Tropical legumes effects on agroforestry system sustainability in the Western Brazilian Amazon[1]

T. C. de Araújo Gomes[2], A.M. Pereira Lunz[2],
R. N. de Souza Moraes[3], V. M. Bessa Lopes[4]

Keywords: *Pueraria phaseoloides*, *Desmodium ovalifolium*, *Flemingia congesta*, management of tropical soils, Brazil.

Introduction

In the Western Brazilian Amazon, the traditional agricultural systems have not been efficient in guaranteeing its agronomic and environmental sustainability, and the socioeconomic welfare of the communities that practice them. The sustainability of the traditional agricultural system in the tropics relies on long fallow periods in between the cropping phases, viable because of the low population densities and high availability of land (Henrot & Brussaard, 1997). There is a demand for the development of sustainable land use alternatives that reconcile the need to increase income and living conditions of the rural population and guarantee the conservation of the natural resources.

Agroforestry systems have been proposed as an alternative. However, they still present problems regarding soil management, the maintenance of the perennial crops productivity and the great demand of labor in the control weeds. As a strategy to attenuate such problems, it has been suggested the inclusion of legume species, which are pruned periodically to supply organic material for the associated commercial crops. This work has the objective of evaluating the effect of the utilization of the perennial legumes *Pueraria phaseoloides*, *Desmodium ovalifolium* and *Flemingia congesta* on the productivity and stability of an agroforestry system in the Western Brazilian Amazon.

Material and Methods

The studies are located in a farmer's field of the District of Nova California (9°47'28"S, 66°41'31"W, 170 m elevation) in the State of Rondônia (frontier area with the State of Acre). According to the system of Köppen, the dominant climate is Am (rainy tropical climate, with rains type Monsoon), presenting a dry station of small duration. The mean annual precipitation is around the 2.250 mm. The mean annual temperature is between 22°C and 26°C, and the hottest period is between August and October.

The works is being developed in Red-Yellow Podzolic soil (Ultisol), in an agroforestry system established in 1989, consisting of the association of peach palm (*Bactris gasipaes*), cupuaçu (*Theobroma grandiflorum*) and Brazil-nut (*Bertholletia excelsa*), planted in the spacing of 7,0 x 4,0m. Were used four treatments (*Pueraria phaseoloides*, *Desmodium ovalifolium* and *Flemingia congesta* - and a control without legume) in four replications. The legume species were planted between the rows of the perennial species in november/95. The legumes are pruned in the beginning and final of the rainy season (November and April, respectively), in such a way as to favor fruit

[1] Funded by Brazilian and ICRAF/ASB Program resources
[2] Empresa Brasileira de Pesquisa Agropecuária (EMBRAPA), P.O. Box 392,69908.970, Rio Branco, Acre,Brazil
[3] Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq)
[4] Universidade Federal do Acre (UFAC)

production and to decrease the effects of the dry season, respectively. The biomass resulting from each cut is deposited under the perennial species. Until now, seven collections of soil samplings were conducted (0-20 cm, 20-40 cm and 40-60 cm of depth) to monitoring the alterations in the pH and levels of K, Ca, Mg, Al, H+Al, P and organic C of the soil strips where the legume species are grown. It was also determined, the zero point of charge and the electric charges of the soil samples (Raij & Peech, 1972, modified by Uehara & Gillman, 1981) collected under one plant of *T. grandiflorum* and *B. gasipaes*, for each plot (0-20 cm of depth).

The decomposition rates and N, P, K, Ca and Mg release pattern of the three legumes leaves was studied from April to November/97 (dry season) and from November/97 to April/98 (rainy season). The "litterbag method" was used. The legumes dry matter production was determined (five prunings until now). The nutrient contributions were also calculated based on the results of the leaf decomposition studies.

The evaluation of the nutritional status of *T. grandiflorum* started in November/98 (end of the flowering phase) and until the end of this productive period (May/99), there will still be proceeded four more collections of leaf material.

