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PRODUCTIVITY, PROFITABILITY, SOIL FERTILITY AND LAND-USE EFFICIENCY OF MORINGA/CASSAVA/SWEET POTATO INTERCROPPING SYSTEMS IN THE HUMID AGRO-ECOSYSTEM OF SOUTHEASTERN NIGERIA

Bassey Archibong ESSIEN *

Department of Horticulture and Landscape Technology, School of Industrial Technology, Akanu Ibiam Federal Polytechnic, Unwana P. M. B. 1007, Afikpo, Ebonyi State.
* Corresponding Author

ORCID Details
Bassey Archibong ESSIEN: https://orcid.org/0009-0007-9243-7152

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ABSTRACT

This experiment was conducted at the Akanu Ibiam Federal Polytechnic, Unwana, Teaching and Research farm of the Department of Agricultural Technology during 2025 cropping season to evaluate the productivity, profitability and land-use efficiency of moringa-based intercropping systems in southeastern Nigeria. The experimental design used was randomized complete block design (RCBD), with seven treatments replicated three times. The treatments were: sole moringa (SMo), sole cassava (SCa), sole sweet potato (SSp), moringa + cassava (Mo + Ca), moringa + sweet potato (Mo + Sp), cassava + sweet potato (Ca + Sp), and moringa + cassava + sweet potato (Mo + Ca + Sp). Results obtained showed that organic carbon, organic matter and nitrogen were significantly improved under moringa-based intercropping. Results also showed that sole cropping produced the highest growth parameters evaluated across the cropping systems, with sole moringa (324.80cm and 36.93cm^2), sole cassava (184.93cm and 62.15cm^2) for plant height and leaf area, respectively, and sweet potato vine length and leaf area (250.73cm and 59.34cm^2). Similarly, result indicated that sole cropping produced the highest yield and yield components with moringa (16.05 and 1.08t/ha for fresh leaf and seed yields), cassava (7.00 and 35.97t/ha of number of roots and tuber yield), and sweet potato (4.22 and 33.40t/ha of number of roots and tuber yield). However, the result generally showed that the treatments on crop yields were statistically significant across the cropping systems. Moreover, LER ranged from 2.22 to 2.50, indicating greater values than 1.0, with moringa-cassava intercrop producing the highest (31.52t/ha) yields in the cropping system. This shows that intercropping had an advantage over sole cropping and more efficient in terms of resource-use. Therefore, moringa-cassava intercropping system could be considered a promising option for improving land-use efficiency, enhancing farm profitability and promoting sustainable crop production in southeastern Nigeria.

Keywords: Productivity, Profitability, Soil Fertility, Land-Use, Moringa/Cassava/Sweet Potato, Intercropping

1 INTRODUCTION

Crop production in southeastern Nigeria is basically dominated by subsistence farming systems practiced by smallholder famers (Essien, 2024). Farmers in the area depend entirely on land for wide range food and tree crops production, food security and income, and is favoured by the humid environmental conditions. However, crop production in the region is increasingly constrained by the declining soil fertility status, high population growth, fragmentation of farm size, rising cost of production and the need to produce more food from the limited resources drive the intensification for improved productivity per unit area as the most viable option to crop production in southeastern Nigeria. These challenges have increased the importance of sustainable cropping systems that can improve productivity, generate higher income and enhance efficient utilization of available resources without being detrimental to the environment.

Intercropping system is one of the widely adopted production practices that offers considerable potential for addressing these challenges. Intercropping being the practice of growing two or more crops simultaneously on the same piece of land, is an important cropping system strategy for sustainable crop production intensification (Pelin et al, 2024). The system enables farmers to exploit and utilize the differences among crops in their growth habits and requirements, especially when compatible crops are properly combined (Maitra et al, 2021). According to Kumar et al, (2020), intercropping can improve the capture and utilization of solar radiation, water, soil nutrients, weed suppression and space while reducing production risks associated with the dependence on a single crop production, but provide farmers with multiple products and sources of income.

Cassava (*Manihot esculenta* Crantz) is an important storage root, stable and industrial crop in southeast and other parts of Nigeria, because of its adaptability to diverse environmental conditions and its ability to produce reasonable yields under relatively low-input conditions, poor soil and tolerance to intermittent drought conditions suitable for smallholder farming systems (Adekunle et al, 2014). Cassava provides food, feeds and raw materials or agro-industrial products and in pharmaceutical industries. Nevertheless, cassava has a relatively long growth period, creating opportunities for integrating compatible short-duration crops within the production system. According to Maitra et al, (2019), there are many different kinds of species of crop that can be used for intercropping such as annuals e.g. cereals and legumes, tuber crops and vegetables, tuber crops and cereals or legumes, perennials, including shrubs and trees or a mixture of the two (annuals and perennials).

