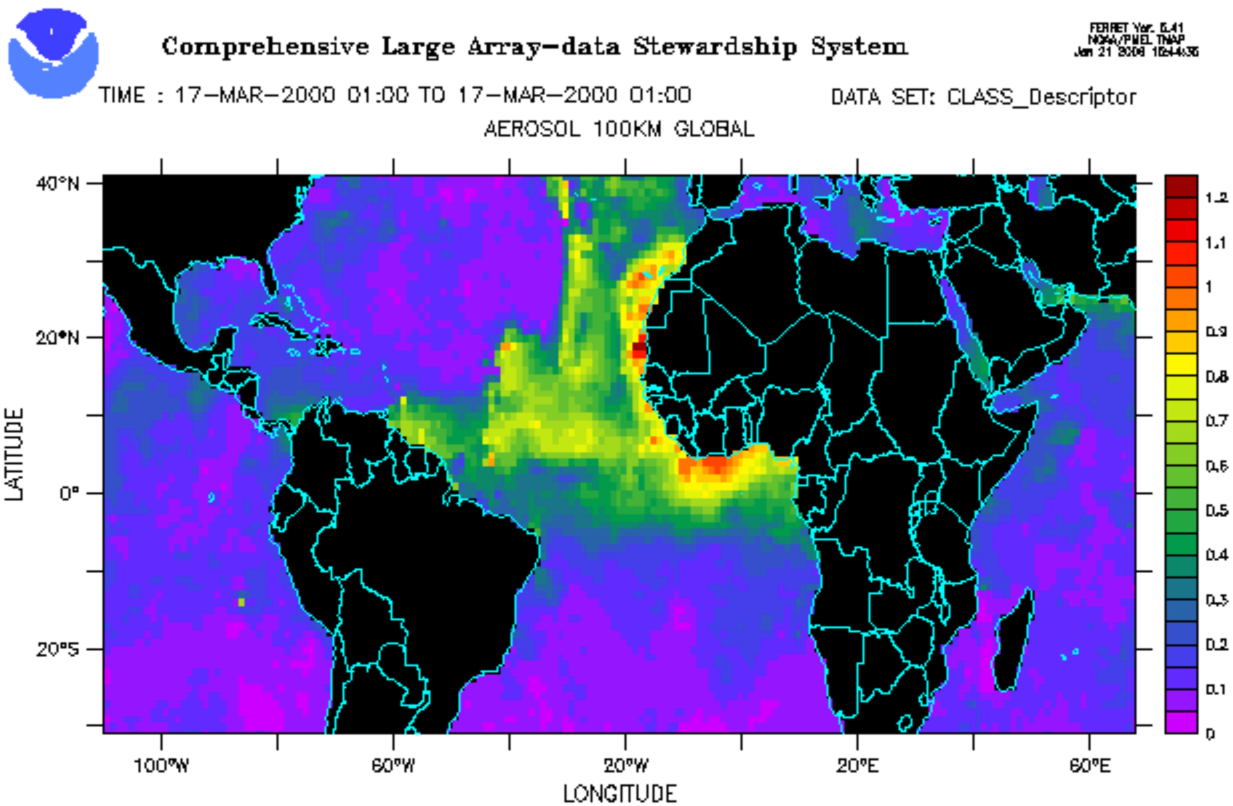
Tropical montane forest under environmental change

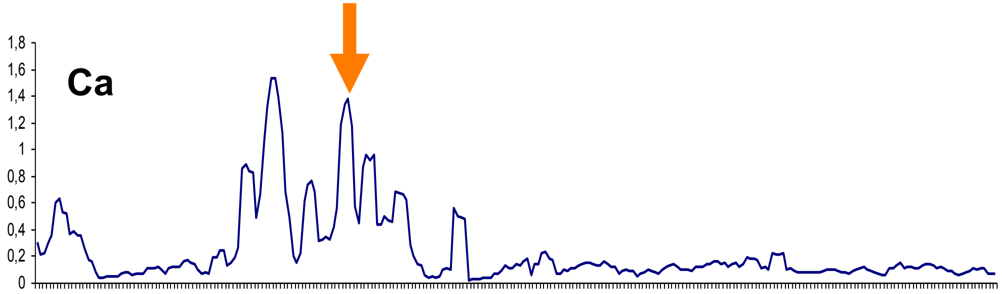
Matter deposition

Boy and Wilcke (2008): *Glob. Biogeochem. Cycle* **22**, GB1027.









Boy and Wilcke (2008): *Glob. Biogeochem. Cycle* **22**, GB1027.

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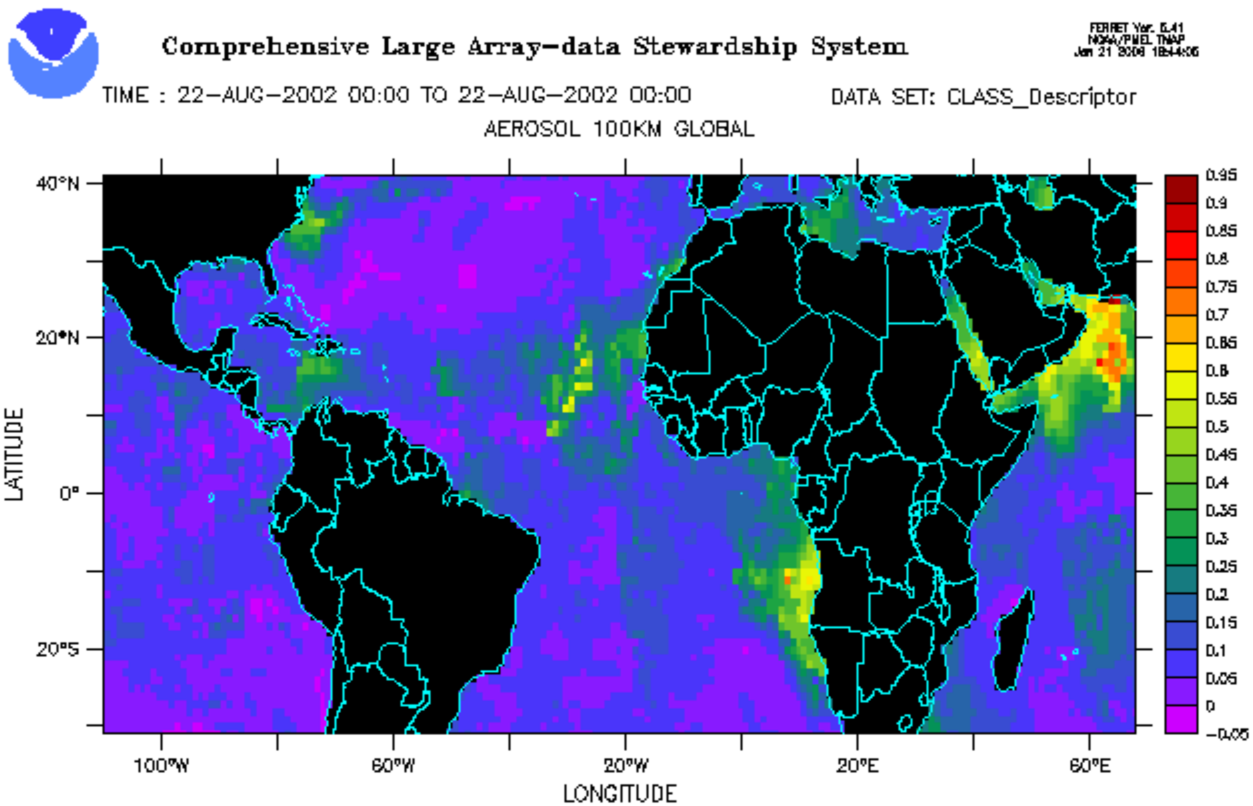

