The origin of stream flow in small Amazon forest and pasture watersheds: an end-member mixing analysis approach

Joaquín Chaves[1], Christopher Neill[1], Helmut Elsenbeer[2], Alex Krusche[3], Sonja Germer[2], and Sérgio Gouveia Neto[3]

[1]The Ecosystems Center, Marine Biological Laboratory, Woods Hole, MA 02543

[2] Universität Potsdam, Institut für Geoökologie, Potsdam, Germany

[3]Laboratório de Ecologia Isotópica, CENA –USP, Piracicaba, SP, Brasil

MBL Biological Discovery in Woods Hole

Founded in 1888 as the Marine Biological Laboratory

Universität Potsdam

cena

USP Universidade de São Paulo
Brasil

Flowpaths:

Precipitation falling in watersheds may take a number of pathways to streams

MBL | Biological Discovery in Woods Hole

Founded in 1888 as the Marine Biological Laboratory

Flowpaths:

Precipitation falling in watersheds may take a number of pathways to streams

- Fast
  - ◎ *Overland flow*
  - ◎ *Shallow subsurface flow*

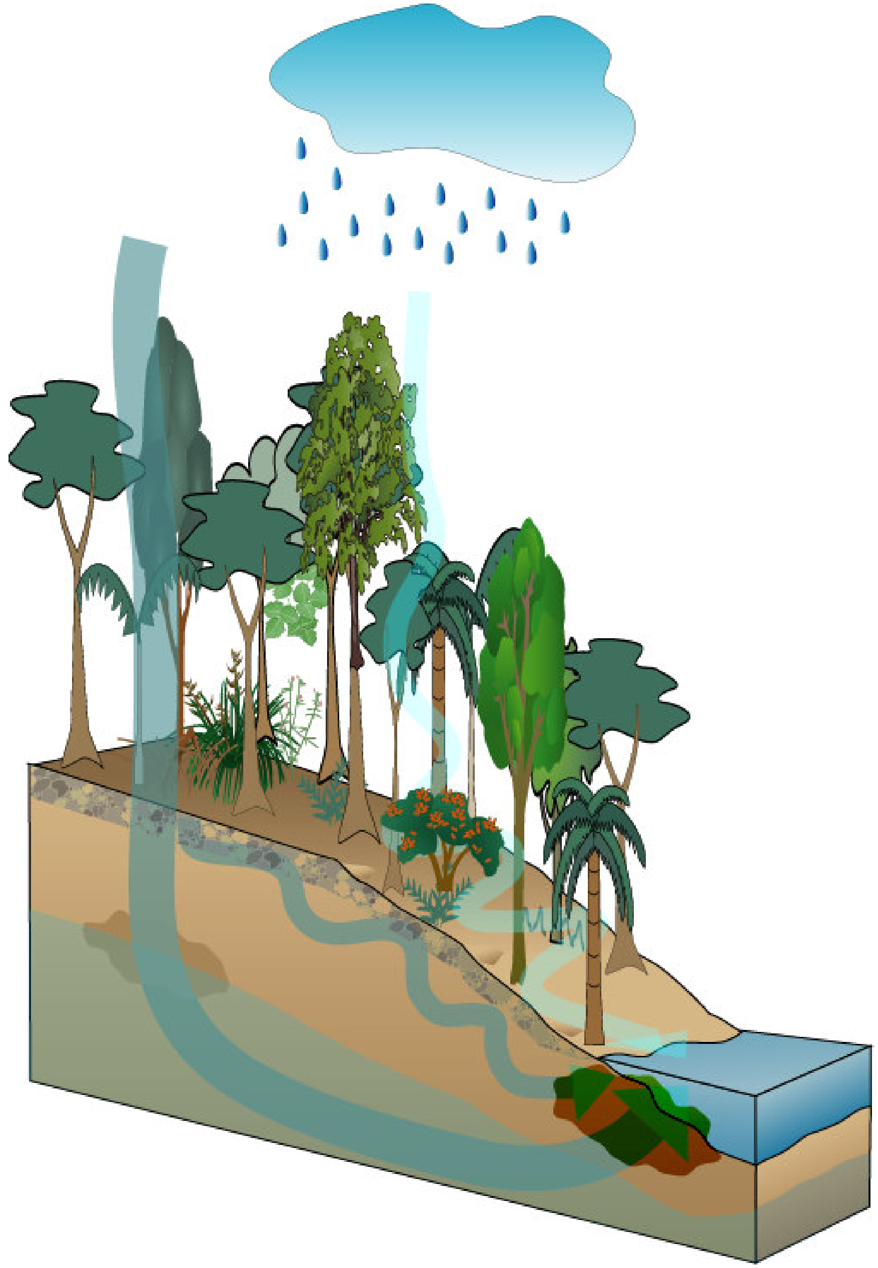
Flowpaths:

Precipitation falling in watersheds may take a number of pathways to streams

- Fast
  - *Overland flow*
  - *Shallow subsurface flow*
- Slow
  - *Groundwater*
  - *Soil water*

Flowpaths:

The conditions encountered by water along flowpaths control biogeochemical transformations that determine stream water chemistry



Flowpaths:

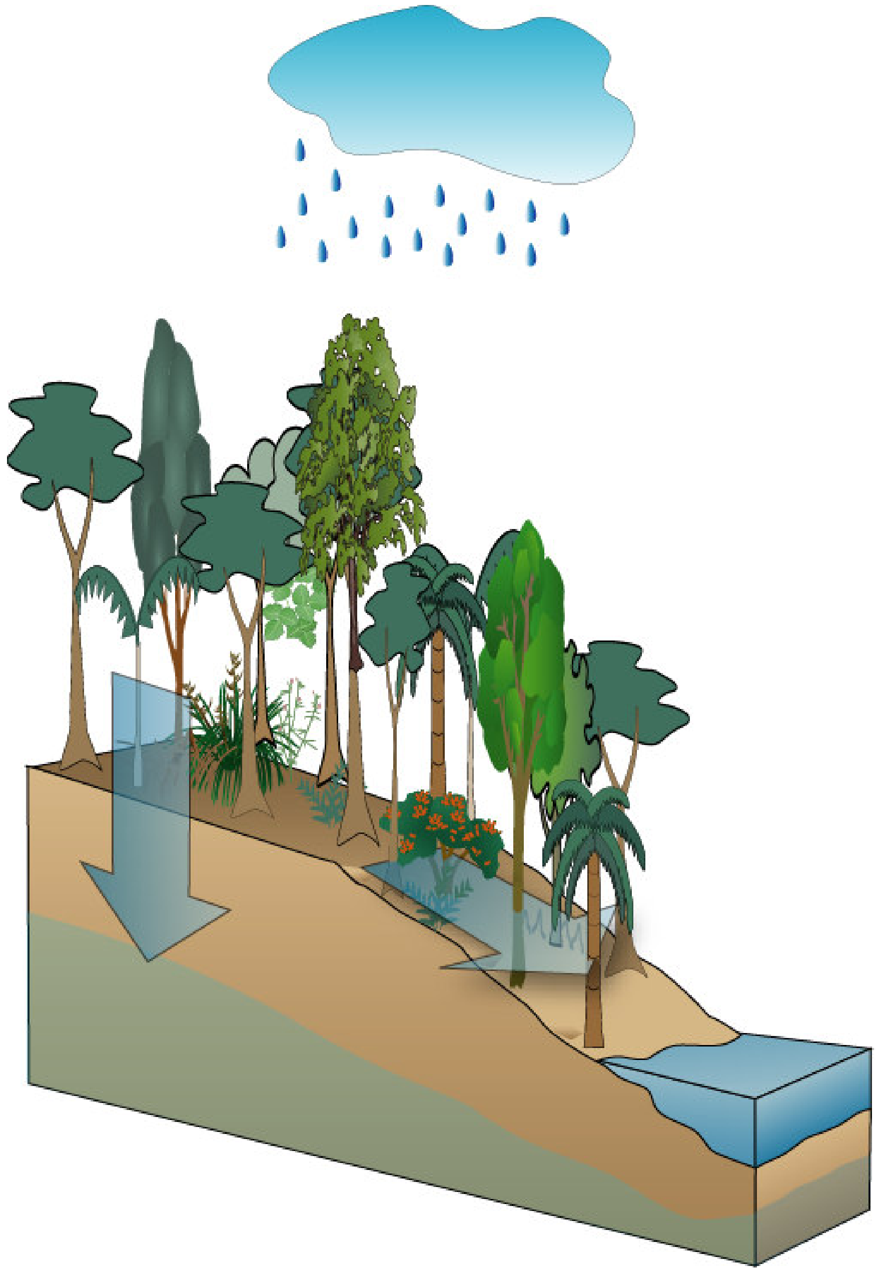
Early thinking:

- High surface infiltrability in undisturbed tropical soils led to predominantly vertical flowpaths
- Precluding fast lateral flows such as overland flow except on steep hillslopes

