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Water and nutrient fluxes as indicators for the sustainability of different land-use systems on the terra firme near Manaus - a project overview

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ABSTRACT

The project compares water and nutrient fluxes in different perennial land-use systems, either monocultures or mixed cropping systems, in order to determine the resource efficiency of perennial land-use systems. In this work, we were comparing monoculture systems with *Theobroma grandiflorum* or *Bactris gasipaes*, polyculture systems with *Theobroma grandiflorum*, *Bactris gasipaes*, *Bixa orellana* and *Bertholletia excelsa* and primary and secondary forest sites.

In the first experimental year, the equipment was installed to measure rainfall, throughfall, stemflow and soil water fluxes. These data combined with measurements of nutrient concentrations inform about the element fluxes. For this purpose, laboratory facilities were implemented to analyze anions and cations in the different land-use systems. Additionally, the nutrient and organic matter content of the soils were studied.

First results showed that the investigated tree species differ in their effect on the water distribution and nutrient accumulation within the different cropping systems.

During the next project phase, we will concentrate on the determination of the nutrient fluxes and nutrient uptake of different tree species in monoculture and in agroforestry systems. The pathways of nutrients will be studied by using tracer techniques. Special emphasis will be made on the investigation of organic pools of N, P and S in soil and soil solution.

RESUMO

Este projeto tem investigado os fluxos de água e de nutrientes em diferentes sistemas de uso da terra, como: monocultivos e sistemas agroflorestais, tem como objetivo determinar à eficiencia do uso dos recursos em sistemas perenes de uso da terra. Neste trabalho, nós comparamos monocultivos compostos por: *Theobroma grandiflorum* ou *Bactris gasipaes*; sistemas agroflorestais compostos por: *Theobroma grandiflorum*, *Bactris gasipaes*, *Bixa orellana* e *Bertholletia excelsa* e áreas de floresta primária e secundária. No primeiro ano, foram instalados equipamentos para avaliação da pluviometria, interceptação da chuva pela copa das plantas, escorrimento da água da chuva pelo tronco e parâmetros para avaliar o fluxo da água no solo. Estes dados analisados conjutamente com as concentrações dos nutrientes permite estimar os fluxos dos elementos. Para este propósito, foram implementados equipamentos e procedimentos laboratoriais que permitem a ánalise de cátions e de ânions. Adicionalmente, o conteúdo e a concentração dos nutrientes na matéria orgânica estão sendo avaliados. Os primeiros resultados mostram que as espécies investigadas diferem na distribuição da água e na acumulação dos nutrientes, dentros dos diferentes sistemas de

cultivo. Durante a próxima fase do projeto, nós prentendemos concentrar os estudos na determinação dos fluxos dos nutrientes e na absorção dos mesmos pelas diferentes espécies cultivadas, tanto nos monccultivos como nos sistemas agroflorestais. Os "caminhos" dos nutrientes serão determinados utilizando-se à técnica de traçadores radioativos. Especial enfâse será dada na investigação das reservas orgânicas de N, P and S no solo e na solução do solo.

ZUSAMMENFASSUNG

Im Projekt ENV 45 werden Wasser- und Nährstoff-Flüsse als Indikatoren für die Nachhaltigkeit unterschiedlicher Landnutzungssysteme untersucht. Monokulturen mit *Theobroma grandiflorum* oder *Bactris gasipaes*, Mischkulturen mit *Theobroma grandiflorum*, *Bactris gasipaes*, *Bixa orellana* und *Bertholletia excelsa* werden mit Sekundär- und Primärwaldflächen verglichen.

