

**Chemical composition of the soilwater in  
the subsurface after the slashing  
and burning of two “Terra Firme” forest  
parcels in Northern Mato Grosso**

**Ralf Gielow & Maria Cristina Forti**

*LMO/CPTEC/INPE, São José dos Campos, SP*

**João Andrade Carvalho Jr**

*FEG/UNESP, Guaratinguetá, SP*

**Ernesto C. Alvarado**

*U. W., Seattle, WA*

**David E. Sandberg**

*USDA Forest Service, Corvallis, OR*

**José Carlos dos Santos**

*LCP/INPE, Cachoeira Paulista, SP*

**II LBA Scientific Conference**

**Manaus, 8-10 July 2002**

*Poster RGIE-0405-001*

# INTRODUCTION

The water in the soil is vital for the plants, and it is a repository of dissolved solids and gases, which are available both for the vegetation and for the soil exchange processes. This mixture is named soil solution. The main gases dissolved are  $O_2$  and  $CO_2$ , and the dissolution of solids present in the soil result in cations such as  $Al^{3+}$ ,  $Ca^{2+}$ ,  $Mg^{2+}$ ,  $K^+$ ,  $Na^+$ ,  $NH_4^+$ ,  $H^+$ , and anions such as  $HCO_3^-$ ,  $Cl^-$ ,  $NO_3^-$ ,  $SO_4^{2-}$ , etc, as well as dissolved organic matter.

The rainwater that reaches the soil surface, percolates through it becoming the soil solution. It interacts with the different parts of the soil, resulting for each one a chemical composition, which reflects their local characteristics. However, if spurious depositions occur, as those derived from anthropic actions such as slashed biomass burnings, its composition may be altered. Therefore, it is important to investigate the extension and evolution of these alterations.

The study of soil solutions is more common in the Northern Hemisphere, with several experimental works evaluating different methods (e.g., Titus et al., 2000; Ludwig et al., 1999; Giesler et al., 1996), which are used for forest, pasture or agricultural soil monitoring. In the Amazon, the monitoring of soil solutions after the slash and burning of forests is still scarce; one such example in the literature is the work of Holscher et al. (1997). It is known (Parker, 1983), that some years after a burning in the Tropics, there is a drastic reduction of the nutrients in the soil. This is due, first, to the removal of the forest and the subsequent interruption of the nutrients recycling in a generally poor soil; second, the leaching of the excess nutrients liberated by the burning, but not completely fixed by the plants that grow afterwards, causes the rapid percolation of the soil solution to deeper layers which are unreachable by their roots.

Thus, the slashing and subsequent burning of forests cause pulses of the diverse chemical species in the composition of the water percolated into the soil, due to the leaching of the ashes by the first post-burning rains. This percolated water interacts with the solid phase of the soil, thus altering the composition of the soil solution, which varies with depth.

This work presents the temporal evolution of the chemical composition of the soil solution, both after the slashing and burning of two "Terra Firme" Amazon forest sites (1999 and 2001), and contiguous to the 1999 site, the consequent accidental burning of the forest understory litter layer. Its main objective is to compare the percolations with reference values determined in a nearby natural site of the same forest.

## FIELD SAMPLING

The experiments were done at the Fazenda Caiabi (9°57'42.2"; 56°20'52.05"), located near Alta Floresta, Mato Grosso, in the Brazilian Deforestation Arc. As the zero-tension lysimeters ("pans") are the most convenient to sample percolated soil solutions (Magid & Christensen, 1993; Ranger et al., 2001), specially if the objective is to determine the loss or gain of solutes in a given layer, seven of such lysimeters were installed in August 1999, before the first burning, in three trenches named G, D and E. In August 2001, the lysimeters in trenches G and E were reactivated, and in the trenches TR1 and TR2, in the second slashed and burned site, new ones were installed. The diagram of the lysimeters installation are sketched on Figure 1 and the corresponding photos are shown on Figures 2 and 3. Each lysimeter was constituted of a 0.1 m<sup>2</sup> slightly inclined polyethylene tray, where the collected soil solution was drained through a plastic tube, without contamination, into a one liter polyethylene bottle. On each sampling day, these bottles were substituted by new ones, capped and then taken to the headquarters of the Fazenda for preliminary processing.

