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Full Length Research Paper

Economic evaluation of soil fertility management options on cassava-based cropping systems in the rain forest ecological zone of south western Nigeria

Makinde, E. A.[1], Saka, J. O.[2]* and Makinde, J. O.[2]

[1]Federal College of Agriculture, A.A.R&T., Ibadan, Nigeria.
[2] Institute of Agricultural Research and Training, Ibadan, Nigeria.

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This study was carried out to determine the economic viability of fertility management options in cassava based cropping systems. Data were obtained from an on-station agronomic trial carried out in 1995 and 1996 in the rainforest agro-ecological zone of south western Nigeria. Economic evaluation was carried out using partial budget and Marginal Rate of Return (MRR) Analyses. The result showed that higher net returns were obtained from inorganic fertilizer (N 285,748 in 1995 and N259,569 in 1996) followed by inorganic fertilizer + Soybean + soybean residue (N274,826 in 1995 and N255,413 in 1996). However, the result of the MRR analysis indicated that farmers stand to gain better if they change from no fertilizer control to either organic fertilizer (278%) or further to inorganic fertilizer with a MRR of 1255% respectively. Similar result was obtained in 1996 with organic fertilizer (494%) and inorganic fertilizer (1115%). However, considering the problem of scarcity often associated with inorganic fertilizer, the choice of organic fertilizer is more likely to be accepted by the farmers.

Key words: Production economics, fertility management, cassava-based cropping systems.

INTRODUCTION

Risk reduction through stability of income and yield are two of the reasons people diversify their crop and livestock systems. Increasing diversity on-farm also reduces costs of pest control and fertilizer, because these costs can be spread out over several crop or animal enterprises (Preston, 2003). In Sub Sahara Africa, intercropping as a form of diversification has however been a prominent feature of smallholder crop production for ages and despite earlier persistent efforts of research to promote monoculture, intercropping has remained a conspicuous feature of cropping systems of smallholder farmers across the sub region. The need to create security against potential risk of monoculture has been one of the driving forces behind intercropping especially among smallholder farmers who depend to a large extent, on vagaries of nature and are as such exposed to a diverse level of risk in their production (Muhammad et al., 2003; Preston, 2003; Tsubo et al., 2003).

However, one of the basic challenges in multi-cropping system is the inherent competition for space soil nutrients moisture etc. among the component crops and when the cultural practice adopted by the farmer does not cater for such competitions adequately; reduction in soil fertility, land degradation and consequently, low productivity result.

Averagely, 60 - 70% of the cropped land is devoted to growing crops in mixtures of two or three crops with cassava-maize-melon intercrop being one of the most popular inter- planting patterns in southern Nigeria (Olukosi et al., 1991).

Cassava is mainly intercropped with maize or upland rice in the tropics. These fast- growing cereals reduce nutrient loss through leaching, runoff and erosion by utilizing a substantial amount of N mineralized (100 to 300 kg N/ha) during the onset of the rainy season (Mueller-Harvey et al., 1985; in Hossner and Juo, 1999). However, maintaining soil fertility and productivity over long periods with inorganic fertilizer application have been shown to result in increased soil degradation and nutrient imbalance (Avery, 1995). This is alongside its scarcity and high cost amidst declining capabilities of farmers to procure external inputs. African farmers have however been known to apply organic manures notably from materials including crop residues as a means of re-

*Corresponding author. E-mail: saka_sakang@yahoo.com.

Table 1. Yield values of maize, melon and soybean under different fertilizer treatments (1995 and 1996)

	Maize Yield (t/ha)		Melon (kg/ha)		Soybean (kg/ha)	
	1995	1996	1995	1996	1995	1996
No Fertilizer	0.91^{b}	0.74^{b}	126.1^{b}	128.3^{b}	183.6^{b}	173.5^{c}
Organic	1.01^{b}	0.76^{b}	167.0^{b}	227.8^{ab}	589.6^{a}	373.0^{a}
Inorganic	1.85^{a}	1.75^{a}	253.7^{a}	297.2^{a}	186.7^{b}	264.0^{b}
Organic + Inorganic	1.64^{a}	1.76^{a}	265.4^{a}	295.7^{a}	435.6^{a}	325.5^{ab}

Values carrying different superscripts within columns are significantly different (P=0.05).

recycling nutrients. Organic manure also improves soil structure, aeration, drainage, transportation and retention of heat and air in the soil; and prevents surface crusting (Cooke, 1982; Agbim and Adeoye, 1991; Latham, 1997).