Results and Discussion

Soil chemical characteristics in the strips of the legumes

Initially, the chemical analyses showed that the pH values tended to decrease in function of soil depth. The values were around 4.3 and 3.5, respectively, for the pH in H2O and KCl 1 mol/l. Such values show the great solubility and availability of aluminum in the experimental area, whose values increased sensibly in greater depths (2.1 - 8,3 $cmol_c.dm^{-3}$) than in the top soil layer. The values of Ca decreased with the increase in soil depth (2.5-0.4 cmolc/dm3), as well as the levels of Mg (1-0.3 $cmol_c.dm^{-3}$) and K (95-46 mg/kg). The values of P were low in the whole experimental area (1-4 mg/kg).

Of the soil samplings conducted, only four were processed. The behavior of K, until the moment shows the most striking pattern. The fall of K levels the strips between the rows of the perennial species, in the layer of 0 - 20 cm of depth, shows that this happens in a more abrupt way in the plots with the legumes, than in the controls. This is a clear evidence of the additional effect of the legumes in the absorption of this nutrient. Ca and Mg presented similar behaviors to each other in the three soil layers sampled. For the layers of 0-20 and 20-40 cm, *Flemingia* showed the most stable behavior in regard to the absorption of these nutrients, in contrast with *Pueraria* and *Desmodium*, whose plots presented soil samples with variable concentrations in function of the time of sampling. Such tendency should be verified by the analyses of the remaining soil samples.

3.2. Zero Point of Charge (ZPC) and soil electric charges

The largest values of ZPC were observed in the control and in the *Pueraria* plots, not differing statistically to each other (Table 1). These values differed of that ZPC found in the *Flemingia* and *Desmodium* plots, which were in lower pH values. Such behavior seems to reflect the chemical composition and the decomposition rate of the legumes phytomass. It was also observed variation of the samples electric charge.

Table 1. Effect legume biomass on the zero point of charge (ZPC) and electric charges of superficial soil samples of a Red-Yellow Podzolic, in an agroforestry system in the Western Brazilian Amazon (means of eight replications)

Treatments	ZPC	Electric Charges ($cmol_c.dm^{-3}$)
Control	3.22 a	2.53 b
Pueraria phaseoloides	3.16 a	2.98 b
Desmodium ovalifolium	3.04 b	3.14 a
Flemingia congesta	3.00 b	3.04 a
CV (%)	3.21	13.76

Means within a column with the same letter are not significantly different (alpha=0.05; Scott-Knott's test)

ZPC was at 2.53 $cmol_c.dm^{-3}$ of soil on the acid side of the zero point of titration in the control, while it was at 3.14 $cmol_c.dm^{-3}$ in those samples from *Desmodium* plots. This result is very important, mainly when it is intended to add chemical fertilizers to the system

Decomposition of the legume leaves

In both phases of the study, the fresh leaves of *Pueraria* tended to present higher concentrations of K (16.28 and 17.33 g/kg) and Mg (3.67 and 4.14 g/kg) than in *Flemingia* and in *Desmodium* and concentrations of P (2.12 g/kg) and N (29.45 g/kg) superior, in the rainy and dry seasons, respectively. During the rainy season, the N concentration tended to be higher in *Flemingia* (33.29 g/kg) and the concentrations of Ca tended to be higher in *Desmodium* (10.66 and 9.92 g/kg), in the two studied seasons.

The decomposition patterns of the legume leaves were clearly seasonal, with material losses more elevated in the rainy season. In both periods of the study, *Pueraria* lost N, K and Mg faster than the other two species, and Ca only in the rainy season. During the dry season, the three legumes presented similar P release patterns. *Desmodium* and *Flemingia* also presented similar release patterns of N, K, Ca and Mg in the dry season and K, in the rainy season. *Flemingia* presented the slowest Ca and Mg release patterns in the rainy season, and *Desmodium* was the species who released P and N more slowly.

More than 50% of the N, P and K of the leaf material of *Pueraria* was released until the second week after the pruning. Long periods of immobilization of Ca and Mg were observed in both periods of the year, except for *Pueraria*. While it stayed with just 44% and 25% of Ca at the end of the studies in the dry and rainy seasons, respectively, *Flemingia* practically didn't release Ca (80% and 94%).

Dry matter production and contribution of nutrients of the legumes leaves

Flemingia is the species that has been presenting the largest annual productions of dry matter (about 10,500 kg/ha) while *Pueraria* has been producing 5,700 kg/ha/year and *Desmodium*, 4,900 kg/ha/year. Based on the initial content of nutrients present in the leaf material of the legumes and in its nutrients release patterns, it was estimated the stock of nutrients potentially available for the fruit trees (Table 2).