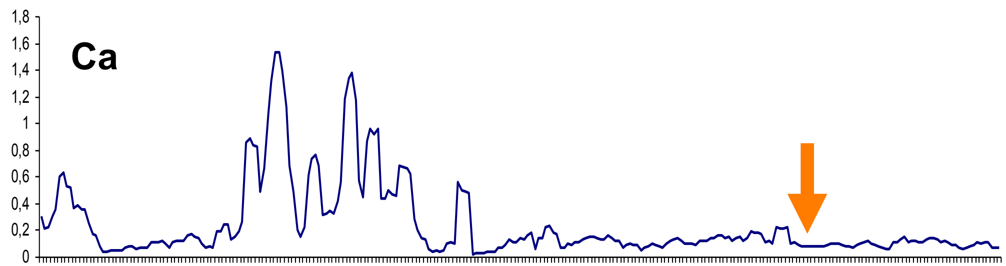

Matter deposition

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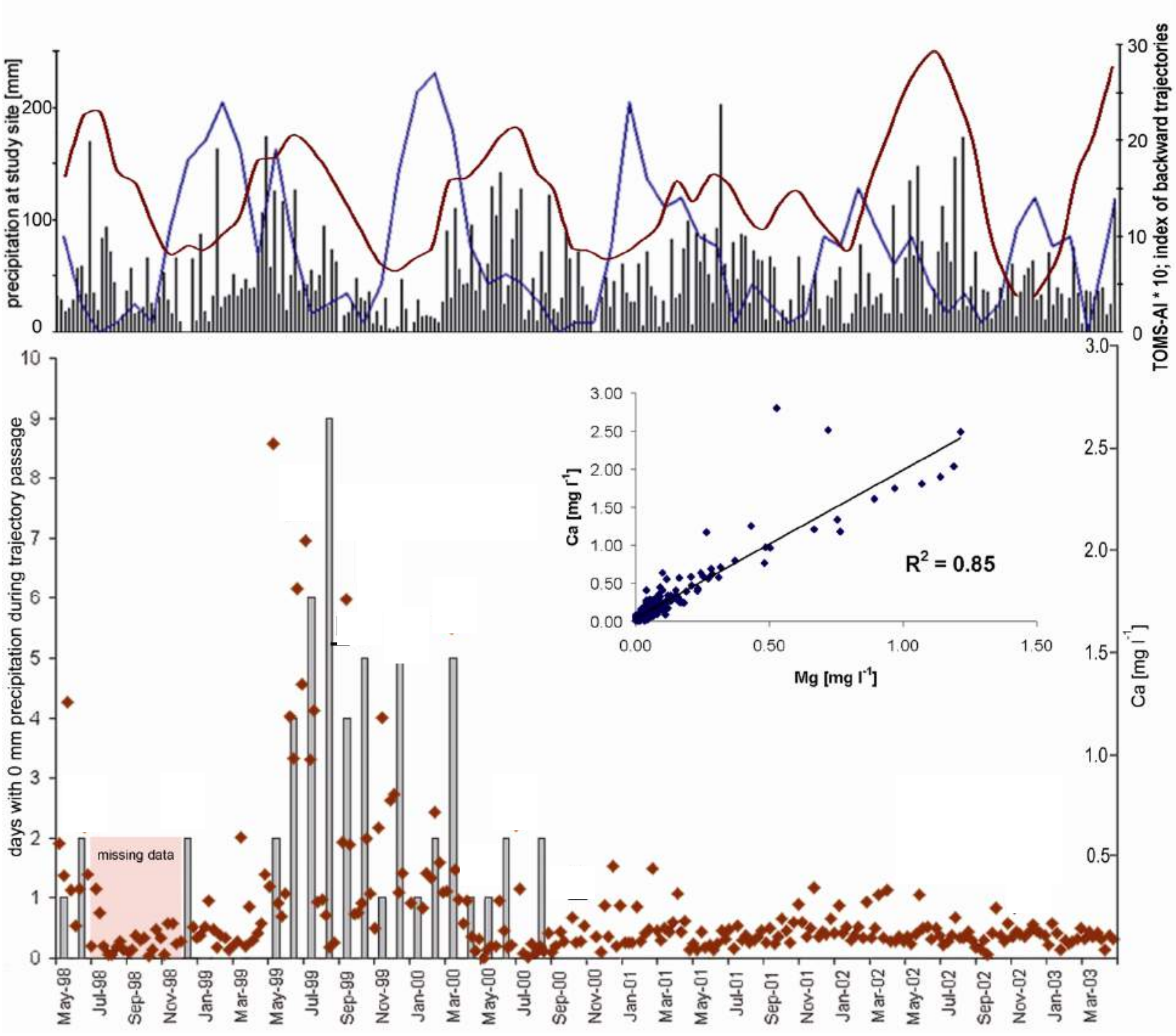
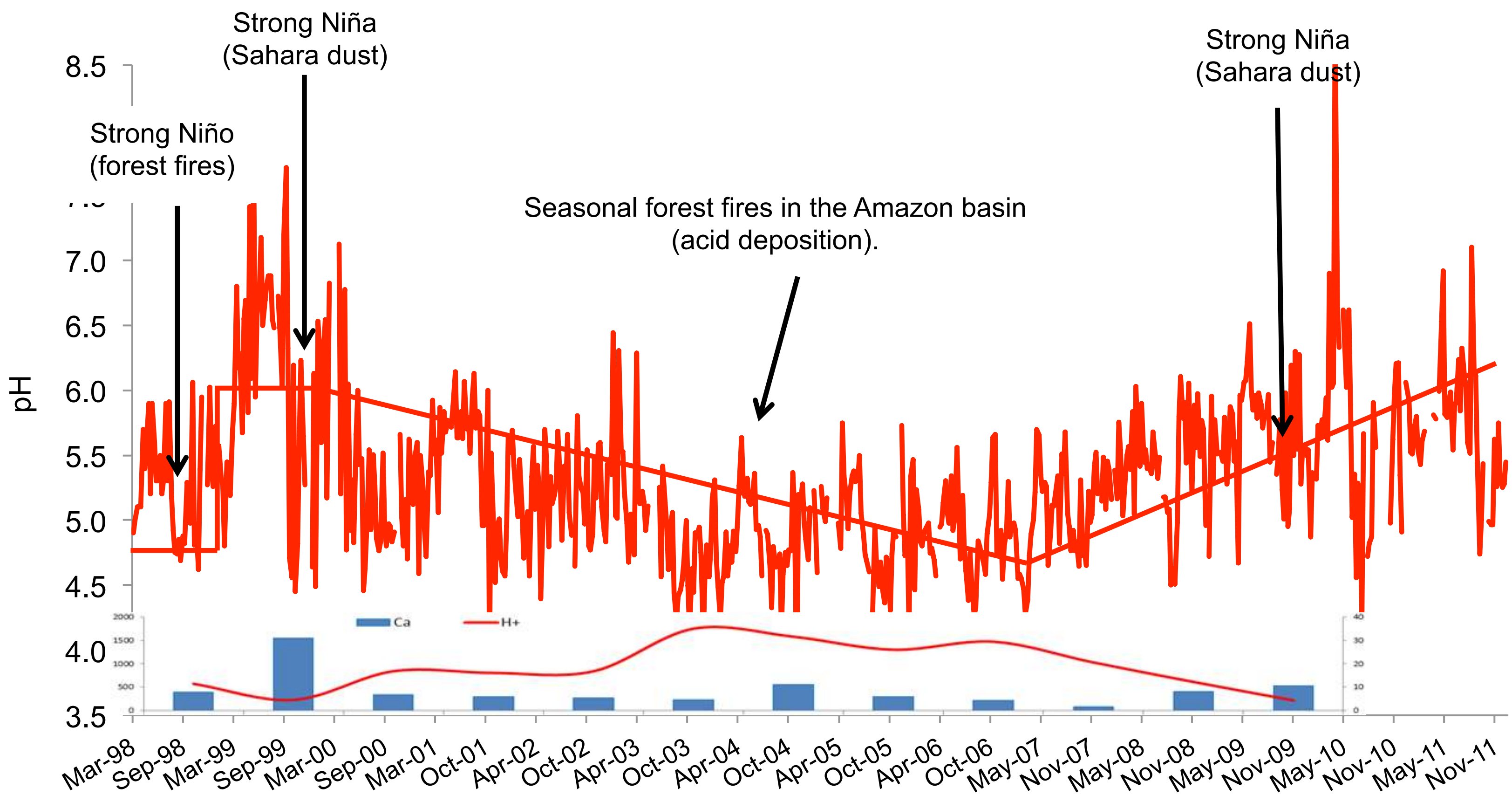
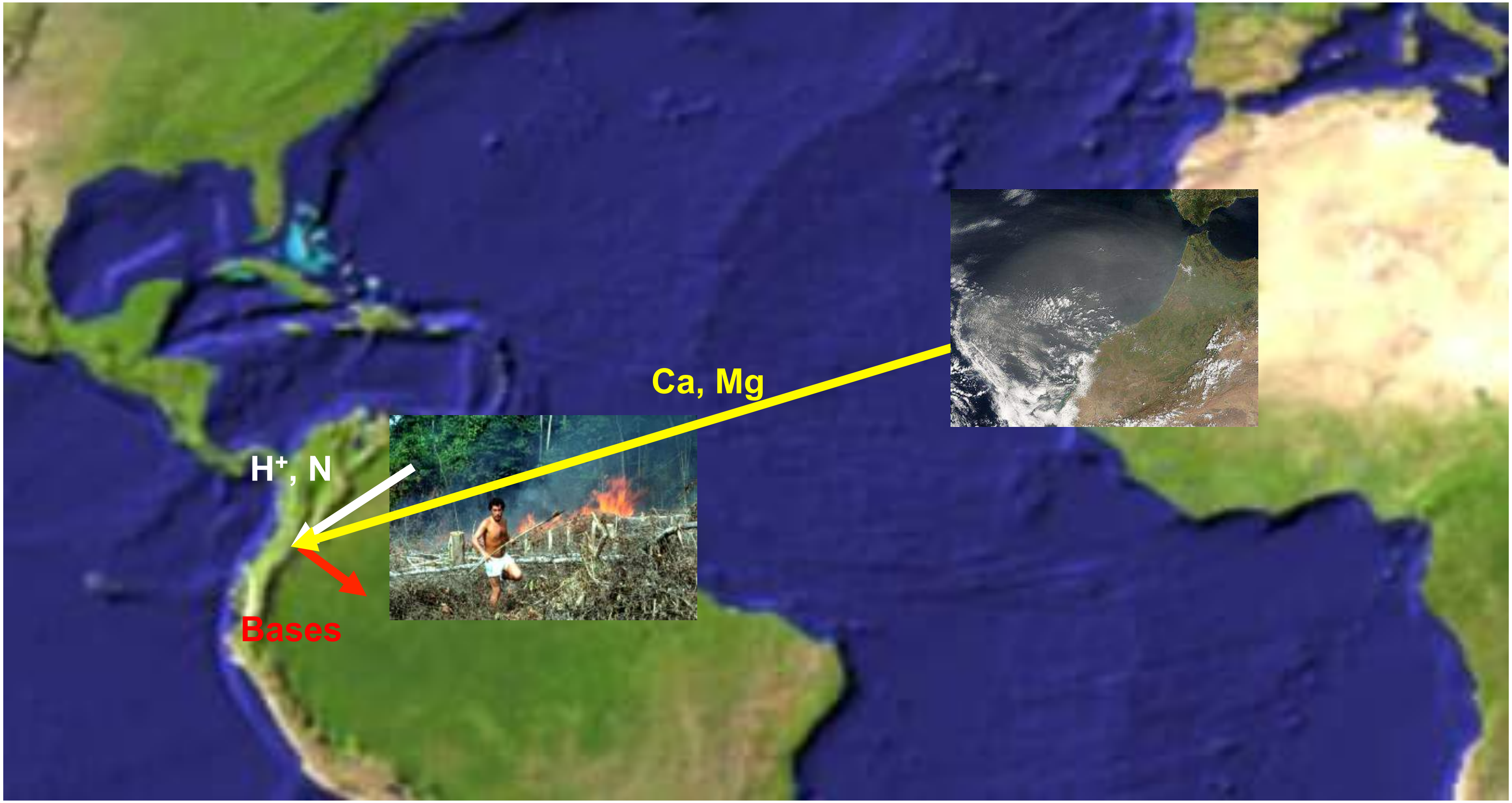