The trench G was excavated inside the natural forest, with a lysimeter installed at the depth of 20 cm. The samples collected in trench G were used as references. The trench D (ESB) was located inside the slashed and burned area denominated site E and described by Carvalho et al. (2001), in which the lysimeters were installed at the depths of 20, 40 and 80 cm. The trench F (ELB) was located in the forest contiguous to site E, where the understory litter was accidentally burned due to the penetration of the fire during burning of that slashed forest site, and its lysimeters were also placed at the depths of 20, 40 and 80 cm. This trench, originally, was destined to constitute the pristine reference location.

The slashing of the forest on site E was done during the end of May 1999, and its burning on August 24, 1999 (DOY 236), just before the first rainfall that occurred on September 6 (DOY 249). The soil solutions were sampled between September 10, 1999 (DOY 253) and January 1, 2000 (DOY 1/2000 = DOY 366/1999). During this period the accumulated rainfall was 682 mm. In 2001, the samplings occurred between October 1 (DOY 274) and December 09 (DOY 343), with an accumulated rainfall of 532 mm after the beginning of the rainy season.

The 2001 slashing (new site F) was effected in May, and its burning on August 20 (DOY 232), with samplings of the percolated waters during the same period of the site E. Because only samples from the lysimeter at 20 cm were available from the reference site, for this study solely samples collected at this same depth were considered.

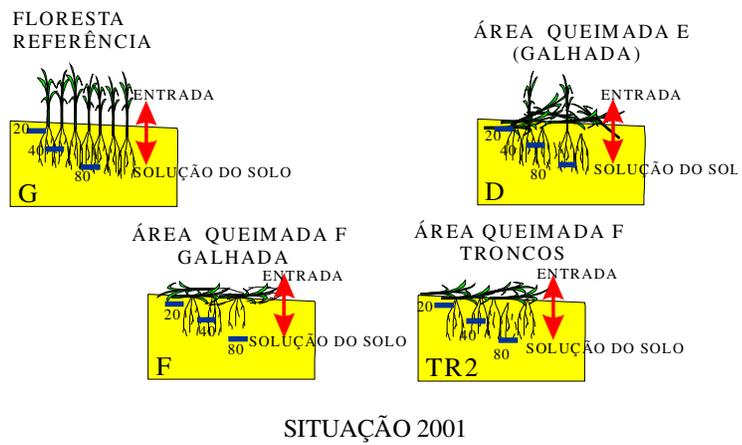
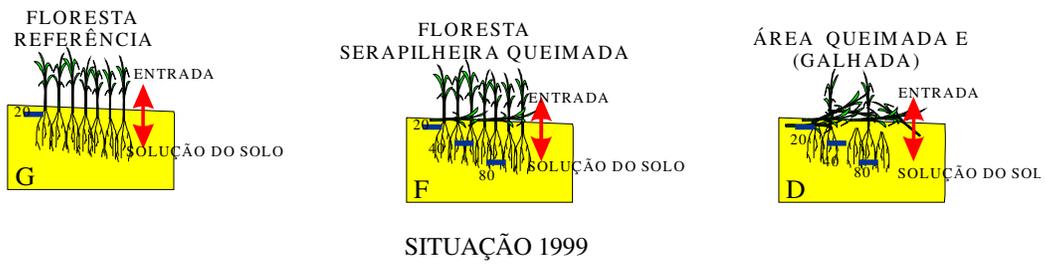


Figure 1 – Configuration of the zero-tension lysimeters in the trenches.



Figure 2 – The 1999 trenches with the zero-tension lysimeters: pristine forest G (left), slashed and burned area D (upper) and burned litter F (right).



Figure 3 – The 2001 trenches with the zero tension lysimeters: pristine forest G (TRG), regrowth of the 1999 slashed and burned area E (TRD), and inside the 2001 slashed and burned area F (TR1 and TR2).