Sweet potato (*Ipomoea batatas* (L.) Lam) on the other hand is another important food crop with considerable potential for integration into cassava-based systems. It is a relatively early maturing crop that produce edible storage roots, providing sustainable quantities of food within a comparatively short period of time (Nyawade et al, 2020). Being a low canopy height crop, allows it to occupy portions of the inter-row space before cassava develops its full canopy. It is noted that, sweet potato like any other root/tuber crops is a heavy feeder that exploit greater volume of soil nutrients and water, and thus require a sustainable cropping systems. Sweet potato grows best in light, well-drained sandy-loam soils, where it contributes to the world's food requirement through its edible parts such as leaves, vines and tubers (Kumar et al, 2020).

Moringa (*Moringa oleifera* Lam) is a multipurpose tree plant (Ojiako et al, 2011), known for its nutritional. Medicinal, environmental and economic importance where almost all the plant parts are rich in nutrients and are used in various domestic, industrial and agricultural uses (Essien et al, 2026, Adebayo et al, 2017). It can also contribute to diversified farm production and potentially improve the economic value of smallholder farming systems, when integrated into crop production systems (Essien, 2024). In the recent times, moringa has attracted serious concern because of its high levels of macro and micro nutrients in its leaves and other parts of the plant, and a very capacity biomass production within a short prod of growth, especially if environmental condition is favourable.

The integration of cassava, moringa and sweet potato in an intercropping system therefore, provides an opportunity to exploit vertical and horizontal differences in crop growth and resource utilization, while the diversification may improve total farm output, providing farmers with different products at different periods of the production cycle that would measure land-use efficiency and profitability. Although cassava-based intercropping is commonly practiced in southeast, there is comparatively limited information on the combined productivity, profitability and land-use efficiency of cassava/moringa/sweet potato intercropping systems, particularly under the specific environmental conditions of southeastern Nigeria. By understanding the interactions among these crops and identifying appropriate planting arrangements, could contributes to the improvement of resources utilization, diversification of farm outputs and increased income among smallholder farmers. Evaluating the combined performance of cassava/moringa/sweet potato under different intercropping arrangements is necessary to identify combinations that provide agronomic and economic advantages to farmers.

Productivity assessment in intercropping systems should not be limited to the yield of individual crops, the combined productivity of the system, economic returns and efficiency of land utilization are equally important considerations, as well as profitability indicators can help determine the economic viability of the production system. Integrating these indicators provides a more comprehensive assessment of the potential benefits of cassava/moringa/sweet potato intercropping. In southeastern Nigeria, where smallholder farmers face increasing pressure to produce more food from limited land resources, productive and profitable crop combinations that could contribute to sustainable intensification by increasing crop diversity, improving land-use efficiency and providing multiple sources of food and income are particularly important. However, there is limited location-specific information on the productivity, profitability and land-use efficiency of this particular crop combinations under the agro ecological conditions of southern Nigeria.

Therefore, evaluating the productivity, profitability and land-use efficiency of cassava/moringa/sweet potato intercropping systems is important for developing sustainable and economically viable cropping strategies in the humid agro-ecosystem of southeastern Nigeria.

2 MATERIALS AND METHODS

2.1 Location and Description of the Experimental Site

The research was conducted at the Teaching and Research Farm, Department of Agricultural Technology, Akanu Ibiam Federal Polytechnic Unwana., located on latitude 5^0. 48^1 N and longitude 7^0. 55^1 E. The climate and vegetation type are generally humid tropical rainforest with annual rainfall of 3500mm and daily temperature range of 32^oC- 21^oC, with relative humidity of between 60-80% (Nkwopara *et al*, 2020). The soils which are derived from shale and sand stone belong to the order 'Ultisol" and have been classified as typic- hapludult (Nkwopara *et al*, 2020). The two main soil types found in the study area are silty-clayey hydromorphic soil and the grey-sandy-clay hydromorphic soils. The silty-clayey hydromorphic soil has a brown loamy top horizon which overlies reddish-brown-silty-clay subsoil (Azu *et al*, 2020).

2.2 Soils Sample Collection and Analysis

Prior to planting, soil samples were collected at five point from the experimental site with soil auger at a depth of 20cm, and samples were bulked into a composite sample. At harvest, soil samples were also collected from each cropping systems. All the soil samples collected were processed and analyzed physic-chemical properties of the soil according to standard methods.

