Agro-Science Journal of Tropical Agriculture, Food, Environment and Extension
Volume 2, Number 2, June 2001 pp. 70 - 80
ISBN 1119-7455

PERFORMANCE OF SEVEN CROP COMBINATIONS IN TWO SOILS OF DIFFERENT LAND-USE HISTORY IN EASTERN NIGERIA

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ABSTRACT

Crop yields obtained from crop mixtures grown in a newly cleared virgin forestland were compared with those from a previously cultivated farmland to assess the crops' performance between the two sites without additional soil amendments. Generally a greater number of soil physicochemical properties were considered agronomically better in the forest than in the previously cultivated land. These soil properties may constitute the driving force for significantly (p≤0.05) higher crop yields in the forestland and include: macroporosity, bulk density, saturated hydraulic conductivity, coarse sand content, pH, soil organic matter, total N, exchangeable acidity and Fe as well as base saturation. In both years, the highest cassava root yields were obtained from either cassava + maize + pigeon pea or cassava + maize intercrops (not from sole cassava plots) even though the only significant (p≤0.05) difference obtained was between cassava + maize + pigeon pea and all four crops combined, and at the cultivated farmland (UNN farm) only. This suggests that it is even disadvantageous to grow cassava as a sole crop in the area. Cassava root yield reduction in 1999 relative to 1998 was higher (70%) in the UNN farm than in the forestland (40%). There was no significant difference due to crop combination on yam tuber yield in both locations in 1998. However, in 1999 sole yam plots gave significantly higher yields than cassava + yam + maize +pigeon pea plots. Increase in tuber yields was obtained in 1999 over 1998 in both locations but it was smaller (<3%) in the forest than in the UNN farm (27%). There was no significant difference due to crop combination on maize grain yield. The pigeon pea yields obtained from sole pigeon pea plots in the forest locations in both years were generally significantly (p ≤ 0.05) higher than those obtained from the other plots. With the land equivalent ratio (LER) obtained ranging from about 1.16 to 3.48, the study shows clearly that it was much better to grow the test crops in mixtures than in pure stands. The number of crops in the mixture should, however, not exceed three as an additional crop led to depressed LER. The recommended intercrop mixture was cassava + maize + pigeon pea.

Key words: Land use, soil properties, intercropping, land equivalent ratio

INTRODUCTION

Farmers in eastern Nigeria grow a variety of staple food crops mostly by intercropping (polyculture) system. Yam (*Dioscorea rotundata*), cassava (*Manihot esculenta*), and maize (*Zea mays*) are the most prominent non-leguminous staple crops cultivated in the area. These crops are often grown in various combinations with leguminous crops like pigeon pea (*Cajanus cajan*) or cover crops like egusi melon (*Cucumeropsis manni*). Pigeon pea has been recognized as one of the oldest food crops, ranking fifth in importance among edible legumes of the world (Morton, 1976; Salunkhe et al., 1986). The advantages associated with intercropping in general are well-documented in literature (Andrew, 1972; Finlay, 1975; Okigbo, 1978, Okorji, 1986; Asadu, 1997 and Kantor, 1999). More than 70% of the food grown in the humid tropics in Africa comes from intercropping (IITA, 1985). Yam- and cassava- based crop mixtures are the most popular among the farmers in the zone and the crops are never planted in rows but in mounds (Asadu, 1989). There is often no distinct pattern of sowing the crops so that the system is better described as mixed intercropping.

Most of the soils of sub-Saharan Africa including those of Southeastern Nigeria (SEN) are low in inherent fertility and also fragile (Asadu *et al.*, 1998; Asadu and Nweke, 1999). Apart from these genetic constraints, in SEN the soils are subjected to high temperatures and rainfall of high intensity and erosivity which result in high leaching and erosion (Asadu, 1990). It has also been reported that the fertility decline in Nigerian soils is associated with abrupt changes in physicochemical properties between the topsoil and subsoil (Lal, 1985).

There are usually higher concentrations of some nutrients in the topsoil owing to greater organic matter content, but the topsoil is more exposed to erosion and leaching than the subsoil.

