Agroforestry Systems with emphasis in *Theobroma grandiflorum* cultivated in low fertility soils[1]

V. Ferreira de Souza [2], M. Locatelli [2*],
R. C. Quisen[3], A. H.Vieira[2]

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Introduction

The intense migratory flux that occurred to Rondonia state, Brazil, especially in the 70s and 80s, has caused intense deforestation, with the subsequent occupation of these areas with annual crops (rice, maize and beans), perennial (coffee and cocoa) and, mainly pastures. Part of the area that is utilized with annual crops is left under fallow for some years, with the objective of slash and burning in the future, and utilization with annual crops during a short period of time and, subsequently use with single perennial crops or pastures. This type of land use normally causes soil degradation, which is characterized by losses of organic matter and nutrients, as well as rapid weed infestation. Using these soils with agroforestry systems is a way of minimizing such effects. The objective of this research is to study appropriate agroforestry systems models for low fertility soils, as well as further our understanding of nutrient dynamics in these systems.

Materials and Methods

The experiment was installed in February 1987, in the Embrapa Rondonia experimental station located in Machadinho d'Oeste, Rondonia state. The coordinates of the local are 9°30' latitude south and 62° 10' longitude west of Greenwich. The climate is classified as Am, according to Koppen, with temperature and annual mean precipitation of 25.5 °C and 2400 mm, respectively. The region relief is flat and the altitude is 130 meters. The soil of the experimental area is a clayey oxisol, and the original vegetation was a primary equatorial forest.

The experiment is composed by the following treatments: 1) Brazil nut (*Bertholetia excelsa)* (12m x 12m), cupuacu (*Theobroma grandiflorum*) (6m x 6m), banana (*Musa sp*) (6m x 6m) and black pepper (*Pipper nigrum*) (6m x 6m); 2) Cordia tree (*Cordia alliodora*) (6m x 6m), cupuacu (6m x 6m), banana (6m x 6m) and black pepper (6m x 6m); 3) peach palm (*Bactris gasipaes*) (6m x 6m), cupuacu (6m x 6m), banana (6m x 6m); 4) Brazil nut (12m x 12m); 5) Cordia tree (6m x 6m) and 6) peach palm (6m x 6m). The experimental design is a randomized complete block design with four replicates.

Results and Discussion

Cupuacu production began three years after planting, harvest 1989/1990, increased until 93/94, drastically declining in the two following harvest, and increasing somewhat in 96/97. In the 97/98 harvest the production was intensively reduced (Table 1). The reduction was probably determined

[1] Research partially financed by ICRAF/ASB
[2] Embrapa Rondonia (Brazilian Enterprise of Agricultural Research) – BR 364, km 5,5 – Caixa Postal 406 – CEP 78900-970 – Porto Velho- Rondonia – Brazil (*Author for correspondence: e-mail: marilia@cpafro.embrapa.br)
[3] Embrapa Amazonia Ocidental (Brazilian Enterprise of Agricultural Research) – Rodovia AM 010- km 29 – Manaus – Amazonas – Brazil

by the delay in the rainy period, which caused high intensity of flower abortion in the months of October and November of 1994, 1995 and 1997. The accumulated cupuacu production was reduced in 26 and 49% when the species was planted in association with Cordia tree and peach palm, respectively, in comparison to the association with brazil nut (Table 1).

Table 1. Cupuacu production, harvest 89/90 through 97/98 (kg/ha), when associated with Brazil nut, Cordia tree and peach palm, and peach palm production, harvests 91/92 through 97/98 (kg/ha), in association with cupuacu and single crop - Machadinho d'Oeste, RO, Brazil, 1998.

Cupuacu production (kg/ha) In association with				**Peach palm production (kg/ha)**	
Harvest	**Brazil nut**	**Cordia tree**	**Peach palm**	**With cupuacu**	**Single crop**
1989/90	266	143	241	-	-
1990/91	781	165	505	-	-
1991/92	2481	736	912	3319	3159
1992/93	3032	1937	1936	8408	6972
1993/94	4062	2421	1722	10535	8976
1994/95	1250	1250	592	5350	4441
1995/96	1296	915	860	8034	7790
1996/97	2628	3.960	1340	5409	5781
1997/98	469	811	170	4501	9151
Sum	16265	12068	8278	45556	46270

Peach palm production began five years after planting, harvest 91/92, increased in the two subsequent harvests, followed by alternate low and high productions (Table 1). It is interesting to observe that the crop in consortium produced only 2% less than the single crop.
Regarding to forest species height growth, it was observed no cupuacu association effect when compared to the single crop (Table 2).

