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The Transformation From Agronomic Experiment to Practical Advice For Farmers: A Case Study with Maize in the Southern Guinea Savannah Region of Nigeria

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Abstract

The development of recommendations that are adoptable by farmers to meet their goals is key to the introduction of improved crop management practices to farmers. An on-farm experiment was conducted to evaluate maize production under farmers (M1) and improved (M2) cultivation and management in three locations (Kabba, Ejiba, and Anyigba) of the southern Guinea Savannah zone of Nigeria. A land suitability evaluation, an evaluation of the yield of maize, and an economic analysis of the two management practices were carried out. Kabba has a potential suitability index of 32.76 and was rated S3 (marginally suitable); Ejiba and Kabba are 84 and 95, respectively; they were rated S1 (highly suitable). The yield performance of maize is in the order of Ejiba<Anyigba>Kabba for location and M2>M1 for management practices. For every $1.00 invested in the adoption of improved cultivation and management practices, the farmer will recover the $1.00 and get an additional $0.4285, $0.6850, and $0.9349 in Kabba, Ejiba, and Ayingba, respectively. The improved management practices are recommended to farmers in the agro-ecological zone. This study established that agronomic experiments should not be limited to field experimentation levels, and the importance of the economic implications of agronomic research findings was emphasized.

Keywords

Soil, suitability, evaluation, production, economics.

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Introduction

Maize is an important staple crop in the world. It has a wide range of varieties adapted to different ecologies and regions of the world. It is grown in every agro ecological zones of Nigeria under rain fed and irrigation agriculture. According to FAO (2018), maize is an important traditional crop in Nigeria, ahead of millet and sorghum. An estimated 3 million hectares are cultivated, and its cultivation in the savannah continues to increase (Aduayi et al., 2002). In 2020, maize production was 11.5MMT, increasing from 0. 931 MMT in 1971 to 11.5MMT in 2020, growing at an average annual rate of 7.57%. (National Bureau of Statistics, 2020). AFEX (2024) reports that maize, Nigeria's dominant cereal crop, represented 32% of total cereal area harvested in 2023. The cultivation area declined by 7% between 2021 (6.2 million ha) and 2022 (5.8 million ha).

Maize is essential to food security in Nigeria (Adewopo, 2019). It is utilized mostly in the animal feed industry; over 60% of the local production is used for the production of animal feed. It is a food source for humans because it is a good source of carbohydrates, some protein, iron, vitamin B, and minerals. 10 to 15 percent is directly consumed by individuals as roasted, boiled, or prepared as porridge. The rest are used in pharmaceutical and confectionary industries.

Sabo et al. (2017) reported that smallholder farmers made a considerable contribution to global agricultural output. They produce the bulk of food in developing countries (IAASTD, 2009). Oke et al. (2022) and Mgbenka and Mbah (2016) reported that over 80% of farmers in Nigeria are subsistence farmers, many of whom are smallholders. This buttresses the report of Agboola and Shittu (2002) that much of the maize produced in Nigeria is produced on a subsistence basis by smallholder farmers. Smallholder farmers are characterized by marginalization in terms of accessibility, resources, information, technology, capital, and assets, but there is great variation in the degree to which each of these applies (Odoemenem and Obinne, 2010). Their farm size is less than 3 ha, however, they play a significant role in food production to the entire nation. A similar scenario is at play in Sub-Saharan Africa where it was reported that a higher percentage of maize cultivation is done by smallholder farmers (Cairns et al., 2021; Macauley, 2015; Smale et al., 2011) who depend on it for both their subsistence and livelihoods.

It was reported by Cairns et al. (2021) that maize production in sub-Saharan Africa increased from 14 metric tons to 80 metric tons from 1961 to 2017. The increase was attributed to an increase in cropped area. This implies that there has not been a significant change in crop and soil management practices among farmers for sustainable and optimum maize production.