Im ersten Jahr wurden die Feldinstallationen zur Messung von Niederschlag, Bestandesniederschlag, Stammabfluss und Bodenwassergehalten und -saugspannungen durchgeführt. Diese Wasserflüsse können mit den Nährstoffgehalten in der Bodenlösung kombiniert werden, um die Nährstoffauswaschung zu bestimmen. Um die Nährstoffgehalte in den Lösungsproben analysieren zu können, wurde ein Labor in der EMBRAPA Amazônia Ocidental aufgebaut, in dem Anionen und Kationen in grossen Probenzahlen bestimmt werden können. In der Bodenfestphase wurde der Gehalt an organischer Bodensubstanz und die Nährstoffgehalte untersucht. Erste Ergebnisse konnten zur Abschätzung des Einflusses verschiedener Baumarten auf die Wasser- und Nährstoff-Flüsse bereits erarbeitet werden. Die untersuchten Baumarten unterscheiden sich in ihrem Einfluß auf die Wasserverteilung und Nährstoffanreicherung innerhalb der Anbausysteme.

In der nächsten Projektphase werden wir uns auf die Untersuchungen der Nährstoff-Flüsse und Nährstoffaufnahme verschiedener Bäume in Monokulturen und Agroforstsystemen konzentrieren. Die Nährstoff-Flüsse werden mit Hilfe von markierten Substanzen untersucht. Besondere Beachtung werden dabei die organisch gebundenen Stickstoff-, Phosphor- und Schwefelverbindungen in Boden und Bodenlösung finden.

INTRODUCTION

The soils on the terra firme are typically poor in nutrients (Schroth et al., 1998; SHIFT ENV-45, 1997). Land-use systems adapted to these conditions must utilize available resources as efficiently as possible and avoid unproductive losses, e.g. through nutrient leaching. Agroforestry systems were frequently hypothesized to reduce nutrient leaching (Sanchez, 1995). Evidence for reduced nutrient leaching by intercropping of trees was reported from different intensive fallows in East Africa (Buresh and Tian, 1998). Whether intercropping different crop trees is a viable method of improving nutrient cycling on the terra firme, e.g. reducing nutrient leaching and increasing nutrient use efficiency, is the aim of our study.

PROJECT DESCRIPTION

The presented studies are carried out at the experimental station of the EMBRAPA Amazônia Ocidental near Manaus. The average precipitation is 2503 mm yr^{-1} (1971-1993) with a maximum between December and May. The soils are classified as xanthic Ferralsols

(FAO, 1988) and are clayey (app. 80 %), of medium organic C and N contents (28.4 mg g^{-1} and 2.3 mg g^{-1}), acidic (pH of 4.0-4.5) and of low base saturation (12-61%) and CEC (0.07-0.7 $mmol_c$ kg^{-1}).

The experiments are conducted on the fields of the SHIFT Program "Recultivation of abandoned monoculture sites by mixed cropping systems in the Central Amazon". In this program, various mono- and polyculture systems with different tree species and annual crops are compared (see other publications in this issue). In our work, the nutrient and water fluxes are being investigated to evaluate the sustainability of the different cropping systems. For this reason, monocultures and polycultures are compared with secondary vegetation and primary forest sites (Table 1). The effects of single trees with contrasting properties on water and nutrient cycling are monitored together with their functions within the polyculture systems. The expected results are information on how a tree with specific features (e.g. deep or shallow rooted) influences the water or nutrient fluxes (e.g. leaching).

Table 1: Treatments, plant species and experimental setup

Monoculture	cupuaçu (*Theobroma grandiflorum*) pueraria (*Pueraria phaseoloides*)
Monoculture	pupunha (*Bactris gasipaes*) for palmito and fruit production
Polyculture	cupuaçu (*Theobroma grandiflorum*) pupunha (*Bactris gasipaes*) castanha (*Bertholletia excelsa*) urucum (*Bixa orellana*) puerária (*Pueraria phaseoloides*)
Secondary vegetation	vismia (*Vismia* spp.)
Primary forest	bacaba (*Oenocarpus bacaba*) mata mata (*Eschweilera* spp.)