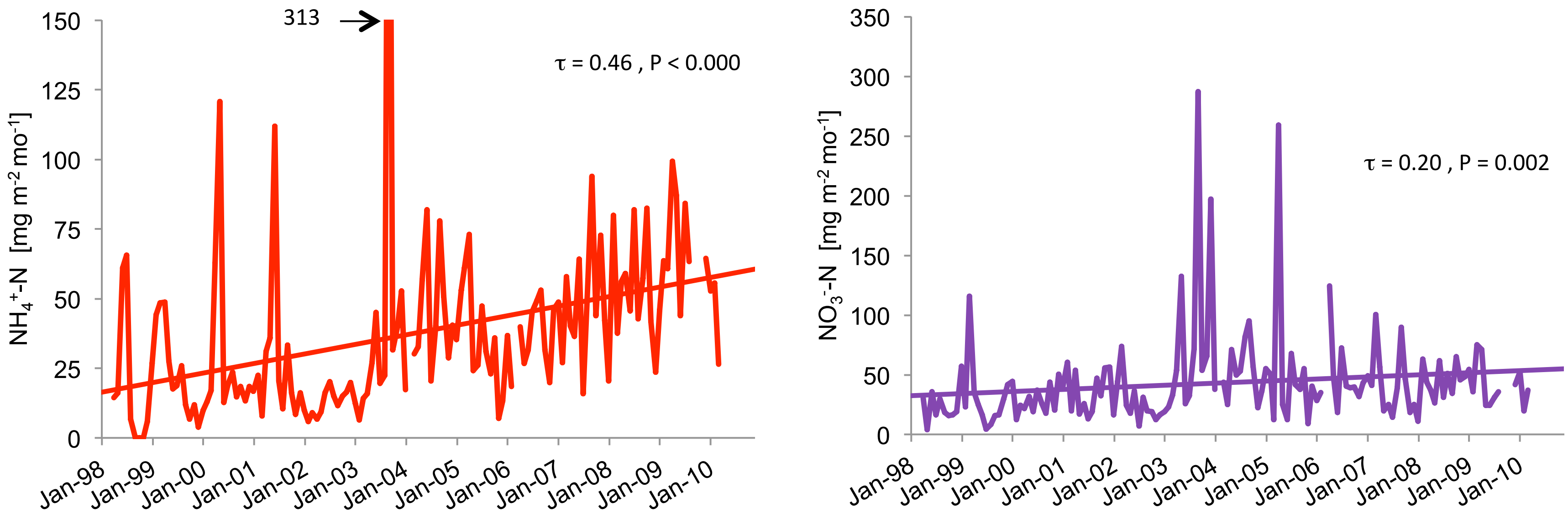


Course of the pH in rainfall and Ca deposition and course of pH in organic layer leachate (insert) between 1999 and 2008.

Matter deposition

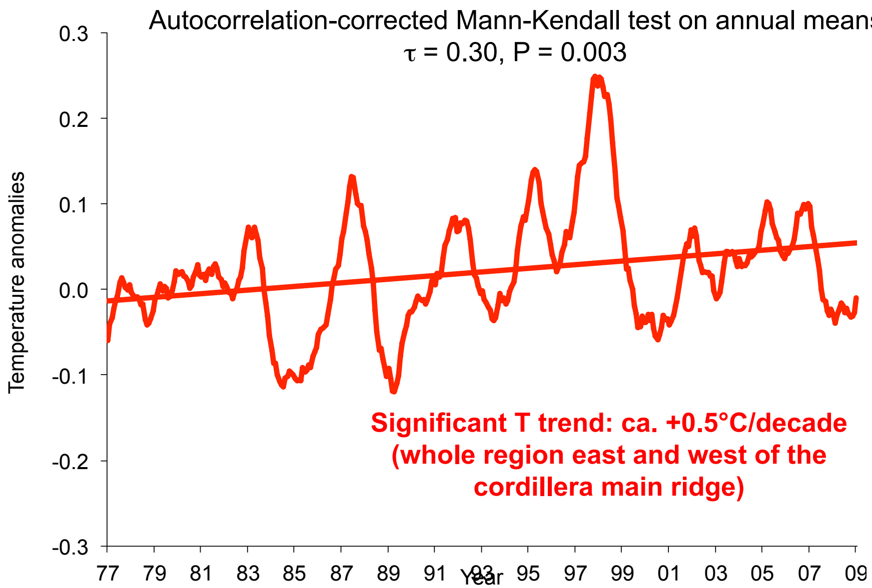


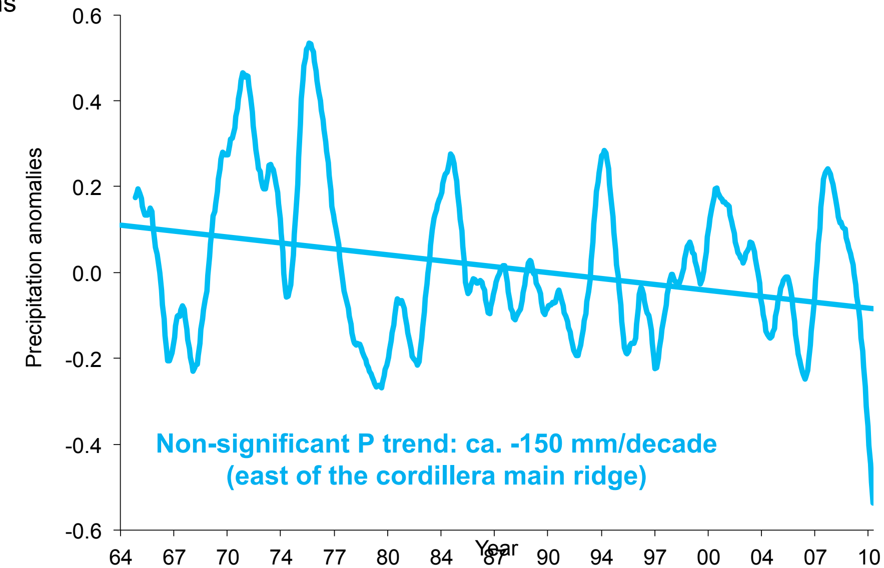
Environmental changes



Course of the NH_4^+-N (left) and NO_3^- deposition (right) with incident precipitation 1998-2010.

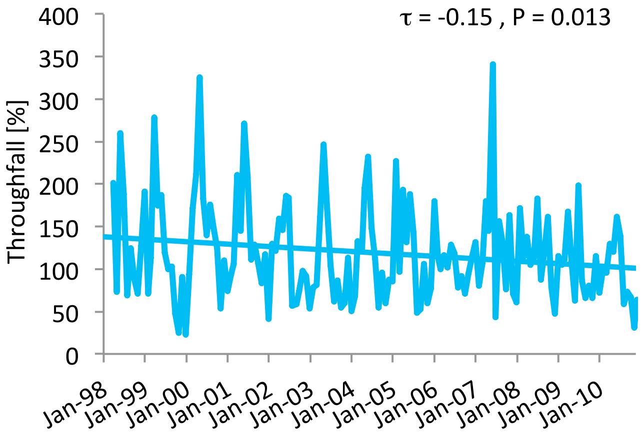
Environmental changes



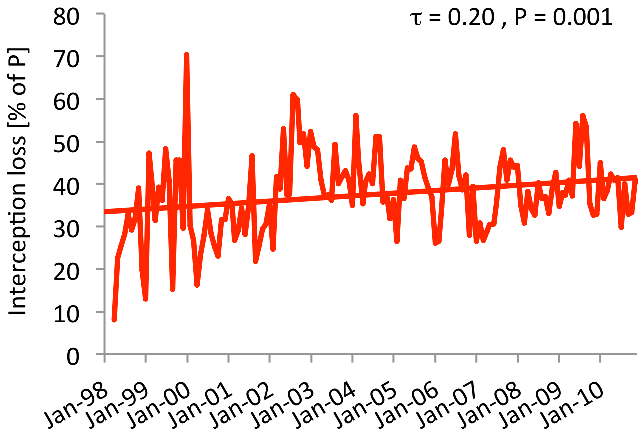


Course of temperature (T) and precipitation (P) anomalies in the area Loja/Zamora (12-month moving averages)

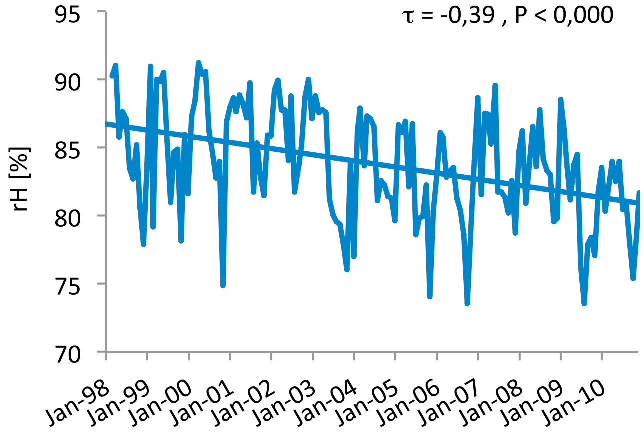
Data from Rütger Rollenbeck and Jörg Bendix, University of Marburg



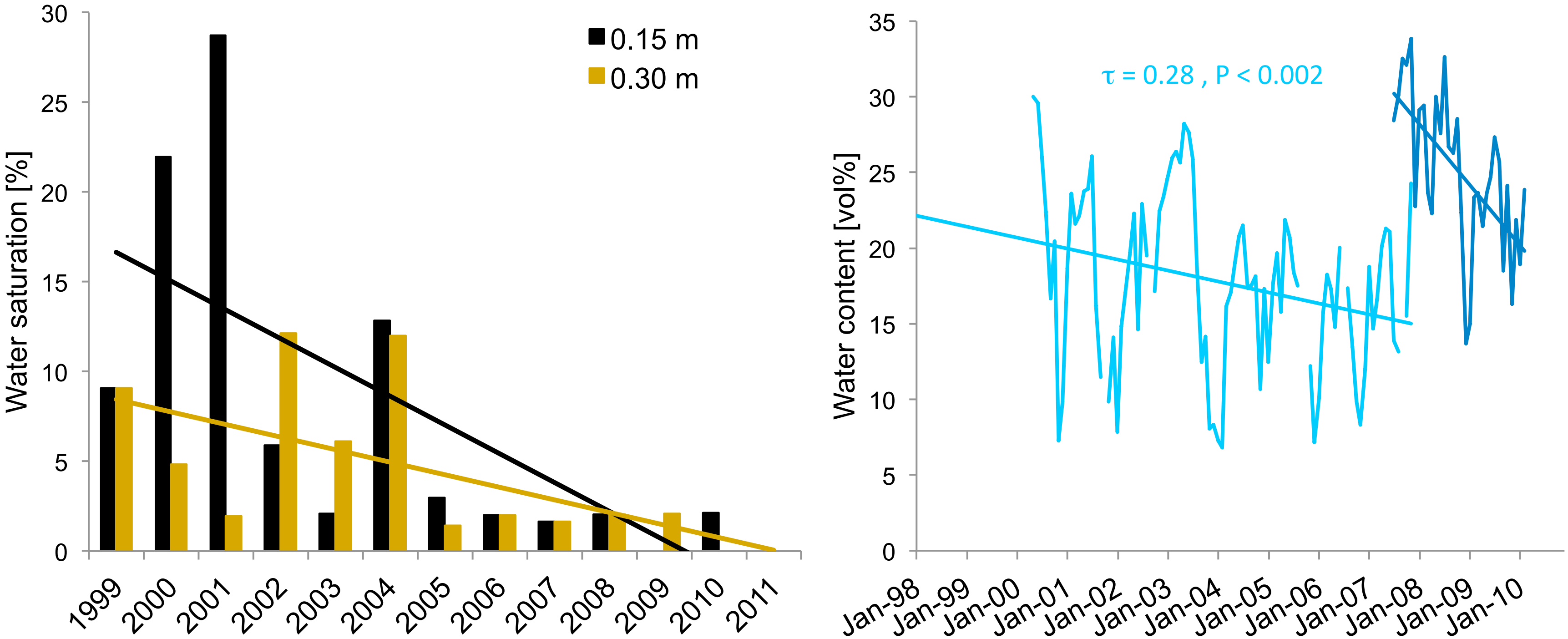
Course of throughfall 1998-2011.



