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# Effect of Integrated Soil Fertility Management (ISFM) Technology on the Productivity and Income of Smallholder Maize Farmers in Benue State, Nigeria

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**ABSTRACT**

*The study examined the effect of Integrated Soil Fertility Management (ISFM) technologies on the productivity and income of smallholder maize farmers in Benue State, Nigeria. The specific objectives were to identify the components of ISFM technologies, determine the costs and returns of the technologies, and assess their effect on productivity and income. A sample of 356 maize farmers was selected from a population of 3,230 registered maize farmers in the state. Data were collected using structured questionnaires and analyzed with one-way ANOVA and gross margin analysis. The profitability test revealed that farmers using cover cropping achieved the highest profit of ₦88,743.51/100kg, while those using zero/minimum tillage realized the lowest profit of ₦73,166.14/100kg. The profitability analysis further showed that ISFM users attained higher returns compared to non-users. Among the technologies, the use of manure yielded the highest mean return (₦90,393.77/100kg), whereas zero/minimum tillage had the lowest mean return (₦73,500/100kg). Farmers applying inorganic fertilizer incurred the highest expenses (₦6,083.49/100kg), while those practicing zero/minimum tillage had the lowest expenses (₦33.86/100kg). Results on the effect of ISFM technology revealed a significant difference in productivity between users and non-users, particularly for inorganic fertilizer, legume intercropping, zero tillage, and agroforestry, all significant at the 1% level. The study recommended reducing implementation costs, improving access to resources, and providing tailored support aligned with farmers' economic priorities. These goals can be achieved through stronger government support, NGO involvement, and the participation of agricultural institutions. Additionally, robust collaborations among government, NGOs, and the private sector are essential for scaling up ISFM adoption in local communities.*

***Keywords: Productivity, ISFM Technology, Smallholder farmers, Income, Benue State***

## 1.0 INTRODUCTION

### *1.1 Background of the Study*

The Integrated Soil Fertility Management (ISFM) is a framework recommended by governments and donors in sub-Saharan Africa for boosting crop productivity through combining fertilizer use with other soil fertility management technologies, based on site conditions (Ande et al., 2017; Horner and Wollni, 2021). Soil nutrient depletion remains a biophysical cause of declining crop yields per area in semiarid areas of sub-Saharan Africa (Sanchez, 2019). Notably, common major limiting nutrients like Nitrogen (N) and Phosphorus (P) are well understood and eliminated through routine use of commercially formulated fertilizer. Soil micronutrients such as Manganese (Mn), Copper (Cu), Iron (Fe), and Zinc (Zn) have shown to improve the efficiency of applied N and P by crops on non-responsive soil (Njoroge *et al*., 2018).

According to Adeyemo *et al.* (2017), the main issue in the Nigerian agriculture is that of low productivity. The greatest threat to sustaining agricultural productivity in the Nigerian farming communities is the declining productivity of soil caused by the loss of soil fertility through the erosion of top-soil brought about by inappropriate land use practices and the loss of soil water content, soil structure and porosity due to persistent laterization of the top soil as a result of continuous exposure to sun by man and animals (Alemayehu, *et al,* 2013). Also with the population growth, demand for land has increased resulting in intense cultivation with little or no fallow periods and the reliance on continuous cropping rather than conservation cropping systems (Assefa and Hans-Rudolf, 2016).

In recent years, Nigeria has seen its maize output decline. According to Okojie (2021), Nigeria is currently producing about 10.5 million metric tons per annum with a domestic demand of 15million metric tons, leaving a supply-demand gap of 4.5million tons per annum. (Federal Ministry of Agriculture 2022). This short-fall in supply has caused prices of maize to increase, posing a major threat to poultry, food and beverage industries and the country's food security. This can be attributed to inability of maize farmers to adopt ISFM technologies such as control soil erosion, shifting cultivation, organic manure, use of improved seed varieties, (Aura 2016).

Admittedly, Vanlauwe and Alley (2019) opined that, the only way to address the problem of low agricultural productivity and environmental degradation is through increased adoption of ISFM technologies, particularly fertilizer use –both organic and inorganic, especially in low-income countries like Nigeria where fertilizer use is lowest. Despite the benefit, of adoption of ISFM technologies in crop production in Nigeria and Benue State in particular, farmers' productivity and income remain low. According to the World Bank report (2016), unless radical interventions occur, projected inorganic fertilizer consumption growth in Nigeria until 2030 will remain at 1.9% per annum. This can be attributed to a range of factors -both economic and non-economic, that hinder adoption of ISFM technologies among farmers World Bank report (2016) on Africa Fertilizer Strategy Assessment.

