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# Slash-and-mulch to reduce nutrient losses in shifting cultivation in the Eastern Amazon

Rolf Sommer[1], Paul L. G. Vlek[1], Horst Fölster[2]

[1] Center for Development Research (ZEF), University of Bonn, Walter-Flex-Str. 3, 53113 Bonn; e-mail: r.sommer@uni-bonn.de ; p.vlek@uni-bonn.de
[2] Institute of Soil Science and Forest Nutrition, University of Göttingen, Büsgenweg 1, 37075 Göttingen; e-mail: hfoelst@gwdg.de

## Abstract
A nutrient balance of a shifting cultivation system in north-eastern Pará (Brazil) was constructed for slash-and-burn as well as fire-free land preparation with two fallow lengths and emphasis on leaching losses. The fire-free land preparation (mulching the fallow vegetation) improved the nutrient balance of shifting cultivation as it avoided nutrient losses through volatilisation without effecting losses through leaching. The quantities of N, K, Ca and Mg flowing through the soil profile were reduce to almost negligible amounts at 3 m depth, and demonstrated the remarkable capacity of the shifting cultivation system with its fallow vegetation to diminish nutrient leaching losses. Shortening the fallow length, from 7 to 3.5 year, did not lead to a higher annual (relative) nutrient losses of the shifting cultivation system regardless of land preparation technique. Only in the case of N higher annual losses could be observed when the fallow was shortened.

**Keywords:** slash-and-burn, mulch, nutrient dynamics, fallow, leaching

## Introduction
The north-east of Pará state in the Eastern Amazon of Brazil was settled over 100 years ago. Today the region is an agricultural landscape with variously-aged secondary vegetation and fields with annual cultures, plantation crops and pastures. Primary forest exists only along rivers and in a few small areas (Watrin, 1994). Small-farm shifting cultivation predominates in the region. Slashing and burning a three to eight years old fallow vegetation is followed by cultivation of maize, beans and cassava for a period of about 1.5 to 2 years. During the subsequent fallow period the secondary (fallow) vegetation regenerates from roots and stumps which survived the cropping period (Jacobi, 1997).
It is well known that burning as land preparation technique causes extensive nutrient losses due to volatilisation. The major C and N-stock accumulated in the above ground biomass, but also large quantities of P, K, Ca, Mg and S are released to the atmosphere (Mackensen et al., 1996). To achieve a balanced nutrient flow, the length of the fallow period would have to be extremely prolonged (> 70 years), which is not feasible due to the pressure on land along with the trend of small-farmers to reduce fallow length. Therefore, a fire-free land preparation through slashing, chipping and mulching is seen as a promising alternative (Kato et al., 1999). This paper studies the effects of this alternative land preparation on the nutrient dynamics during the subsequent cropping phase. The fallow length and its effect on the nutrient balance was additionally considered.
It was anticipated that applying large amounts of biomass to the soil surface would lead to higher loss of nutrients by leaching. Therefore, the movement of solute nutrients in the soil profile was especially considered. Results were compared with those of traditionally burned plots.

## Study region

Field studies were carried out within the bilateral, German-Brazilian SHIFT-Project in the municipality of Igarapé-Açu in the north-eastern part of the Brazilian state of Pará. In this humid tropical region the dry season lasts from September to December, mean annual precipitation ranges from 1700 to 2400 mm and mean annual temperature lies between 25°C and 26°C. Soils (loamy sandy typic Udults) are characterised by low P-availability, that limits plant growth of both, natural vegetation and crops (Gehring et al., 1999; Kato et al., 1999).

