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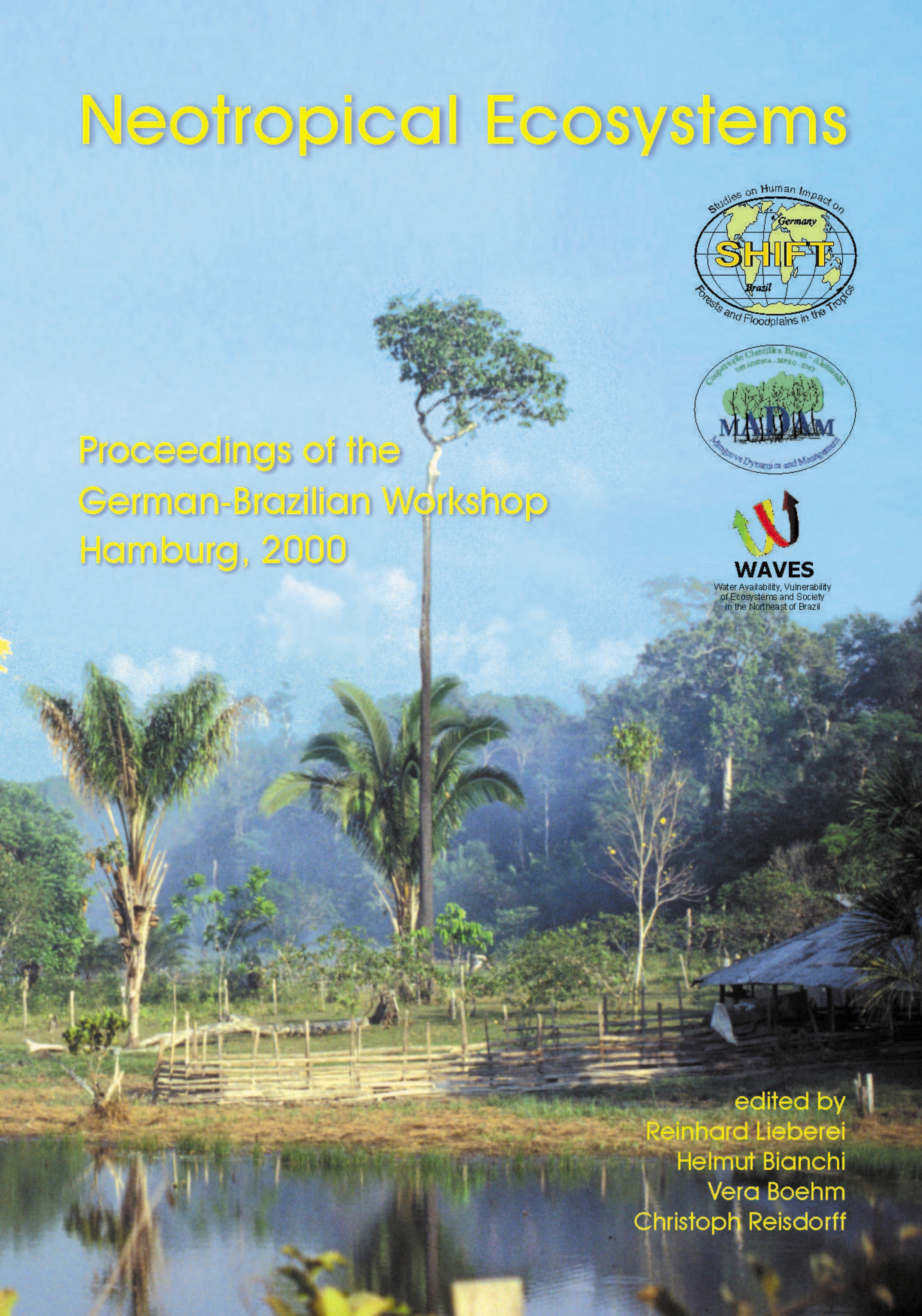

Studies on Human Impact on Forests and Floodplains in the Tropics
SHIFT

MADAM
Mangrove Dynamics and Management

WAVES
Water Availability, Vulnerability of Ecosystems and Society in the Northeast of Brazil

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Deep Rooting Secondary Vegetation – an Indispensable Component of Shifting Cultivation?