2.3 Experimental Design and Treatments

The experimental site was cleared, tilt and demarcated into blocks and plots, and were laid out in a randomized complete block design (RCBD) with seven treatments [Sole Moringa (SMo), Sole Cassava (SCa), Sole sweet potato (SSp), Moringa + Cassava (Mo + Ca), Moringa + Sweet potato (Mo + Sp), Cassava + Sweet potato (Ca + Sp) and Moringa + Cassava + Sweet potato (Mo + Ca + Sp)] replicated three times. Each plot of the experimental area measured 4m x 4m.

2.4 Planting and Planting Methods

Seed viability was done on moringa seeds by soaking the seeds with 1% Mercuric Chloride for 30minutes, and ten seeds were placed on a soaked filter paper in a petri-dish and was monitored daily for 3 days, and the germination/viability percentage were computed. Moringa, cassava and sweet potato were planted in the rows within the plots at a distance of 1m x1m each for sole and intercropped rows. Three moringa seeds were planted per hole at a depth of 3cm. On emergence, the seedlings were thinned down to 1 plant/stand at 2 weeks after emergence (WAE). Cassava variety used was TMS 98/0505 released by IITA (6 months maturing variety). The choice of the variety was because it has ecological adaptability, with intermediate height and with little or no branching habit. The stem were cut at 25cm long with at least 5 nodes. The stem were planted at an inclined position of about 45^0 on the crest of the ridge. Sweet potato variety used was Umuspo 1 (orange fleshed skin) obtained from National Root Crop Research Institute, Umudike, Abia State, Nigeria. The vines were cut 30cm of length with at least five nodes, and were planted 1m x 1m on the crest of a prepared ridge constructed on a 4m x 4m plots, with at least three nodes buried in the soil at a slanting position.

2.4.1 Field Maintenance:

Weeds were controlled manually with hoe during the growth period. This was done as at when necessary. During weeding, ridges were remolded at each weeding period.

2.4.2 Data collection and Analysis

The determination of growth (plant height, leaf number, leaf area) parameters was done at 2 weeks interval. Five plants in each treatment row were randomly selected and tagged for measurement from each plot. However, yield and yield components parameters were taken at harvest from each crop.

2.5 Data Analysis

All the growth and yield parameters of all the crops collected were subjected to statistical analysis of variance (ANOVA) using Genstat package and treatment means that showed least significant difference at 5% probability level were separated using LSD (P≤0.05).

2.5.1 Cost – Benefit Analysis

Cost-benefit of producing sole and crop mixtures as affected by cropping systems was analyzed using partial budgeting to determined economic returns. The land equivalent ratio was determined by the use of Mason e al, (1986) procedure.

3 RESULTS

3.1 Soil Physico-chemical Properties of the study site

The pre and post planting soil physic-chemical properties of the study area is shown in Table 1. The results of the particle size analysis revealed that the experimental soil was texturally classified as clayey-loam, with sand content exceeding 38.00g/kg. The soil reaction generally indicated alkaline conditions, irrespective of the cropping systems evaluated. The pre-planting soil analysis showed low values of organic carbon and organic matter (1.90% and 3.29%), respectively. However, a significant increase in the values of both organic carbon and organic matter were observed in the cropping systems where moringa was intercropped compared to sole cropping across the cropping systems (Table 1). Generally, the soil of the study area were characterized by low soil fertility status, and the post-harvest soil analysis revealed a significant improvement in soil fertility analysis under the moringa-based intercropping systems.

Table 1: Pre and Post Soil Physico-chemical Properties of the Study area

Pre – Soil Analysis						**Post – Soil Analysis**						
Properties	Value	CS/P	Tx	CLT	Sa	pH (H_2O)	OC	OM	TN	Av.P	K	Ca
Sand(g/kg^{-1})	38.41	SMo	Cl	40.14	38.20	4.01	2.10	2.98	0.21	5.80	0.18	1.06
Clay(g/kg^{-1})	34.82	SCa	Cl	40.15	38.19	4.00	1.90	1.00	0.12	5.10	0.06	0.04
Texture	CL	SSp	Cl	40.14	38.19	4.02	0.94	1.60	0.18	5.00	0.02	1.01
pH(H_2O)	4.20	Mo+Ca	Cl	40.14	38.20	4.01	2.56	3.60	0.31	6.06	0.08	1.01
OC (%)	1.90	Mo+Sp	cl	40.16	38.21	4.00	2.54	3.65	0.26	6.00	0.12	1.00
OM (%)	3.29	Ca+Sp	cl	40.15	38.21	4.02	2.54	3.11	0.26	6.01	0.12	1.00
TN (%)	0.25	Mo+Ca+Sp	cl	40.16	38.20	4.02	3.30	3.44	0.34	6.98	0.25	1.08
Av.P(mg/kg)	5.62											
K(cm0l/kg)	0.06											
Ca(cmol/kg)	3.18											
Mg (cmol/kg)	1.00											
Na (cmol/kg)	0.02											