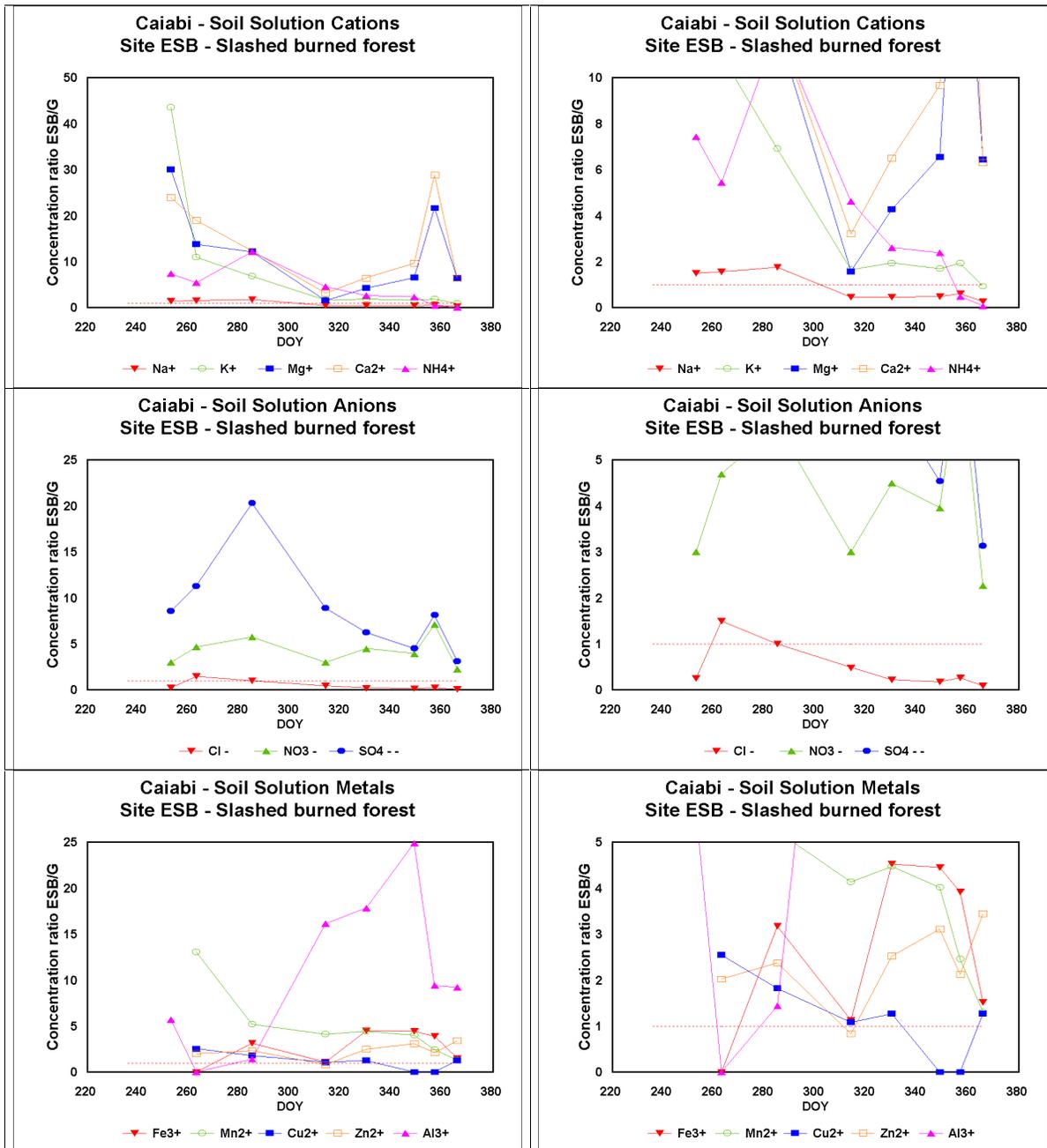


Figure 4 – Temporal evolution of the ratios between the soil solution concentrations at depth 20 cm and the reference concentrations wmv, for the 1999 slashed and burned site (ESB); the amplifications for the smaller values are shown at the right.