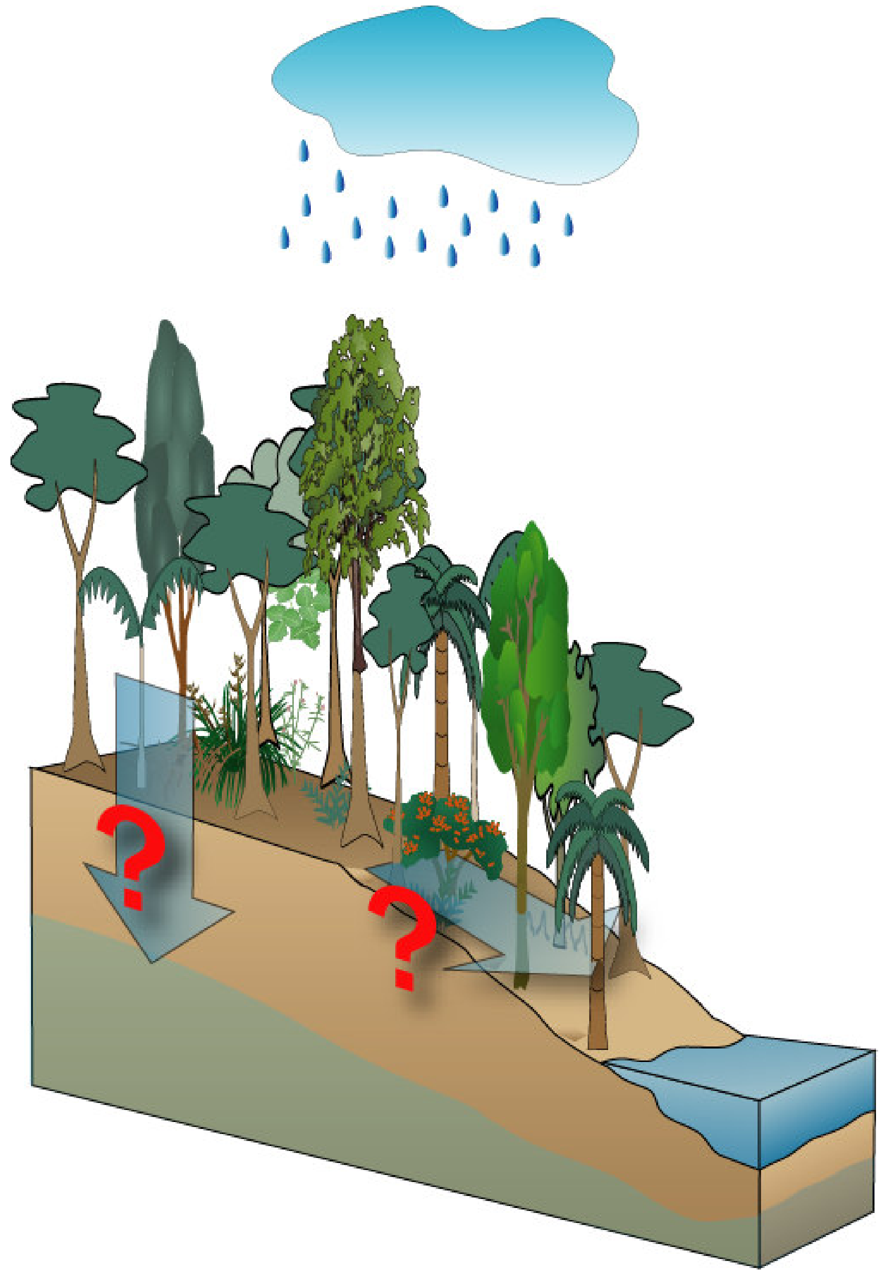
Flowpaths:

Recent work :

Rainfall intensities can exceed soil infiltration capacities, leading to lateral flows



Flowpaths:



Question :

What is the importance of vertical vs. horizontal flowpaths to stream flow in lowland Amazon forest?

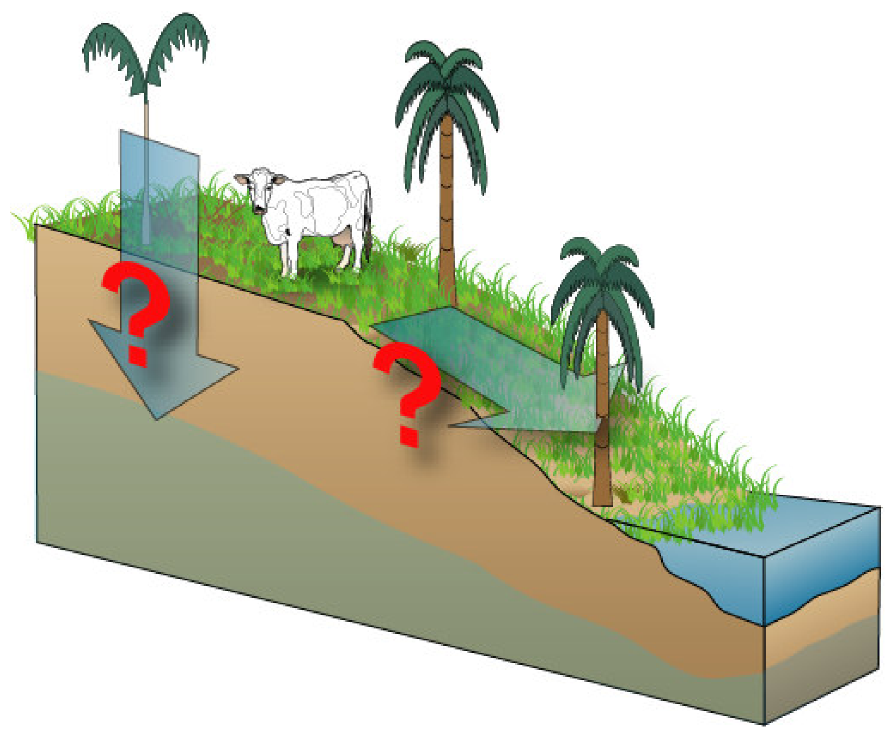
MBL Biological Discovery in Woods Hole

Founded in 1888 as the Marine Biological Laboratory

Flowpaths:

Question :

How does the contribution of these flowpaths change as forest is converted to pasture?



End-Member Mixing Analysis (EMMA)

Journal of Hydrology, 116 (1990) 321–343
Elsevier Science Publishers B.V., Amsterdam — Printed in The Netherlands

[3]

MODELLING STREAMWATER CHEMISTRY AS A MIXTURE OF SOILWATER END-MEMBERS — AN APPLICATION TO THE PANOLA MOUNTAIN CATCHMENT, GEORGIA, U.S.A.

RICHARD P. HOOPER , NILS CHRISTOPHERSEN[2] and NORMAN E. PETERS
[1]*U.S. Geological Survey, Water Resources Division, Doraville, GA 30360 (U.S.A.)*
[2]*Center for Industrial Research, Environmental Chemistry Division, Oslo (Norway)*

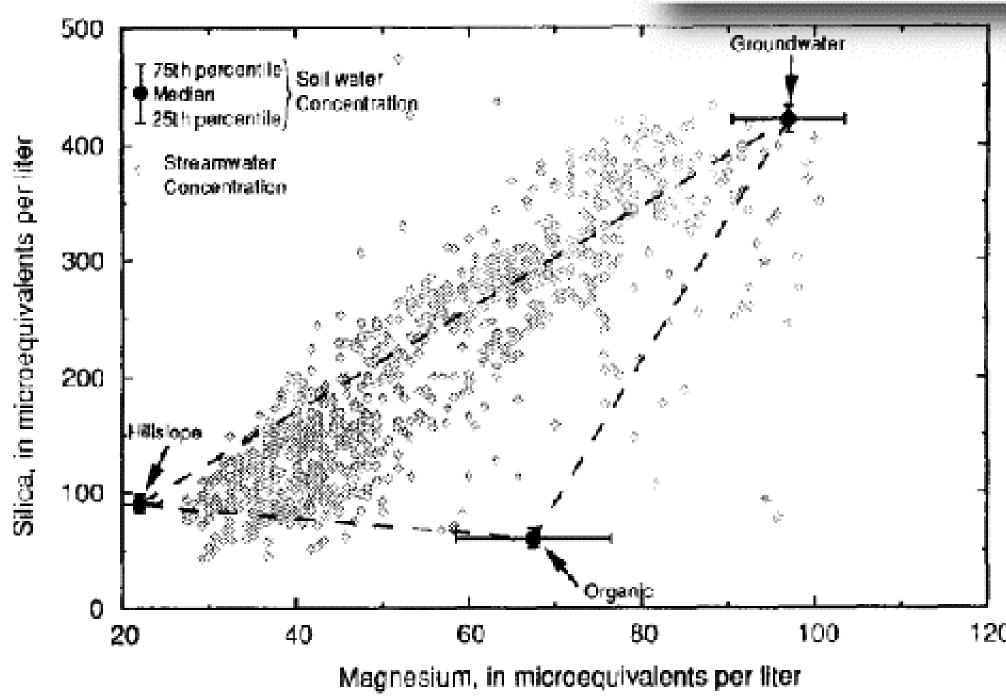


Fig. 3. Dissolved silica and magnesium EMMA plot.