Agricultural activities provide the most potent example of human interference effects on soil fertility depletion especially through crop harvest, animal grazing and bad cultural practices (FDALR, 1982; Asadu, et al., 1999). Farmers, through cultivation activities, deplete soil nutrients. This is more obvious in SEN because the fallow system has almost disappeared due to increasing population pressure (Nweke *et al.*, 1994). When crops of different rooting systems are grown together as in mixed intercropping, the crops deplete entire root zone leaving the soil bereft of nutrients for the next cropping season. With a shortened fallow period or no fallow at all as is the case in SEN, and when coupled with mixed intercropping, the soil becomes poorer with lapse of time. The cost, non-availability, side effects and less experience of the farmers about type, rate, and time of application of fertilizers constitute the major constraints facing the use of mineral fertilizers by the local farmers (Nweke *et al.*, 1991; Asadu and Ugwu, 1997).

The target of this work is to evaluate the performance of some common crop mixtures containing legume species as a soil-enriching component, in soils with contrasting land-use history in eastern Nigeria.

MATERIALS AND METHODS

Study Location

This study was conducted in Nsukka which is located on 06^0 52'N, 07^0 24'E and elevation of 447 m above sea level within the derived savanna zone of SEN. It has two seasons the rainy and the dry seasons. The former usually lasts from April to October with a short break (*August Break*) normally in the month of August. Average annual rainfall is about 1550 mm; more than 85% of this falls within the rainy season. The average minimum temperature is about 22 ^{0}C and the maximum is 30 ^{0}C while the average relative humidity is rarely below 60%.

Site Preparation, Crop Mixtures and Experimental Design

Two sites, about 2 km apart, were chosen for the study. One was a virgin forest while the other was at the University of Nigeria, Nsukka (UNN) experimental farm. The latter had been under cultivation for at least 25 years but under fallow for about 8 years prior to the establishment of the trials in 1998. The forest was dominated by some wild economic trees like oil bean (*Pentaclathra macrophylla*), ogbono (*Irvengia gabonensis var gabonensis*) and oil palm (*Elaesis guinensis*). Grasses were not found as undergrowths as opposed to the case in regenerated forests.

The site for the study was completely cleared of vegetation by cutting the trees and shrubs, removal of trunks and stumps, and burning the remaining vegetation after drying. The making of ridges (1 m x 1m) with local hoes then followed. The UNN farm was dominated by grass species mainly *Andropogon* spp. The grasses were also slashed and burnt before ridges were made like in the case of the forest. No mineral fertilizer was applied since it was intended also to see how the legume could contribute to soil fertility re-generation under continuous cultivation.

The following crops and crop mixtures were selected by a step down technique based on prior knowledge of the commonest staple food crops grown by the local farmers: Cassava + yam + maize + pigeon pea (T1), Cassava + maize + pigeon pea (T2), Cassava + pigeon pea (T3), Sole cassava (T4), Sole pigeon pea (T5), Sole maize (T6) and Sole yam (T7). These seven crop treatments were arranged in a randomized complete block design and replicated three times at the two sites for the two successive years, 1998 and 1999. Apart from the cassava variety which was an improved variety (TMS 30572) bred at IITA, other crops were local bests.

The trials were established between the 15 and 18 May each year. Each crop was planted at a spacing of 1m x 1m on the crest of the ridges for all crops in plots under sole crops and also for yam and cassava in mixtures. Maize and pigeon pea were planted by the sides of the ridges in mixtures. However, two grains of maize and two seeds of pigeon pea were planted per hole as done by the local farmers in the area. This population was maintained in both plots of the sole and crop mixtures. In each location an area of 20 m^2 at the centre of each plot was harvested for the analysis. The estimated crop yield parameters were root, shoot weight and harvest index (ratio of agricultural/biological yield) of cassava; weight of grain/seed, and husk/chaff of maize and pigeon pea; weight, shape index (length/width) of tubers of yam. The grains/ seeds were dried to moisture content of about 15% before the final weight was obtained.

Soil Sampling and Analysis

In both 1998 and1999, loose soil samples were collected from each of the replicate plots at two depths, 0-20 and 20-40 cm with an auger before cultivation commenced. Prior to analysis, the samples were air-dried, gently crushed and sieved with a 2-mm sieve. Undisturbed samples were also collected with soil core samplers for determining bulk density, pore-size distribution, and saturated hydraulic conductivity.