There are myriad challenges facing maize production in Nigeria. They have been categorized into socioeconomic such as insecurity, natural disaster, high cost of labour, inadequate storage facilities, lack of access to agricultural information, resistant to modern improved technologies and limited access to capital and credit facilities (Adewopo, 2019; Abdulaleem et al., 2019; Girei et al., 2018; Mgbenka and Mbah, 2016), soil environmental and biological factors such as poor soil fertility, pests and diseases and periodic drought caused by irregular rainfall distribution Abdulaleem et al., 2019; Girei et al. 2018) and poor crop management practices such as irregular or improper plant spacing, poor seed bed preparation, poor post-harvest maize residue management and poor timing of operations (Falade and Labaeka, 2020).

There is an increase in demand for maize for human consumption, livestock and agro-allied industries. This has been attributed to population growth, industrialization, urbanization, and changing dietary habits of consumers (Egwuma et al., 2019). The local production did not meet up with local and export market demand; this has led to the importation of maize into Nigeria in recent years. An estimated 215 tonnes were imported in 2016 (FAOSTAT, 2018).

In order to increase maize production, farmers are faced with two major alternatives. The first is to increase the number of land areas cropped, and the second is to improve cultivation practices to ensure optimum and sustainable production. The first alternative has been exploited and did not give the desired result; therefore, farmers are left with the second option. The latter option is referred to as Sustainable intensification, a process whereby crop yields are increased through increased resource use and resource use efficiency, without land expansion and with minimal adverse environmental impact (Rusinamhodzi et al., 2020, Struik and Kuyper, 2017).

There has been several research on crops improvement in Nigeria, this brought about the compilation of recommended practices for important crops including maize in Nigeria by (FFD, 2002). However, the adoption of these recommended practices is low among farmers in that most of the agronomic research and recommendations did not state the economic implications of the practices. Meanwhile, farmers are more interested in the economic implications and value of adopting new management and production innovation. They are particular about the significant extent to which it is better than their current practice. The desired impact of agronomic research will be felt in the agricultural sector if the research is more of on-farm research conducted on farmers’ fields and consideration is given to the economic implication of results for recommendations to end users. There is also a need for an improvement in the current farmers' practice for optimum and sustainable maize production.

The study area is important to maize production and has the potential to contribute significantly to the local demand and export, therefore, the need for this study is pertinent to efforts in the development of sustainable maize production in Nigeria.

The objectives of this study are to evaluate maize production under farmers' practice and improved management in three locations of the southern Guinea Savannah zone, Nigeria and conduct an economic analysis of the field data for farmers’ recommendation.

Materials and methods

Description of the study areas

The study areas are: Kabba on 7º51'29.46"N and 6º03'45.03"E, Ejiba on 8º17'20.97" and 5º39'17.31", and Ayingba on 7º28'57.02" and 7º13'35.56" all in the southern Guinea Savannah agro ecological zone of Nigeria. The areas have a climate that is typical of the humid tropics. The majority of the population of the area is into agriculture, and they are mostly smallholder farmers.

On farm experiment

The experiment was conducted between 2021 and 2023 planting sessions. Maize farmers' field was identified and selected in each of the locations through the extension agent of the Agricultural Development Agency.

The experiment consisted of two treatments (Table 1): M1 = Maize farmers' cultivation and management practices and M2 = improved cultivation and management practices for southern guinea savannah zone of Nigeria (FFD, 2002).

The treatments were replicated four times and laid out in a randomized complete block design in each of the locations.

Soil sampling and analysis

Profile pits were dug in each of the locations, described, and sampled for laboratory analysis. The slope, flooding, drainage and texture were determined on the field. The total nitrogen, available phosphorus, pH, organic matter, exchangeable cations, cation exchange capacity and base saturation were determined in the laboratory with methods described by IITA (1979).

Data collection

At harvest, the grain yield per plot was measured with a weigh balance, and the costs of all operations were recorded in naira and converted to the naira-dollar exchange rate as of September 2022.