We are working together with other SHIFT projects dealing with parameters of sustainability at the same sites which include the functions of soil fauna (ENV 54), microorganisms (ENV 23) and water and nutrient fluxes (ENV 42). The close cooperation with these projects gives the possibility of working with interdisciplinary approaches which are indispensable for evaluating sustainability.

The assessment of the water and nutrient fluxes included measurements of the precipitation input, throughfall, stemflow, soil fluxes, changes of soil nutrient contents and plant uptake (Figure 1). The fluxes were determined throughout the year to allow comparisons between the dry and wet season fluxes. The soil water suction was measured up to a depth of 250cm, the water content up to 150cm and the soil solution nutrient contents up to 200cm (Table 2).

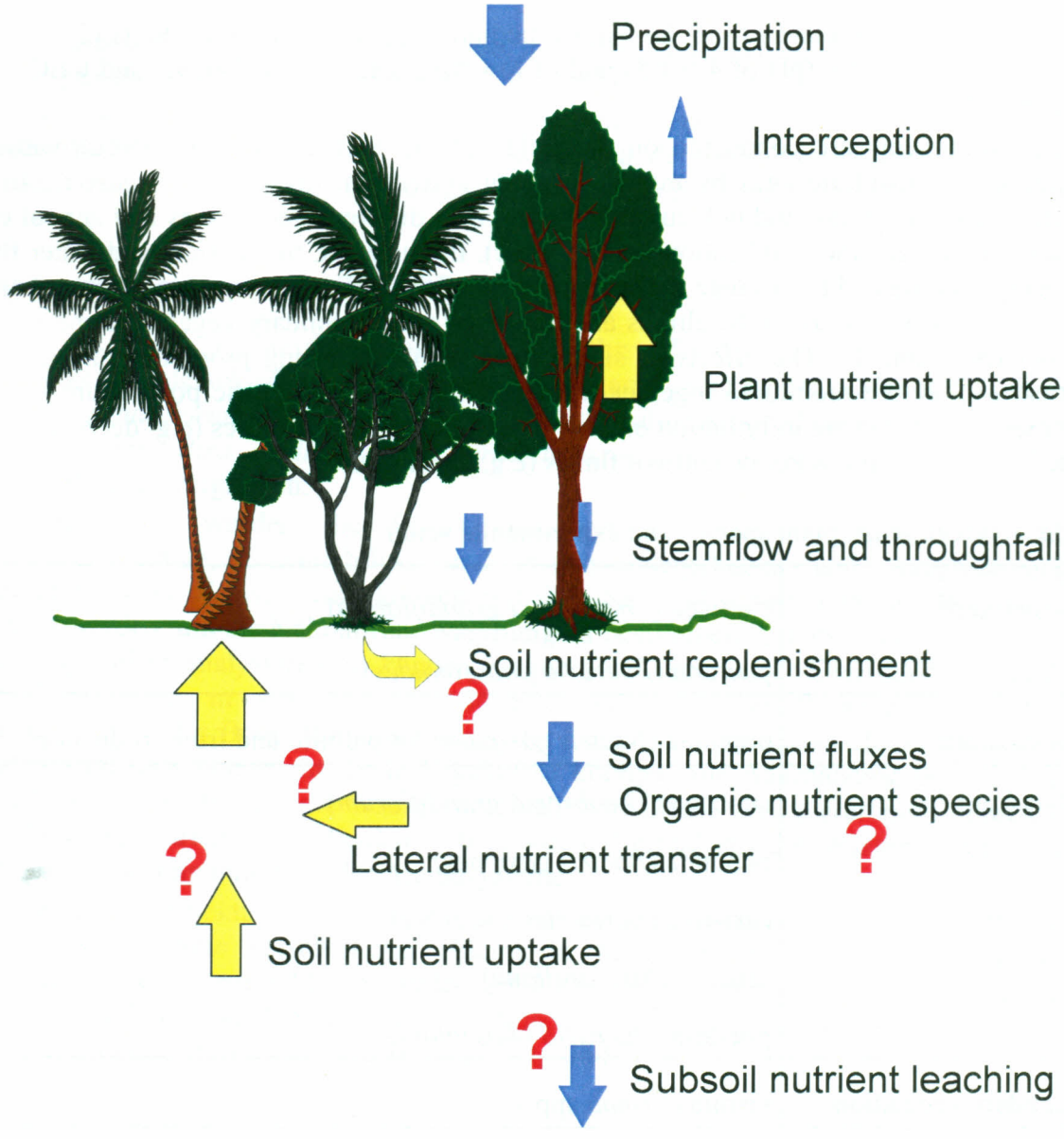

Figure1: Measurements of water and nutrient fluxes.

Table 2: Measurements and instrumentation at the experimental site

parameter	treatments[1]	depth	duration
precipitation	all		1996-97
throughfall	all		1996-97
stem flow	all (not pueraria)		1996-97
soil water suction	all	10, 30, 90, 150, 250cm	1996-98
soil water content	all	10, 30, 90, 150cm	1996-98
soil solution nutrients	all	10, 60, 200cm	1996-98
soil nutrients	all	up to 200cm	1996-98
belowground biomass	pc2	up to 200cm	1995-96
aboveground biomass	pc2, mc cup, mc pup		1995-96

[1] as described in Table 1

FIRST RESULTS

After the successful establishment of the laboratory in Manaus, all nutrient analyses could be done at the EMBRAPA Amazônia Ocidental. The extensive field installations were completed at the beginning of 1996 and throughout the cropping season from 1996-97 routine measurements could be conducted.

Within the course of this cropping season, first data could be gathered which allow highly important conclusions about the impact of different tree species in mixed cropping systems. These results will be discussed in the other publications in the issue, and only the most important results are summarized here.