Particle-size distribution analysis was done by the Bouyoucos (1951) method using sodium hexametaphosphate as the dispersant. Bulk density was determined by the core method (Blake, 1965). The saturated hydraulic conductivity was obtained according to the modified Klute (1965) method.

The soil pH was determined in duplicate both in water and in 0.1N KCl using Beckman's zeromatic pH meter, in a soil: liquid suspension of 1:2.5. Exchangeable bases were extracted with neutral, 1N ammonium acetate (NH_4OAc). Calcium and Mg were determined by atomic absorption spectroscopy while K and Na were determined using flame photometry. Exchangeable acidity was determined by the method outlined by Mclean (1965). Effective cation exchange capacity (ECEC) was obtained by summing up the total exchangeable bases (TEB) and total exchangeable acidity (TEA). Base saturation was calculated from 100TEB/ECEC.

Total nitrogen was determined by the macro-Kjeldahl method (Bremner, 1965). Organic carbon was determined by the method of Walkley and Black (1934), and soil organic matter (SOM) content was obtained by multiplying the percentage carbon by 1.724. Available P was determined by Bray 2 method (Bray and Kurtz, 1945). Exchangeable Fe and Cu were determined according to methods described by AOAC (1990); exchangeable Mn and Zn according to Vogel (1964) method, and available B according to Hatcher and Wilcox's (1950) method.

Statistical Analysis

An analysis of variance (ANOVA) was carried out on the soil and yield parameters using the method described in SAS (1985) and the mean differences were compared to their corresponding least significant differences at 95% confidence level. The percentage changes (Y) in selected yield parameters between the two crop years were calculated from the equation below

$$Y = 100(z-x)/x$$

where z = 1999 value

x = 1998 value.

The performance of the crop mixtures was further evaluated using land equivalent ratio (LER) calculated from the equation derived from Kantor (1999):

$$LER = Y_{1i}/Y_{1p} + Y_{2i}/Y_{2p} + \ldots\ldots + Y_{ni}/Y_{np}$$

where

Y_{1i} = yield of crop 1 in intercrop

Y_{1p} = yield of crop 1 in pure stand

Y_{ni} = yield of crop n in intercrop

Y_{np} = yield of crop n in pure stand

The resulting figures usually indicate the land needed to grow both crops together compared to the amount of land needed to grow the pure stands of each. Values greater than unity indicate advantage of intercropping while values less than unity indicate disadvantage of intercropping (Kantor, 1999). The LER was computed using only the major agricultural yields of the various crops namely, root yield for cassava, tubers for yam, grain for maize and seed for pigeon pea. The graphic illustration of LER vs number of crops in crop mixtures was performed using XY plot programme of Excel on Windows.

RESULTS

Soil Information

The major differences in the soils (e.g.SOM, pH, total N) were found to be in the 0-20 cm depth and the differences have been associated with their use history. In 1998, nineteen soil properties showed significant ($p \leq 0.05$) differences between the two locations while in 1999, only fifteen of them showed similar trend (Table 1). The largest difference was obtained in the content of silt (about 137% higher in the UNN farm soil) and the least was obtained in the soil pH (about 9% higher in the UNN soil also). However, apart from these two properties as well as clay content, microporosity, bulk density and exchangeable boron, all the other 13 properties were higher in the forest soil and

Table 1: Comparison of means of soil physicochemical properties obtained from 0-40cm depth in both years that showed significant differences between the two locations