Land suitability evaluation

The suitability evaluation of the land in each location was conducted with the conventional parametric method (FAO, 2007; Ogunkunle, 1993). Relevant land characteristics/qualities requirements for maize (Table 2) were compared with land characteristics/qualities of each location. Five land quality groups were used: climate (c), topography (t), wetness (w), soil physical properties (s), and soil fertility (f). The final (aggregate) suitability class indicates the most limiting characteristics of the pedons and was computed using the equation: IP = A√B/100xC/100…F/100. Where: IP = index of suitability, A = the overall lowest characteristics B, C…., F = the lowest characteristics in each land quality group. The suitability classes S1 (highly suitable), S2 (moderately suitable), S3 (marginally suitable), N1 (currently not suitable) and N2 (potentially not suitable) are equivalent to index of productivity value of 100-75, 74-50, 49-25, 24-12.5 and 12.4-0 respectively.

Data analysis

Yield data was analyzed with ANOVA and means of the treatment in each location were ranked with Least Significant Difference (LSD) at the 5% level of significance.

Economic analysis

The economic analysis of maize production in the locations was done following the method suggested by the International Maize and Wheat Improvement Center (CIMMYT) (1988). It involved the computation of the following:

1. The partial budget: The adjusted yield was calculated by adjusting the yield obtained from the field downwards by 10% with the standard assumption that farmers

Cost	M1	M2
Land preparation	Plough and ridge	Plough, harrow and ridge
Seed rate per kg/ha	10-15	25
Spacing	Haphazard	75 by 25 cm at one plant per stand
Weed control	Pre-emergence + handweeding	Pre and post emergence
Fertilizer use	Based on blanket recommendation. Single application of 200kg NPK 20:10:10	Based on soil fertility map of Nigeria. First application of 300kg NPK 20:10:10 and second application of 200kg urea
Control of army worm and stem borer	Single application of control	Integrated control measures
Harvesting, shelling and packaging	Hand shelling in the house and packaging	Use of maize sheller and packaging on the farm.

Source: Agricultural Development Programme and FFD (2002)

Table 1: Comparison of treatments.

Land qualities	S1 (100-85)	S2 (84-40)	S3 (39-20)	N1 (19-0)
Climate (c):				
Annual rainfall (mm)	>850	750-600	600-500	-
Length growing season(days)	150-220	110-149	90-109	-
Mean annual temperature (°C)	22-28	18-16	16-14, 36-30	-
Relative humidity (%)	50-80	42-36	36-30, >80	-
Topography (t)				
Slope (%)	0-2	3-8	9-16	>30
Wetness (w) :				
Flooding	F0,	F1, MR	F1	Poor
Drainage	Good	imperfect	Poor	Poor
Soil physical properties (s):				
Texture	SiC, SiCL, CL, SiL, SL, C, SCL	LFS, LCS	CS, S	S
Fertility (f):				
Cation exchange capacity (cmol/kg clay)	>24	24- 16	<16	
Base saturation (%)	>50	20-35	<20	
Organic matter (%), 0-50cm	>20	8- 12	< 8	
pH (H_2O)	5.5-7.0	5.0-8.0	5.0-8.0	
Available phosphorus (mg/kg)	>22	7-13	3-7	<3
Total Nitrogen (%)	>0.15	0.08-0.10	0.04-0.08	<0.08
Extractable K (cmol/kg)	>0.50	0.20-0.30	0.10-0.20	<0.10

Note: FO – No Flooding, F1 – Seasonal Flooding, MR – Flooding Rare CL- Clay Loam, SCL- Sandy Clay Loam, SL - Sandy Loam, LS - Loamy Sand, L – Loam, LFS - Loamy Fine Sand, LCS - Loamy Coarse Sand, FS - Fine Sand, Sic - Silty Clay, Sicl - Silty Clay Loam, SC - Sandy Clay, S –Sand, S1 – Highly Suitable S2 – Moderately Suitable S3 – Marginally Suitable, N1 – Currently Not Suitable

Source: Abagyeh et al. (2016)

Table 1: Comparison of treatments.

will obtain yields lower than those obtained in the experiment. The gross field benefit is the value of one kilogram of the crop to the farmer, net of harvest costs that are proportional to yield. The cost that varies is the cost incurred in the field operations. The net benefit is calculated by subtracting the total costs that vary from the gross field benefit.