Course of interception loss 1998-2011.



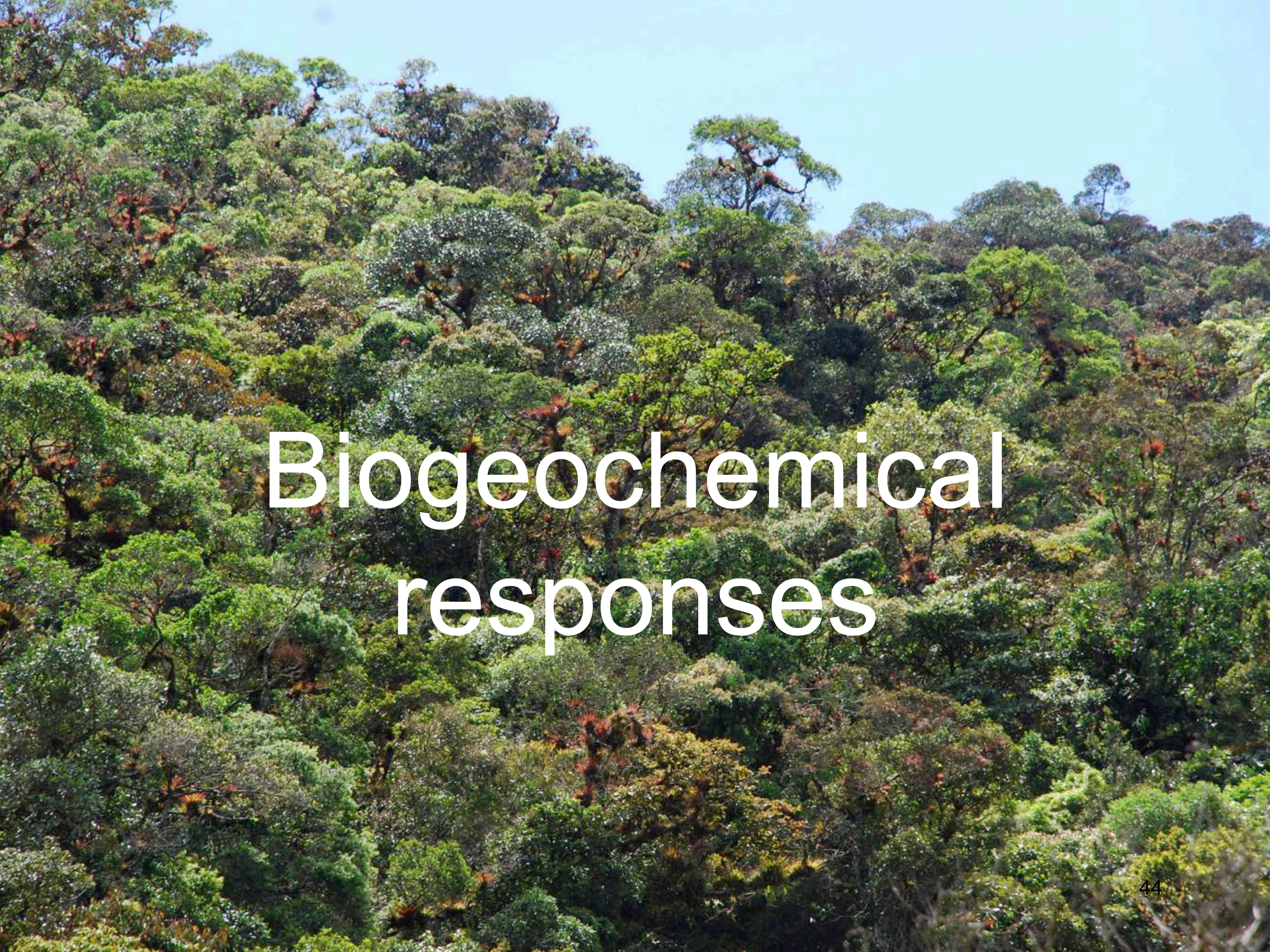
Course of relative air humidity (rH) 1998-2011.

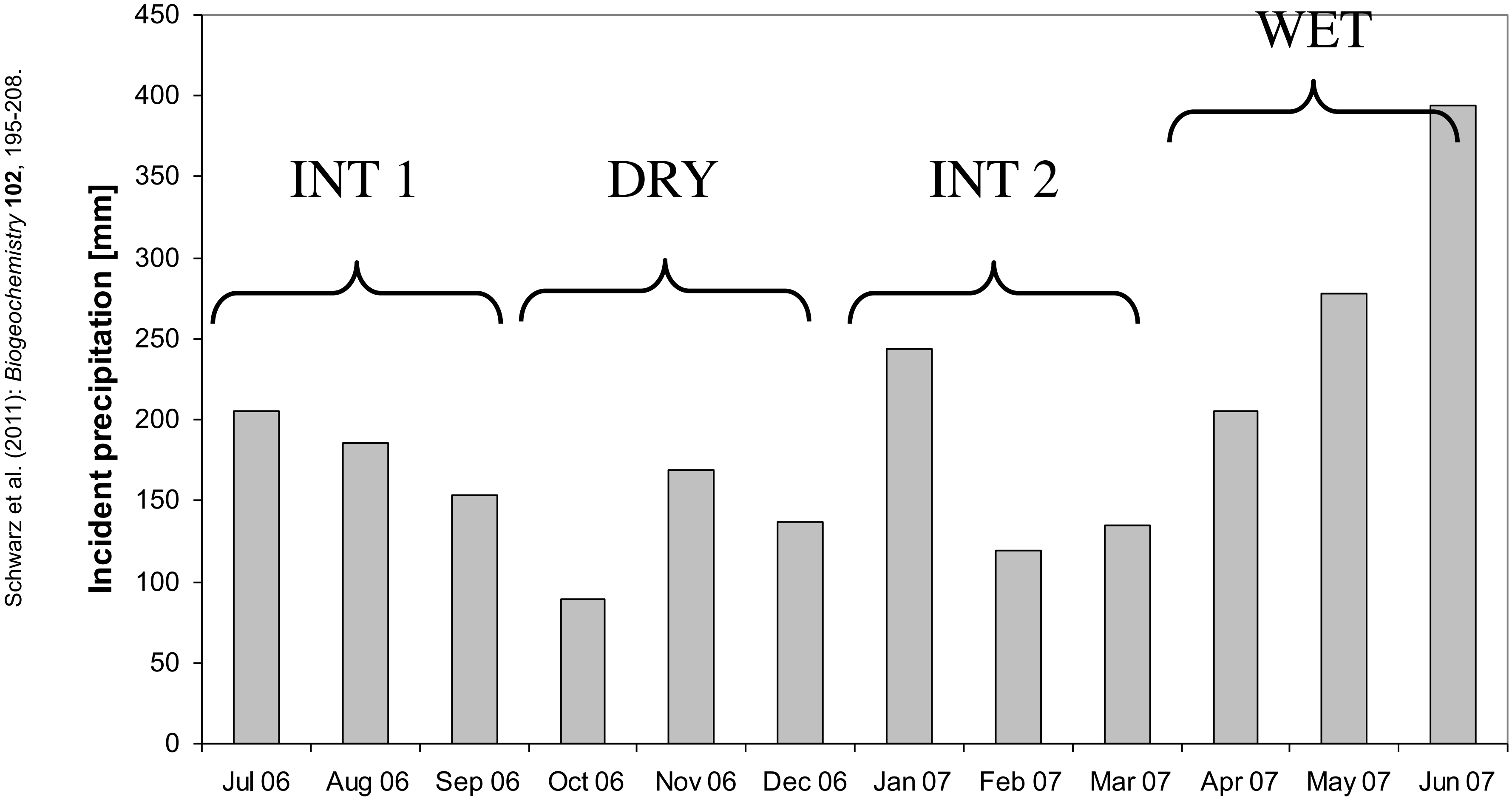


Frequency of soil water saturation (indicated by a matric potential of 0 MPa) at 0.15 und 0.30 m mineral soil depth (left) and water content in the organic layer (right) 1998-2011.