Soil property	Year/Location			Year/Location		
	1998 Forest	1998 UNN farm	$LSD_{(0.05)}$	1999 Forest	1999 UNN farm	$LSD_{(0.05)}$
Clay (%)	23.5	27.7	2.6	24.3	26.7	1.98
Silt (%)	3.0	7.1	2.9	3.2	4.5	ns
Fine sand (%)	24.1	17.0	1.80	41.4	53.7	ns
Total sand (%)	73.4	66.3	5.0	72.5	68.8	1.9
Macroporosity (%)	15.9	6.8	4.8	20.0	5.3	5.6
Micropoprosity (%)	16.9	28.9	4.6	35.5	35.4	ns
Bulk density(g cm^{-1})	1.42	1.60	0.10	1.32	1.44	0.10
Hydr. cond. (cmh^{-1})	43.3	35.5	5.2	120.2	45.2	28.1
pH	4.3	4.7	0.1	4.3	5.6	0.3
Organic matter (%)	2.03	1.07	0.18	3.39	1.81	0.79
Total N (%)	0.106	0.065	0.009	0.14	0.09	0.04
Exch. K ($cmolkg^{-1}$)	0.13	0.07	0.04	0.06	0.07	ns
Exch. Ca ($cmolkg^{-1}$)	0.77	0.60	0.11	2.18	1.69	ns
Exch. Mn ($cmolkg^{-1}$)	0.66	0.24	0.12	0.107	0.191	0.117
Exch. Fe ($mgkg^{-1}$)	76.7	11.0	24.6	83.3	58.6	23.05
Exch. Cu ($mgKg^{-1}$)	1.13	0.61	0.33	0.34	0.65	0.199
Exch. B ($mgKg^{-1}$)	4.62	6.19	0.88	33.1	56.1	22.34
Exch. Zn ($mgKg^{-1}$)	12.14	7.90	1.60	5.9	6.82	ns
Avail. P ($mgKg^{-1}$)	14.7	8.0	3.2	5.4	6.45	ns

ns = not significant

mostly appear to have more agronomic advantages.

Those properties that did not manifest significant differences between the locations in 1999 were microporosity, exchangeable Mn and Zn, as well as silt and fine sand contents. However, the differences in base saturation, total exchangeable acidity (TEA), coarse sand, and total porosity were significant between the two locations. Apart from TEA, the others were higher in the forestland (Table 1).

Effects of crop mixture and location on crop yields

Cassava

The mean root yields and harvest index (HI) shown in Table 2 indicate that the differences between the treatment (crop mixture) means were not significant in the case of the forestland in both years. It is, however, interesting to note that the highest root yields (17 t ha^{-1} in 1998 and 10 t ha^{-1} in 1999) were obtained from crop mixtures T2 (cassava + maize + pigeon pea) and T3 (cassava + pigeon pea) instead of T4 (the sole cassava plot). There was a depression of about 40% against the 1998 value at the forest and > 60% at the UNN farm site. The yield depression averaged about 52% in the intercrop and slightly higher (57%) in sole crop

The 1998 results from the UNN farm location (Table 2) showed a highly significant ($p<0.01$) crop mixture effect on the root yield. Crop combination T2, gave significantly higher yield than each of T4 (sole cassava) and T1 (cassava + yam + maize + pigeon pea). However, the difference between the root yield from T2 (cassava + maize + pigeon pea) and T3 (cassava + pigeon pea) was not significant. Again there was no significant difference in relation to the harvest index. The 1999 root yields obtained from the UNN farm location (Table 2) showed no significant effect of crop mixture on the root yield. Significantly higher harvest indices were obtained from T3 (cassava + pigeon pea) and T4 (sole cassava) than from T1 (cassava + yam + maize + pigeon pea) and T2 (cassava + maize + pigeon pea).

Table 2 indicates that location effect was highly significant ($p < 0.001$) on both the root yield and harvest index in both years. Higher yields were obtained from the forestland than from the UNN farm.

Yam

Table 3 shows that treatment effects were not significant on yam yield parameters in both locations in 1998 but were significant ($p<0.05$) in 1999. The effects of treatment on the shape index (better shaped tubers) in both locations were not significant.

Table 2: Mean effects of crop mixture and location on cassava yield parameters in 1998 and 1999 in the two locations

Treatment combination	Root yield (t ha^{-1})	Harvest index	Root yield (t ha^{-1})	Harvest index
	1998 Forestland		1999 Forestland	
T1 = C+P+M+Y	13.3	0.28	9.1	0.29
T2 = C+P+M	17.0	0.29	9.6	0.26
T3 = C+P	16.5	0.27	9.7	0.29
T4 = SC	15.7	0.27	7.8	0.23
F-test	ns	ns	ns	ns
LSD(0.05)	11.50	0.12	2.87	0.15
	1998 UNN farm		1999 UNN farm	
T1 = C+P+M+Y	8.4	0.66	3.1	0.58
T2 = C+P+M	11.9	0.69	2.3	0.53
T3 = C+P	10.0	0.67	2.4	0.63
T4 = SC	9.1	0.68	2.8	0.63
F-test	**	ns	ns	*
LSD(0.05)	2.37	0.05	2.01	0.05
	1998 location		1999 location	
Forestland	15.61	0.28	9.03	0.27
UNN farm	9.88	0.68	2.67	0.59
F-test	**	**	**	**
LSD(0.05)	3.36	0.06	2.47	0.05

C = cassava, P = pigeon pea, M = maize, Y yam, S = sole; ns, *, ** = not significant, significant at 0.05 and 0.01 probability level respectively.