2. Marginal analysis: The dominance analysis was done by listing the treatments in order of increasing costs that vary; the treatment with net benefits that are less than or equal to those of a treatment with lower costs that vary is ranked 'dominated'. The marginal rate of return expressed in percentage was calculated by dividing marginal net benefit (the change in net benefits between the treatments) by the marginal cost (the change in cost between the treatments).

Sensitivity analysis

A sensitivity analysis was conducted to evaluate the impact of key soil properties on maize yields and land suitability. This analysis helps identify the most critical factors influencing productivity and provides insights for targeted soil and crop management interventions

Results and iscussion

Land suitability evaluation for maize

The matching of the land characteristics/qualities requirements for maize in Table 2 with the land characteristics/qualities of the study locations in Table 3 resulted in the land suitability ratings in Table 4.

Rainfall, length of growing season, and relative humidity were optimum in the three sites, therefore, they were rated highly suitable (S1). The mean annual temperature was not favourable in Kabba, it was rated marginally suitable (S3). Maize is broadly adapted to different agro-ecological zones of Nigeria; farmers can adopt farming technologies and methods that are adaptable to each agro-ecological zone based on the climatic peculiarities of each ecological zone (Egbetokun et al., 2014).

Land qualities	Kabba	Ejiba	Anyigba
Climate (c):			
Annual rainfall (mm)	1,570	1,346	1,600
Length growing season(days)	160	180	185
Mean annual temperature (°C)	30	22	25
Relative humidity (%)	60	75	73
Topography (t)			
Slope (%)	3.7	1.8	2.6
Wetness (w) :			
Flooding	F0	F0	F0
Drainage	Imperfect (mottled)	Imperfect (mottled)	Good
Soil physical properties (s):			
Texture	SCL	SL	SL
Fertility (f) :			
Cation exchange capacity (cmol/kg clay)	12.60	17.22	26.18
Base saturation (%)	90	70	75
Organic matter (%), 0-50cm	1.80	2.83	2.14
pH (H_2O)	6.05	5.74	5.90
Available phosphorus (mg/kg)	8.35	12.32	25.50
Total nitrogen (%)	0.18	0.27	0.20
Extractable K (cmol/kg)	0.51	1.16	0.82

Note: FO – No Flooding, SCL- Sandy Clay Loam, SL - Sandy Loam

Source: Metrological, field, and laboratory data

Table 3: Land characteristics/qualities of the study locations.

The major variations experienced are in the time of planting and the number of plants. In some locations, maize is planted twice (early and late planting) per annum, while it is planted once in some. The climatic condition of Ejiba and Anyigba are more favourable for the planting of maize twice per annum.

The slope is optimum for Ejiba and Anyigba. It was rated S1 while it was moderately suitable (S2) in Kabba. Jimoh et al. (2016) reported a slope range of 2% to be highly suitable for maize production in some parts of Nigeria. Fasina and Adeyanju (2007) also reported that a slope of < 3 % may favour mechanical operation.

Flooding was rated S1 in the three locations. Drainage was S1 in Anyigba and S2 in the other sites.

The soil texture of sandy clay loam and sandy loam is optimum for maize production in the three sites. The result is similar to the findings of Kefas (2016) and Jimoh et al. 2016) in other parts of the savannah zone of Nigeria.

Fertility limitations cation exchange capacity is rated below S1 in Kabba and Ejiba (S3 and S2, respectively). Organic matter is S3 in all the sites, while available phosphorus is S2 in Kabba and Ejiba. These properties constitute limitations to maize production in the study locations.