Legend: CS/P = cropping system/properties, Tx = texture, cl = clay-loam, CLT = clay content, Sa = sand, OC = organic carbon, OM = organic matter, TN = total nitrogen

3.2 Effects of Intercropping Systems on Moringa Growth Performance

Results obtained (Table 2) shows the influence of Moringa-based intercropping system on the growth performance of Moringa. There was significant difference (P≥0.05) among the cropping systems on plant height and leaf area. However, results findings indicated that sole Moringa (SMo) cropping produced the highest growth attributes (324.80cm, 13.50 and 36.93cm) for plant height, leaf number and leaf area, while Moringa + Cassava + Sweet potato (Mo + Ca + Sp) crop combinations produced the least growth attributes.

Table 2: Effects of Intercropping Systems on Growth and Growth Components of Crops

Moringa				Cassava				Sweet potato			
CS	PH	LN	LA	CS	PH	LN	LA	CS	VL	LN	LA
SMo	324.80	13.33	36.93	SCa	184.93	195.33	62.15	SSp	250.73	101.39	59.34
Mo+Ca	184.62	13.57	34.71	Mo+Ca	162.53	114.90	61.98	Mo+Sp	246.70	93.60	51.30
Mo+Sp	177.51	13.47	35.67	Ca+Sp	163.54	115.87	62.00	Ca+SP	247.18	94.87	52.34
Mo+Ca +Sp	162.31	15.53	24.65	Mo+Ca +Sp	156.13	107.47	60.88	Mo+Ca +Sp	186.33	70.60	43.15
LSD0.05	6.30	ns	1.26	LSD0.05	0.62	0.11	ns	LSD0.05	2.80	0.04	0.07

Legend: CS = cropping system, SMo = sole moringa, SCa = sole cassava, SSp = sole sweet potato, PH = plant height, LN = leaf number, LA = leaf area

3.3 Effects of Intercropping Systems on Cassava Growth Performance

The results presentation in Table 2 revealed significant difference (P≥0.05) among the cropping systems evaluated. Sole cassava cropping recorded the highest (184.93cm, 195.33 and 62.15cm) values for plant height, leaf number and leaf area growth parameters assessed, whereas cassava-based intercropping systems cassava + Mornga + Sweet potato (Ca + Mo + Sp) exhibited the lowest (156.13cm, 107.47 and 60.88cm) values for plant height, leaf number and leaf area, respectively.

3.4 Effects of Intercropping Systems on Sweet potato Growth Performance

There was significant difference (P≥0.05) among the cropping system on growth performance of sweet potato measured. However, results (Table 2) revealed that sole sweet potato significantly produced the longest vine length (250.73cm), highest number of leaves (101.39), and the widest leaf area (59.34cm) values compared to Moringa + Cassava + Sweet potato (Mo + Ca + Sp) intercropping that had the shortest vine length (186.33cm), lowest number of leaves (70.60), and the narrowest leaf area (10.15cm) values.

3.5 Effects of Intercropping Systems on Crop Yield and Yield Components

3.5.1 Moringa

Data presented in Table 3 show yield and yield components of Moringa, as significantly affected by intercropping systems. The significant difference (P≥0.05) were observed among the different treatments with regards to number of pods/plant, leaf yields and seed yield. However, sole moringa cropping produced the highest number of pods (23.81), followed by moringa + cassava + sweet potato crop mixtures (16.70), while moringa + cassava intercrop produced the least number of pods (15.69). Results (Table 3) revealed that sole moinga cropping produced the highest seed yield (1.08t/ha) while moringa + cassava recorded the least seed yield of 0.79t/ha.