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Abstract

Small-farm shifting cultivation predominates the Bragantina region in the Eastern Amazon of Brazil. Secondary forest/fallow vegetation is an integral part of this land-use system. We questioned why trees of this fallow vegetation are maintaining a deep-reaching root system (at least 6 m), though only the surface soil (~0-20 cm) is fertile, and whether and why the fallow vegetation should really be seen as an essential part of (improved) shifting cultivation in the Bragantina region. To answer these questions, the water and nutrient dynamics of shifting cultivation were studied focusing on deep soils. During the dry season in 1997 a 4-year-old fallow vegetation was able to noticeably deplete the soil water store down to 6 m depth. The annual uptake from 0.9 to 6 m soil depth reached 400 mm. Assuming an equivalent uptake of dissolved nutrients out of this layer led to the assumption that the fallow vegetation has a capacity to pump up nutrients, which are out of reach for the shallow roots-system of regular crops, namely maize, cowpea or cassava or of cash-crops like passion fruit or black pepper. Indeed, considerable amounts of nutrient were leached below 0.9 m soil depth during a 1.5-year cropping period after slash-and-burn. During further percolation, however, the amounts of nutrients were successively reduced due to the anion and cation exchange capacity of the prevailing kaolinite soils. At a soil depth of 3 m, only negligible amounts of nutrients were leached during the cropping period. The retention of nutrients by the deep soil matrix beyond the time of cropping increases the possibility for an efficient uptake of these nutrients by the fallow vegetation, which rapidly re-establishes after abandonment of cropping. Maintaining this feature however, limits the scope of prolonged cropping and any agriculture that reduces the vitality of the fallow vegetation.

Keywords

Secondary forest, Fallow vegetation, Shifting cultivation, Deep soil, Leaching, Nutrient recycling, Subsoil nutrient accumulation, AEC, CEC.

1 Introduction

In the Bragantina region situated in the northern Pará, shifting cultivation predominate, which is mostly practiced by smallholders with properties less than a hundred hectares. After land preparation by slash-and-burn, maize, beans and cassava are sequentially cultivated for a period of 1.5 to 2 years. In the subsequent fallow period the woody fallow vegetation regenerates from roots and stumps, which survived the cropping period. The fallow is necessary to restore soil fertility, which rapidly declines during cropping, but also to control crop pests and to diminish weed pressure. Additionally, the regrowing fallow vegetation accumulates nutrients in the biomass. Part of them is mineralized during the burning and can provide moderate fertilization for the crops. Most amounts of these nutrients, however, are volatilized in this process and exported off the fields. Thus, from an ecological point of view, these systems are only sustainable, when nutrient exports are balanced by atmospheric deposition, which requires adequately long fallow periods.

Nowadays however, shifting cultivation is under change. Demographic pressure on land leads to an intensified cultivation with shortened fallow periods (3-7 years) and a move to semi-permanent crops like passion fruit (*Passiflora edulis*) or pepper (*Piper nigrum*). This development endangers the essential function of the fallow period, and as a consequence, in the long run, soil fertility deteriorates and land degrades creating a need for encroaching on primary forest areas.

In this context, there is a strong necessity to find alternative management practices to secure smallholders livelihood and to prevent environmental damage. We questioned whether a fallow period would really require the secondary, woody vegetation and what are its essential contributions for the cropping system.

Amazonian primary forests as well as secondary forest have long been considered to have a shallow root system. However, recent studies of the deeper subsoil using pits or auger revealed a deep-extending root system for primary forests in South-Pará (Nepstad et al., 1991) as well as for the fallow vegetation in the Bragantina region (Sommer et al., 2000; Figure 1).