The major on-going environmental changes are

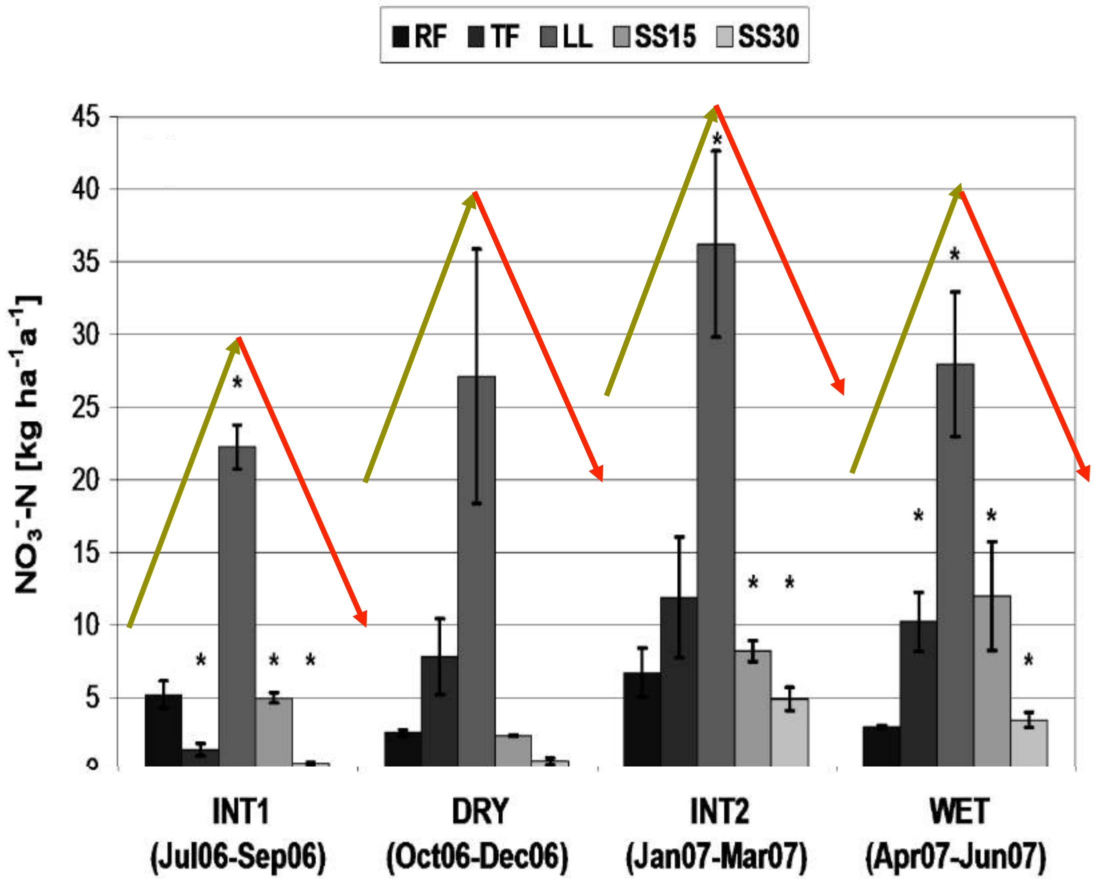
- Increasing N deposition and
- increasingly dry microclimate.


Biogeochemical responses



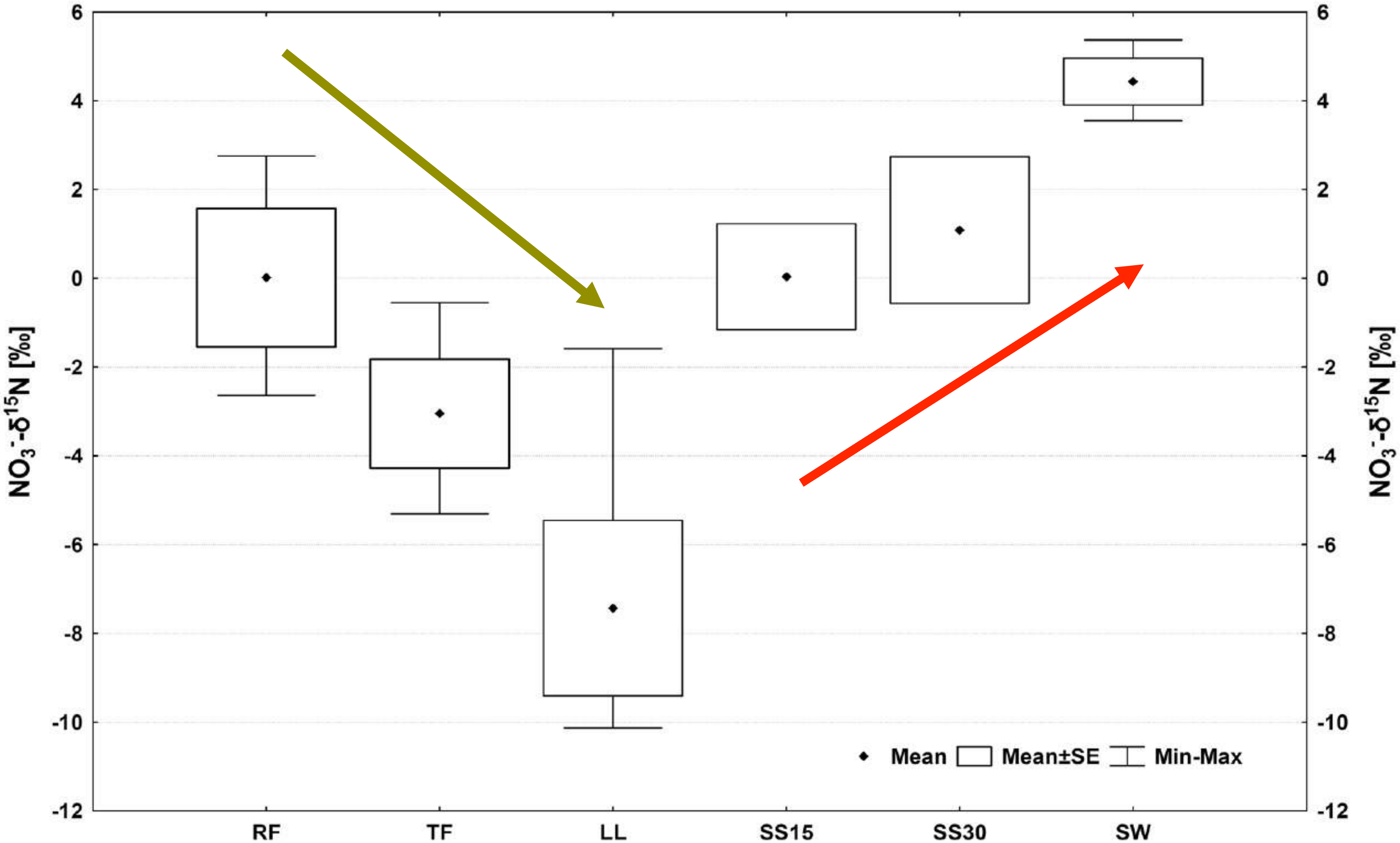
Annual course of incident precipitation and definition of seasons.

Schwarz et al. (2011): *Biogeochemistry* **102**, 195-208.



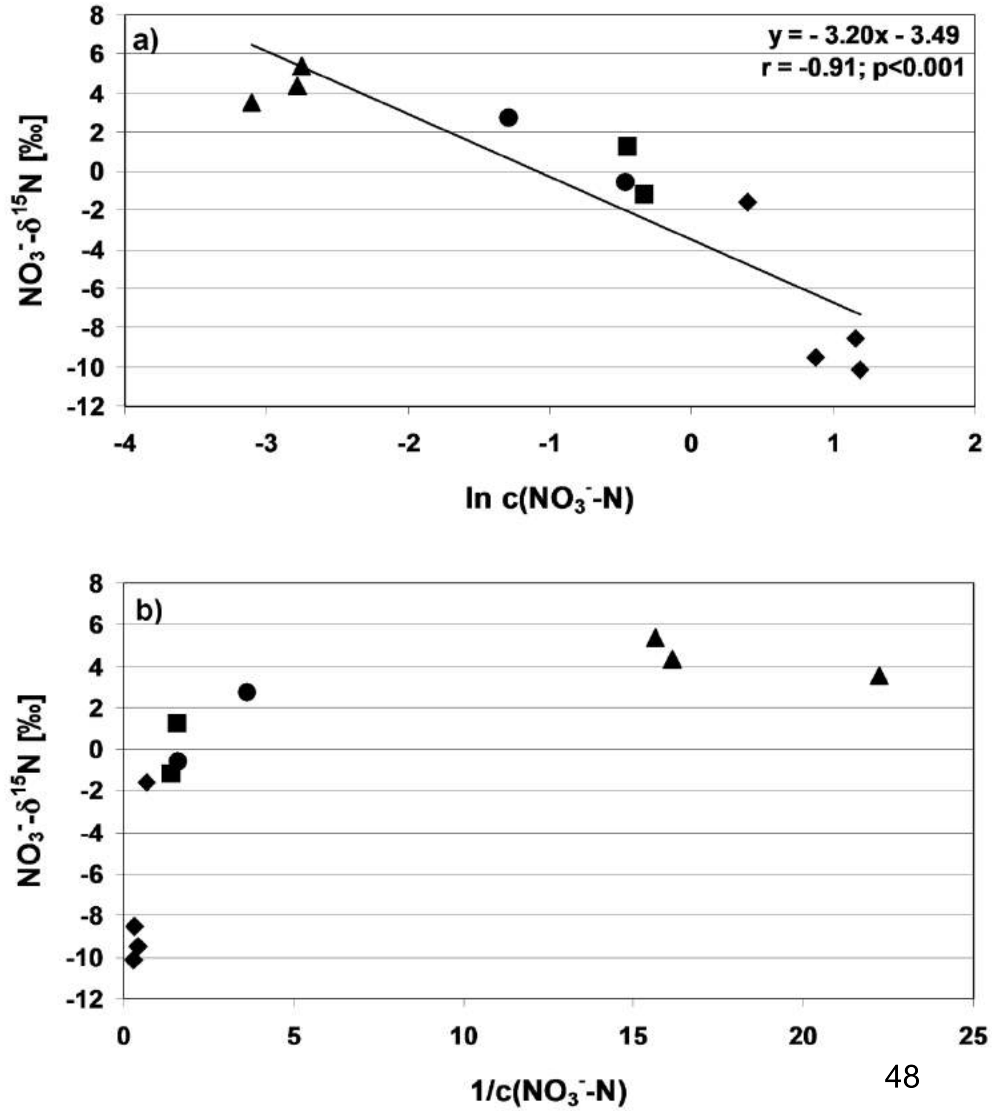
Nitrate-N fluxes in four differently wet seasons.

Schwarz et al. (2011): *Biogeochemistry* **102**, 195-208.