Table 3: Mean effects of crop mixture and location on yam yield parameters in 1998 and 1999 in the two locations

Treatment combination	Tuber yield (t ha^{-1})	Shape index	Tuber yield (t ha^{-1})	Shape index
	1998 Forest		1999 Forest	
T1 = C+P+M+Y	7.6	1.26	8.3	1.06
T7 = SY	10.9	1.35	10.7	1.19
F-test	ns	ns	**	ns
LSD(0.05)	9.29	0.16	2.09	0.17
	1998 UNN farm		1999 UNN farm	
T1 = C+P+M+Y	5.1	1.02	5.2	0.96
T7 = SY	6.8	1.05	9.9	1.12
F-test	ns	ns	*	ns
LSD(0.05)	3.05	0.17	4.22	0.25
	1998 Location		1999 Location	
Forest	9.3	1.31	9.5	1.12
UNN farm	6.0	1.04	7.5	1.05
F-test	*	*	ns	ns
LSD(0.05)	1.52	0.05	5.72	0.12

C = cassava, P = pigeon pea, M = maize, Y yam, S = sole; ns *, **, = not significant, significant at 0.05 and 0.01 probability level respectively.

A comparison of yam yields (Table 3) obtained from both locations in 1998 gave a significant ($p<0.05$) location effect on both the tuber weight and shape index. A higher yield (≅ 9 vs 6 t ha^{-1}) was obtained from the forestland than from the UNN farm.

Maize

In both years, the effect of crop mixture was not significant on either the dry grain or stover yields of maize (Table 4). The mean cob weights obtained in 1998 from T1 (all crops) and T2 (cassava + maize + pigeon pea) were significantly ($p<0.05$) lower than that from T6 (sole maize) plots. Similarly the mean obtained from T2 (cassava + maize + pigeon pea) was significantly ($p<0.05$) higher than that from T1 (all crops). In 1999 at the UNN farm site, the values from both T1 (all crops) and T2 (cassava + maize + pigeon pea) were nearly similar but significantly ($p<0.05$) higher than that obtained from T6 (sole maize). For both the stover and seed yields only the difference between stover yield from T6 (sole maize) and T1 (all crops) at the UNN farm in 1998 (Table 4) was significant ($p<0.05$).

Table 4: Mean effects of crop mixtures on maize yield parameters in 1998 and 1999 in the two locations (kg ha^{-1})

Treatment combination	Cob weight (field dry)	Stover weight	Grain weight	Cob weight (field dry)	Stover weight	Grain weight
	1998 Forestland			1999 Forestland		
T1= C+P+M+Y	150	35	90	4300	420	1300
T2 = C+P+M	280	63	200	4500	450	1630
T6 = SM	630	65	170	4200	330	1030
F-test	**	ns	ns	ns	ns	ns
LSD(0.05)	80	69	160	4300	630	2250
	1998 UNN farm			1999 UNN farm		
T1= C+P+M+Y	150	8	60	1400	90	200
T2 = C+P+M	430	54	160	1530	130	270
T6 = SM	640	83	220	770	120	280
F-test	ns	*	ns	**	ns	ns
LSD(0.05)	510	48	260	670	110	440

Notes C = cassava, P = pigeon pea, M = maize, Y yam, S = sole; ns *, **, *** = not significant, significant at 0.05, (and <0.001 probability level respectively.