Table 3: Effects of intercropping system on Crop Yield and Yield Components

Moringa						Cassava				Sweet potato					
CS	NOP	NOS/P	FLY	DLY	SY	CS	NOR	WOTG	TY	TR	CS	NR	MR	RTY	TR
SMo	23.81	15.90	16.05	2.88	1.08	SCa	7.01	193.23	35.97	5.37	SSp	4.22	2.13	33.40	0.78
Mo+Ca	15.69	14.83	17.03	3.01	0.77	Mo+Ca	6.55	168.40	31.09	5.42	Mo+Sp	2.77	1.89	28.90	0.68
Mo+Sp	16.40	15.41	18.05	3.32	1.06	Ca+Sp	3.50	142.00	26.45	5.33	Ca+SP	1.66	1.00	22.07	1.09
Mo+Ca+Sp	16.70	15.80	18.01	3.07	0.97	Mo+Ca+Sp	3.91	138.38	25.08	5.52	Mo+Ca+Sp	2.09	0.91	25.18	0.98

LSD 0.05	2.71	ns	0.22	0.08	0.02	LSD 0.05	1.18	2.40	2.20	0.22	LSD0.05	1.18	0.11	2.16	0.28

Legend: CS = cropping system, SMo = sole moringa, SCa = sole cassava, SSp = sole sweet potato, PH = plant height, LN = leaf number, LA = leaf area

3.5.2 Cassava

Results obtained (Table 3) consistently showed that sole cassava cropping significantly increased cassava yield and yield components across the parameter measured. It was observed from the study that sole cassava cropping had 33.97t/ha of yield whereas moringa + cassava + sweet potato produced the least storage root yield of 25.06t/ha. On the contrary, tuber ratio was significantly higher (5.52) when moringa + cassava + sweet potato was intercropped, followed by moringa + cassava intercrop ((5.42), while cassava + sweet potato produced the least (5.33) tuber ratio.

3.5.3 Sweet potato

The results (Table 3) revealed variations on the yield and yield components of sweet potato under different cropping systems. Sole sweet potato cropping recorded the highest number of storage roots (4.22), number of marketable storage roots (2.13), fresh biomass weight (25.70kg), and tuber yield (33.40t/ha). In contrast, cassava + sweet potato recorded the lowest number of storage roots (1.66) and tuber yield (22.07t/ha), while moringa + cassava + sweet potato cropping system produced the lowest number of marketable storage roots (0.91). However, the result revealed that cassava + sweet potato cropping system produced the highest tuber ratio (1.09) whereas, moringa + sweet potato produced the least (0.68) value of tuber ratio.

3.5.4 Cost-Benefit Ratio

Findings from the study (Table 4) revealed that Land Equivalent Ratio (LER) ranged from 2.22 to 2.50, showing greater values than 1.0. The result showed that the highest intercropped yield was when moringa was intercropped with cassava (31.52), followed by cassava + sweet potato (30.13), while the least yield was when moringa was intercropped with cassava + sweet potato (1.07) in the cropping systems.

Table 4: Effects of Intercropping on Land Equivalent Ratio (LER)

CS	Sole cropping	Intercropping				LER
		Mo+Ca	Mo+Sp	Ca+Sp	Mo+Ca+Sp	
Moringa	1.75	1.55	1.70	-	1.07	2.43
Cassava	33.60	31.52	-	30.13	22.43	2.50
Sweet potato	30.16	-	26.45	20.60	19.80	2.22

CS = cropping system, Mo = moringa, Ca = cassava, Sp = sweet potato

4 DISCUSSION

4.1 Effects of Intercropping on Soil Fertility Status

The relatively high proportion of sand in the study area suggests that quartz may have constituted a major component of the soil's mineral fraction. The low organic carbon and organic matter contents indicated a generally poor soil fertility status, which may limit nutrient availability and subsequent crop productivity. Similarly, the low nitrogen content, particularly when below the critical level of 1.00%, may be associated with rapid organic matter mineralization and nutrient losses through leaching, especially under high rainfall conditions in the humid tropical environment. These findings are consistent with the report of Azu et al, (2018), who observed that soils n the humid region of southeastern Nigeria are characterized by high quartz content and often require organic amendments to improve productivity.

The results further revealed improved nitrogen (N) and phosphorus (P) availability under moringa-based intercropping systems compared to sole cropping system. This improvement may be attributed to the contribution of morings residues combined with other crop residues to soil organic matter and nutrient cycling, as well as enhanced biological activity within the soil through litter decomposition, root turnover and the subsequent mineralization of organic materials.

Furthermore, the increased phosphorus availability observed under moringa-based intercropping relative to sole cassava and sweet potato, may be linked to improved organic matter accumulation, enhanced microbial activity and release of phosphorus during the decomposition of plant residues. However, findings suggest that incorporating

moringa into cassava – and sweet potato-based cropping systems could contribute to improved soil fertility management and support sustainable crop production in southeastern Nigeria. By diversifying crop production and enhancing nutrient recycling, moringa-based intercropping may offer additional benefits to small-holder farmers operating under the conditions of limited farm inputs such as fertilizer, and other soil fertility inputs. Such systems could also contribute to greater resilience in crop production. This observation supports the argument by Pelin et al, (2024) that the selection of appropriate cropping systems should consider both their productivity and their capacity to maintain soil health under changing environmental conditions.