The investigated tree species differ in their effect on water distribution within the cropping systems (Schroth et al., 1998b): pupunha and castanha concentrate rain water near their stem, whereas cupuaçu has little effect on water distribution. The nutrient contents of throughfall and especially stemflow differ also between species, with highest P concentrations in the stemflow of urucum. There are also differences in nutrient availability in the soil, with urucum again having highest P availability. N concentrations in the soil solution show a distinct pattern of marked fluctuations in the topsoil, constantly low availability in 60 cm, and constantly high concentrations in the deeper subsoil under the rooting zones (200 cm). This indicates N losses through leaching. The litter feeding fauna of the tree species differs in abundance and diversity of certain groups, with cupuaçu having low diversity and pupunha high diversity. The organic matter content is higher in soils under cupuaçu than pupunha; a large portion of this organic matter and also of the soil nitrogen is found in labile soil pools of

the coarse sand and particulate organic matter fractions indicating readily available nutrient pools (Lehmann et al., 1998).

FUTURE ACTIVITIES

The short time of 1.5 years which was available up to now for the determination of water and nutrient fluxes did not allow conclusions about the sustainability of the investigated systems. This will only be possible after the continuous monitoring of system fluxes over a longer period of time. Furthermore, the results available up to now indicated research needs in the following areas: (i) the subsoil nutrient fluxes below 200cm could not be investigated up to now and it is not clear if the trees are able to retrieve nutrients from below 200cm or whether nutrients at that depth are lost for the system and susceptible to leaching. The high amounts of nitrate found at 200cm depth indicate the relevance of this flux. (ii) The organic nutrients in soil and soil solution are an important nutrient pool; the proportion of organic nitrogen in the soil solution amounted to over 50%, that of phosphorus even to more than 90%. These fluxes must not be neglected in a study about nutrient fluxes and more detailed studies on their nature and dynamics will be included in the next project phase from 1998-2002. In order to support the existing conclusions and facilitate the investigation of the complex nutrient fluxes in the different land-use systems, tracer studies will be employed. These tools will enable us to assess the nutrient cycling and to conclude on the sustainability of the investigated land-use systems.

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