Parr et al. (1990) further observed that an important feature of sustainable agriculture is its lower dependence on chemical fertilizer and recycling of on-farm crop residues to maintain or improve soil fertility. The sustenance of practices that incorporate such condition invariably depends to a large extent on its effectiveness in increasing productivity and generating commensurate returns; as farmers have been shown (Sevilleja, 2000; Clayton, 2005) to constantly weigh the resulting cost and benefit associated with changing from one practice to another. The aim of this study therefore is to determine the best intercrop and fertility management option in a cassava-based intercropping system for optimum economic benefit.

MATERIALS AND METHODS

Data for this study were obtained from an agronomic field trial conducted at the Ibadan Station (lat. 7^{0} 22" N, long. 3^{0} 50"E) of the Institute of Agricultural Research and Training in the rainforest agro ecological zone of South western Nigeria. Total annual rainfall of the experimental site during the period was 1492mm and 1425mm for 1995 and 1996 respectively. Average daily temperatures ranged between $17.1^{o}C$ and $35.1^{o}C$ with a mean minimum relative humidity of 23% in February and a maximum of 79% in August.

The experiment was laid out in a split plot design with nutrient source as the main plot and soybean residue management as the subplot. The main treatment included: organic fertilizer (OF); inorganic fertilizer (In) and a mixture of organic and inorganic fertilizer (AF). The sub treatments were: soybean planted with residue removed (S), soybean planted with residue retained (R). A no fertilizer treatment (NF) and a no-soybean planted treatment served as the control treatment for the main plot and the subplot of sizes 20.5 m x 6 m and 5.5 m x 4.0 m respectively

The sole organic fertilizer treatment was an equal mixture of domestic waste and cow dung applied at 10t/ha while inorganic fertilizer was 150 kg N supplied as Urea and 50 kg P as single super phosphate fertilizer per hectare. The mixture of organic and inorganic fertilizer treatment contained 5 t/ha of organic fertilizer and 75 kg N + 25 kg P/ha. Crop varieties are: maize (TZE comp.311) established at 1.0 m x 5.0 m; 2 seeds/stand; Melon (Western local) established at 1.0 m x 1.0 m; 2 seeds/stand at the beginning of the rains; cassava (TMS.30572) planted at 1.0 m x 1.0 m ten weeks after planting maize and melon and Soybean (TGX 536-02D) sown at 5 cm intra-row spacing in between the cassava rows while soybean residue was recycled into the soy-bean retained plots.

In determining the most economically acceptable treatment, partial budget analysis was carried out to estimate the gross value of the component crops using the adjusted yield (CIMMYT, 1988; Asumadu et al., 2004) at 2005 market price for the crops and inputs. The prevailing rates paid to farm labourers at the location were used to estimate the labour cost that vary. The accruing net benefit and the costs that vary were then compared across the treatments in dominance analysis based on the criterion that any treatment that had net benefit equal to or lower than that of another treatment with lower cost is dominated and as such would not be considered for investment by the farmer (CIMMYT, 1988). Also, marginal analysis was carried out on the undominated treatments in a stepwise manner, starting from one treatment with the lowest costs that vary to the next. This is to show how the net benefit from a decision to change from one cropping system to another increases with cost. Usually, a minimum rate of return is fixed as the baseline for acceptance of an option in order to account for the cost of capital, inflation and risk. In this regard, several authors have established that for the majority of situations, the minimum rate of return acceptable to farmers is between 40 and 100% (CIMMYT 1988; Dillon and Hardaker, 1993; Asumadu et al ., 2004). A minimum rate of return criterion of 50% (CIMMYT, 1988) was set for the Marginal Rate of Return (MRR) analysis as the treatments require that farmers change from one cropping system to another without having to learn new skills or acquire new equipments. Consequently, any treatment that returns MRR above 50% is considered worthy of investment by farmers.