4.2 Effect of Intercropping on Crop Growth and Growth Components

The significant differences observed among the cropping systems (Table 2) suggest that the type of cropping system adopted influenced the growth performance of crops. The superior growth parameters recorded under sole cropping could be attributed to the reduced competition for essential growth resources, including light, water, nutrients and space. Therefore, under sole cropping, crop plants have greater access to these resources, which promote vegetative development including plant height, leaf production and canopy expansion. In contrast, the relatively lower growth parameters observed under moringa-based intercropping systems could be associated with interspecific competition between moringa and the other associated crops in the cropping systems for available growth resources and the physical growing space. Such competition may limit the resource availability and utilization to individual crop plant, thereby reducing their vegetative growth and vigour. However, the differences in growth components among crop species could be attributed to the inherent crop species characteristics. This agrees with the work of Gomez et al, (2022), who stated that different varieties of a particular crop respond differently to intercropping.

The result of the study also revealed that increase in growth components could be as a result of differences in crop varieties and nature of the competition in the cropping systems. This indicated that the differences in plant growth components probably reflects the differences in the nature of competition between the crops involved, ins sole and intercrop cropping, and in the intake of growth resources among crop species in the intercropping systems. The reduction in growth parameters of intercrop plot could be as a result of levels of competition for growth resources. This interpretation is consistent with the findings of Essien (2024), who reported that the decrease in plant height at higher plant densities resulted in plant competition for space and growth resources and nature of the cropping system. Findings therefore suggest that the intensity of competition in a mixed cropping system depend not only on the nature of component crops but also on their compatibility and resource-use characteristics.

4.3 Effects of Intercropping Systems on Yield and Yield Components of Crops

The significant increase in crop yields and yield components in the cropping system could be as a result of crop compatibility among crop species in crop mixtures. This could be as a result of the intensity of competition for growth resources that might have coincided with the peak of available growth resources for each crop for germination, sprouting, active growth and translocation of photosynthesis, and probably depended on low interspecific competition in moringa/cassava, moringa/sweet potato and cassava/sweet potato intercrop, indicating that the component crops might have transmit an amount of solar energy to other crops. This agrees with the work of Maclaren (2023), who reported that cassava/maize intercrops appeared to have depended largely on low interspecific competition and the ability of the maize components to transmit sufficient light energy to lower canopy cassava.

The observed yield improvements could be attributed to crop diversification through compatibility in the intercropping system, which enhances the productivity of land per unit area. This suggests that intercropping can improve the overall system productivity without requiring additional land, while potentially increasing the resilience and sustainability of crop production. The result further revealed variations in the components crops across the cropping systems. These variations could be associated with the adaptability of each crop to different intercropping arrangements, particularly its erect growth habit of cassava and moringa, which probably facilitated resource sharing and complementarity among the component crops. Moreover, the compatibility of moringa cassava and sweet potato intercrop n yield differences could be attributed to the ability of the crop mixture's complementarity and compatibility with sweet potato as a short seasoned crop. This agrees with the work of Amoake et al, (2022), who reported that cassava/maize intercrop has been a productive system and compatible mainly because maize is a short season crop while cassava is a long duration crop. The study on storage root yield and yield components showed that number marketable storage tuberous root yields were significantly affected by the intercropping, probably because of increased with increase in the number of crop population under the additive mixture series. This is in line with the work of Ogwuche et al, (2023), who stated that cassava tuber increase with increase in the number plant population in the field.

4.4 Effects of Intercropping on Crop Productivity and Profitability

The assessment of intercrop productivity from the study revealed that intercropping has an advantage over sole cropping, using the land equivalent ratio (LER), despite high production cost associated with the crop mixtures. This advantage could be attributed to the complementarity in growth pattern of the component crops, particularly the

combination of crops with different growth periods, which might have enhance resource utilization within the cropping system. This means that intercrop system was more efficient in terms of resource-use than the sole cropping. This agrees with the work of Takim et al,(2020), who reported that LER were higher in intercropping plots, indicating yield advantage over sole cropping, demonstrating a better land utilization and cumulative yield of maize-sweet potato intercrop.