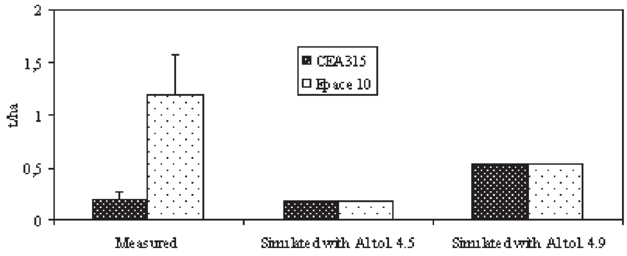

Fig. 1: Root mass density under fallow vegetation from 0 to 6 m soil depth and its cumulative percentage distribution (secondary x-axis at the bottom); modified according to earlier studies of SOMMER et al. (2000); bars denote the standard error, n=60

In the south of Pará, NEPSTAD et al. (1994) showed that deep roots are necessary for a sufficient water supply of the evergreen forest in the dry season. An uptake of deep soil water by secondary forest (fallow vegetation) in the north of Pará was also suggested by HÖLSCHER et al. (1997) according to micro-meteorological measurements. To prove his suggestions, we monitored the deep soil water depletion under a fallow vegetation during the dry season in 1997.

The feature of the fallow vegetation to establish a deep root system, however, might also be important regarding the nutrient dynamics of shifting cultivation. If active in deep-soil water uptake, an equivalent nutrient uptake would be likely. This would substantially influence the nutrient efficiency of this land-use system, in this case, diminishing the losses by leaching. Therefore, leaching was quantified under a slash-burned site during a cropping phase.

2 Material and Methods

To determine deep soil water uptake, a 4-year-old secondary vegetation was chosen. Beginning in April 1997, the annual dynamics of the soil water pressure head at different depth in the soil profile were recorded with tensiometers. The soil water movement then was modeled (inversely) using laboratory soil-water retention curves, pedo-transfer functions and applying the soil water model, Hydrus-1D (VAN GENUCHTEN, 1987).

To study the cultivation-induced leaching, a 7-year-old fallow vegetation was selected. This was slashed and burned in December 1996. Maize (*Zea mays)* was sown at the end of January 1997, cowpea (*Vigna unguiculata*) followed at the end of May and cassava (*Manihot esculenta*) at the end of June. Maize-cobs were harvested in mid-June 1997, beans at the beginning of August 1997. The last (sixth) weeding was done in mid-March 1997, and then fallow vegetation was allowed to regrow. The cropping phase ended with harvesting of the cassava-tubers at the end of June 1998. Concentrations of dissolved nutrients were determined in samples of soil solution taken biweekly at 0.9 m, 1.8 m and 3 m soil depth using suction-cup lysimeters (each time 6 repetitions). The nutrient concentrations were combined with water fluxes derived from the soil water model applied on the cultivation site.

3 Results and Discussion

Due to El Niño influence the dry season of 1997 was exceptionally intensive, with only one rainfall event (5.1 mm on the 22nd of September) between the 28th of August and the 11th of November and a total of 148 mm rainfall until beginning of the rainy season on the 8th of January 1998. Within the dry season, according to results of the soil water model, the transpiration of the fallow vegetation amounted to 154 mm (Table 1). As much as 74% of this transpiration-water was extracted out of the soil profile below 0.9 m soil depth. Considering the whole year, 400 mm of water originated from the soil layer of 0.9 to 6 m depth. In 1998 this was even 427 mm due to the fact that the dry season in this year was comparably moderate with frequent rainfalls replenishing the soil-water store allowing undiminished (unstressed) transpiration.