RESULTS

Grain yield

There were no significant differences in maize grain yields from both inorganic fertilizer and a mixture of organic and inorganic fertilizers but grain yields from both were significantly higher than yields from organic fertilizer application and the control plots in both 1995 and 1996. A similar trend was observed for melon yield in 1995 but in 1996, melon yield under organic fertilizer was not significantly different from melon seed from inorganic and Organic + inorganic fertilizer treatments (Table 1).

Soybean yields were most favoured with organic fertilization. Yields from complementary application of organic and inorganic fertilizers were comparable but inorganic fertilizer gave a significantly lower yield as well as the no fertilizer (control) treatment (Table 1). Cassava

Table 2. Cassava tuber yield under different fertilizer and residue management treatments in 1995 and 1996.

Year	Treatment	No soybean planted	Soybean planted	Soybean planted + residue	Mean
1995	No Fertilizer	21.3	17.9	18.5	19.3[b]
	Organic	23.8	20.1	22.9	22.3[a]
	Inorganic	20.9	18.3	20.9	20.1[b]
	Organic + Inorganic	21.3	19.1	20.5	20.3[b]
	Mean	**21.9 [a]**	**18.9 [a]**	**20.7 [a]**	
1996	No Fertilizer	17.3	14.5	15.9	15.9[a]
	Organic	21.8	16.3	18.5	18.9[a]
	Inorganic	17.4	14.4	17.7	16.5[a]
	Organic + Inorganic	17.4	16.7	18.3	17.5[a]
	Mean	**18.5 [a]**	**15.5 [b]**	**17.6 [a]**	

Mean values followed by different superscripts across rows and columns in a year are significantly different (P=0.05)

root yield was not significantly affected by either fertilizer type or residue management in 1995. However, organic fertilizer application gave the highest average root yield of 22 t/ha. In 1996, soybean residue management significantly affected cassava root yield while cassava/soybean intercrop without residue incorporation gave significantly lower yields, but the residue recycling gave yield values comparable to sole cassava (Table 2).

Partial budget and marginal rate of return (MRR) analyses.

The economic analysis of the farm operations using the partial budget techniques are presented in Tables 3 and 4. In 1995, higher net benefit of ₦285,748 and ₦274,826 were obtained from inorganic fertilizer and inorganic + Soybean +soybean residue respectively while a lower net benefit of ₦194,907 and ₦ 190,789 were obtained from No fertilizer +soybean +residue and No fertilizer + soybean respectively (Table 3).

In 1996, inorganic fertilizer and inorganic fertilizer + soybean + residue returned higher net benefits of ₦259,569 and ₦255,413 respectively while lower net benefit of ₦ 164,914 and ₦155,260 were obtained from No fertilizer + soybean + residue and No Fertilizer + soybean respectively (Table 4).

However, the dominance analysis rendered 9 of the 12 treatments unacceptable for investment as there are other treatments with higher net returns at lower cost thereby leaving 3 treatments for the marginal rate of return (MRR) analysis. The MRR analysis however showed that for both years, MRR values for changing from the no-fertilizer control to organic fertilizer were 278 and 494% respectively. Also, changing further from organic to inorganic fertilizer returns MRR values of 1255 and 1115% in 1995 and 1996 respectively (Tables 5 and 6).

DISCUSSION

The results have shown that while the inorganic fertilizer component gave a higher net benefit, lower net benefit were synonymous with No fertilizer components. The MRR which shows the additional profit accrued by changing from one option to the other in the order of increasing cost shows that in both years, farmers stand to gain a marginal rate of return higher than 50% of the cost of changing from the control to any of the two undominated treatments (organic and inorganic fertilizer) with the change to inorganic fertilizer giving the best result.

Among the environmental factors that interact in the field with a crop, soil nutrient is perhaps the most important because of its agronomic importance in crop performance. Inorganic fertilizer is the most readily available means of replenishing soil fertility and consequently improved crop performance. However, experience in recent past has revealed the sustainability constraints associated with scarcity of inorganic fertilizer hence the need to consider readily available alternatives. The empirical evidence from this study has revealed both agronomic and economic potential benefits in the use of organic fertilizer. Though not the best option, the results in the two years indicated that farmers stand to gain in return for every ₦100 invested in changing from the no fertilizer option to application of organic fertilizer, a sum of ₦278 (1995) and ₦494 (1996) respectively. Although, the inorganic fertilizer + soybean + residue ranked among the treatment with the highest net benefit in the partial budget analysis, the fact that the net benefit is achievable at a higher cost relative to inorganic fertilizer renders the treatment dominated and less attractive to a characteristic capital constrained population of peasant farmers especially when there is another option with a higher net benefit at lower cost.