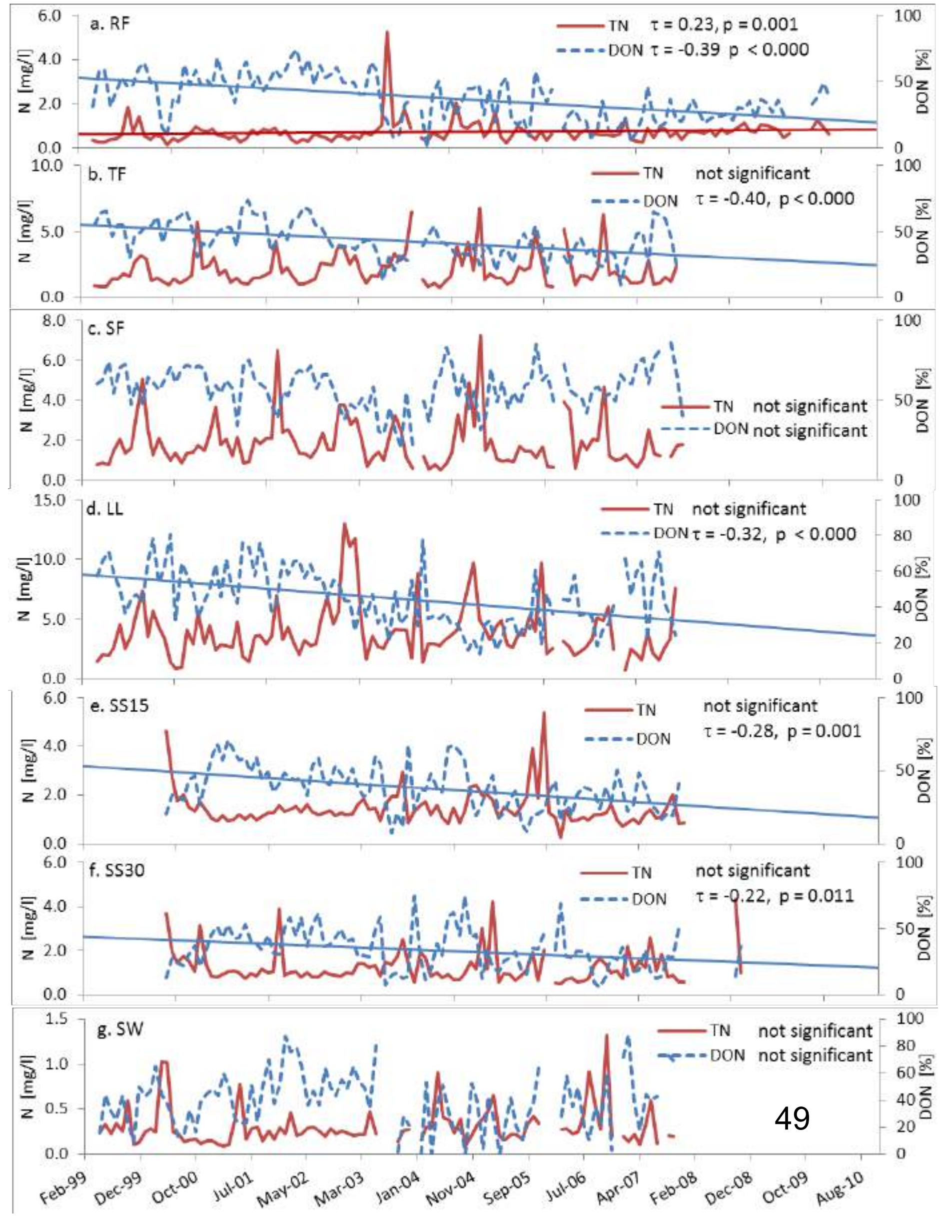


Boxes and whiskers of $\delta^{15}N$ values of NO_3^- in ecosystem solutions (May 1998-April 2001).

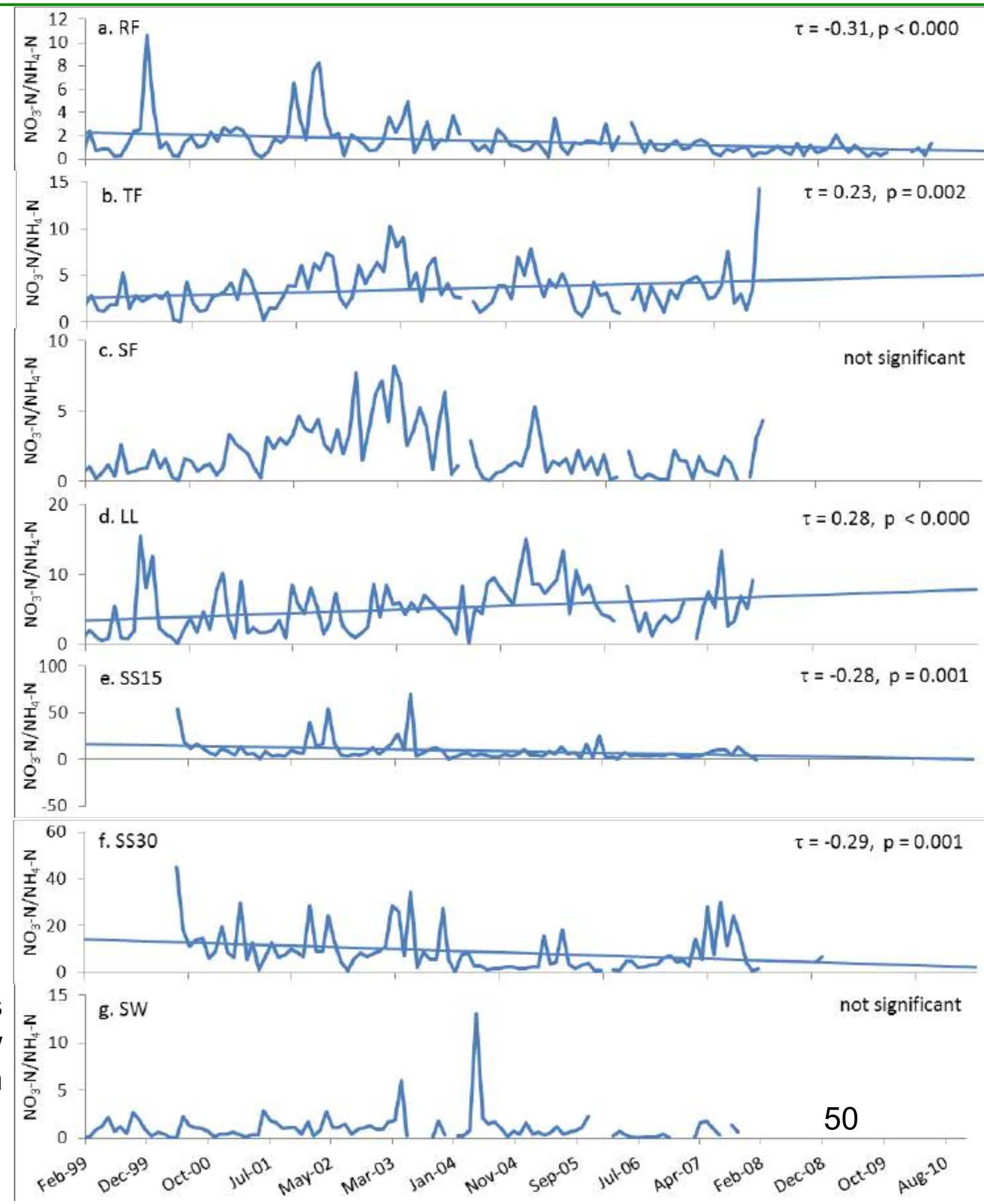
Schwarz et al. (2011): *Biogeochemistry* **102**, 195-208.



Relationship of a) logarithm of NO_3^--N concentration and b) reciprocal NO_3^--N concentration with $\delta^{15}N$ of NO_3^- as an indication of denitri-fication and mixing, respectively, in LL (diamonds), SS15 (rectangles), SS30 (circles) and SW (triangles).



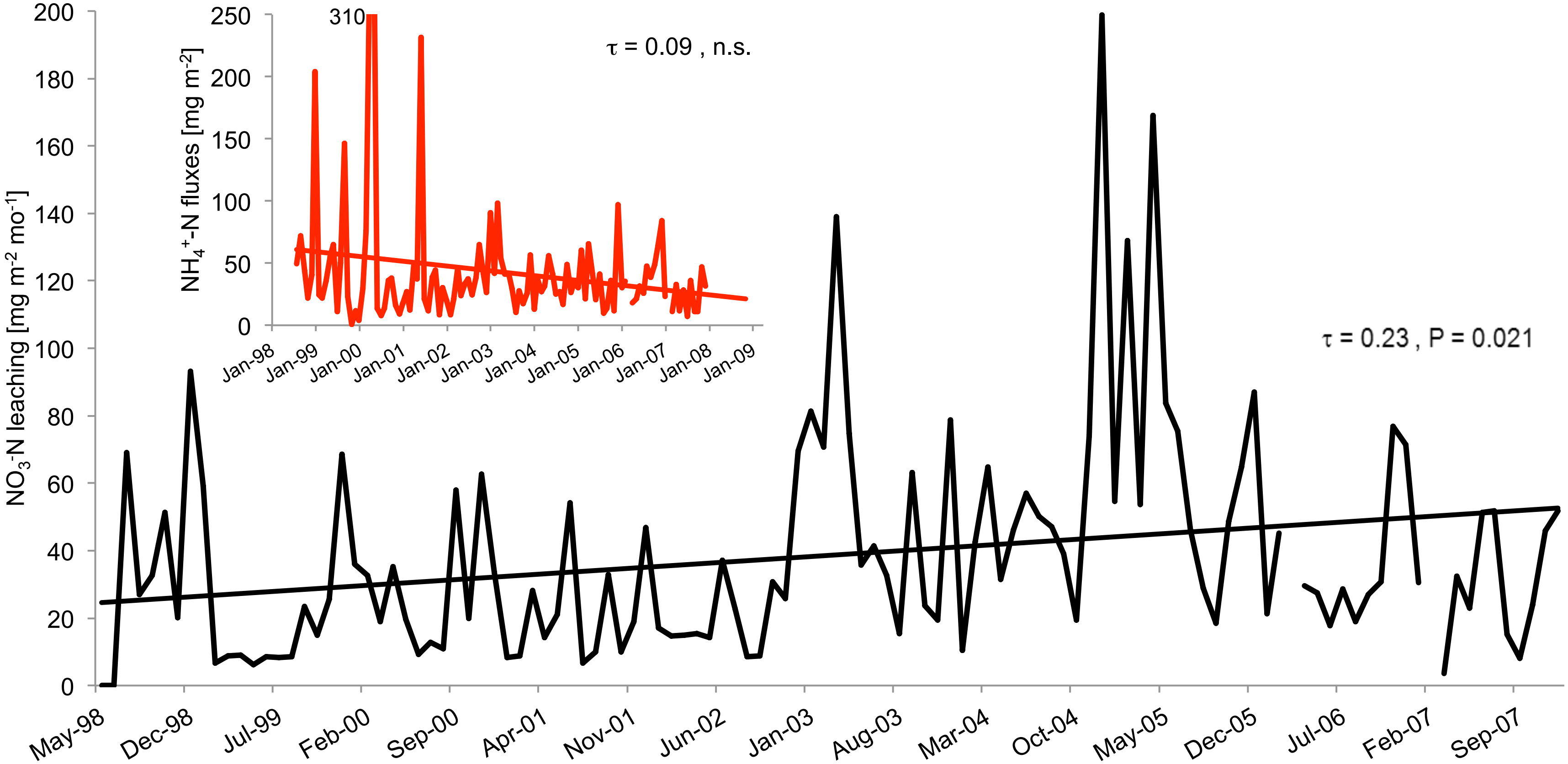
Mean temporal course of total N (TN) concentrations and dissolved organic N (DON) contributions 1999-2010 in **a.** rainfall (RF), **b.** throughfall (TF), **c.** stemflow (SF), **d.** litter leachate (LL), **e.** mineral soil solution at 0.15 m depth (SS15), **f.** mineral soil solution at 0.30 m depth (SS30), and **g.** stream water (SW).