Soil depth	22/8/97 - 8/1/98		1997		1998	
	[mm]	[%]	[mm]	[%]	[mm]	[%]
0 - 0.9 m	40	26	730	65	853	67
0.9 - 3 m	41	27	199	18	223	18
3 - 6 m	73	47	202	18	204	16
Sum	154		1131		1280	

Tab. 1: Soil water extraction under a four-year-old fallow vegetation from 22nd of August 1997 to 8th of January 1998 and for the years 1997 and 1998 considering different soil layers; percentages are related to the extraction from 0 to 6 m

Though about two-third of the annually transpired water was taken up from the upper 0.9 m soil-layer, deep soil layers contribute to a remarkable extent to the water supply of the vegetation. This might help to explain why most of the fallow species are able to maintain an evergreen canopy during the dry season.

Maize, cowpea and cassava with a generally shallower root system did not deplete the soil water store below 3 m depth and water from 0.9 to 3 m contributed less than 10% to the annual water uptake.

Considerable amounts of nutrients were leached below the rooting zone of these crops. At 0.9 m depth, these were 77 kg Nitrate-N, 1.3 kg P, 25 kg K, 149 kg Ca, 34 kg Mg, and 7 kg S per hectare over the two-year cropping period. However, during further percolation, nitrate, K, Ca and Mg were strongly reduced, so that losses at 3 m decreased to about 9 kg Nitrate-N, 13 kg K, 45 kg Ca, and 10 kg Mg per hectare over the two years (Table 2).

Soil depth	Nitrate-N	K	Ca	Mg
	------------------ [kg ha^{-1} 2a^{-1}] ---------------------			
0.9 m	-77	-25	-149	-34
1.8 m	-28	-5	-87	-21
3 m	-9	-13	-45	-10

Tab. 2: Amounts of leached nutrients during the cropping period 1997-1998 considering reference soil depths of 0.9, 1.8 and 3 m

The decrease with depth in the amounts of dissolved nutrient was apparently related to the cations and anions exchange capacity. The effective cation exchange capacity (ECEC) of the soil at 0.9 m depth was determined to amount to around 1 cmolckg^{-1} slightly decreasing to around 0.5 cmolckg^{-1} at 3 m. ANURUGSA (1998) studied the anion exchange capacity (AEC) of soil of the study region out of 30-50 cm depth. According to his sequential batch experiments AEC reached 0.08 cmolckg^{-1} at a soil-pH adjusted to 6.5 increasing to 0.4 cmolckg^{-1} at a pH of 3.1. Though the ion exchange capacity of the deeper soil is rather low, due to the thickness of the profile, nevertheless, large amounts of exchangeable ions can be retained. Furthermore, as is characteristic for such variable-charge soils, it has to be assumed that the anion and cation exchange capacity even increases with an increase in the ionic strength of the percolating soil-water induced by the cropping activities.

The deeper soil layers, however, are out of the reach of roots of maize, cowpea, cassava and passion fruit, but are accessible for the deep-rooting fallow vegetation. Assuming an equivalent uptake of dissolved nutrients during water extraction, a nutrient-pumping mechanism seems likely. The retention of nutrients beyond the time of cropping, thus, provides the opportunity for the regrowing fallow vegetation to take up and to recycle these nutrients. Moreover, it is likely that due to a decreasing ionic strength of the percolating soil-water after abandonment of cropping, retained ions are released during the fallow period and would be exported if not recycled by the fallow vegetation.

4 Conclusions

Our results on the water balance of the 4-year-old fallow vegetation prove that even young secondary vegetation is able to extract deep soil water, a characteristic, up to now, only verified for primary forest. Additionally, a safety net against leaching is provided by this vegetation, when integrated into shifting cultivation. Intensified cultivation by semi-permanent or permanent crops suppresses the rootstock of the fallow vegetation and, thus, delays or even extinguishes its re-establishment. Hence, not only the function of the fallow vegetation to accumulate nutrients in the biomass and to shade out persisting weeds is undermined, but also the nutrient efficiency of these systems is strongly reduced, in the long run endangering agricultural productivity and ecosystem functioning as a whole.

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