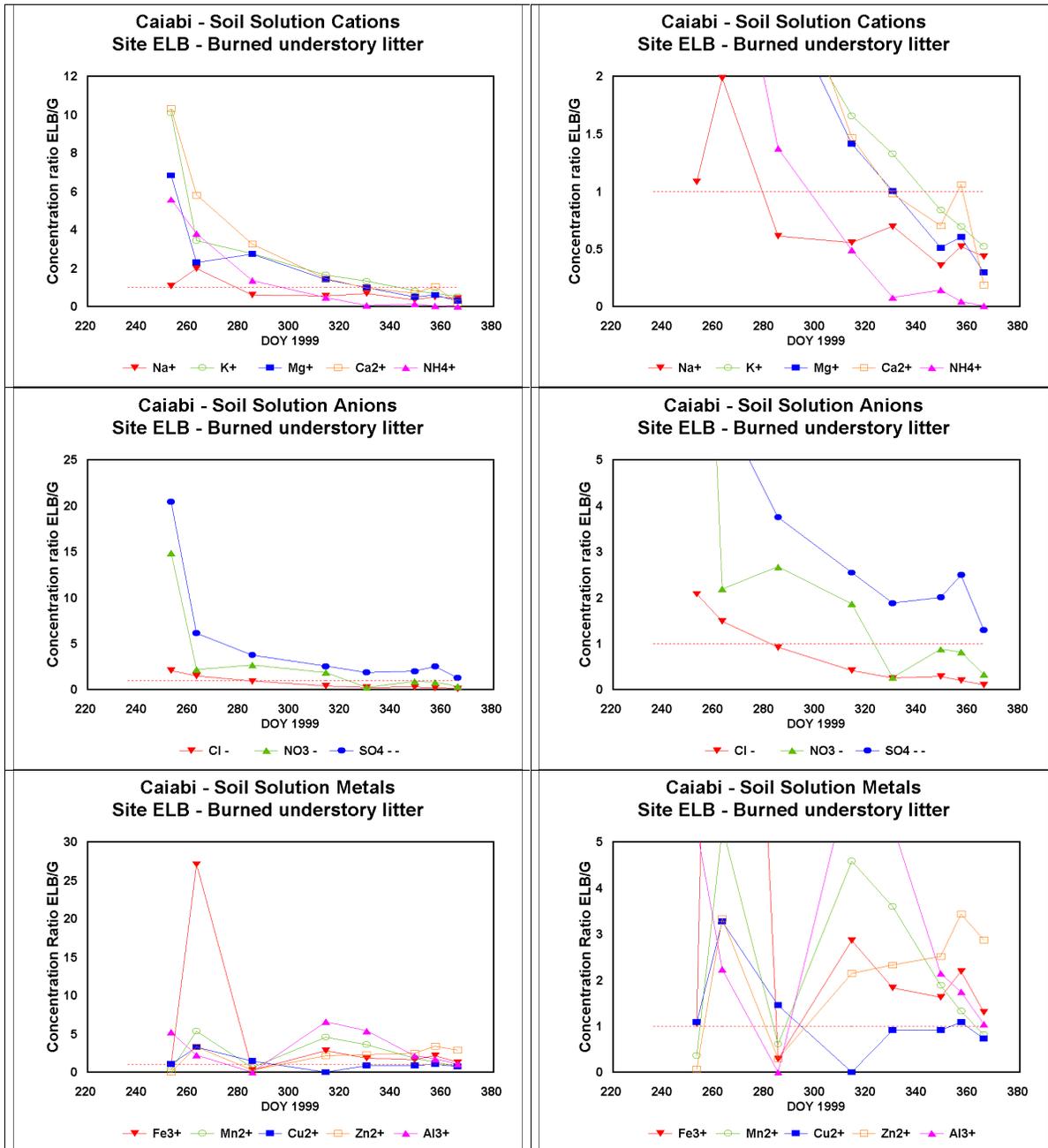


Figure 5 – Temporal evolution of the ratios between the soil solution concentrations at depth 20 cm and the reference concentrations wmv, for the 1999 understory burned litter site (ELB); the amplifications for the smaller values are shown at the right.