WATER RESOURCES RESEARCH, VOL. 42, W08434, doi:10.1029/2005WR004419, 2006

Investigating the applicability of end-member mixing analysis (EMMA) across scale: A study of eight small, nested catchments in a temperate forested watershed

April L. James[1,2] and Nigel T. Roulet[1,3]

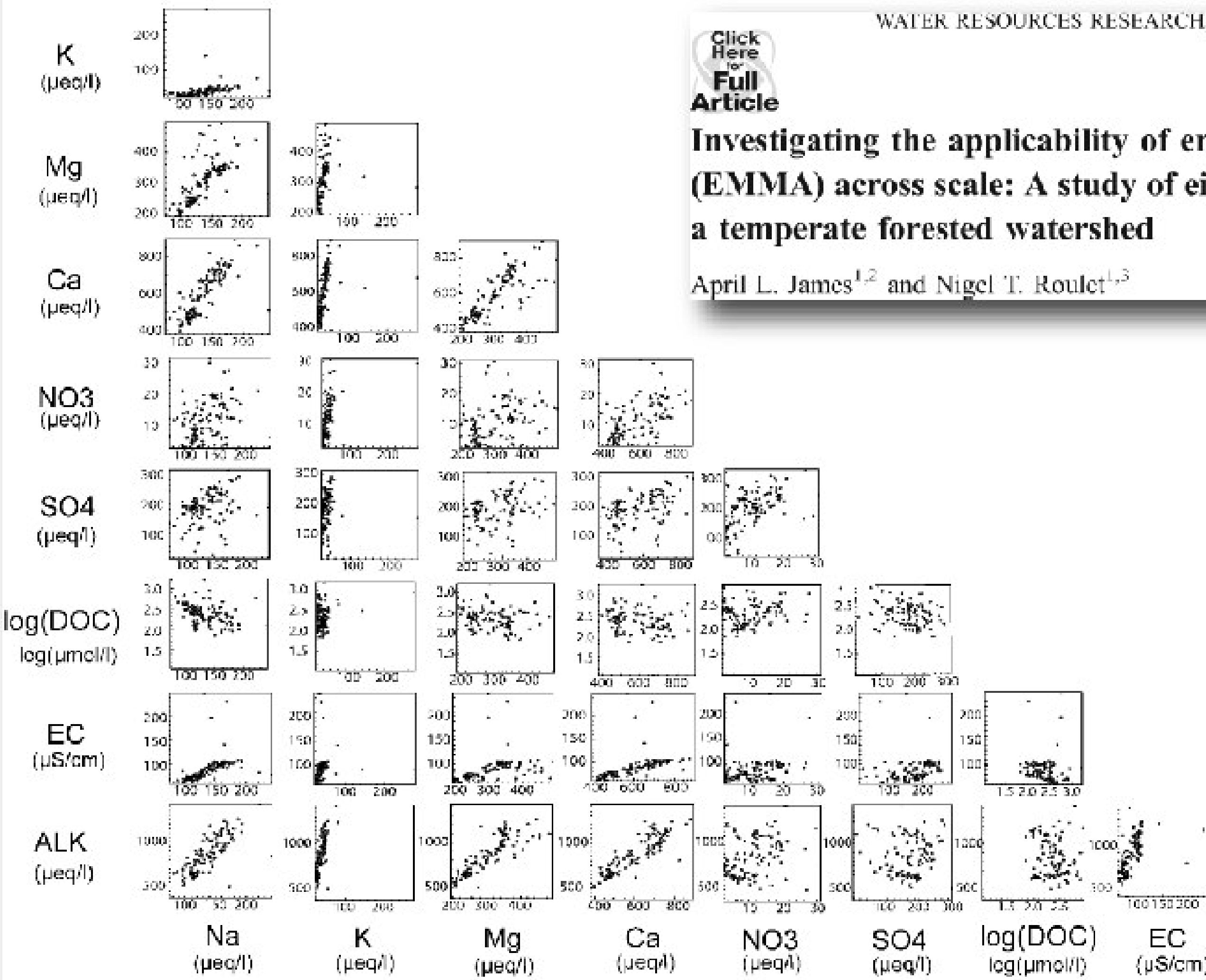


Figure 4. Bivariate solute plots of Lk catchment (147 ha) stream water chemistry, located at the outflow of the Westcreek watershed (n = 123). Ions and ALK are in units of µeq/L; DOC is in units of log (µmol/L); EC is in units of µS/cm.

WATER RESOURCES RESEARCH, VOL. 42, W08434, doi:10.1029/2005WR004419, 2006

Click Here for Full Article

Investigating the applicability of end-member mixing analysis (EMMA) across scale: A study of eight small, nested catchments in a temperate forested watershed

April L. James[1,2] and Nigel T. Roulet[1,3]

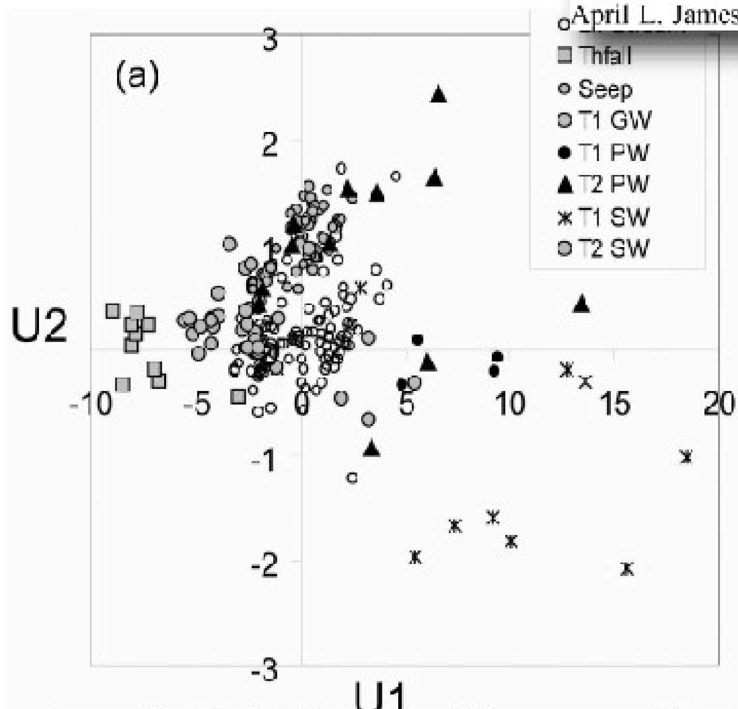


Figure 10. Lk (147 ha) 2-D mixing space or Uspace: (a) Lk stream water chemistry only and (b) stream water chemistry from all catchments. Projected values of end-members represent average observed values from individual instruments (e.g., wells, piezometers, lysimeters). These data are also used in the calculation of the median value of each end-member represented in Table 5.

End-Member Mixing Analysis (EMMA)

❖ Principal Component Analysis (PCA)

"*The main purpose of PCA is to find a lower-dimensional space, U, where most of the observations can be assumed to lie within a specified accuracy*" Christophersen & Hooper, 1992

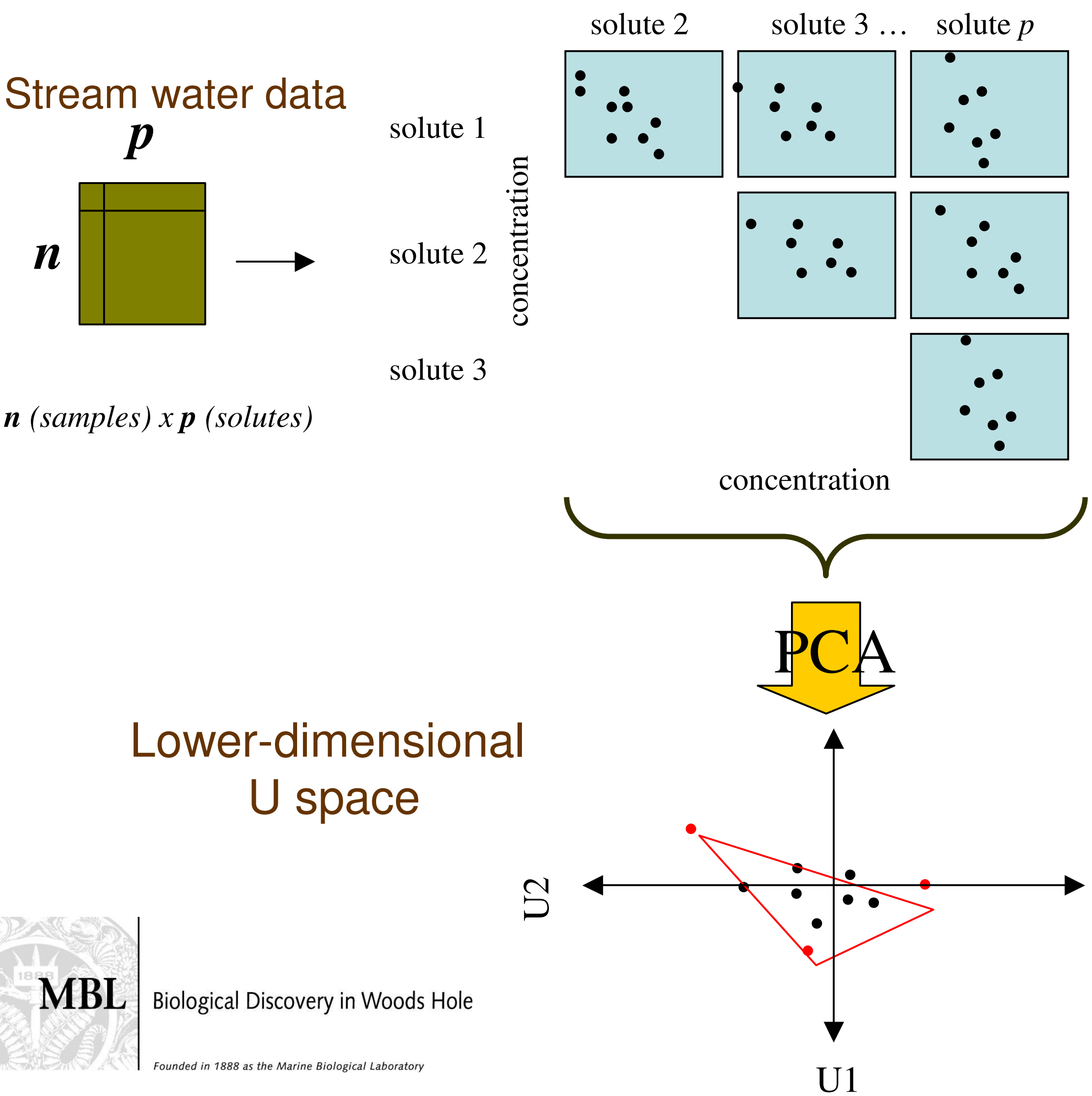
References:

Christophersen, N & Hooper RP **Multivariate Analysis of Stream Water Chemical Data: The Use of Principal Components Analysis for the End-Member Mixing Problem**. WATER RESOURCES RESEARCH, VOL. 28, NO. 1, PAGES 99–107, 1992

Hooper RP **Diagnostic tools for mixing models of stream water chemistry.** Water Resources Research, Volume 39, Issue 3, pp. HWC 2-1, 2003

End-Member Mixing Analysis (EMMA)

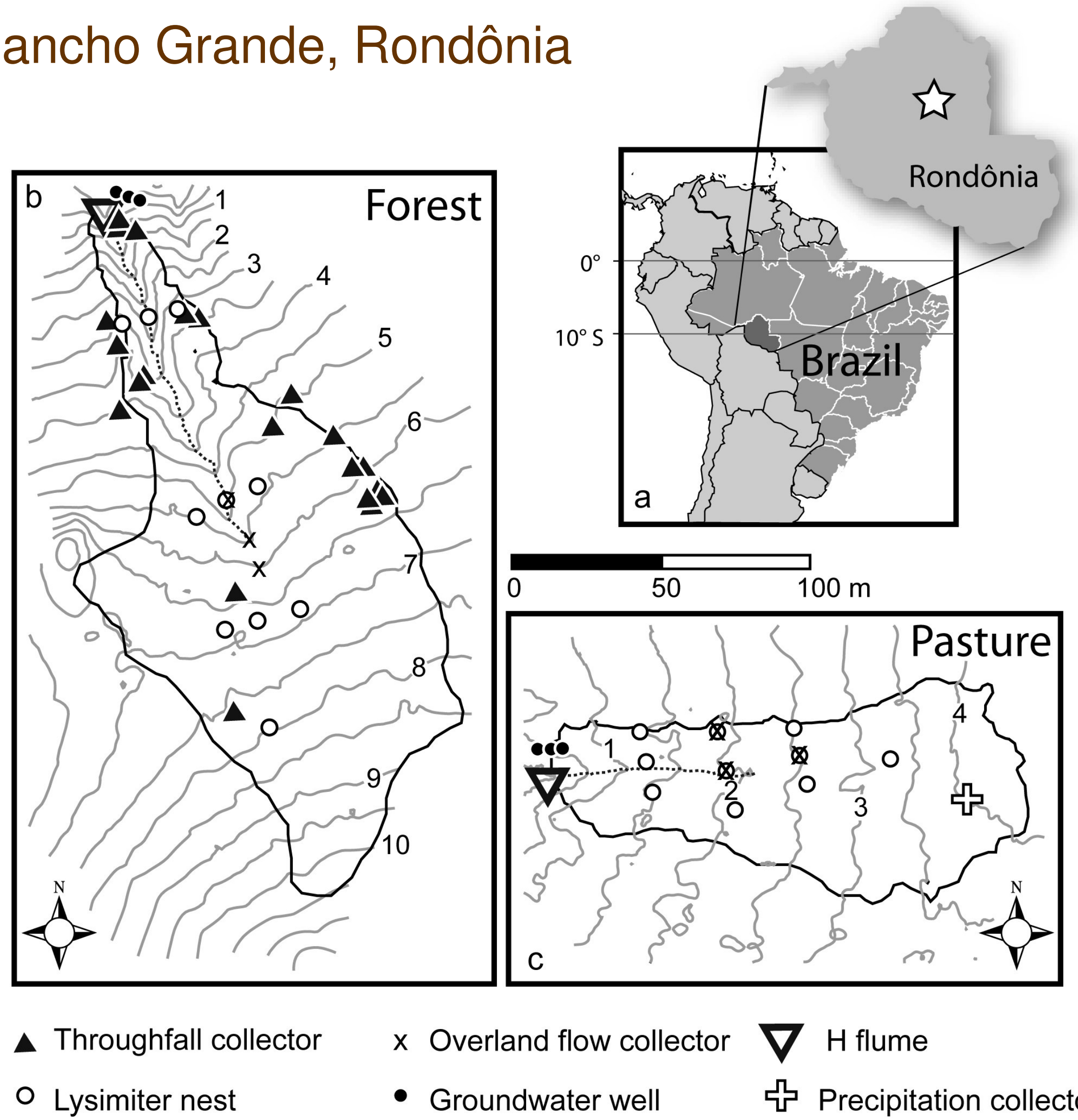
❖ Principal Component Analysis (PCA)…*in a nutshell*



$$\begin{pmatrix} 1 & 1 & 1 \\ -1.96 & 7.37 & 1.36 \\ -1.15 & 2.76 & -0.88 \end{pmatrix} \begin{pmatrix} x \\ y \\ z \end{pmatrix} = \begin{pmatrix} 1 \\ -2.8 \\ 2.6 \end{pmatrix}$$

Study site:

Fazenda Rancho Grande, Rondônia



MBL Biological Discovery in Woods Hole

Founded in 1888 as the Marine Biological Laboratory

Surface

12.5 cm

20 cm

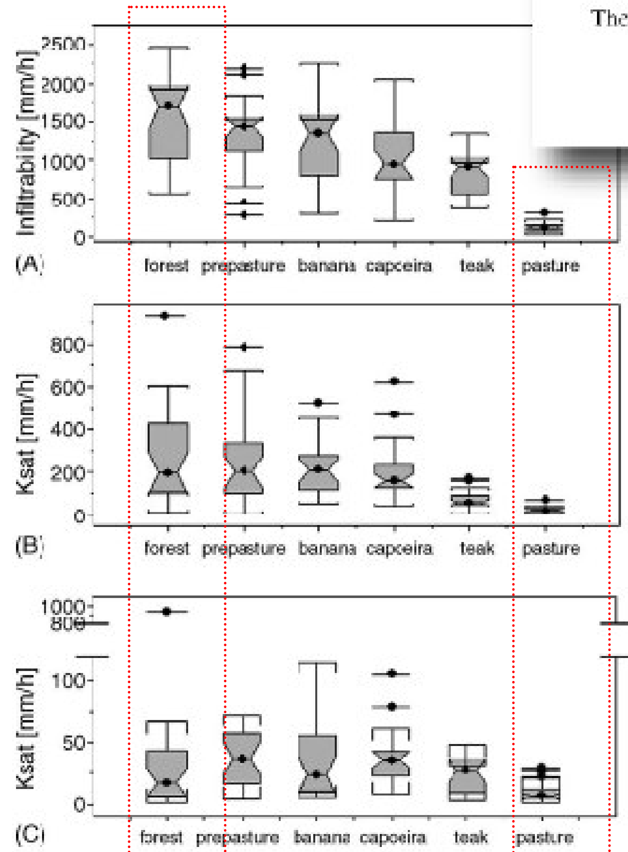


Fig. 3. Infiltrability and Ksat as a function of land use (at surface, at a depth of 12.5 and 20 cm: panels A–C, respectively). The crossbar within the box shows the median, the length of the box reflects the interquartile range, the fences are marked by the extremes if there are no outliers, or else by the largest and smallest observation that does not qualify for an outlier. Outliers are defined as data points more than 1.5 times the interquartile range away from the upper or lower quartile. The notches represent the 95% confidence interval for the median, and overlapping notches from two box plots indicate that there is no significant difference between the medians.

