Rapid Water Changes in a Highly Aggregated Xanthic Ferralsol of the Central Amazon

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Under humid tropical conditions, rainfall amount and intensity are usually very high and may lead to large nutrient losses by leaching. Additionally, the Ferralsols of the central Amazon are characterized by high aggregation and high saturated hydraulic conductivity. In this contribution, we investigated (i) the soil water dynamics of a Xanthic Ferralsol to a soil depth of 4 m in order to evaluate the extent of rapid water percolation into the subsoil, and (ii) the effect of different indigenous tree crops on soil water contents.

TDR and tensiometers were installed under *Theobroma grandiflorum* (Willd. ex Spreng.) K. Schum. (cupuaçu); *Bactris gasipaes* Kunth. (peachpalm); *Bertholletia excelsa* Humb.&Bonpl. (Brazil nut); *Bixa orellana* L. (annatto) in a multi-strata agroforestry system. TDR were installed at 0.1, 0.3, 0.9 and 1.5 m depth in three replicates. Additionally, a soil pit was dug up to 3 m depth. TDR and tensiometers were inserted at 0.1, 0.3, 0.9, 1.5, 2.5, 3.5 and 4.5 m from the side. The instruments reached below the canopy of *Theobroma and Bactris* and *Pueraria phaseoloides* (Roxb.) Benth. (pueraria). Additionally, a data-logger system was installed with TDR at 0.1 and 0.9 m, and tensiometers at 0.1, 0.3, 0.9, 1.5, 2.5 and 3.5 m depths. A mobile meteorological station was built next to the soil pit. Soil water measurements were done in weekly intervals with the manual equipment and in 5 and 15 minute intervals using the logger system during in rainy season.

After a heavy storm, soil water suction decreases within a few minutes up to a depth of 0.9-1.5 m, but significantly later at greater depths. Mean water contents at time scales of weeks and months, however, do not show a pronounced fluctuation during the rainy season. Therefore, high resolution soil water measurements are needed to evaluate rapid changes after rainfall events. Weekly measurements are not suitable to assess water percolation, but are sufficient for evaluating soil water availability for crop growth.

Soil water depletion was highest at the topsoil for annatto and cupuaçu, and decreased rapidly with depth. In contrast, peachpalm took up water homogeneously from the soil profile to 1.5 m depth. Brazil nut was not able to utilize subsoil water as well as it was anticipated from the tap root found from root excavations. The legume cover crop pueraria did not take up soil water at a depth of 0.9 m and below. Soil water dynamics under peachpalm may indicate that this palm is better able to utilize subsoil water (0.9-1.5 m). and reduce nutrient leaching than the other investigated tree crops or the cover crop. Especially under the high leaching conditions of the aggregated soils and high rainfall regime, nutrient uptake from the topsoil may not reduce nutrient leaching due to the rapid soil water percolation even to greater depths.

Soil Water Availability as Affected by the Cover Crop *Pueraria Phaseoloides* in the Central Amazon

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Cover cropping is a common technique in fruit tree plantations of the tropics. One of the many reasons for planting a cover crop is the improvement of soil physical properties, an improved nutrient cycling, input of atmospheric N_2 by biological fixation and reduction of erosion. Whether and to what extent cover crops can influence soil water contents through effects on evaporation losses is not known for Xanthic Ferralsols in central Amazonia. In order to study the effects of the cover crop Pueraria phaseoloides on soil water cycling, TDR probes (time domain reflectometry) were installed at 0.1 m increments to 1 m depth. Soil water measurements were done weekly for 5 months. Precipitation and interception were measured automatically and manually. Transpiration and stomatal conductance were

determined with a porometer. Continuous measurements were done during 10 hours for leaves exposed to direct sunlight and for shaded leaves. The results show that about 80 % of the rainfall can be stored as interception by the cover crop. This also decreases the danger of soil surface sealing by direct rain impact (splash). The maximum radiation was 1800 and 900 $mmol.m^{-2}s^{-1}$, with an estimated transpiration of 25 and 17 $mmolm^{-2}s^{-1}$ for sun-exposed and shaded leaves, respectively. The mean soil water storage under pueraria amounted to 436 mm, which was higher than the amount observed under bare soil with 386 mm. These results show that under the experimental conditions, there is a higher soil water availability under the cover crop that in bare soil due to reduced evaporation from the soil surface. Under these conditions, a cover crop may play an important role in water conservation and hence crop production on Xanthic Ferralsols of the central Amazon.