Similarly, despite the fact the inorganic fertilizer gave the best result in terms of net benefit and MRR values,

Table 3. Partial Budget Analysis of the different fertilizer and residue management treatments in 1995

1995	No Fertilizer			Organic Fertilizer			Inorganic Fertilizer			All Fertilizer		
Benefits (Yield in kg/ha)	NF	NF+S	NF+R	OF	OF+S	OF+R	In	In+S	In+R	AF	AF+S	AF+R
Cassava	21,340	17,870	18,520	23,780	20,130	22,920	20,940	18,290	20,910	20,340	19,100	20,460
Maize	913	913	913	1013	1013	1013	1850	1850	1850	1643	1643	1643
Melon	126	126	126	167	167	167	254	254	254	265	265	265
Soybean	0	188	180	0	602	578	0	192	182	0	447	425
Adjusted Yield												
Cassava	19206	16083	16668	21402	18117	20628	18846	16461	18819	18306	17190	18414
Maize	821.7	821.7	821.7	911.7	911.7	911.7	1665	1665	1665	1478.7	1478.7	1478.7
Melon	113.4	113.4	113.4	150.3	150.3	150.3	228.6	228.6	228.6	238.5	238.5	238.5
Soybean	0	169.2	162	0	541.8	520.2	0	172.8	163.8	0	402.3	382.5
Cassava Value @ N7/kg	149380	125090	129640	166460	140910	160440	146580	128030	146370	142380	133700	143220
Maize value @ N65/kg	59345	59345	59345	65845	65845	65845	120250	120250	120250	106795	106795	106795
Melon value @ N130/KG	14742	14742	14742	19539	19539	19539	29718	29718	29718	31005	31005	31005
Soybean value @ N60/kg	0	10152	9720	0	32508	31212	0	10368	9828	0	24138	22950
Total Benefit	223467	209329	213447	251844	258802	277036	296548	288366	306166	280180	295638	303970
Cost that Vary												
Material costs												
Soybean 42kg @ N120	0	5040	5040		5040	5040		5040	5040		5040	5040
Inorg Fert 200 @ N2,200/50kg	0	0	0	0	0	0	8800	8800	8800	8800	8800	8800
Total Material Cost	0	5040	5040	0	5040	5040	8800	13840	13840	8800	13840	13840
Labour Cost												
Planting of soybean	0	4500	4500	0	4500	4500	0	4500	4500	0	4500	4500
Inor fert applicatn (4mds/ha)							2000	2000	2000	2000	2000	2000
Org fert applicatn (15 mds/ha)				7500	7500	7500				7500	7500	7500
soybean resd applctn (4mds/ha)						2000			2000	2000	2000	2000
Soybean Harvesting (18mds/ha)		9000	9000		9000	9000		9000	9000		9000	9000
Total labour cost	0	13500	13500	7500	21000	23000	2000	15500	17500	11500	25000	25000
Total cost that vary	0	18540	18540	7500	26040	28040	10800	29340	31340	20300	38840	38840
Net Benefit	223467	190789	194907	244344	232762	248996	285748	259026	274826	259880	256798	265130

— US$1=₦ 126

Table 4: Partial Budget Analysis of the different fertilizer and residue management treatments in 1996.