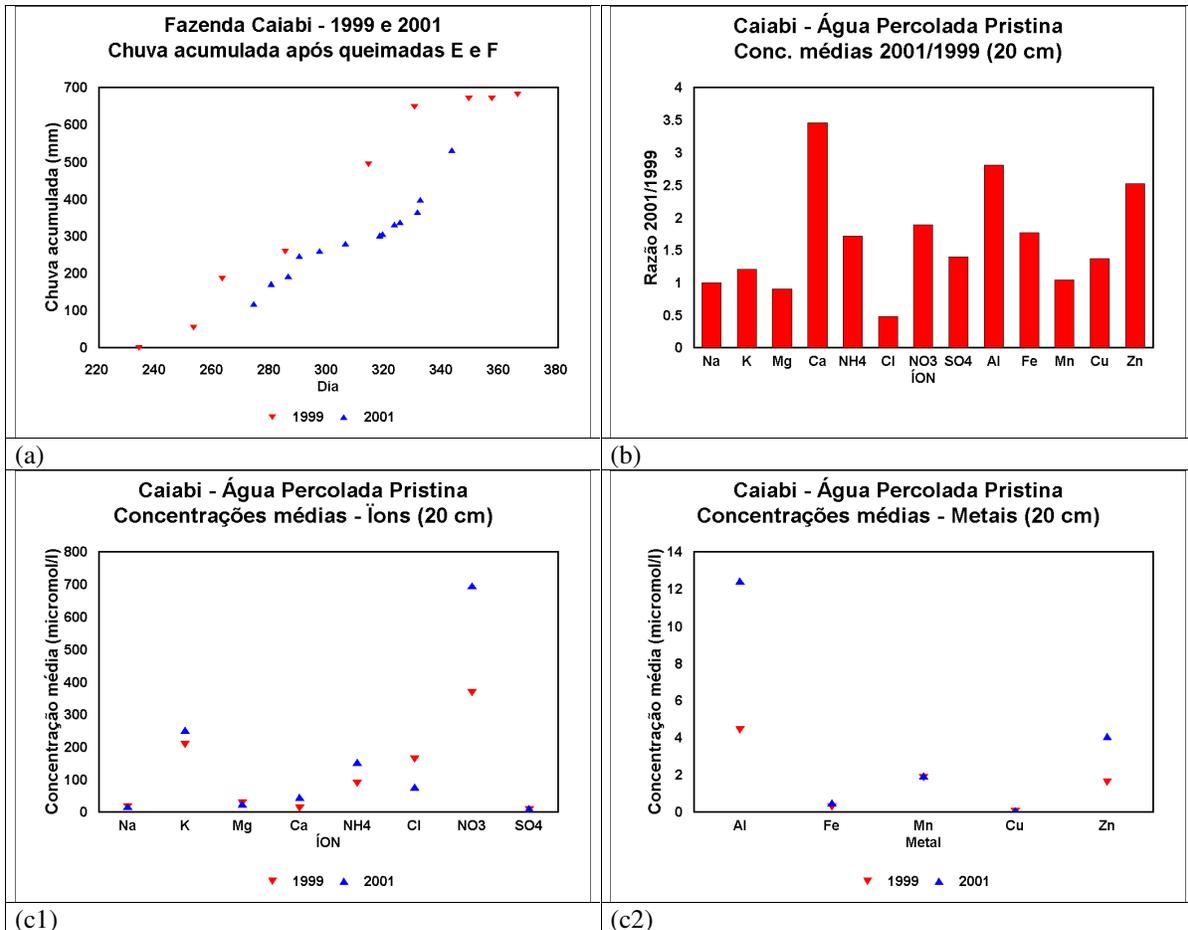


Figure 6 - (a) Accumulated rainfall after the burnings E (1999) and F (2001); (b) ratios 2001/1999 between the average pristine concentrations of the ions and (c) the absolute concentrations.