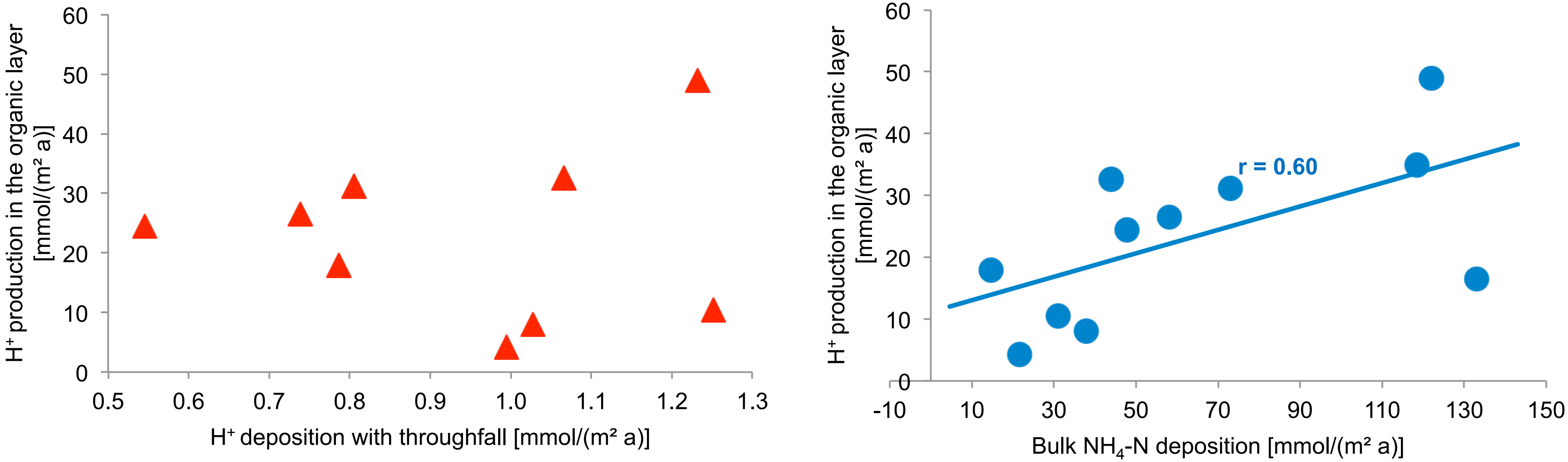
Mean temporal course of NO_3-N/NH_4-N concentration ratios 1999-2010 in **a.** rainfall (RF), **b.** throughfall (TF), **c.** stemflow (SF), **d.** litter leachate (LL), **e.** mineral soil solution at 0.15 m depth (SS15), **f.** mineral soil solution at 0.30 m depth (SS30), and **g.** stream water (SW).

Tropical montane forest under environmental change

Biogeochemical responses

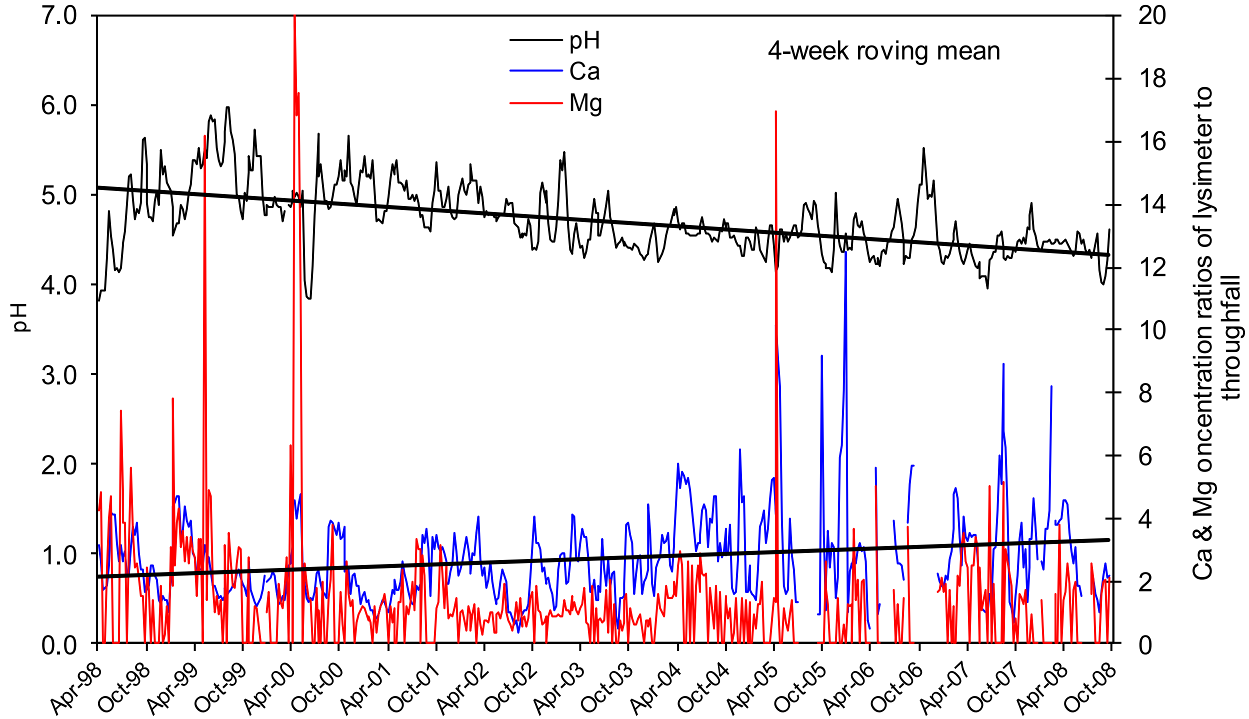


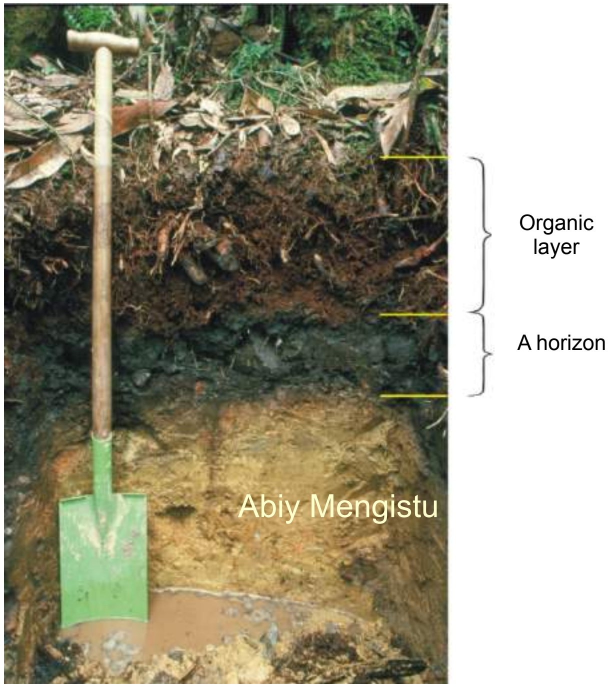
Course of the NO_3-N leaching from the organic layer 1998-2007.



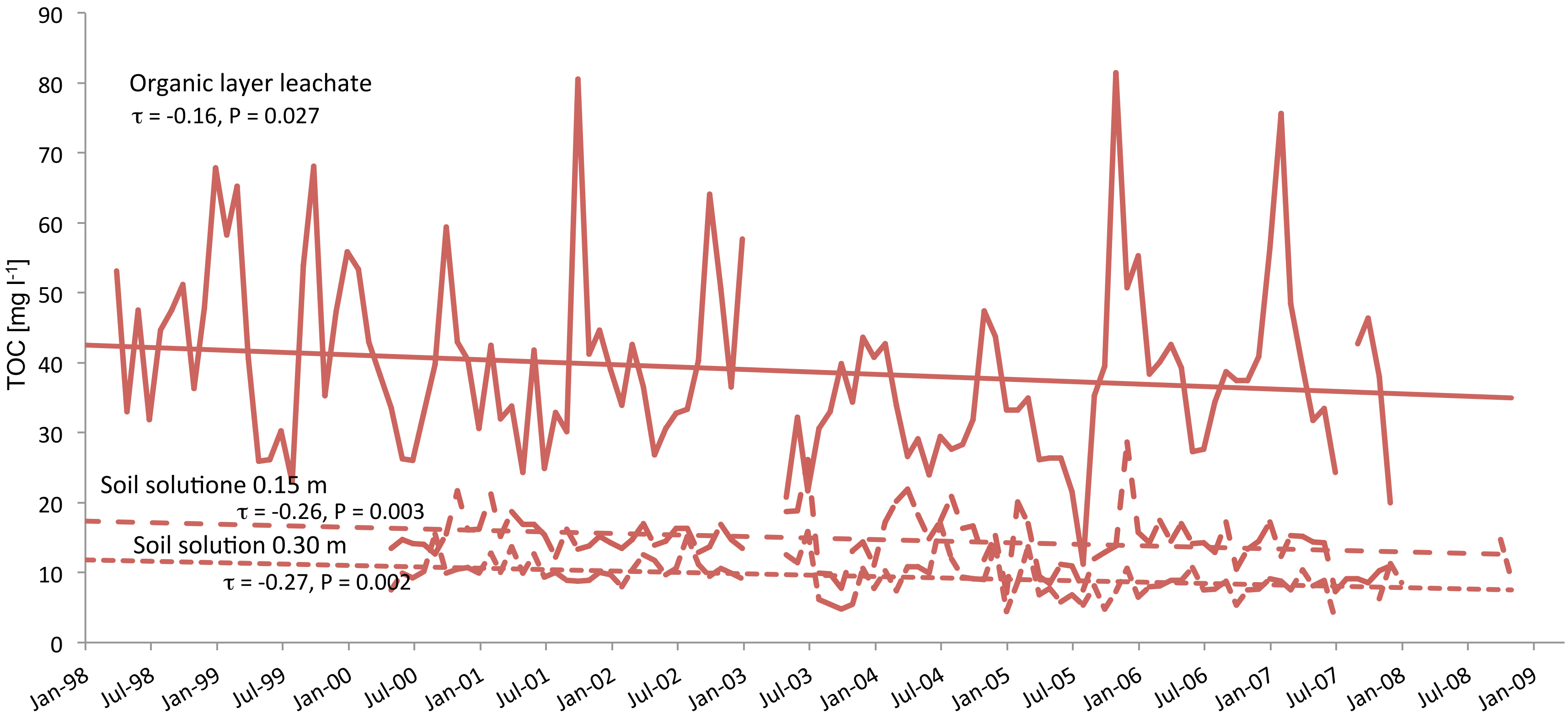
Relationship between H^+ fluxes with throughfall (left) and bulk NH_4-N deposition (right) and H^+ production in the organic layer 1999-2008.