Several studies such as Norjo and Ajasi (2019) who examined the impact of intergraded soil ferity management in Ghana, also, Boansi *et al* (2024) examine the Impact of Integrated soil ferity management on maize yield, yield gap and in income in northern Ghana, Urmi *et al*., (2022). An assessment of the effect of erosion in sensitive clay landslide: a case study of Saint-Jude Landslide. In: Geo Calgary, also Hassan and Otman (2018) examined the impact of intergraded stringer management technology on maize productivity in Northern Nigeria all targeted at boosting maize production in the country focus mainly on resource use efficiency in maize production, and how socio-economic variables influence output of maize farmers. Presently the study on the effectiveness of ISFM technologies adopted by smallholder maize farmers in Benue State which dwells on the economic significance of ISFM has been underexplored. Hence, this study is aimed at bridging this knowledge gap. The broad objective of the study was to examined the effect of ISFM technologies on the productivity and income of small-scale maize farmers in Benue State. The specific objectives were to;

1. identify the components of ISFM technologies of maize farmers in the study area?
2. examined the costs and returns of the ISFM technology?
3. determined the effect of ISFM technologies usage on productivity and wage income of smallholder farmers?

## 2. Review of Related Empirical Studies

Adem, *et al.* (2023) carried out an investigation on the elements that could influence the adoption of integrated soil fertility management (ISFM) practices as well as their impact on maize yield. This study is based on a pseudo-panel collected by Ethiopia's central statistical agency (CSA) in collaboration with the World Bank. A Multinomial Endogenous Switching Regression model (MESR) was employed to achieve the specified objectives. The findings revealed that 15% of plots received no soil fertility-enhancing treatments, while 35% received a combination of inorganic fertilizer and manure to boost soil fertility. The average maize yield in the study was 3.44 tons per hectare, which was nearly equal to the average national yield in the prior year. Finally, maize yield was significantly influenced by soil fertility management measures, whether used alone or in combination of two or more soil fertility enhancing technologies. The extent of the impact, however, varies significantly depending on the inputs employed. Thus, using manure or compost alone had a moderate but significant impact on maize yield, but using inorganic fertilizer in combination with manure had the biggest impact. Therefore, policies that support the expansion of ISFM practices should be promoted. Farm households also receive technical assistance and training to better understand the use of ISFM practices, and policies that promote them should be expanded.

In a research study conducted by Omisore (2013) revealed that the use of only urea to improve soil fertility gave a gross margin of ₦87,683/ ha while the combined use of organic manure and inorganic fertilizer gave a gross margin of ₦74,184/ha. The study also indicated that even though the use of only urea had high yield response, it was not as cost efficient as the combined use of organic manure and inorganic fertilizer. The use of only urea in the production of maize gave a variable cost of ₦114, 893.00 and the combined use of organic manure and inorganic fertilizer incurred a lower variable cost of ₦101, 627.00 per hectare respectively. Hence, a rational maize farmer would like to produce optimally at the minimum cost of production and adopt the use of the integrated soil fertility management.

Mutoko *et al.* (2015) investigated the contribution of integrated soil fertility management (ISFM) practices to both technical and allocative efficiencies in the maize farming system of Kenya. To determine efficiency gains from ISFM, we compared efficiencies of two groups of smallholders: those within the contact areas and their counterfactuals. We estimated Cobb-Douglas stochastic functions based on maize production data collected from a stratified sample of 373 farmers. The results indicate that farmers who applied ISFM were more efficient both technically and allocatively than those who did not. Application of ISFM practices increased technical and allocative efficiencies by 26 and 30%, respectively.

## 3.0 METHODOLOGY

### *3.1 Study Design*

The study adopted the survey design approach to achieve the research objectives. The study is correlation in terms of methodology as it involved collection of data from different farmers within a short period of time. A correlation research design according to Bhandri (2021), investigates the relationship between variables without controlling or manipulating any of them.

### *3.2 The Study Area*

The study was conducted in Benue State. The State was created in 1976, located in the Middle Belt region of Nigeria. Benue State derives its name from River Benue, the second largest River in Nigeria. It lies approximately between latitudes 6 and 8º N and longitudes 7 and 10º E. The State shares boundaries with five other states namely, Nasarawa, to the North, Taraba to the East, Cross River to the South and East-Enugu to the South-East, and

Kogi to the West. The Southern part of the State shares boundary with Republic of Cameroon. The State is also bordered on the North by 280 km River Benue, and is traversed by 202 km of River Katsina-Ala in the inland areas. The State has a total land area of about 30,955 square kilometers and administratively it is divided into 23 Local Government Areas. Benue State has an estimated population of 6,219244, and is made up of 913,159 farm families (2020). Benue state is blessed with fertile soil for agricultural activities and as such has her slogan as the food basket of the nation, the inhabitants engage in the production and marketing of Cereal crops like Maize, Sorghum, Gunea Corn, Rice, Beans, Soybeans, Groundnut, Beniseed, Melon, and so on, unlike tubers like Yam, Cassava, potatoes and so on, including Vegetables and other cash crops.