The actual suitability index ratings revealed that Kabba is currently not suitable (N1) with an actual suitability index of 10.49. Ejiba and Anyigba were marginally suitable (S3), with actual suitability indexes of 18.33 and 19.49, respectively. The soils were placed in classes l ower than S1 (highly suitable) as a result of characteristics/qualities (limiting factors) that were lower than S1. Fertility limitations for maize production are typical of Nigerian soils. A similar view was held by Orimoloye et al. (2019), Abagyeh et al. (2016), Kefas (2016), Jimoh et al. (2016, Ezeaku (2011), and Oluwatosin (2005). Fertility limitations underscore the need for sustainable soil management practices. The use of organic amendments (e.g., compost, manure) and inorganic fertilizers should be carefully balanced to avoid over-reliance on chemical inputs, which can lead to soil degradation and environmental pollution. Furthermore, conservation agriculture practices, such as minimum tillage, crop rotation, and cover cropping, can be adopted to improve soil structure,

Land qualities	Kabba	Ejiba	Anyigba
Climate (c):			
Annual rainfall (mm)	S1 (100)	S1 (100)	S1 (100)
Length growing season(days)	S1 (100)	S1 (100)	S1 (100)
Mean annual temperature (°C)	S3 (39)	S1 (100)	S1 (100)
Relative humidity (%)	S1 (100)	S1 (100)	S1 (100)
Topography (t)			
Slope (%)	S2 (84)	S1 (100)	S1 (95)
Wetness (w) :			
Flooding	S1 (100)	S1 (100)	S1 (100)
Drainage	S2 (84)	S2 (84)	S1 (100)
Soil physical properties (s):			
Texture	S1 (100)	S1 (100)	S1 (100)
Fertility (f):			
Cation exchange capacity (Cmol/Kg clay)	S3 (35)	S2 (50)	S1 (95)
Base saturation (%)	S1 (100)	S1 (100)	S1 (100)
Organic matter (%), 0-50cm	S3 (20)	S3 (20)	S3 (20)
pH (H_2O)	S1 (100)	S1 (100)	S1 (100)
Available phosphorus (mg/kg)	S2 (84)	S2 (84)	S1 (100)
Total Nitrogen (%)	S1 (100)	S1 (100)	S1 (100)
Extractable K (cmol/kg)	S1 (100)	S1 (100)	S1 (100)
Actual suitability index	N1 (10.49)	S3 (18.33)	S3 (19.49)
Potential suitability index	S3 (32.76)	S1 (84)	S1 (95)

Note: S1 – Highly Suitable S2 – Moderately Suitable S3 – Marginally Suitable N1 – Currently Not Suitable
Source: Land suitability evaluation analysis

Table 4: Land suitability ratings of the locations for maize.

enhance water retention, and reduce erosion, thereby promoting long-term soil health. These will ameliorate fertility limitations. Under this consideration, the potential suitability ratings of the locations improved, with Kabba having a potential suitability index of 32.75 and rated S3 (marginally suitable) while Ejiba and Anyigba were highly suitable with an index of 84 and 95, respectively. The improvement in the suitability ratings is a pointer that agronomic practices targeted towards improving soil fertility will lead to improved maize production. For improved and sustainable maize production, the adoption of improved cultivation and management practice is inevitable by farmers in the study locations. However, the adoption of these practices by farmers could be hindered by socio-cultural barriers. Addressing these barriers is critical to ensuring the successful implementation of sustainable agricultural practices (Barbosa Junior, 2022).

Sensitivity analysis of limiting properties that can be altered by management

The sensitivity analysis (Table 5) indicates that organic matter, soil pH, and total nitrogen significantly affect crop yields, while CEC, available phosphorus, and extractable potassium also play essential roles. By concentrating on interventions that target these key properties, farmers can improve soil fertility, increase yields, and promote sustainable agricultural production. Continuous monitoring and adaptive management are vital for preserving soil health and productivity over the long term.