Table 5: Mean effects of the crop mixtures on pigeon pea yield parameters in 1998 and 1999 in the two locations (kg ha^{-1})

Treatment combination	Chaff weight	Seed weight	Chaff weight	Seed weight
	1998 Forestland		1999 Forestland	
T1= C+P+M+Y	10	10	14	12
T2 = C+P+M	20	10	50	35
T3 = C+P	10	10	34	18
T5 = SP	150	90	57	45
Location mean	48	30	40	28
F-test	***	**	*	*
LSD(0.05)	20	30	33	24
	1998 UNN farm		1999 UNN farm	
T1= C+P+M+Y	10	10	36	47
T2 = C+P+M	10	10	24	28
T3 = C+P	10	10	28	50
T5 = SP	40	30	25	36
Location mean	18	15	28	40
F-test	**	*	ns	ns
LSD(0.05)	10	10	12	37

C = cassava, P = pigeon pea, M = maize, Y yam, S = sole; ns *, **, *** = not significant, significant at 0.05, 0.01 <0.001 probability level respectively.

Table 6: Summary of land equivalent ratios (LERs) obtained in both locations for the two years

Intercrop system	1998 Forest	1998 UNN farm	1999 Forest	1999 UNN farm
Sole Cassava	1	1	1	1
Sole yam	1	1	1	1
Sole maize	1	1	1	1
Sole pigeon pea	1	1	1	1
C+ P	1.16	1.43	1.65	2.25
C+ M+P	2.37	2.36	3.61	2.57
C+M+P+Y	2.09	2.27	3.48	3.66

C = cassava, P = pigeon pea, M = maize, Y = yam

Pigeon Pea

Table 5 shows that in 1998, both the seed and chaff yields of pigeon pea obtained in both locations from the sole pigeon pea plots were significantly ($p \leq 0.05$) higher than those from other plots grown to other crop combinations. Similarly, in 1999 at the forest location, both yields obtained from the T5 (sole pigeon pea) plots were significantly ($p \leq 0.05$) higher than those from both T1 (cassava + maize + yam + pigeon pea) plots and T3 (cassava + pigeon pea) plots. Significantly higher yields also of pigeon pea were obtained from the forest location than from the UNN farm and in 1999 than from 1998.

Assessment of mixtures using land equivalent ratios (LER's)

The LERs obtained in each location in both years

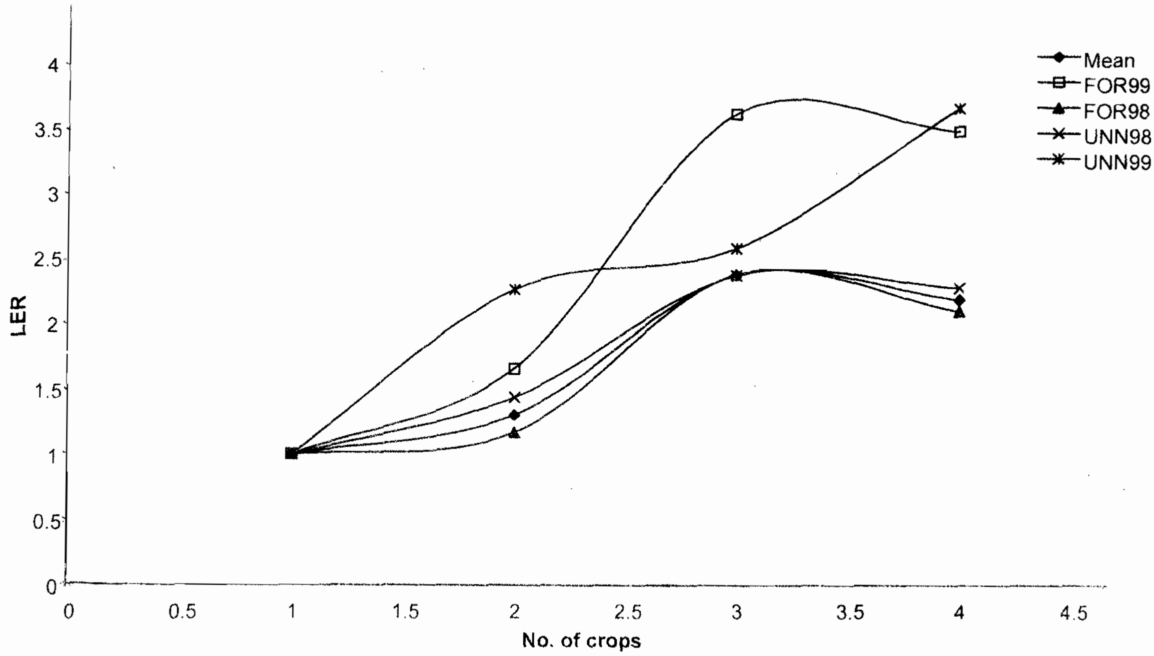

Figure 1: Plot of all the LERs against the number of crops in each intercrop (FOR98. FOR99 = data from forest in 1998 and 1999: UNN98. UNN99 = data from UNN farm in 1998 and 1999)