## Methods

The balance of the above-ground nutrient dynamics were calculated determining the nutrient input and output-quantities (fertiliser, atmospheric deposition, gaseous losses and extraction of harvest products and of firewood). To investigate the below-ground leaching losses, concentrations of solute nutrients were combined with a soil-water balance. Therefore, samples of soil water solution were taken biweekly using suction cups. Additionally, the annual patterns of the soil-water pressure head at different depth in the soil profile were recorded with tensiometers. The soil water movement then was modelled using laboratory soil-water retention curves, pedo-transfer functions and a capillary-based model (van Genuchten, 1980).
Microclimatic parameters (precipitation, net-radiation, air temperature, humidity, wind speed) were determined to predict the potential evapotranspiration, the so called 'sink-term' in the soil-water model.
All measurements were conducted over 1.5 years of traditional agricultural land use (maize-beans-cassava) and at the same time in a three-year-old secondary vegetation as a control. Starting the agricultural phase, in November/December 1996, two different fields with secondary vegetation, 3.5 respectively 7 years old, were slashed. The age of the preceding secondary vegetation represents the minimum and maximum fallow length of slash-and-burn agriculture in its recent form. One half of each field then was burned, the other was mulched. For the latter treatment, a tractor-force-driven modified maize chopper was used. Tensiometers and suction cups were installed at different depths horizontally, slightly inclined in 3 m and 6 m deep soil pits on every field in every treatment (mulched, burned) and in the three-year-old secondary vegetation. Micro-meteorological parameters and tensiometer data were taken automatically every fifteen minutes with a solar-energy supplied data logger system.
Following site preparation, on both sites maize (Zea mays) was planted (spaced 0.5 m x 1 m) at the end of January 1997 following beans (Vigna unguiculata) at the end of May (spaced 0.3 m x 0.5 m) and cassava (Manihot esculenta) at the end of June (spaced 1 m x 1 m). Maize was fertilised with 60 kg N $ha^{-1}$ (urea), 26.2 kg $ha^{-1}$ P (triple-super-phosphate) and 24.8 kg $ha^{-1}$ K (KCl). Beans received 10 kg N $ha^{-1}$, 21.8 kg $ha^{-1}$ P and 41.2 kg $ha^{-1}$ K of the same kind of fertiliser, on both cultures broad-spread by hand. Maize-cobs were harvested in mid-June 1997, beans (+pods) at the beginning of August 1997. The last (sixth) weeding was done in mid-March 1997, then fallow vegetation was allowed to re-grow. The cropping phase was terminated with harvesting the cassava-tubers at the end of June 1998.

## Results and Discussion

Considering the burnt plots, gaseous losses of nutrients proved to be the major output flux (Table 1). The biomass of site 1 and site 2 came up to 29 t $ha^{-1}$ and 47 t $ha^{-1}$ dry matter, respectively. As much as 98 % of the N bound in that biomass was volatilised on both sites. But also considerable amounts of P (90 % of site 1 biomass stock,), K (54 %), Ca (58 %) Mg (69 %) and S (88 %) were lost from site 1 and site 2 (data not shown).

Table 1: Nutrient inputs and outputs of the two study sites (for site two only sum is given; deposition modified after Hölscher, 1995; Biological Nitrogen Fixation according to Thielen-Klinge, 1997).

| | N | P | K | Ca | Mg | S |
|---|---|---|---|---|---|---|
| | | | [kg ha$^{-1}$] | | | |
| **Site 1** (3.5 years of fallow preceded) | | | | | | |
| Deposition | 13 | 4 | 11 | 28 | 14 | 20 |
| Fertiliser | 70 | 48 | 66 | 31 | 0 | 0 |
| BNF | 12 | | | | | |
| Volatilisation | -238 | -7 | -49 | -148 | -27 | -32 |
| Harvest (burnt) | -125 | -22 | -77 | -14 | -14 | -7 |
| Leaching (burnt) | -14 | -1 | -9 | -44 | -8 | -4 |
| Harvest (mulched) | -112 | -22 | -83 | -14 | -12 | -7 |
| Leaching (mulched) | -7 | -1 | -3 | -20 | -6 | -12 |
| Burnt | **-275** | **22** | **-53** | **-123** | **-32** | **-31** |
| Mulched | **-24** | **29** | **-3** | **25** | **-5** | **1** |
| **Site 2** (7 years of fallow preceded) | | | | | | |
| Burnt | **-383** | **18** | **-147** | **-196** | **-41** | **-35** |
| Mulched | **-11** | **29** | **-5** | **23** | **3** | **14** |

On both sites and for both treatments no differences in crop yields could be detected. This corroborates former studies by Kato et al. (1999), who demonstrated that with fertiliser application yields with burning and mulching are similar, overcoming the yield reduction without fertilisation. The nutrient exports with harvested products were the most important quantities regarding the mulched plots, but they also constituted a great share of the losses on the burnt plots and, in the case of P and K, even exceeded losses via volatilisation. Summing input and output quantities on the burnt plots N as well as K, Ca, Mg and S showed a negative balance. On the mulched plots this was only the case for N and K (on site 1 also Mg) with slightly negative values, whereas the other elements achieved a slightly positive balance. P in both cases and both fields gave a positive outcome that was effected by the fertiliser input of 48 kg P ha$^{-1}$.