Yield of maize

The data on the yield of maize is presented in Table 6. There was significant difference ($P>0.05$) between yield obtained from farmers' practice (M1) and that of the improved cultivation and management practice (M2). M2 was significantly higher than M1 with average yield of 4530, 5950 and 5860 compared to 3500, 4530 and 4410 at Kabba, Ejiba and Ayingba respectively. This can be attributed to higher seeding rate, defined spacing, effective weed and pest control and higher fertilizer doses in M2 than M1. The low adoption of improved crop production practices, as highlighted by Obiechina (2012) and Mgbenka and Mbah (2016), is a significant factor contributing

Soil Property	Kabba			Ejiba			Anyigba		
	BV	C	IY (%)	BV	C	IY	BV	C	IY
Cation exchange capacity (Cmol/kg clay)	12.60	11.34–13.86	±5–10	17.22	15.50-18.94	±5–10	26.18	23.56–28.80	±5–10
Base saturation (%)	90	81–99	M	70	63-77	±5–10	75	67.5–82.5	±5–10
Organic matter (%), 0-50 cm	1.80	1.62–1.98	±8–12	2.83	2.55-3.11	±8–12	2.14	1.93–2.35	±8–12
pH (H2O)	6.05	5.44–6.66	±10–15	5.74	5.17-631	±10–15	5.90	5.31–6.49	±10–15
Available phosphorus (mg/kg)	8.35	7.52–9.19	±5–10	12.32	11.09–13.55	±5–10	25.50	22.95–28.05	±5–10
Total Nitrogen (%)	0.18	0.16–0.20	±10–15	0.27	0.24–0.30	±10–15	0.20	0.18–0.22	±10–15
Extractable K (cmol/kg)	0.51	0.46–0.56	±5–10	1.16	1.04–1.28	±5–10	0.82	0.74–0.90	±5–10

Note: BV = Base line; C = ±10% Change; IY = Impact on Yields, m = minimal

Source: Economics analysis

Table 5: Summary of sensitivity analysis result of soil properties.

Treatment	2021	2021	2023	Average yield (kg/ha)
KabbaM_1	3615b	3450b	3435b	3500
KabbaM_2	4540a	4655a	4395a	4530
EjibaM_1	4654b	4238b	4458b	4450
EjibaM_2	6007a	5965a	5878a	5950
AyingbaM_1	4390b	4650b	4190a	4410
AyingbaM_2	5940a	5895a	5745b	5860

Note: Means in a column or row followed by the same letters are not significantly different at 5% level of probability.

Source: Field data and statistical analysis

Table 6: Maize yield in the locations.

to the low yield output of arable crops in Nigeria. This challenge is further compounded by environmental factors (such as climate variability and soil degradation) (Olumide, 2022) and socio-cultural barriers (such as traditional practices and limited access to resources) (Salisu, 2022).

The yield varies slightly by the year for all the treatments in the locations, and this can be attributed to environmental and biological factors, which vary by year. Between the locations, Ejiba had a higher average yield for each of the treatments than the other locations, this is not surprising because most land qualities are more suitable for maize in Ejiba than other locations. The rank of the yield performance of maize in the location is as follows: Ejiba>Ayingba>Kabba. The result on yield was in agreement with the land suitability ratings of the location in this study. The actual suitability rating was reflected in the yield of maize under farmer's management (M1), while M2 revealed the potential suitability.

Economic analysis of maize production in the locations

The partial budget analysis is presented in Table 7. The gross field benefits of the plots that received the recommended management practices by FFD (2002) (M1) were higher than those that were cultivated with the farmer's practice (M1). Kabba is $1,916.19 and $1,480.50, Ejiba is $2,516.85 and $1,882.35 while Anyigba is $2,478.78 and $1865.43 for M2 and M1 respectively. There is variation in the cost of land preparation, seed, herbicide, fertilizer, pest control, and shelling due to different intensities of operations and quantities required by each practice. Labour also varies. An average Nigerian earns a minimum of $2.6 in a day, which amounts to the minimum wage of $77 in a month (National Bureau of Statistics, 2020), therefore, the cost of labour in the three locations is not below the minimum wage, although it is lower in Kabba than others. This explained the lowest total cost that varies of $388 and $693 for M1 and M2 at Kabba. The highest for M1, $430, is at Ayingba, and the highest for M2 is $768 at Ejiba. The net benefit revealed that there is a higher benefit in M2 than M1 in all the locations. $1,092.5 and $1223.19, $1493.35 and $1748.85, and $1,435.43 and $1,731.78 were recorded for M1 and M2 at the three locations, respectively. It is noted that subsistence farmers participate in farm operations along with the members of their family and friends in some cases. Alabi and Abdulazeez (2018) affirm that In most agrarian communities of Nigeria, family size is seen