1996	No Fertilizer			Organic Fertilizer			Inorganic Fertilizer			All Fertilizer		
Benefits (Yield in kg/ha)	NF	NF+S	NF+R	OF	OF+S	OF+R	In	In+S	In+R	AF	AF+S	AF+R
Cassava	17,330	14,460	15,870	21,840	16,340	18,530	17,410	14,420	17,660	17,440	16,660	18,290
Maize	740	740	740	760	760	760	1750	1,750	1,750	1,760	1,760	1,760
Melon	128	128	128	228	228	228	297	297	297	296	296	296
Soybean	0	176	172	0	382	364	0	257	271	0	334	318
Adjusted Yield												
Cassava	15597	13014	14283	19656	14706	16677	15669	12978	15894	15696	14994	16461
Maize	666	666	666	684	684	684	1575	1575	1575	1584	1584	1584
Melon	115.2	115.2	115.2	205.2	205.2	205.2	267.3	267.3	267.3	266.4	266.4	266.4
Soybean	0	158.4	154.8	0	343.8	327.6	0	231.3	243.9	0	300.6	286.2
Cassava Value @ N7/kg	121310	101220	111090	152880	114380	129710	121870	100940	123620	122080	116620	128030
Maize @ N65/kg	48100	48100	48100	49400	49400	49400	113750	113750	113750	114400	114400	114400
Melon @ N130/kg	14976	14976	14976	26676	26676	26676	34749	34749	34749	34632	34632	34632
Soybean @ N60/kg	0	9504	9288	0	20628	19656	0	13878	14634	0	18036	17172
Total Benefit	184386	173800	183454	228956	211084	225442	270369	263317	286753	271112	283688	294234
Cost that Vary												
Material costs												
Soybean 42kg @ N120	0	5040	5040		5040	5040		5040	5040		5040	5040
Inorg Fert 200 @ N2,200/50kg	0	0	0	0	0	0	8800	8800	8800	8800	8800	8800
Total Material Cost	0	5040	5040	0	5040	5040	8800	13840	13840	8800	13840	13840
Labour Cost												
Planting of soybean	0	4500	4500	0	4500	4500	0	4500	4500	0	4500	4500
Inor fert applicatn (4mds/ha)							2000	2000	2000	2000	2000	2000
Org fert applicatn (15 mds/ha)				7500	7500	7500				7500	7500	7500
Soybean resd applictn (4mds/ha)						2000			2000	2000	2000	2000
Harvesting of soybean (18mds/ha)		9000	9000		9000	9000		9000	9000		9000	9000
Total labour cost	0	13500	13500	7500	21000	23000	2000	15500	17500	11500	25000	25000
Total cost that vary	0	18540	18540	7500	26040	28040	10800	29340	31340	20300	38840	38840
Net Benefit	184386	155260	164914	221456	185044	197402	259569	233977	255413	250812	244848	255394

— US$1=₦ 126

Table 5. Dominance and Marginal Rate of Return Analysis (1995)

Treatment	Cost	Net Ben	Dominance	Incremental cost	Incremental benefit	MRR (%)
NF	0	223467	U			
OF	7500	244344	U	7500	20877	278.36
In	10800	285748	U	3300	41404	1254.67
NF+S	18540	190789	D			
NF+S+R	18540	194907	D			
AF	20300	259880	D			
OF+S	26040	232762	D			
OF+S+R	28040	248996	D			
In+S	29340	259026	D			
In+S+R	31340	274826	D			
AF+S	38840	256798	D			
AF+S+R	38840	265130	D			

Table 6. Dominance and Marginal Rate of Return Analysis (1996)

Treament	Cost	Net benefit	Dominance	Incremental cost	Incremental Benefit	MRR (%)
NF	0	184386	U			
OF	7500	221456	U	7500	37070	494.267
In	10800	259569	U	3300	38113	1154.94
NF+S	18540	155260	D			
NF+S+R	18540	164914	D			
AF	20300	250812	D			
OF+S	26040	185044	D			
OF+S+R	28040	197402	D			
In+S	29340	233977	D			
In+S+R	31340	255413	D			
AF+S	38840	244848	D			
AF+S+R	38840	255394	D			

the scarcity characterizing its supply limits farmers' access and consequently its wide usage by the farmers.

Conclusion

Experience and empirical evidence have shown that for the majority of situations, the minimum rate of return acceptable to farmers will be between 50 and 100% (CIMMYT, 1998). However, because the technology surrounding the use of organic fertilizer does not require procurement of new complex equipment that would require intensive training, the minimum acceptable rate of return adopted in this study is 50% in which case both the organic fertilizer and inorganic fertilizer options fall within the acceptable rate of return. Considering the scarcity associated with inorganic fertilizer however, the choice of organic fertilizer is more likely to be accepted by the farmers.

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