### *3.3 Population of the Study/ Sample Size and Sampling Technique*

The population of the study consist of 3230 registered smallholders' maize farmers in Six Local Government Areas of the State, two each from the Agricultural Zones comprising Zone A: Vandeikya and Kwande Local Governments, Zone B: Gboko and Guma Local Governments, and Zone C: Oju, and Otukpo Local Governments. (BNARDA 2024).

The sample size was determined using Taro Yamen's formula for finite population. This formula is giving as follows:

$$n = \frac{N}{[1+N(e)^2]}$$

Where:

n=sample size (3230)

N=finite population

e= level of significance (0.05)

1=constant

The sample size was determined thus:

$$n = \frac{3230}{1+3230(0.05)^2}$$

$$\frac{3230}{9.075}$$

n=356

### *3.5 Method of Data Collection*

The study utilized questionnaire to obtain primary data.

### *3.6 Variable Specification/ Model Specification*

Variables used in the study were;

**Age** was measured in years

**Gender** was measured using dummy variable (l=male, 0=female)

**Household size** was measured in numbers.

**Educational level** was measured in years spent in formal education.

**Marital status** was measured using dummy variable (1=married, 0=not married)

**Farming experience** was measured in years; it represents the number of years the respondent has spent in farming.

**Farm size** was measured in hectares.

**Cooperative membership** was measured using dummy variables (1= member, 0=none member)

**Farm implements** were measured in naira.

**Fertilizer** was measured in naira.

**Pesticides** measured in naira.

**Herbicides** measured in naira.

**Dependent variable:** Output; (returns on farm management)

### *3.7 Model specification*

### *3.7.1 Gross Margin Analysis*

The Gross Margin analysis was used to determine the profitability and returns on the ISFM technologies used by these farmers (objective ii)

The gross margin analysis is calculated by using the following formula:

GM = TR – TVC --------------------(1)

Where:

GM = Gross margin per Kg in naira

TR = Total returns in naira

TVC = Total variable cost in naira

**3.7.2. Returns on Investment**

**(ROI) = TR-TVC**

**TVC -------------(2)**

TR = Total Revenue

TVC= Total Variable Cost

## 4.0 RESULT AND DISCUSSION

### *4.1 Component of ISFM Technology Used by the Respondents*

The component of ISFM technology used by maize farmers is presented in Table 2. The findings indicated that, 70.0 % of the maize farmers adopted inorganic fertilizer, 59.8% used manure, 36.9% used cover cropping, 19.8% used legume intercropping, 16.8% used agroforestry 13.1% used crop rotation, 8.9% used Zero/minimum tillage, while 7.7% used none of the ISFM components. This result is in line with findings of (Otieno *et al.* 2021) who opined that, majority of the farmers prefer the use of manure and inorganic fertilizer as soil fertility management approach. On the use of inorganic fertilizer and manure it can be inferred that, maize farmers adopt Inorganic fertilizers because they are rich in specific nutrients like nitrogen, phosphorus, and potassium (NPK) that can release quick nutrients that are readily available to plants, which can boost maize yields in the short term. This is in consonance with the findings of Vanlauwe *et al*. (2015) who observed that inorganic fertilizers, is adopted in various regions across sub-Saharan Africa to improve crop yield, soil health, and long-term sustainability.

On the use of agroforestry which is the least among them, it can be inferred that because agroforestry systems often require initial investment in planting trees or integrating trees into cropping systems, which may not provide immediate financial returns. Maize farmers typically seek practices that offer quick returns to boast their productivity and livelihood. This in line with the findings of Dechaineux, and Renaud, (2020) who reported that farmers are faced with economic, technical and policy challenges in adapting to agroforestry practices.