Cost	KabbaM$_1$	KabbaM$_2$	EjibaM$_1$	EjibaM$_2$	AnyigbaM$_1$	AnyigbaM$_2$
Average Yield (kg/ha)	3500	4530	4450	5950	4410	5860
Adjusted Yield (kg/ha)	3150	4077	4005	5355	3969	5274
Gross field Benefits ($/ha) at $0.47/kg*	1,480.50	1,916.19	1,882.35	2,516.85	1,865.43	2,478.78
Land preparation	79.00	129.00	68.00	120.00	66.00	92.00
Seed at $1.31 per kg	15.00	35.00	20.00	35.00	20.00	35.00
Planting	40.00	70.00	45.00	80.00	45.00	90.00
Herbicide ($/ha)	12.00	24.00	20.00	40.00	22.00	45.00
Labour for application of herbicide ($/ha)	11.00	22.00	14.00	28.00	16.00	30.00
Labour for hand weeding ($/ha)	28.00	0	30.00	0	35.00	0
Cost of fertilizer ($/ha)	78.00	150.00	78.00	150.00	78.00	150.00
Cost of fertilizer application ($/ha)	30.00	60.00	30.00	80.00	40.00	80.00
Control of Army worm and stem borer	30.00	68.00	30.00	85.00	38.00	85.00
Shelling	65.00	135.00	60.00	150.00	70.00	140.00
Total cost that vary ($/ha)	388	693	395	768	430	747
Net Benefit ($/ha)	1,092.5	1,223.19	1,493.35	1,748.85	1,435.43	1,731.78

Note: Computation was made based on the exchange rate of naira to dollar as at September, 2022
*Price as at September 2022
Source: Economics analysis

Table 7: Partial budget.

as an advantage to the household head as it signifies the availability of farm labour. Therefore, farmers in the study locations can beat the cost of labour through family labour.

The high benefits and lower total costs that vary in Ayingba for M2 in comparison with the other locations led to the tagging of Ayingba M2 as the dominated (D) site in comparison to others (Table 8) in this study. This implies that Ayingba has comparative advantage over the other locations for maize production. is a location to be sought after for maize production within the southern guinea savannah zone of Nigeria.

Treatment	Total costs that vary ($/ha)	Net benefits($/ha)
KabbaM$_1$	388	1,092.50
EjibaM$_1$	395	1,493.35
AyingbaM$_1$	430	1,435.43
KabbaM$_2$	693	1,223.19
AyingbaM$_2$	747	1,731.78
EjibaM$_2$	768	1,748.85

Source: Economics analysis

Table 8: Dominance analysis.

The marginal rates of return are presented in Table 9. Kabba had a marginal rate of return of 42.85%, Ejiba had 68.50%, and Ayingba had 93.49%. This implied that for farmers to deviate from their usual practice, adopt and invest $1.00 in the improved cultivation and management practice for maize production used in this study, they will recover the $1.00 and get an additional $0.4285, $0.6850, and $0.9349 in Kabba, Ejiba and Ayingba, respectively. Alabi and Abulazeez (2018) reported lower return on investment by maize farmers in Kaduna, northern guinea savannah agro ecological zone of Nigeria. Lower returns were also reported from other locations in Nigeria (Girei et al., 2018; Abdulaleem et al., 2017). All the reports were for farmers' practice. It may be necessary for farmers to obtain loans in other to be able to make extra investment on the improved practice. According to the guideline of CIMMYT (1988), the minimum rate of return is set between 60% to 100% considering the 5% to 8% bank interest rate for agricultural loan in Nigeria.