Although cassava yield was reduced under intercropping compared to sole cropping (Table 4), the yields obtained from sweet potato and moringa compensated for the reduction, resulting in higher LER values in the intercrop plots. This suggests that the intercropping systems utilized land more efficiently and produced a greater combined yield than the corresponding sole cropping. The observed productivity advantage could be associated with differences in the component crops' requirements for growth resources. Ikeh et al (2012) reported that combining crops with different resource requirements could minimize interspecific competition and improve the overall production of intercropping systems.

In terms of economic performance, the moringa + cassava intercrop recorded the highest cost-benefit ratio of 2.50, indicating its superior economic advantage among the cropping combinations evaluated. This shows that in the different cropping systems, the revenue generated exceeded the production costs, demonstrating their economic viability. These findings indicates that although intercropping may involve higher initial production costs, and reduced yields of individual component crops, the combined output and economic returns can compensate for these advantages. Therefore, the moringa/cassava intercropping system could be considered a promising option for improving land-use efficiency, enhancing farm profitability and promoting sustainable crop production in southeastern Nigeria.

5 CONCLUSION

Findings from the study revealed that intercropping systems involving mronga, cassava and sweet potato demonstrated considerable potential for improving crop productivity, soil fertility, land-use efficiency and farm productivity. These systems could contribute to enhanced yield stability, improve food security and increased income generation, particularly under prevailing economic challenges. Among the cropping combinations evaluated, moringa + cassava intercropping recorded higher productivity and profitability, suggesting that the two combined crops may complement each other in resource utilization more efficiently than some of the other crop combinations. Furthermore, the observed improvement in soil fertility status (nitrogen (N), and phosphorus (P) availability under moringa + cassava, moringa + sweet potato and moringa + cassava + sweet potato intercropping system highlight the potential contribution of moringa-based intercropping to soil fertility enhancement. The comparable net cost-benefit performance of the moringa/cassava system further supports its potential as a viable and economically beneficial cropping strategy. These findings underscore the importance of integrating mroinga into existing cropping systems to promote sustainable agricultural production. Therefore, the development and adoption of location-specific and farmer-adapted intercropping system, taking into account farm size, resource availability, and farmers 'production objectives, are recommended. Such systems could enhance resource-use efficiency, improve soil fertility, increase farm profitability, and strengthen the sustainability of crop production in the humid agro-ecosystem of southeastern Nigeria.

STATEMENTS ON COMPLIANCE WITH ETHICAL STANDARDS

Disclosure of conflict of interest

The author declares no conflict of interest.

REFERENCES

[1] Adebayo, A.G., Akintoye, H.A. & Shokalu, A.O. (2017). Soil chemical properties and growth response of Moringa oleifera to different sources and rates of organic and NPK fertilizers. *Int. J. Recycl Org Waste Agricult* 6, 281–287 (2017). https://doi.org/10.1007/s40093-017-0175-5

[2] Adekunle, Y.A., V. I. Olowe, F. O. Olasantan, K. A. Okeleye, P. O. Adetiloye & J. N. Odedina (2014). Mixture productivity of cassava-based cropping system and food security under humid tropical conditions. *Food and Energy Security* 2014; 3(1); 46 – 60. Doi.10.1002/fes3.46

[3] Amoako, O. A., Adjebeng-Danquah, J., Agyare, R. Y., Tengey, T. K., Puozaa, D. K. & Kassim, B. Y. (2022). Growth and yield performance of cassava under different plant population densities of two cowpea varieties in a cassava/cowpea intercrop *International Journal of Agricultural Technology* 2022 Vol. 18 (5):1917-1936. http://www.ijat-aatsea.com

[4] Azu, D. E. O., Uche, Nkechi & Nwanja, O.U. (2020): Moringa compost and poultry manure effect on soil nutrient indices, growth and yield of Amaranthus in Ebonyi State. *Journal Agricultural and the Environment, Sustainable Agric. Environ* (2020) 18 (1): 169-179.

[5] Azu, D. E. O., V. E. Osodeke, I. M. Ukpong and A. F. Osisi (2018). Chemistry and Mineralogy of soils derived from different parent materials in Southeastern Nigeria. *International journal of Plant and soil Sciences*, 25 (3): 1 – 16.

[6] Essien, B. A., D. E. O. Azu, S. I. Ijearu, C. E. Ogu, H. Akuma and U. Anthony (2026). Germination and Seedling Growth of Moringa (Moringa oleifera) as Influenced by Seed Treatments and Sources in Southeastern Nigeria. Acta Botanica Plantae, 5 (1): 50 – 56. https://doi.org/10.51470/ABP.2026.05.01.50

[7] Essien, B. A. (2024). Evaluation of Moringa/Cassava/Maize/Sweet potato Intercropping Systems in Owerri Humid Rain Forest Zoneof Southeastern Nigeria. Ph>d Thesis (Unpublished), Owerri. Federal University of Technology, Owerri. Pg 3 – 4.