Available online at www.sciencedirect.com

Forest Ecology and Management 222 (2006) 29–38

Forest Ecology and Management

www.elsevier.com/locate/foreco

The influence of land-use changes on soil hydraulic properties: Implications for runoff generation

Beate Zimmermann [a,*], Helmut Elsenbeer [a], Jorge M. De Moraes [b]

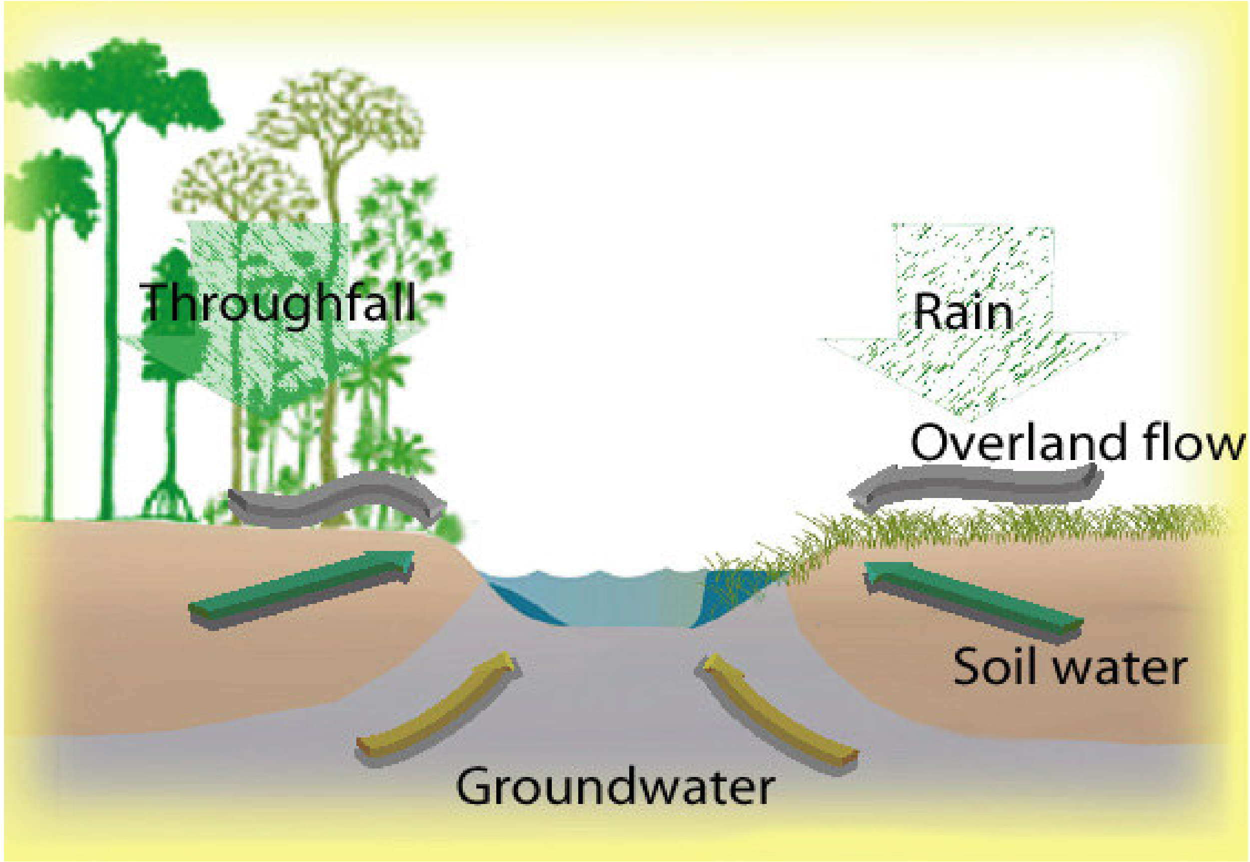
Study site:

Fazenda Rancho Grande, Rondônia

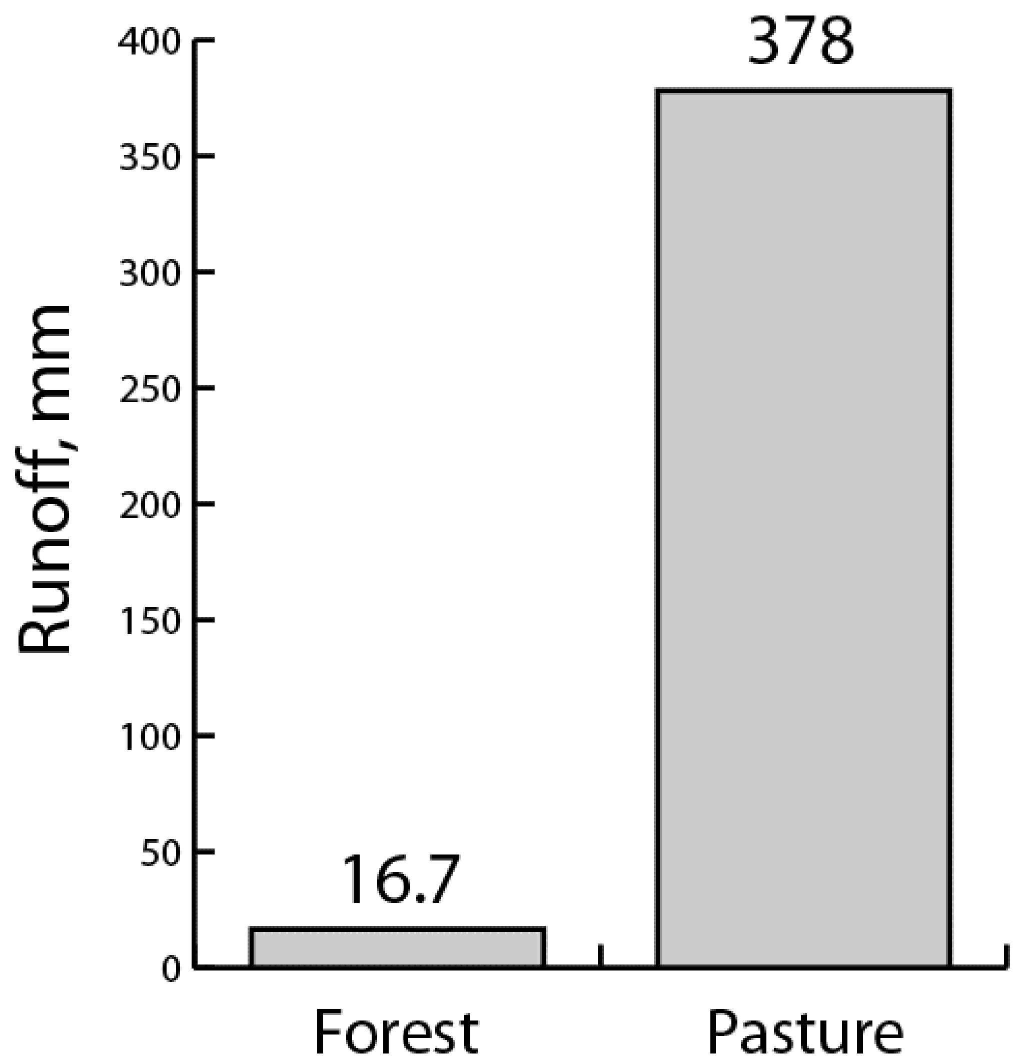
Photos: C.Neill

Study site:

Fazenda Rancho Grande, Rondônia

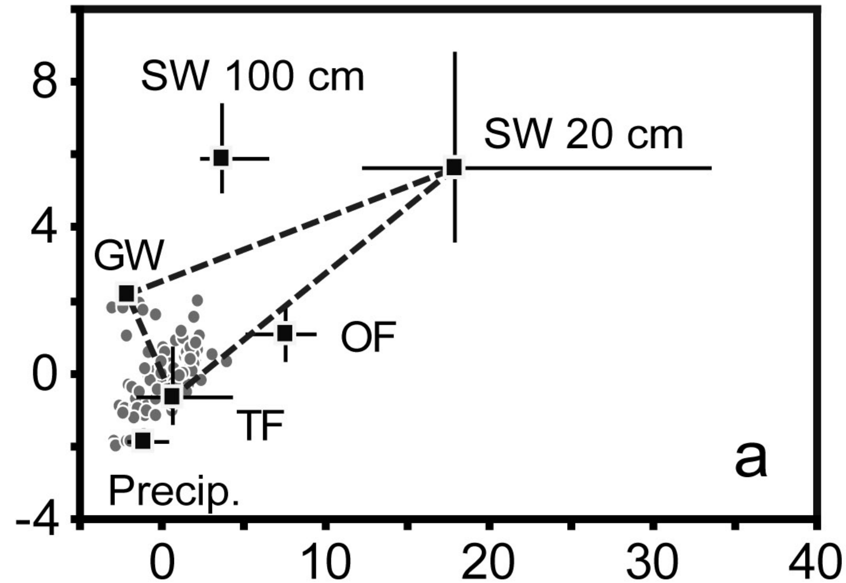


Water yields



Mixing Diagrams:

Forest



U2

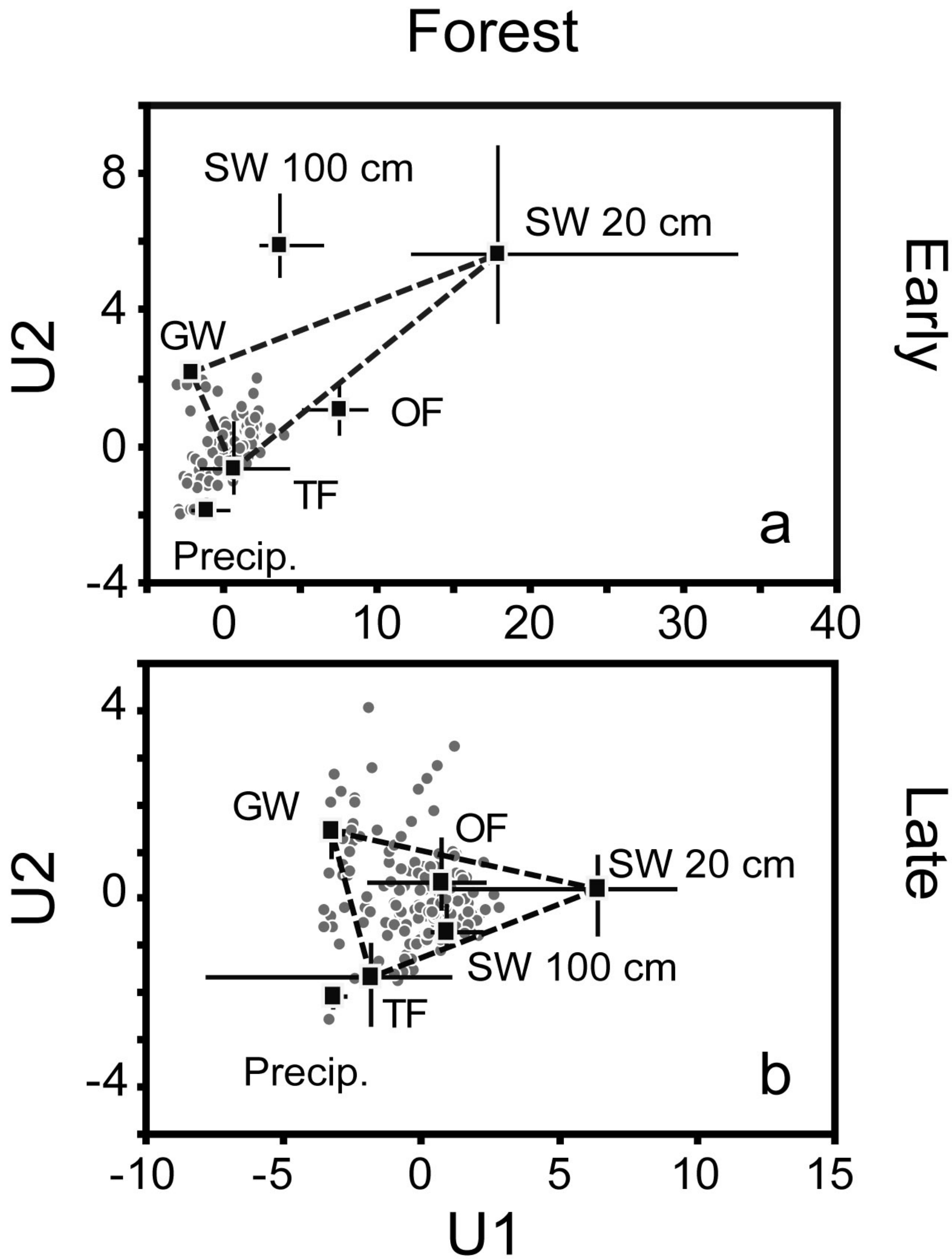
Early

U2

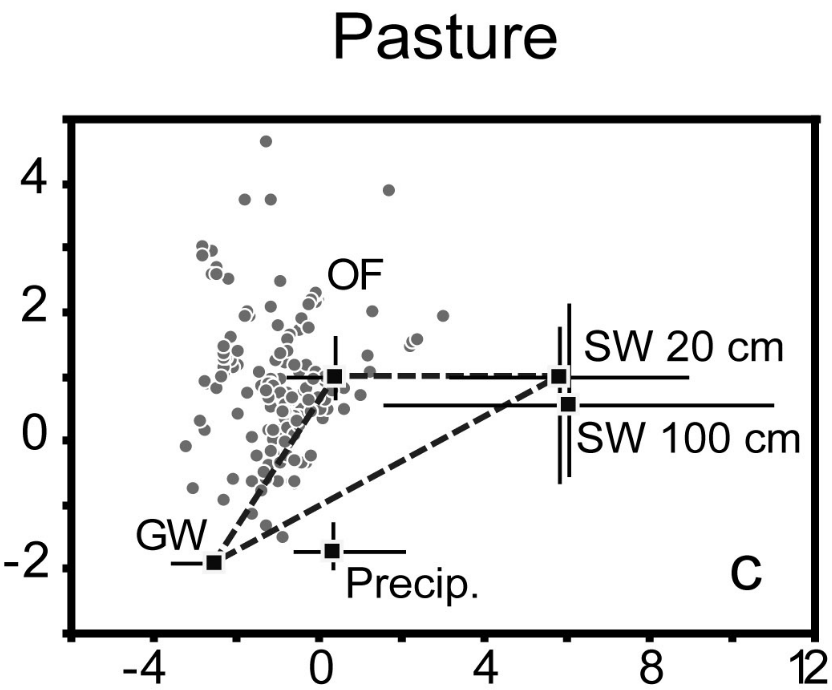
Late

U1

Mixing Diagrams:



Mixing Diagrams:



U2

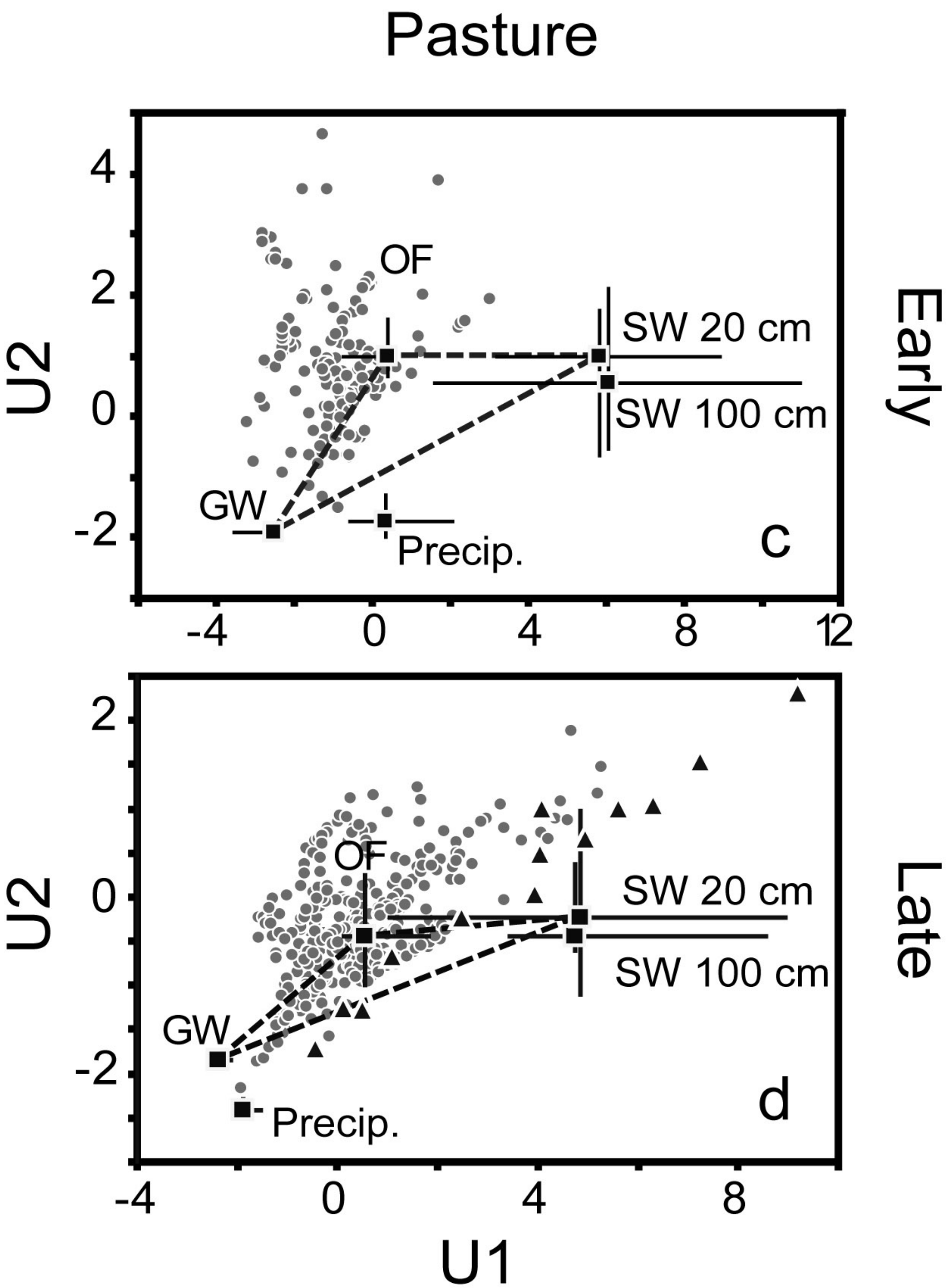
Early

U2

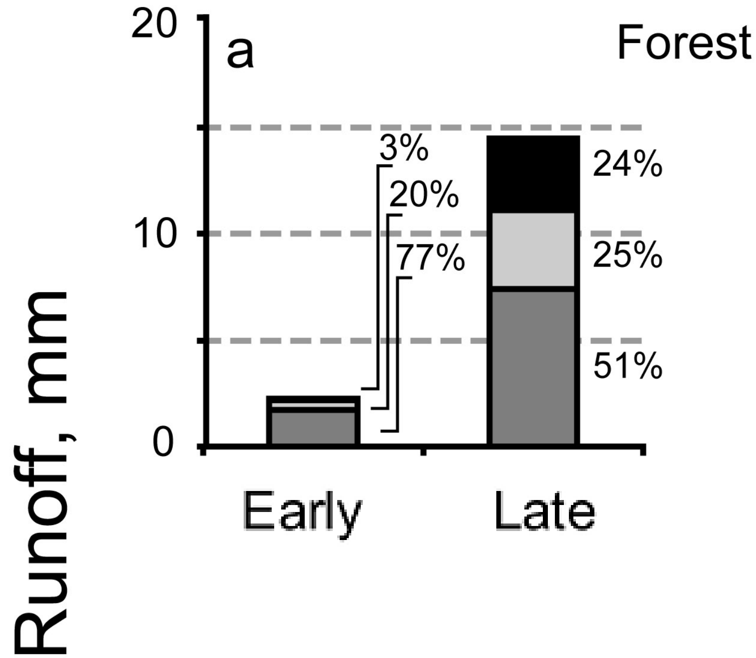
Late

U1

Mixing Diagrams:

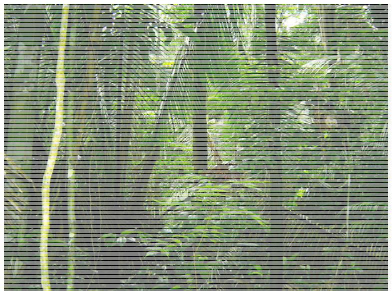


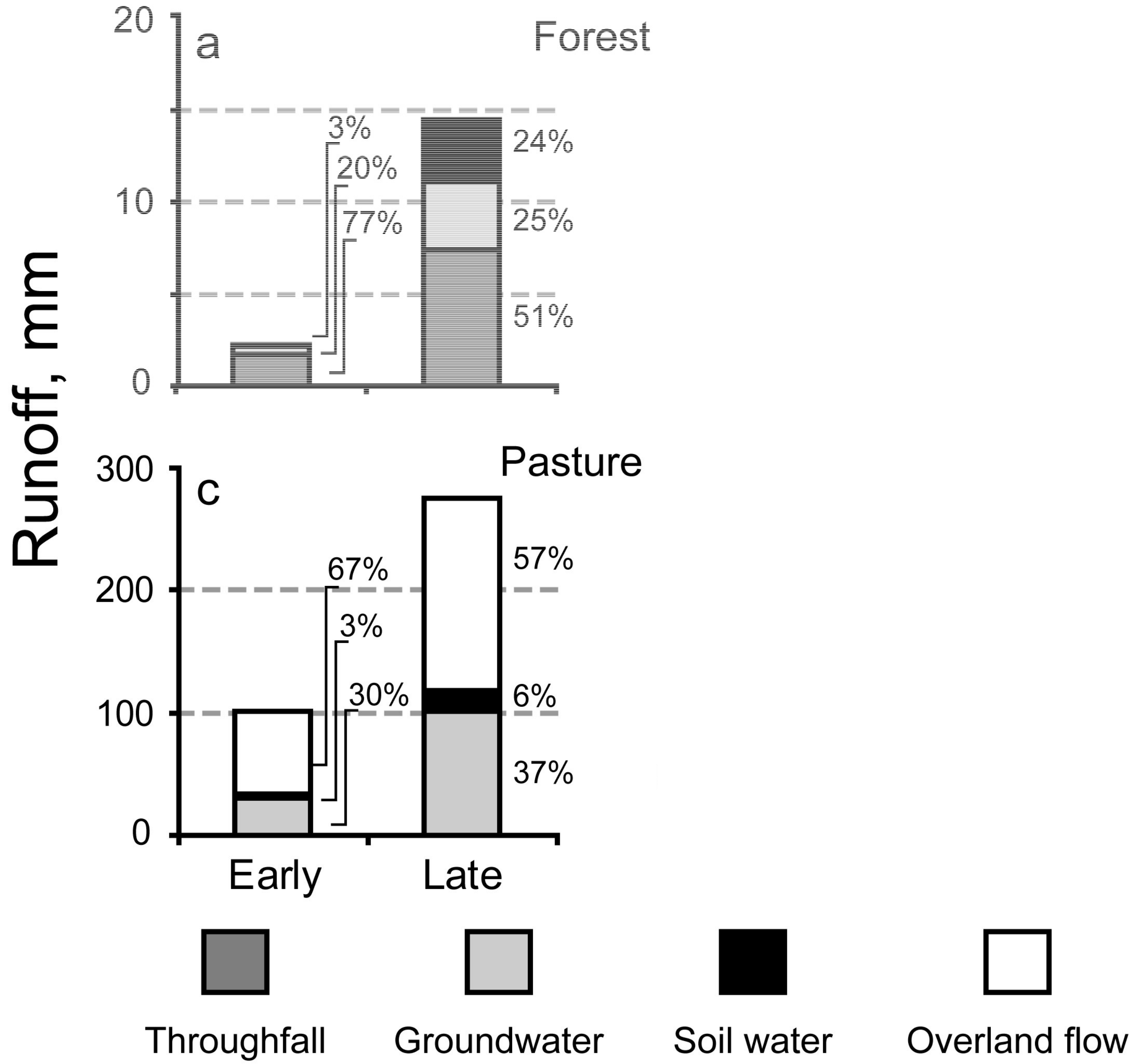
Overall Results:



Throughfall Groundwater Soil water Overland flow

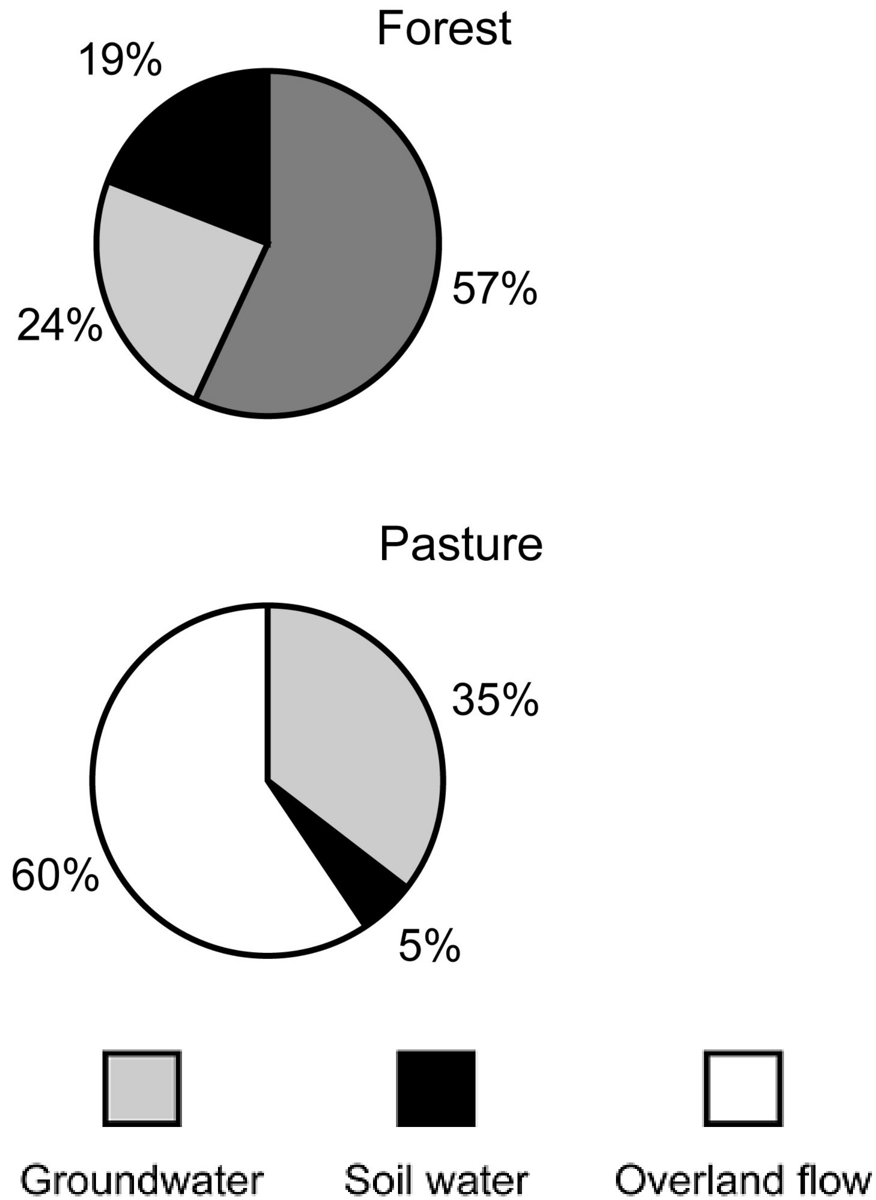
Overall Results:





Overall Results:

Entire rainy season



Conclusions:

- Surface flow increased dramatically after the establishment of pasture.
- Sources to storm flow to small streams changed considerably following deforestation
- Transition to pasture caused a shift towards predominantly faster flowpaths
- Flowpath hydrology in pasture is “simpler” than in forest

We are we going with this:

- Use these results to tests our knowledge and observations about the biogeochemistry of these landscapes.
- Test EMMA at larger scales (1^{st}, 2^{nd} order catchments).
- Apply these approach in areas of the Amazon where mechanized, large scale agriculture is growing rapidly.