**Table 1 Component of ISFM technology used by maize farmers (n= 337)**

| ISFM components | Frequency | Percentage * |
|---|---|---|
| Inorganic fertilizer | 236 | 70.0 |
| Cover cropping | 123 | 36.9 |
| Manure | 199 | 59.8 |
| Legume intercropping | 66 | 19.8 |
| Agroforestry | 56 | 16.8 |
| Crop rotation | 44 | 13.1 |
| Zero/minimum tillage | 30 | 8.9 |

Source: Field Survey data 2024 *= Multiple response existed hence percentage >100

### *4.2 Costs and Returns of ISFM Technology Used by Maize Farmers*

The cost and returns in the use of ISFM technology is presented in Table 3. The result indicated that crop rotation technology has a mean cost of ₦1,676.92 per kg and a mean return of ₦82000.00, inorganic has a mean cost of ₦6083.49 per kg with a mean return of ₦87,221.86 kg, manure has a mean cost of ₦1,718.18 per kg with a mean return of ₦903,93.77 per kg, cover cropping has a mean return of ₦771.61 per kg with a mean return of ₦89,515.12 per kg, legume intercropping has a mean cost of ₦494.82 per kg with a return of ₦81,272.67, zero/minimum tillage has a mean cost of ₦333.86 per kg with a return of ₦73,500.00 per kg, agroforestry has a mean cost of ₦1,002.32 per kg with ₦81,089.29 per kg, while maize farmers who did not adopt either of the ISFM technology incurred the mean cost of ₦1,037.78 with a return of ₦813,89.62 per kg.

The findings on the use of manure which has the highest mean return can be inferred that because manure is often readily available on farms especially for mixed crop-livestock farmers, making it a cost-effective soil fertility amendment compared to chemical fertilizers or advanced technologies like agroforestry. This is in line with the report of Kihara *et al* (2016) who noted that smallholder farmers preferred inputs like manure due to their low cost and direct impact on soil fertility.

The findings on zero/minimum tillage which has the lowest with the mean cost of ₦333.86 and mean return of ₦73,500.00 can be inferred that zero/minimum tillage limit the incorporation of organic matter and nutrients into the soil, resulting in lower nutrient availability for crops. This is in consonant with the findings of Lampurlanés *et al.* (2016) who opined that Zero tillage practices decrease soil evaporation due to stubble retention.

### *4.3 Profitability Test of ISFM Technology Used by Maize Farmers*

Table 3 shows the profitability test of ISFM technology used by maize farmers in the study area. The result shows that, there is a significant difference in the costs and returns of ISFM technology used by the maize farmers. Details of the findings shows that crop rotation has a significance difference with the return of ₦82000, inorganic fertilizer has a significant difference with the returns of ₦87,221.86, manure has a significance difference with the return of ₦903,93.77, cover cropping has a mean difference of ₦89,515.12, legume intercropping had a mean different of ₦81,272.67, users of zero/minimum tillage had the return of ₦73,500.00, agroforestry had mean significant return of ₦89,089.29. All the ISFM technology used by maize farmers shows a positive and significant return in profit at 1% level. This implies that maize farmers have the potentials to increase their investment into ISFM technology in the study area. The findings show that users of manure record the highest significant return in the study area. Again, this can be inferred that because farmers can collect manure from their livestock or acquire it locally, avoiding high transportation or procurement costs associated with other synthetic fertilizers or other ISFM technologies. Also, most maize farmers also keep livestock, providing a steady source of manure, ensuring a reliable supply. This is in consonant with the revealed of Barmire and Manyong (2013) who reported that smallholder farmers who used organic manure earned higher net returns than alley cropping practice in the rain forest.

The result further indicated that the users of zero/minimum tillage record a lower return as compared to other ISFM technologies though significant at 1% level. This can be attributed to the fact that, Zero or minimum tillage focuses on long-term sustainability and land conservation, which may not directly translate into short-term yield gains. This is in agreement with the findings of Adam and, Abdulai (2023) who observed a relatively higher maize yields when transitioning from short-term into medium- to long-term zero/minimum tillage adoption, potentially due to the gradual improvement in soil health (i.e., chemical, physical, and biological properties) over time.

**Table 3 Costs and Returns of ISFM Technology Used by Maize Farmers**

| ISFM technology | Mean return (₦/100kg | Mean cost (₦/100kg) |
|---|---|---|
| None | 1002.32 | 1037.78 |
| Zero/minimum tillage | 73500.00 | 333.86 |
| Legume intercropping | 81272.67 | 494.82 |
| Crop rotation | 82000.00 | 1676.92 |
| Inorganic fertilizer | 87221.86 | 6083.49 |
| Agroforestry | 89089.29 | 1002.32 |
| Cover cropping | 89515.12 | 771.61 |
| Manure | 90393.77 | 1718.18 |

**Source: Field Survey data 2024**

### *4.4 Effects of ISFM Technology on the Productivity of Maize Farmers*

Table 4 shows the effects of ISFM technology on the productivity of maize farmers; the findings determine if there is significant difference on the productivity between users and non-users of ISFM technologies among maize farmers. The results show a significant difference in the productivity between users of inorganic fertilizer, legume intercropping, zero tillage, and agro forestry all at 1% level.