The leaching part of the output quantities was especially monitored. At depths of 90 cm, 180 cm and 300 cm, soil water was sampled with suction cups. In Figure 1, the nitrate concentrations of the soil solution of site 2 at these depths for the cropping period of 1.5 years are shown. The concentration peaks at 90 cm depth do not seem to fully reappear at the deeper soil layers at later times, though nitrate is a highly soluble compound. As a result, remarkable differences with respect to the sampling depth in nutrient outflow quantities could be detected, when combining nutrient concentration with the water fluxes representing the considered depths. This was the case for nitrate, but also for K, Ca and Mg (Table 2).

Figure 1: Concentration of Nitrate in the soil solution at different soil depth during 1.5 years of cropping on site 2, burnt treatment.

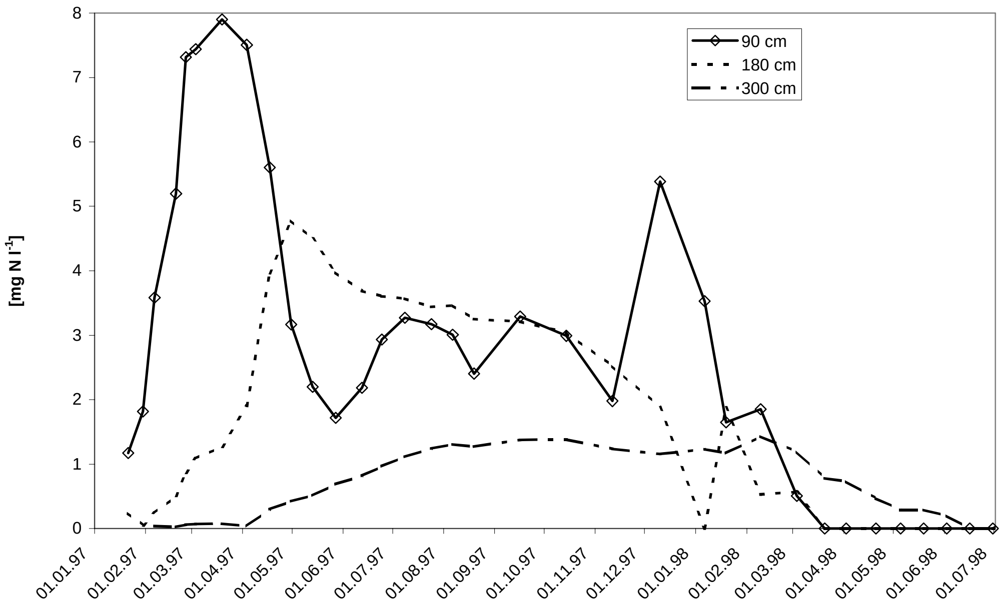



Table 2: Nutrient outflow quantities over the cropping phase of 1.5 years (site 2) considering different (sampling) depth.