Treatment	Kabba	Ejiba	Ayingba
Difference in Cost that varies($/ha)	305	373	317
Difference in net benefits ($/ha)	130.39	255.50	296.35
Marginal rates of return (%)	42.85	68.50	93.49

Source: Economics analysis

Table 9: Marginal rates of return.

Sensitivity analysis of the components of economic analysis

The sensitivity analysis of the components of economic analysis (Table 10) shows that maize yield and fertilizer costs have the most significant impact on profitability. By focusing on improving yields and implementing cost-saving measures in fertilizer use, farmers can greatly enhance their net profitability. Furthermore, optimizing

Cost	BV	C %	IMGB	IMTC %
Maize Yield (kg/ha)	3500-5860	±10	±10%	-
Land preparation	66.00-129.00	±10		±2–3
Seed at $1.31 per kg	15.00-35.00	±10		±1–2
Planting	40.00-90.00	±10		±1–2
Herbicide ($/ha)	12.00-45.00	±10		±1–2
Labour for application of herbicide ($/ha)	11.00-30.00	±10		±1–2
Labour for hand weeding ($/ha)	28.00-35.00	±10		±1–2
Cost of fertilizer ($/ha)	78.00-150.00	±10		±3–5
Cost of fertilizer application ($/ha)	30.00-80.00	±10		±1–2
Control of Army worm and stem borer	30.00-80.00	±10		±1–2
Shelling	60.00-150.00	±10		±2–3

Note: BV= Baseline values; C= ±10% Change; IMGB = Impact on Gross Benefits; IMTC = Impact on Total Costs
Source: Land suitability evaluation analysis

Table 10: Summary of sensitivity analysis of economic evaluation variables.

land preparation, shelling, and other cost factors can improve overall cost efficiency. Continuous monitoring and adaptive management are crucial for maintaining profitability and ensuring sustainable maize production.

The findings of this study have significant long-term implications for improving maize productivity, enhancing food security, and promoting sustainable agriculture in the southern Guinea Savannah zone of Nigeria. However, the variability in yields and suitability across locations underscores the need for site-specific recommendations and adaptive management practices. Sustainable practices to resolve fertility problems can also reduce environmental degradation, such as soil erosion and nutrient depletion, ensuring that farmland remains productive for future generations. The findings from the southern Guinea Savannah zone can be scaled to other regions with similar agro-ecological conditions, such as the northern Guinea Savannah and Sudan Savannah zones of Nigeria and neighboring countries in West Africa. However, scaling up the adoption of improved practices requires addressing socio-cultural barriers, providing institutional support, and leveraging technology to ensure that innovations reach smallholder farmers. Scaling up requires adaptation to local conditions, including soil types, rainfall patterns, and socio-cultural contexts.

Conclusion

The conduction of the experiment on the farmer's field allowed farmers to have a firsthand experience of the implication of their practices and the recommended practices for maize production. Limitations to maize production in the study area are mean annual temperature, slope, drainage, low cation exchange capacity clay, low organic matter, and low available phosphorus. For every $1.00 invested in the adoption of the improved cultivation and management practice, the farmer will recover the $1.00 and get an additional $0.4285, $0.6850, and $0.9349 in Kabba, Ejiba, and Ayingba, respectively. The improved management practice is recommended to farmers in the agro ecological zone. However, achieving environmental sustainability and overcoming socio-cultural barriers to adoption require a multifaceted approach that integrates technical, economic, and social interventions. By addressing soil fertility limitations, promoting climate-smart practices, and engaging farmers in participatory decision-making, stakeholders can create an enabling environment for sustainable agricultural development. Additionally, addressing socio-cultural barriers, such as limited access to resources and risk aversion, is essential to ensure the widespread adoption of improved practices and the long-term resilience of farming communities. Further research on the assessment of other important crops in agro ecological zones of Nigeria in other to identify locations that has comparative advantage for specific crops in the zone is also recommended.

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