Table 2. Legumes leaf dry matter and nutrients (kg/ha) released from April/97 to April/98 (disregarding those present in the branches and stems) - (means of four replications)

Treatments	Leaf Dry Matter		Nitrogen		Phosphorus	
	On pruning	Decomposed on the period	On pruning	Released on the period	On pruning	Released on the period
P. phaseoloides	2569.53	2043.52	78.73	65.94	5.30	4.59
D. ovalifolium	1982.63	1148.22	48.10	23.79	2.18	1.59
F. congesta	4839.63	2671.89	146.69	86.44	9.08	6.92
	Potassium		Calcium		Magnesium	
	On pruning	Released on the period	On pruning	Released on the period	On pruning	Released on the period
P. phaseoloides	43.70	42.19	22.26	15.20	10.27	9.27
D. ovalifolium	17.69	14.82	20.60	5.96	5.69	2.41
F. congesta	58.46	51.07	33.41	4.78	7.19	2.39

Despite of the largest amount of *Flemingia* leaf dry matter, the amounts of N, P and K released in the studied period, approach those released by *Pueraria.* The surplus not liberated quickly tends to accumulate in the system under organic form. In addition, the supply of Ca and Mg for *Flemingia* is limited, not showing any restriction for *Pueraria.*

The nutritional state of the cupuaçu (Theobroma grandiflorum)

The first evaluation of the nutritional state of cupuaçu trees, after three years of handling of the system, showed no difference among the treatments, with relationship to the concentrations of N, K, Ca and Mg (Table 3). The P concentrations differed statistically, with slightly higher concentration in the leaves collected from the control. The obtained data seem to reflect the previous rest period (dry season) and physiological stage of the sampled plants (end of the flowering phase).

Table 3. Concentrations of N, P, K, Ca and Mg in cupuaçu (*Theobroma grandiflorum*) leaves at the end of the flowering phase (means of four replications). November/98

Treatment	N	P	K	Ca	Mg
			$g.kg^{-1}$		
Pueraria phaseoloides	12.35 A	1.05 B	16.28 A	10.68 A	6.18 A
Desmodium ovalifolium	11.99 A	1.04 B	19.29 A	13.26 A	6.13 A
Flemingia congesta	11.87 A	1.06 B	17.59 A	9.03 A	5.46 A
Control	11.20 A	1.10 A	19.43 A	11.37 A	6.84 A
CV (%)	11.26	2.57	10.83	22.69	8.11

Means within a column with the same letter are not significantly different (alpha=0.05; Scott-Knott's test)

Productive behavior of the cupuaçu (Theobroma grandiflorum)

Until the moment only information regarding productivity of cupuaçu was collected during two agricultural years (Table 4). In these two occasions, the fruit trees that received the biomass of *Flemingia* tended to be more productive. From the growing period of 96/97 to 97/98 it was observed an increase in productivity in the plots with *Pueraria* and a yield reduction in the control plots. The behavior observed in the control plots seems to be related to the severe drought that took place in the last agricultural year season, as a result of the "El Ninho" phenomenon.

Table 4. Productive behavior of cupuaçu (*Theobroma grandiflorum*) in two agricultural years in the function of the treatments employees (means of four repetitions)

Treatments	Fruits weight (kg/ha)	
	Crop 96/97	Crop 97/98
Control	3416	2296
Pueraria phaseoloides	3823	4243
Desmodium ovalifolium	4088	4174
Flemingia congesta	4714	4696

Conclusions

The results obtained until now indicate that the cation stocks in the soil, particularly of K, are decreasing rapidly, even with the increased efficiency of use of these nutrients though the action of the associated legumes. This indicates that it will be necessary to supply these nutrients, especially K, through application of chemical fertilizers and to reduce the nutrient exportation through the utilization of crop residues.

The whole research work will be concluded until August 1999. Up to that point will also be concluded the studies about the stock of nutrients in the system, the effects of the legumes on the microbial biomass and micorrhyza fungi, as well as the estimation of nutrient exported from the cropping area through the fruits harvested.

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