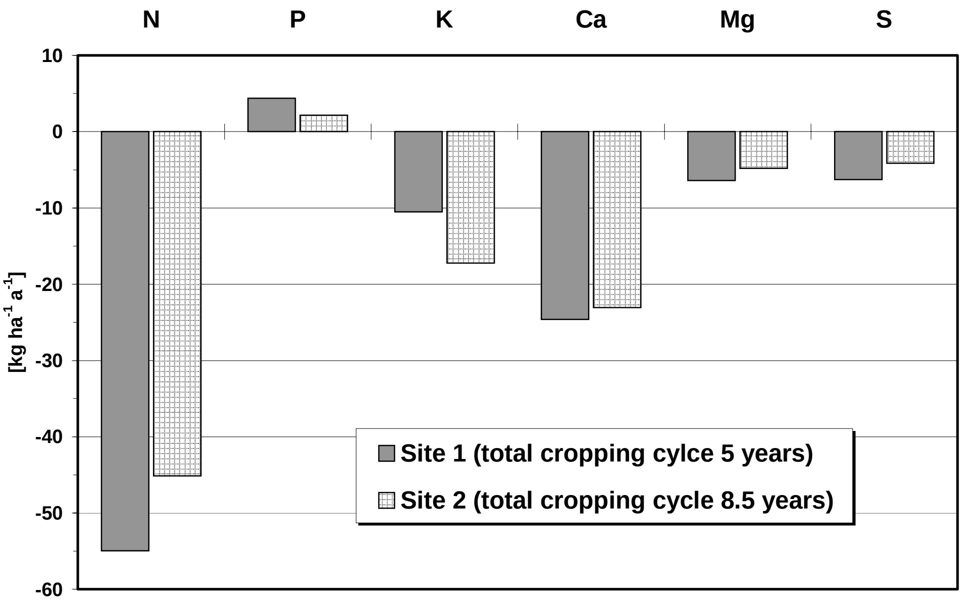
| Depth | Nitrate | | K | | Ca | | Mg | |
|---|---|---|---|---|---|---|---|---|
| | burnt | mulched | burnt | mulched | burnt | mulched | burnt | mulched |
| | | | | [kg ha$^{-1}$] | | | | |
| 90 cm | -68 | -16 | -21 | -16 | -133 | -89 | -30 | -16 |
| 180 cm | -30 | -10 | -4 | -4 | -84 | -64 | -20 | -12 |
| 300 cm | -8 | -8 | -11 | -7 | -41 | -39 | -9 | -8 |

Under the burnt treatment 60 kg ha$^{-1}$ of the amount of nitrate that was still present at 90 cm depth, did not reach 300 cm. The mulched treatment did not show such high amounts at 90 cm and also did not show such drastic reduction over the profile. The outflow quantities at 300 cm depth under both treatments, therefore, reached the same amount (8 kg ha$^{-1}$; considered as leaching portion in Table 1). Potassium, Ca, and Mg showed comparable flux reduction patterns over depth. At least one half of the amounts calculated for 90 cm depth had disappeared at 300 cm soil depth and, again, higher amounts were detected for the burnt treatment at 90 cm soil depth compared with the mulched treatment.

It thus seems, that despite application of large amounts of chopped biomass on the field when mulching the fallow vegetation, no higher leaching losses should be expected over the cropping period of 1.5 years compared with traditional slash-and-burn. Moreover, independent of land preparation technique, i.e. of the amount of solute nutrients in the uppermost soil layer, the shifting cultivation system in its current form has a capacity to store or to re-cycle nutrients out of these layer, and in that, to reduce leaching losses to negligible amounts.

To compare the nutrient balance of site 1 and site 2, the results of Table 1 were related to the actual length of shifting cultivation. This includes the length of fallow as well as the length of the cropping period (which did not differ). Higher amounts of nutrients lost for instance throughout a comparably longer shifting cultivation period necessarily do not mean higher overall (relative) losses. On the burnt treatments shortening the fallow length to 3.5 years only, as was the case for site 1, led to higher N losses compared to site 2 (7 years of fallow), but diminished losses for K and even increased gains in the case of P (Figure 2). Ca, Mg, and S losses remained on approximately the same level independent of shortening the length of the fallow period.

Figure 2: Mean annual nutrient balance of the two burned plots (=total gains or losses divided by the years of cropping)




At least, considering the nutrient balance, it has to be in doubt that prolonged fallow periods really can diminish nutrient losses and improve the sustainability of land use, when land preparation still includes burning.

## Preliminary conclusions

The fire-free land preparation can improve the nutrient balance of shifting cultivation avoiding nutrient losses through volatilisation without increasing losses through leaching. Outflowing quantities of solute N, K, Ca and Mg differed greatly, when different depth were set as outflow boundaries, leading to the conclusion that the shifting cultivation system can prevent these nutrients from being leached.
Shortening fallow length may not lead to higher, unacceptable nutrient losses. No clear trend in this regard was detectable.

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