(Table 6) indicate that, in all cases, intercropping was far better than sole cropping by minimum increases of 16% obtained in the case of cassava + pigeon pea in the 1998 yield data from the forest and a maximum of 248% obtained in the case of all the crops combined in the year 1999 at the forest location. All the intercrop systems were, however, not equally efficient with respect to sole cropping. The reason for this variation is not easily discernible from the current data.

An XYplot of LER vs number of crops (Fig. 1) shows the relationship between all the LER values obtained with respect to the number of crops and the mean values obtained in both locations. Increase in LER appears to be exponential when the number increases from two to three but declines just after the number exceeds three. Only the values obtained in 1999 at the UNN location (UNN99) did not follow this trend. However, the overall mean for the entire location (mean) for the two years followed the same trend. Assessment of the crop mixtures using LER also supports the inference made using the cassava + maize + pigeon pea intercropping option, for the area under study. However, it is more beneficial to grow the test crops in mixtures with the best option is to combine a maximum of three crops preferably cassava + maize + pigeon pea.

DISCUSSION

The summary of the soil characteristics shows that the different land uses adopted in the locations affected the fertility status of both soils. On the average, the soil properties that may be considered agronomically better in the forest location such as macroporosity, hydraulic conductivity, bulk density, SOM, and total N may be associated with the differences in SOM. This is because higher SOM is often obtained from virgin land than from a previously cultivated land, as is the case with the UNN farm. In Nsukka area, there still exist some isolated virgin forests owned by communities. Such forests are considered 'virgin' because they have no history of previous cultivation in the past. This information was obtained from the natives through an interview. The forests are often reserved for such uses as fetching of firewood, hunting, collection of wild edible fruits and vegetables as well as for idol worship. Soil organic matter influences the other properties because it is strongly correlated with them (Mbagwu et al., 1983; Orkwor and Asadu, 1998).

The lowest cassava root yield and harvest index obtained from sole crops than crop mixtures suggest that there could have been extra shoot yield from the sole cassava plot, which did not manifest in root yield. The mean root yields obtained in 1998 were, however, comparable to values reported for the same cassava variety (TMS 30572) used in the Nsukka environment (Nnodu et al., 1995) but in 1999 the mean was lower probably due to nutrient degradation.

The mean root yield for both years from the forest location (12.3 t ha^{-1}) was close to11.89 t ha^{-1} reported by Nweke (1996) for the sub-Saharan African subregion while that from the UNN location (6.3 t ha^{-1}) was almost one half of this value. This difference in yield between the locations can be inferred from the differences in the soil physico-chemical properties due to their use history (Table 1). The decreases in both exchangeable K (>50%) and available P (>60%) which are major nutrients often required by cassava for good yields could account for the drop in cassava yields from 9.9 t ha^{-1} to 2.7 t ha^{-1} between 1998 and 1999 at the UNN farmland. Unlike the forest soil, the UNN farm had been under cultivation for about 25 years although it was under fallow for up to 8 years before 1998 when the trials were established. Thus, based on the requirements of the crops studied, virtually all the properties were better in the forestland than at the UNN farm. Other soil properties, the values of which decreased in the location within the corresponding period and which might have contributed to the decline in yield, were exchangeable Mn, Zn ,and available P (Table 1).

The trends in cassava yields at both locations suggest that it is better to grow cassava in combination with other crops than as a sole crop based on the root yield alone especially with respect to the forest location. This assertion is strengthened when the yields from the component crops are considered as well as the improvement in the soil N expected from pigeon pea. In addition to increased yields and insurance against pests and diseases, intercropping has been found to increase biodiversity, stability and financial diversification of the farm (Andrew, 1972; Finlay, 1975: Okorji. 1986; Asadu, 1997; Kantor, 1999).