Table 2. Brazil nut and Cordia tree height (m) in single plots and in consortium with cupuacu – Machadinho d'Oeste, Rondonia, Brazil. 1998

Brazil nut (m)			*Cordia tree (m)*	
Age (months)	**Single**	**Consortium**	**Single**	**Consortium**
35	4.0	4.1	6.3	5.6
47	6.0	6.5	8.3	7.6
58	8.1	8.8	8.6	8.6
72	10.9	11.6	10.5	9.7
88	13.7	13.9	11.3	10.7
100	16.0	16.6	12.2	11.5

Litter total dry weight was measured in the plots in consortium (Treatments 1,2 and 3) and was higher than in the single plots (Treatments 4, 5 and 6) for the two harvest periods each year (dry – 1st and 3rd, rainy– 2nd and 4th), as it is observed in Table 3.

Table 3. Litter dry weight (kg/ha) for the years of 1996 and 1997 – Machadinho d'Oeste, Rondonia, Brazil, 1998.

Treatment	1st collection (1996)	2nd collection (1996)	3rd collection (1997)	4th collection (1997)	*MEANS*
1	7192	2652	3767	3537	4287
2	4437	1997	2946	2236	2904
3	5069	2750	3509	3329	3665
4	1132	794	2272	915	1278
5	2038	422	1273	548	1070
6	3569	1470	1724	1637	2100

The consortium of brazil nut x cupuacu x black pepper (treatment 1) has shown the highest amount of litter (Table 3) and also the highest quantities of N, P, Ca and Mg and the second of K (Table 4). These results can partially explain the higher cupuacu productivity when associated with Brazil nut, when compared with Cordia tree and peach palm, because in this treatment there is a higher nutrient availability for cycling in the system.

Table 4. N, P, K, Ca and Mg (kg/ha) in the litter – Machadinho d'Oeste, Rondonia, Brazil, 1998.

Treatment	**N**	**P**	**K**	**Ca**	**Mg**
1	94.8	3.6	15.4	108.1	17.0
2	76.3	2.8	21.3	43.8	15.7
3	68.4	3.6	7.5	48.8	14.1
4	24.8	0.9	3.8	14.8	4.7
5	32.9	1.1	12.2	18.7	7.3
6	41.9	2.9	6.4	26.6	7.8

Based in the nutrient amount found in the cupuacu fruits and peach palm racemes, in the 96/97 and 97/98 harvests, it was estimated the nutrient export through the harvests along all the productive cycle (Table 5). It is evident that the peach palm racemes nutrient exportation (Treatment 6) was much superior than cupuacu fruits (Treatments 1 and 2). The combination of crops (Treatment 3) overcame the Treatment 6 exportation for N, K and Mg, was inferior for P, but was similar for Ca.

Table 5. N, P, K, Ca and Mg amounts (kg/ha) exported by cupuacu fruits (Treatment 1 and 2), peach palm racemes (Treatment 6) and cupuacu fruits and peach palm racemes (Treatment3) during the productive cycle – Machadinho d'Oeste, Rondonia, Brazil, 1998.

Treatment	**N**	**P**	**K**	**Ca**	**Mg**
1	61.4	13.1	57.2	8.9	9.9
2	44.7	9.9	49.0	7.5	7.2
3	226.6	48.2	178.4	57.6	24.0
6	221.9	52.7	135.7	58.2	16.1

With the results obtained it is possible to hypothesize that the highest cupuacu productions when associated with brazil nut was caused by a better nutrient cycling associated with a medium exportation to the fruits. The lower productions when planted with peach palm were caused by a high nutrient exportation, mainly by peach palm racemes, in spite of a probable good nutrient cycling in the system.