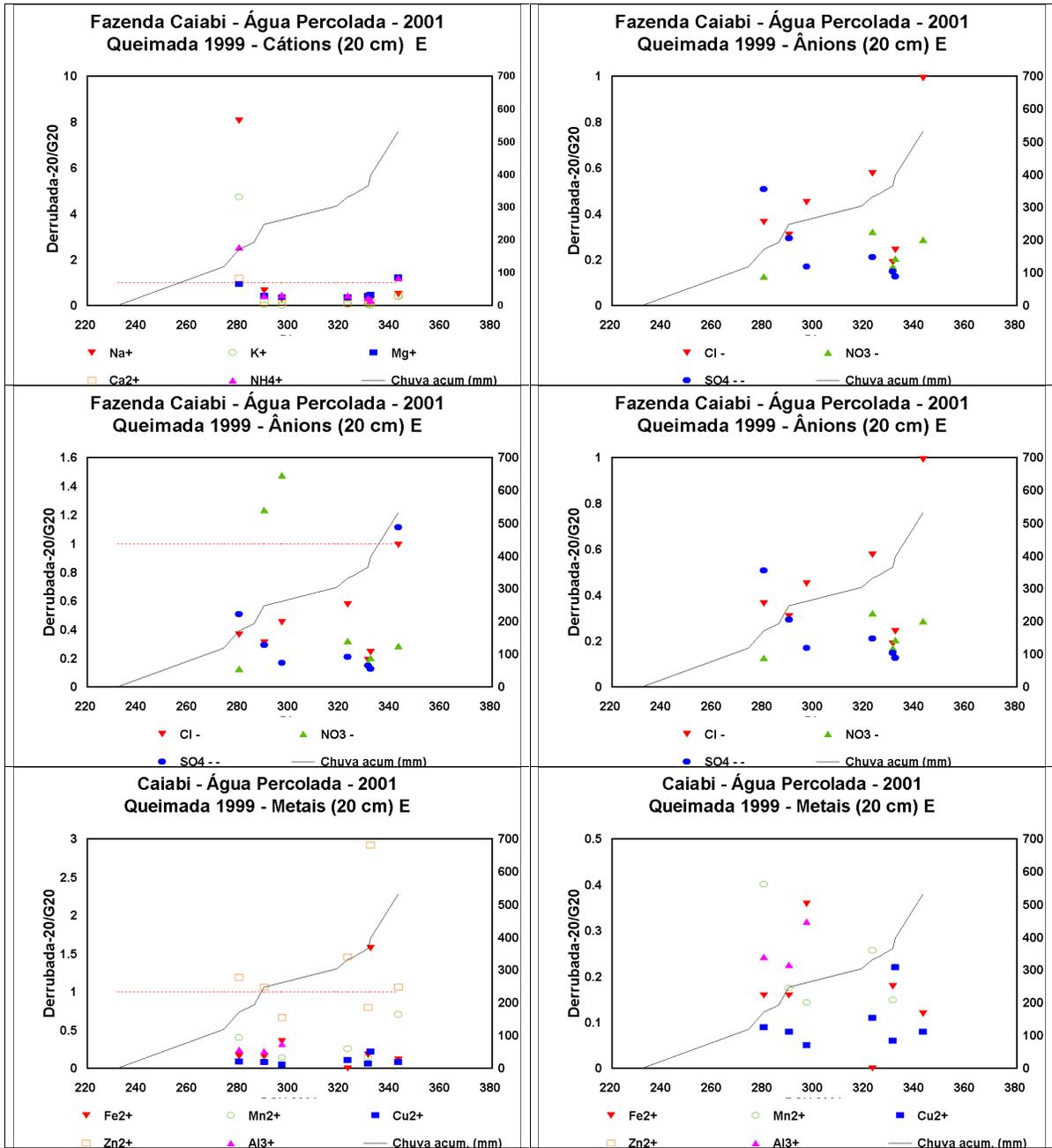


Figure 7 – Temporal evolution, in 2001, of the ratios between the soil solution concentrations at depth 20 cm and the reference concentrations wmv, under the 1999 slashed and burned site E (ESB); the amplifications for the smaller values are shown at the right.