[8] Gomez-Fernandez, A., P. O. Collins, R. Mark, P. Javier, I. Carlos, G. Guillermo and enM. Rub (2022). Disparities among crop species in the evolution of growth rates: The role of distinct origins and domestication histories. *New phytologist* (2022), 233: 995 – 1010.

[9] Ikeh, A. O., U. N. Ndaeyo, G. A. Iwo, S. A. Aderi, J. E. G, Ikorgu, E. C. Nwachukwu and B. A. Essien (2012). Effects of cropping systems on growth and yield of yam (*Dioscorea rotundata*) Genotype and Egusi melon (*Colocynthis cirullus*) on an ultisol. *International Journal of Applied Research and Technology,* 1(1): 119 – 131

[10] Kumar, R., Lal, M., Naresh, R. K., Kumar, M., Yadev, S., Kumar, R., Chandra, M. S. and Rajput, P. (2020). Influence of balanced Fertilization on Productivity, Nutrient use efficiency and Productivity of Rice in Inceptisol: A Review. *Int. J. Cuur. Microbial. Appl. Sci.*, 2020, 9, 568 – 590.

[11] MacLaren, C., Wycliffe, W., Kamaluddin, T. A., Lieven, C., Andrew, M., Christian, S., Bernard, V. & Jonathan, S. (2023). Predicting intercrop competition, facilitation, and productivity from simple functional traits. *Field Crop Research*, Volume 297, 1 June 2023, 108926. https://doi.org/10.1016/j.fcr.2023.108926

[12] Maitra, S., A. Hossain, M. Brestic, M. Skalicky, P. Ondrisik, K. Brahmachiari, T. Shanker, P. Bhadra, J. B. Palai, J. Jena, U. Bhattacharya, S. Dvvada, S. Lalichetti and M. Sairam (2021). Intercropping – A low input Agricultural strategy for food and Environmental Security. *Agronomy*, 11, 343.

[13] Maitra, S.; Palai, J.B.; Manasa, P.; Kumar, D. P. (2019). Potential of intercropping system in sustaining crop productivity. *Int. J. Agric. Environ. Bio-Res*., 12, 39 – 45.

[14] Mason, S. C., D. E. Leithner, J. J. Vorst, and E. Salazar (1986). Cassava-Cowpea and Cassava-Peanut Intercropping II. Leaf Area Index and Dry Matter Accumulation. *Journal of Agronomy*, 78: 47 - 53.

[15] Nkwopara, U.N., Ahukaemere, G. M., Ezekorene, C. O., Onwudike, S. U. & Osisi, A. L. (2020). Characterization and classification of selected soil under different land fallow length in an ultisol in a humid tropical environment. *Int'l Acad. J. App. Biomed Sci*. 1 (1): 34 – 42.

[16] Nyawade, S., Gitari, H. I,. Karanja, N. N., Gachene, C. K., Schulte-Geldermann, E., Sharma, K. and Parker, M. (2020). Enhancing climate resilience of rain-fed potato through legume intercropping and silicon application. *Front. Sustain. Food Syst.,* 4, 345 – 566.

[17] Ogwuche, T.O., Diebiru-Ojo, M.E., Najimu, A., Ossai, C.O., Ekanem, U., Adegbite, B., Oyebode, G. & Kulakow, P. (2023). Performance and Stability of Improved Cassava (Manihot esculenta Crantz) Clones in Demand Creation Trials in Nigeria. *Crops* 2023, 3(3), 209–219. https://doi.org/10.3390/ crops3030020

[18] Ojiako, F. O., N. C. Adikuru & C. A. Emenyonu (2011). Critical issues in investment, production and marketing of Moringa oleifera as an industrial Agricultural raw material in Nigeria. *J. Agric. Res. and Dev*. 10 (2):39-56.

[19] Pelin, T., H. Canci, I. Turhan, A. Isci, M. Scherzinger, M. Kordrostami and E. Yol (2024). The advantages of Intercropping to improve productivity in food forage production – A Review. Plant Production Science, 27 (3): 35 – 40.

[20] Takim, F. O., Gideon, Z. N., Oluwafemi, O. O. & Israel, O. O. (2020). Effect of population density of sweet potato on the yield of maize-sweet potato intercrop for weeds suppression in southern guinea savannah Nigeria. *Pak. J. Weed Sci. Res*., 26(2): 215-230