Acknowledgements

We thank Alexandra A. Montebelo and Gustavo G. Baldi at the Centro de Energia Nuclear na Agricultura in Piracicaba for conducting the chemical analyses. Shelby Hayhoe, Sonya Remington, Mathew Shamey, TobiasVetter, and LisaWerther helped during the field work phase of this study. Support for this study was provided by the US National Science Foundation grant DEB-0315656 and by grants from Brazilian agencies FAPESP # 03/13172-2 and CNPq # 420199/2005-5. Special thanks to the Schmitz family for allowing us to work on their land.

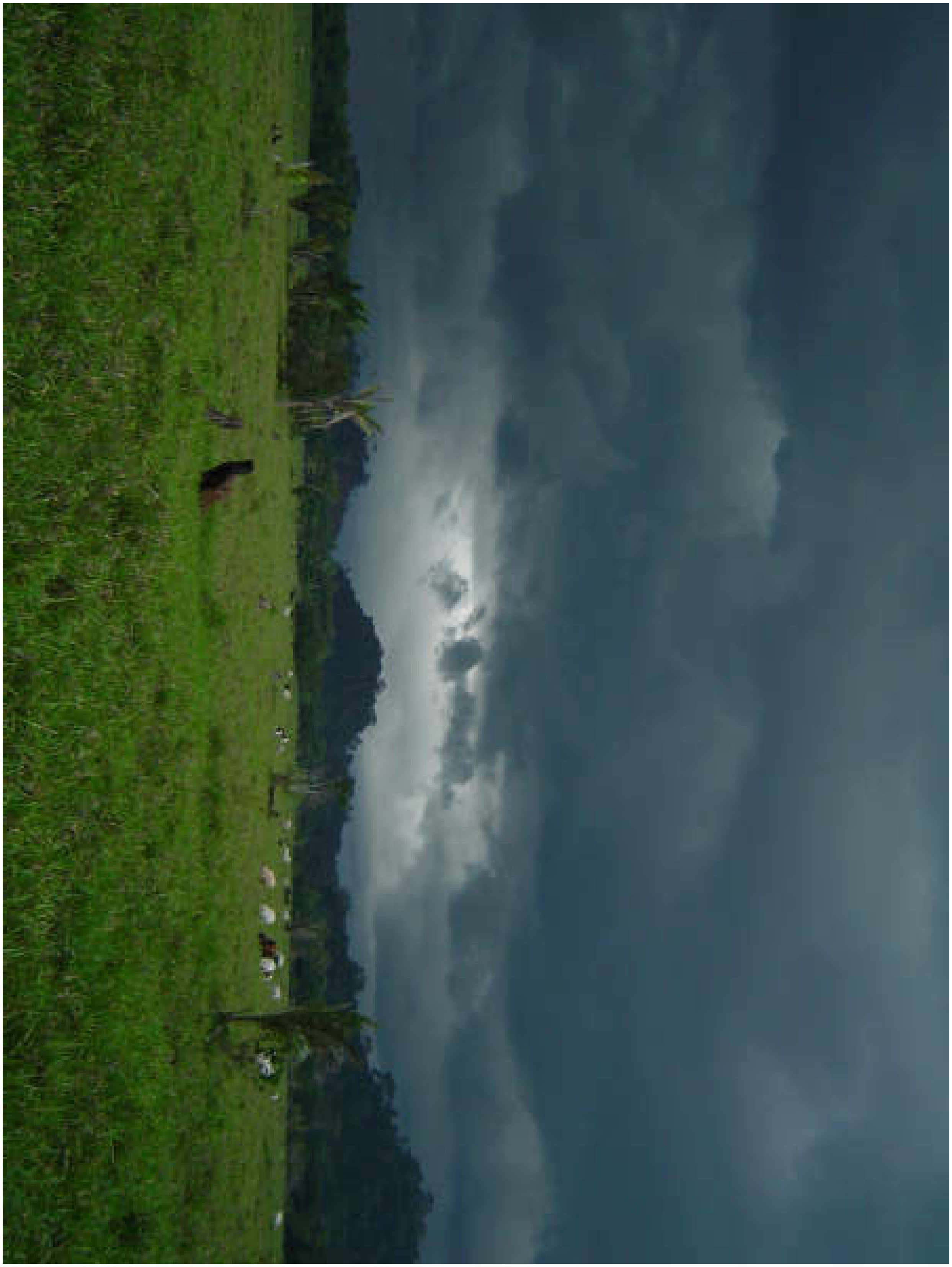
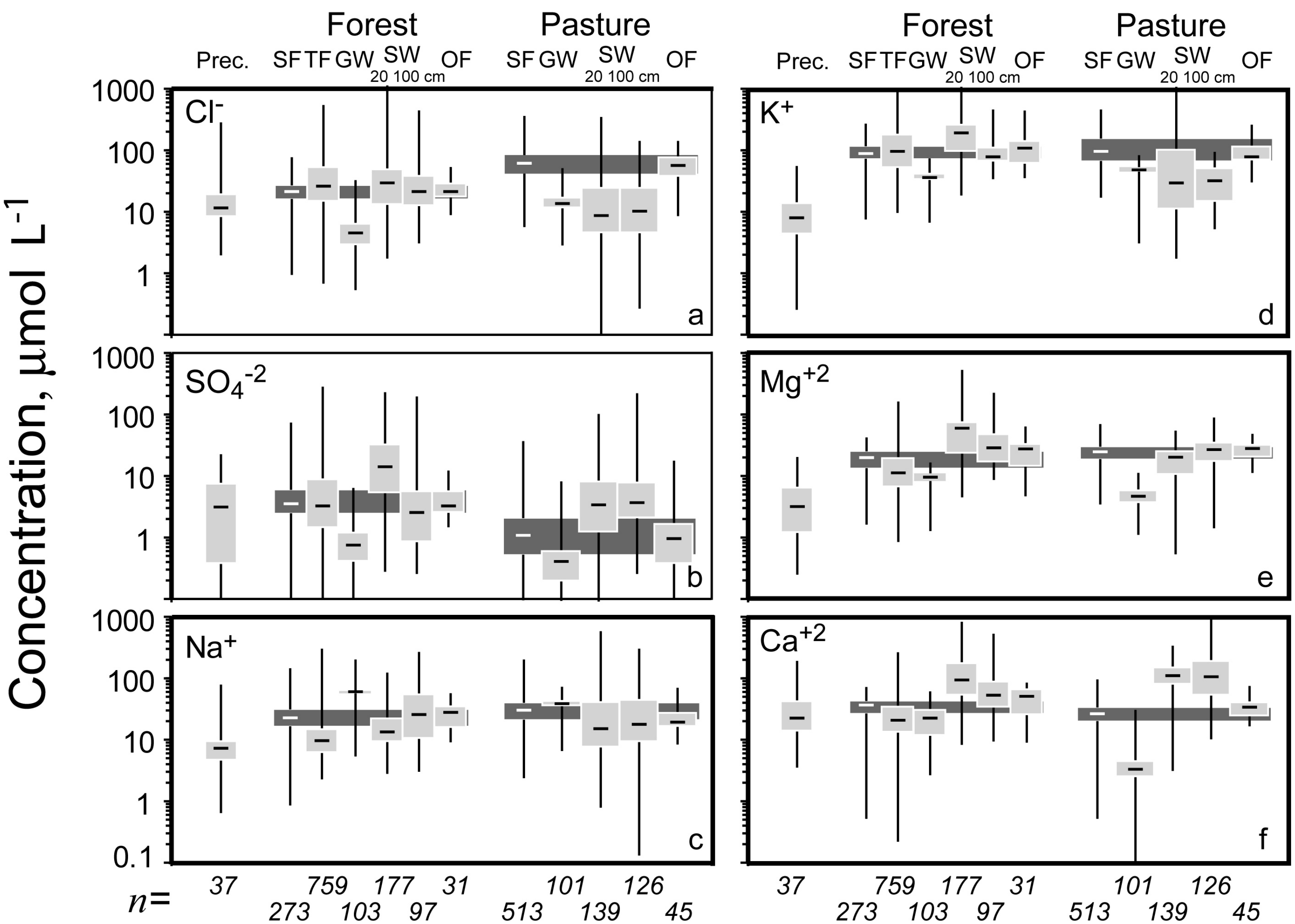


Photo: Lisa Werther



Forest
Pasture
Prec.
SF TF GW SW OF
SF GW SW OF
20 100 cm
Concentration, µmol L-1
1000
100
10
1
0.1
Cl-
SO4-2
Na+
K+
Mg+2
Ca+2
a
b
c
d
e
f
n=
37
759
177
31
273
103
97
101
126
513
139
45

Table 1: Precipitation and runoff at the research watersheds during the period of study.

		Early [a]	Late [b]	Total
Precipitation events, count		73	90	163
Precipitation, mm		1020	1164	2184
Runoff, mm (# events)	Forest	2.2 (15)	14.5 (29)	16.7 (44)
	Pasture	101 (20)	277 (35)	378 (55)
Sampled events, count	Forest	10	12	22
	Pasture	11	16	27
Precipitation during sampled events, mm	Forest	332	352	684
	Pasture	313	311	624
Runoff during sampled events, mm	Forest	0.6	2.1	2.6
	Pasture	29.1	104.4	133.5

[a] Early rainy season, from August 4th to December 31st, 2004.

[b] Late rainy season, from January 1st 2005 to April 25th, 2005