The non-significant difference in yam yield 1998 between the crop mixtures suggests that growing yam in association with other crops is better than growing it alone. Even in the case of 1999, the overall benefits (in terms of yields) from the component crops (cassava, maize, and pigeon pea) would be definitely more than the tuber yield differences between T7 (sole yam) and T1 (all four crops combined). This supports that intercropping in these cases is advantageous. As in the case of cassava, the significant location effect on tuber yields can be related to differences in soil physico-chemical properties (Table 1). The most limiting nutrient in root and tuber production, which is nitrogen (Obigbesan, 1978), and those highly demanded by yam, K and P (Sobulo, 1972), were all significantly ($p < 0.001$) higher in the forest soil than at the UNN farm at the time of planting. The lower bulk density in the forest also aids easier tuber and root penetration and expansion (Ohiri and Ezumah, 1990) while higher organic matter results to better improvement of CEC (Asadu and Nweke, 1999).

The higher shape index (better shaped tubers from forestland) can be discerned from the significantly ($p < 0.001$) lower bulk density of the forest soil. The forest soil had higher SOM content and better loose soil consistence, conditions that favour yam tuber penetration and expansion (Ezumah, 1986; unpublished conference paper). The bulk density values obtained from the 0-20 cm depth of the forest soil are within the range (1.2 – 1.56 gcm^{-3}) reported by Ohiri and Nwokoye (1984) for good performance of yam. The slight increases in yam yield in 1999 might have been due to those changes in the soil physical properties such as bulk density and hydraulic conductivity in addition to substantial increases in both SOM and total N in both locations (Table 1). In addition to land use, tillage would also have contributed to these changes because tillage tends to loosen the soil and this often results to lower bulk density, higher saturated conductivity, and increased aeration that enhances SOM mineralization and N availability.

The non-significant effects of crop mixtures on most maize yield parameters suggest that sole maize cropping may not be as advantageous as intercropping maize with other crops. In Nepal, a LER of 1.68 has been reported for a pigeon pea + maize intercrop (Paudel, 2001) indicating 68% better performance for intercrop of maize with pigeon pea than their yields when cultivated solely.

The pigeon pea yields indicated that pigeon pea grown alone performed better than when grown with other crop, indicating competition between the crops for plant growth factors mainly light and soil nutrients. This can be considered a disadvantage of intercropping on pigeon pea performance. However, pigeon pea is known to grow slowly at the initial stage comparing with maize but covers up more quickly towards the time maize is about to be harvested. This advantage was given as the major reason for a high LER of 1.68 obtained from a pigeon pea + maize intercrop in Nepal (Paudel, 2001). However, the disadvantage of reduced yield is normally weighed against the advantages obtained from intercropping as well as soil enrichment resulting from pigeon pea cultivation. It has been found that pigeon pea does not require artificial rhizobial inoculation because it can be nodulated by indigenous rhizobia and can fix atmospheric N (Faris, 1983). Pigeon pea can fix as much as 70 kg N ha^{-1} per season till the mid-pod-fill stage and has, thus, been then described as the superb crop for intercropping with cereals and other non-fixing crops (Phatak et al., 1993). Even though the mean yields obtained from the sole crop plots were significantly different from those from plots grown to a mixture of the other crops, the farmers often prefer mixed intercropping as the cash returns from intercropping have been shown to be significantly higher than from monoculture (Andrew, 1972; Finlay, 1975; IITA, 1985; Asadu, 1997).

CONCLUSION

A comparison of the physicochemical properties of soils of a newly cleared virgin forest and previously cultivated land in Southeastern Nigeria showed that measures of 15 properties were significantly different between them and can be attributed to their use history. Generally all the staple food crops tested in both locations performed better at the forest location owing to more favourable soil physicochemical properties. Between the two cropping years, the yields of yam slightly increased, those of maize and pigeon pea improved substantially, while that of cassava decreased. The changes in crop yields were explained in relation to variations in soil properties.

Acknowledgement

The Cassava Program of the International Institute of Tropical Agriculture (IITA) sponsored this study. The authors gratefully acknowledge its financial support. The contributions of the reviewers towards improving the quality of this paper are also acknowledged.

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