On the users of inorganic fertilizer productivity gap, this could be due to the immediate nutrient availability provided by inorganic fertilizers, which directly influences plant growth and yield. Non-users, constrained by nutrient-deficient soils and limited access to inputs, cannot achieve the same level of productivity. This is consistent with findings from ISFM research, as detailed by Morris (2018), who opined that fertilizer play critical role in addressing soil nutrient deficiencies and enhancing crop yields.

On the significant different between the users of legume intercropping and non-users can be inferred that because Intercropping optimizes resource use, such as light, water, and nutrients, by utilizing complementary growth patterns of maize and legumes, while sole cropping may not utilize resources as efficiently, resulting in lower overall productivity. The productivity different is in consistent with the findings of Snapp *et al.* (2020) who reported that legume intercropping plays a significant role in nitrogen fixation, soil fertility improvement, and resource efficiency in boosting crop yields.

On the significant difference in the productivity between users of zero tillage and non-users can be inferred that because zero tillage minimizes soil disturbance, preserving soil structure and improving water infiltration and retention. This provides maize with a stable root environment and consistent moisture levels, leading to higher productivity. While conventional tillage disrupts soil structure, increasing the risk of erosion, compaction, and reduced water-holding capacity, which negatively impacts maize yields. This reveal is in agreement with the findings of Derpsch *et al.* (2020) who emphasized the benefits of improved soil structure, moisture conservation, and enhanced nutrient use efficiency under zero tillage.

On the significant difference in the productivity between users of agro forestry and non-users can be inferred that because tree canopies reduce evaporation and provide shade, while root systems improve soil structure, enhancing water infiltration and retention. While non-agroforestry systems are more prone to moisture loss through evaporation, leading to water stress and reduced maize productivity. This is in conformity with the findings of Garrity *et al*. (2010) who reported that agro forestry helps to improved soil fertility, erosion control, and biodiversity.

**Table 4 Effect of ISFM Technology on Productivity of Maize Farmers (per 100kg bag)**

| Variable | Mean (100kg per bag) | Mean difference | t-value | p-value |
|---|---|---|---|---|
| Users of crop rotation | 30.45 | 7.605 | 1.175 | 0.246 NS |
| Non users of crop rotation | 22.85 | | | |
| Users of inorganic fertilizer | 26.31 | 3.200 | 4.367 | 0.000*** |
| Non users of inorganic fertilizer | 18.11 | | | |
| Users of manure | 23.28 | -1.612 | 0.648 | 0.418 NS |
| Non-Users of manure | 24.89 | | | |
| Users of cover cropping | 23.53 | -0.629 | -0.287 | 0.774NS |
| Non-Users of cover cropping | 24.16 | | | |
| Users of legume intercropping | 31.27 | 9.128 | 3.017 | 0.003*** |
| Non-Users of legume intercropping | 22.14 | | | |
| Users of zero tillage | 38.83 | 16.384 | 3.955 | 0.000*** |
| Non-Users of zero tillage | 22.45 | | | |
| Users of agro forestry | 31.63 | 9.257 | 2.892 | 0.005*** |
| Non-Users of agro forestry | 22.37 | | | |

Source: Field Survey data 2024 =***Sig 1% NS =Not Significant

## 5.Conclusion and Recommendations

Evidenced from the study has shown that, majority of the farmers preferred the use of inorganic fertilizer and manure as an ISFM technology components in the study area because they are rich in specific nutrients like nitrogen, phosphorus, and potassium (NPK) that can release quick nutrients that are readily available to plants, which can boost maize yields in the short term. It can also be deduced that the adoption of ISFM technologies by maize farmers in the study area appears to be primarily driven by its cost-effectiveness and potential for maximizing returns. This underscores the importance of economic viability as a key determinant in farmer's decision-making processes when considering new agricultural technologies.

The significant difference in profit between the users and non-users of ISFM technologies among maize farmers in the study area underscore the economic advantage of using these practices. This finding highlights the potential of ISFM technologies to enhance profitability and supports their promotion as viral strategy for improving agricultural productivity and livelihoods.

### *5.1 Recommendations*

The following recommendations were made based on the findings of the study;

i. In other to enhance wider adoption of ISFM technologies among farmers, efforts should focus on reducing implementation costs, improving access to resources, and providing tailored support that aligns with farmers economic priorities. This is achievable via government support, NGOs and agricultural institutions.

ii. Agricultural research institutes, extension houses should double their efforts in organizing workshops and field demonstrations to show the economic benefits of ISFM practices to farmers, highlighting the return on investment.

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