Tropical montane forest under environmental change
Biogeochemical responses

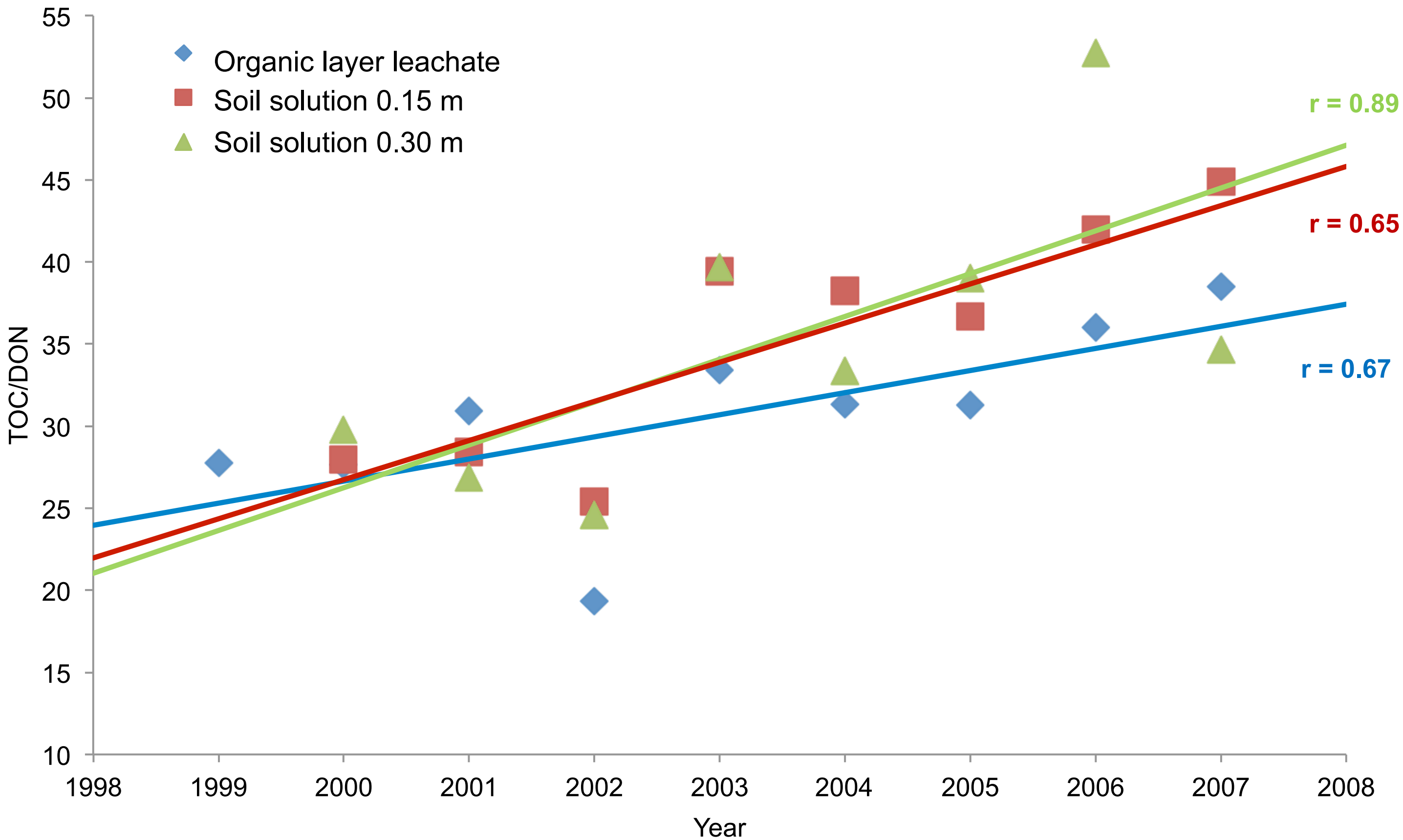




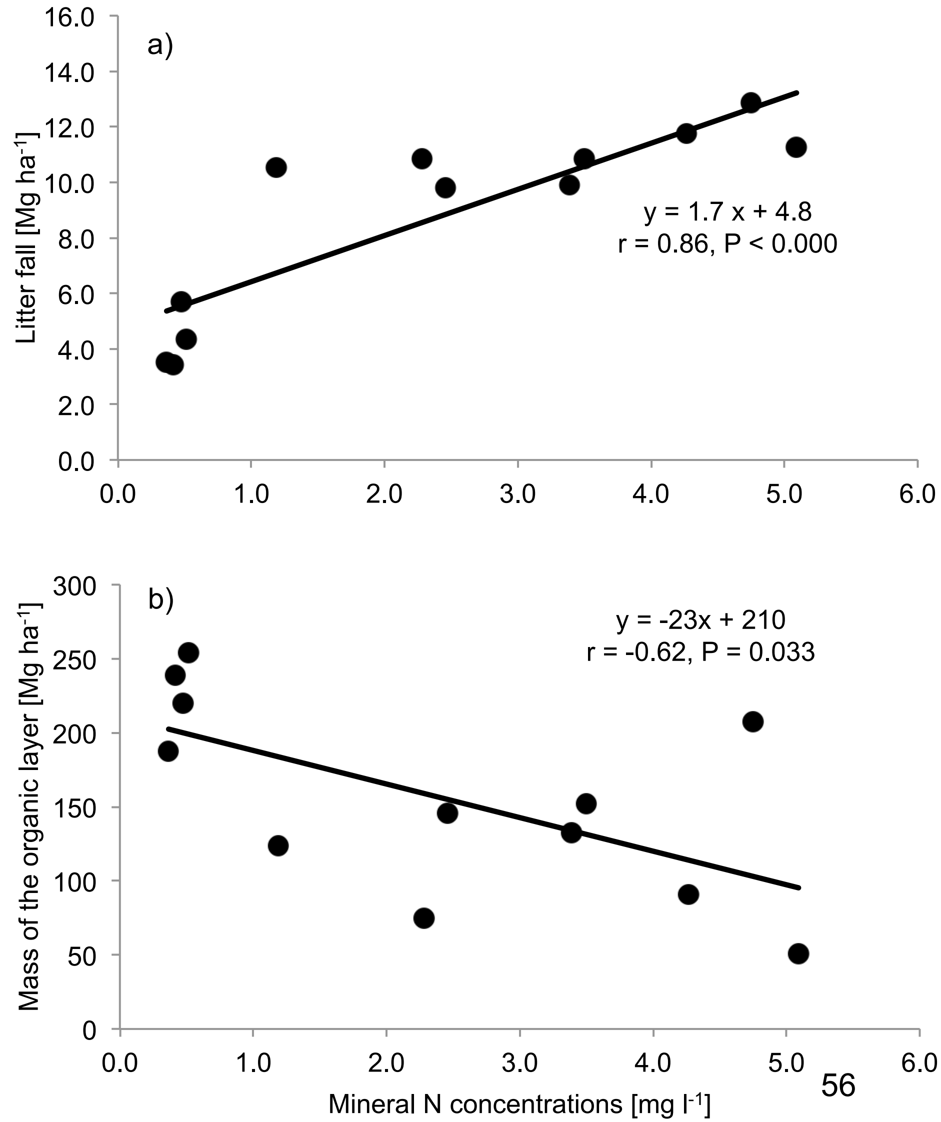
Course of the pH values in litter leachate and concentration ratios of Ca and Mg in litter leachate/throughfall.



Course of the TOC concentrations in soil solution 1999-2008.



Course of the TOC/DON ratios in dissolved organic matter 1999-2008.



Relationship between N_{min} ($NH_4^+ + NO_3^-$) concentrations in organic layer leachate and (a) litterfall and (b) mass of organic layer (12 measurement sites).

The forest responds to N deposition and increasing dryness with

- an inorganic turn of the nitrogen cycle,
- a more open nitrogen cycle with nitrate losses from the organic layer,
- soil acidfication with base metal losses, and
- accelerated turnover of reactive organic matter pools such as the dissolved fraction

Thus even remote tropical montane forests are starting to be pushed out of stable equilibrium!

Acknowledgments

- Doctoral students: Yasin Syafrimen, Katrin Fleischbein, Rainer Goller, Jens Boy, Myra Sequeira, Maren Meyer-Grünefeldt, Hans Wullaert, Agnes Rehmus, Sophia Leimer
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- José Luis Peña Cavinagua, Universidad Nacional de Loja
- Numerous students at all stages of their study programs.
- Earth System Science Research Center – Johannes Gutenberg University Mainz
- Nature and Culture International – Loja, Ecuador
- Ministerio del Ambiente, Republic of Ecuador
- Deutsche Forschungsgemeinschaft (FOR 402 und 816)