Importance of *Pueraria Phaseoloides* for the N Cycle in Tropical Tree Production

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Apart from their effects on soil protection, legume cover crops have an important role for nutrient cycling in fruit production systems in the humid tropics. The objective of this study was to analyze the biomass production and nutrition of Pueraria phaseoloides as a cover crop grown in three different agroforestry systems (System 1: *Theobroma grandiflorum, Bactris gasipaes* and *Hevea* spp; System 2: *Theobroma grandiflorum, Bactris gasipaes*, *Bertholletia excelsa* and *Bixa orellana*; System 3: *Theobroma grandiflorum, Hevea* spp, *Cocus nucifera* and *Citrus sinensis*) at two levels of fertilization (100 % + additional dose of P and 30 % of fertilization recommended to individual useful plants), and its potential to contribute to the N stocks of the cropping system by biological N_2 fixation. The study was conducted on experimental plots with the dimensions of 32 by 40 m using three replications planted in 1993. The soil of the study site is a Xanthic Ferrasol (FAO/UNESCO). For estimating the aboveground biomass, the litter and plant nutrition of Pueraria, five subsamples of 0.25 m^2 were collected from the area between the tree rows in each plot in June 1998. The samples were dried at 70°C for 48 hours and nutrient contents (N, P, S, K, Ca, Mg, Fe, Mn, Zn and Cu) were measured using standard analytical procedures. The biological N_2 fixation was determined in both the dry and rainy season in system 1 (100% fertilization) using ^{15}N isotope dilution. Three different reference plants were used which had similar growth characteristics and were not fixing atmospheric N_2 (*Rolandra fruticosa, Maieta* sp, and a *Cyperaceae* species). Ammoniumsulfate with 10 atom% ^{15}N excess was applied at a rate of 50 mg m^{-2} in microplots of 1 m^2. Statistical analyses were done with ANOVA using a randomized complete block design.

The K and Ca contents in the biomass were influenced by fertilization indicating that nutrient applications to the trees can improve cover crop nutrition. As a consequence, a positive correlation was found between the aboveground biomass and the K contents ($R=0.51$; $P< 0.03$). Additionally, N and P contents ($R=0.63$; $P<0.005$) as well as N and Mg contents ($R=0.56$; $P< 0.01$) were significantly related to each other. However, the type of cropping systems was the main factor controlling growth and the nutritional status of *Pueraria.* The aboveground biomass and litter of *Pueraria* ranged from 2.2 to 6.1 and from 2.7 to 7.7 Mg ha^{-1}, respectively. The highest aboveground biomass and litter production was found in systems 3 with the most scattered plant distribution. The N content of *Pueraria* reached 57-177 kg ha^{-1} in the aboveground biomass with similar values in the litter of 48-165 kg ha^{-1}. In contrast, the amounts of Ca in the litter were enriched in comparison to the biomass, whereas K was depleted due to rapid leaching from decomposing litter. With the exception of K, the nutrients stocks in *Pueraria* litter were more than twice as high as the nutrients applied by fertilization. Consequently, nutrient turnover of *Pueraria* was an important process in the nutrient cycling of the fruit tree production system. The N in *Pueraria* derived from biological N_2 fixation estimated by ^{15}N enrichment reached values from 9 to 45% and was higher throughout the wet than the dry season. Thus, 32-158 kg N ha^{-1} of the biomass N were derived from atmospheric N_2, exceeding the amounts of N added by fertilization.

The large nutrient uptake and return through litter indicated a rapid nutrient cycling at the plant-topsoil interface, thus reducing leaching and keeping nutrients in available form. The considerable amount of biologically fixed N_2 was a relevant and important addition to the N pool of the cropping systems.