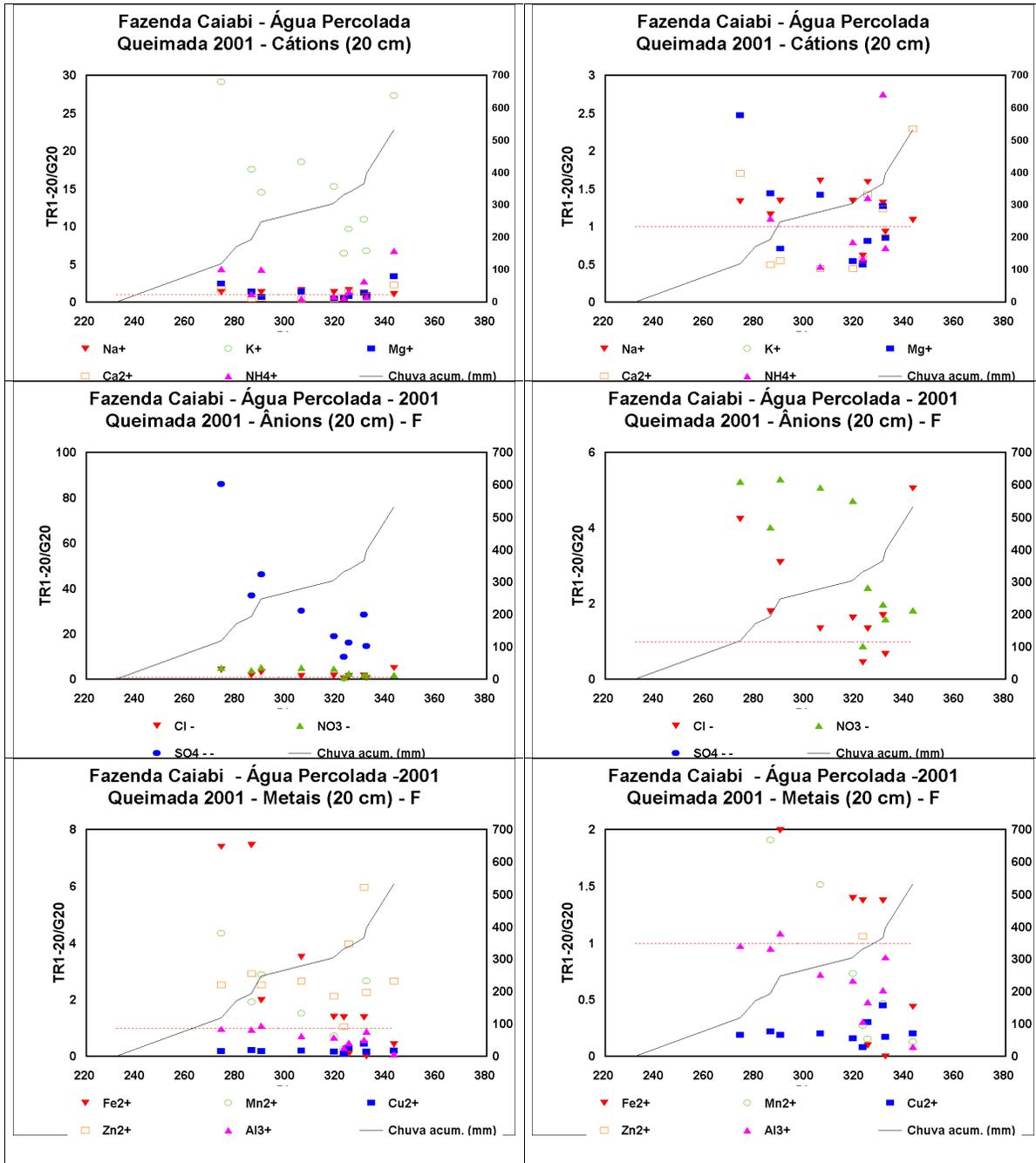


Figure 8 – Temporal evolution, in 2001, of the ratios between the soil solution concentrations at depth 20 cm and the reference concentrations wmv, under the 2001 slashed and burned site F; the amplifications for the smaller values are own at the right.

# PRELIMINARY CONCLUSIONS

There are substantial differences among the evolutions of the chemical composition of the soil solutions collected at 20 cm depths of the unburned reference "Terra Firme", the understory burned litter and the slashed burned sites.

At the burned sites, soon after the subsequent rainfalls, there were strong concentration pulses of the ions in the soil solutions, in general followed by decays toward, and below, their weighted mean values (wmv) in the unburned one. The 1:1 ratios are shown by the horizontal lines in the figures. This behaviour indicates that the ions percolate to deeper layers, which are possibly not reachable by the roots of the plants, thus meaning a loss of ions caused by the burnings. Also, two years after the 1999 slashed site burning, the ratios were below 1:1 for all ions. Otherwise, for the 2001 burning, the maxima of the ratios were usually lower than in 1999, probably due to a smaller combustion efficiency in 2001, caused by rainfall between the slashing and burning days. A more detailed study of this rather complex soil process is still underway, and it will be complemented with the results of the analyses of the soil solutions that are still being collected with all lysimeters. It also includes the determination of the properties and the chemical composition of soil samples already collected, and possible should consider finding the hydraulic properties of the local soil.

# ACKNOWLEDGEMENTS

To the Fundação de Amparo à Pesquisa do Estado de São Paulo – FAPESP, Brazil (Project 98/00104-9) and the USDA Forest Service (Project PNW 99-5147-1-CA) for financial support. To the Conselho Nacional de Desenvolvimento Científico e Tecnológico – CNPq ( processo CMC-005/001 ) and Instituto Brasileiro do Meio Ambiente – IBAMA , for the permission to burn area. To the Riva Family , owner of the Fazenda Caiabi, for the cession of the site.

## REFERENCES

Appelo, C.A.J., Postma, D. 1994 *Geochemistry, groundwater and pollution*. Rotterdam: Balkema. Ch. 1.

Carvalho Jr, J. A., Costa F.S., Veras C.G.A, Sandberg D.V., Alvarado E.C., Gielow R., Serra A.M. & Santos J.C. 2001. Biomass fire consumption and carbon release rates of a rainforest clearing experiments conducted in Northern Mato Grosso, Brazil. *Journal of Geophysical Research* Vol. 106(No. D16): 17877-17887

Forti, M.C., Melfi, A.J., Astolfo, R. & Fostier, A-H. 2000 Rainfall chemistry composition in two ecosystems in the northeastern Brazilian Amazon (Amapá State). *Journal of Geophysical Research* Vol. 105 (D23): 28895-28905.

Giesler, R., Lundstrom, U.S. & Grip, H. 1996. Comparison of soil solution chemistry assessment using zero-tension lysimeters or centrifugation. *European Journal of Soil Science* Vol. 47(No. 3): 395-405.

Holscher, D., Ludwig, B., Moller, R.F. & Folster, H. 1997. Dynamic of soil chemical parameters in shifting agriculture in the Eastern Amazon. *Agriculture Ecosystems & Environment* Vol.66 (No. 2):153-163.

Ludwig, B., Meiwes, K.J., Khanna, P., Gehlen, R., Fortmann, H. & Hildebrand, E.E. 1999. Comparison of different laboratory methods with lysimetry for soil solution composition - experimental and model results. *Journal of Plant Nutrition and Soil Science* Vol. 162(No. 3): 343-351.

Magid, J. & Christensen, N. 1993. Soil solution sampled with and without tension in arable and heathland soils. *Soil Science Society of America Journal* Vol. 57(No.6): 1463-1469.

Parker, G.G. 1983. Throughfall and stemflow in the forest nutrient cycle. *Advances in Ecology Research* Vol.13: 57-132.

Ranger, J., Marques, R. & Jussy, J.H. 2001. Forest soil dynamics during stand development assessed by lysimeter and centrifuge solutions. *Forest Ecology and Management* Vol. 144(No. 1-3): 129-145.

Titus, B.D., Kingston, D.G.O., Pitt, C.M. & Mahendrappa, M.K. 2000. A lysimeter system for monitoring soil solution chemistry. *Canadian Journal of Soil Science* Vol. 80(No.1): 219-226.

