



Assessment of the use of Integrated Soil Fertility Management Practices among Smallholder Maize Farmers in Nasarawa State, Nigeria

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Abstract— This study assessed the adoption and utilization of Integrated Soil Fertility Management (ISFM) practices among smallholder maize farmers in Nasarawa State, Nigeria, with specific focus on: (i) determining the effect of households' socio-economic factors on farmers' uptake and use of ISFM technologies; and (ii) ascertaining the various soil fertility management strategies employed by smallholder farmers. A multi-stage sampling technique was employed to select 300 respondents across six communities in three Local Government Areas (Lafia, Doma, and Nasarawa Eggon). Data were collected using structured questionnaires and analyzed using descriptive statistics, binary logistic regression, and a 5-point Likert scale. The logistic regression results showed that age ($p=0.022$), education ($p=0.001$), annual income ($p=0.032$), extension contact ($p=0.005$), and association membership ($p=0.033$) significantly influenced ISFM adoption. Regarding soil fertility management strategies, chemical fertilizer use dominated at 89%, followed by combined organic-inorganic application (81.7%) and crop rotation (78%). The study concludes that ISFM adoption is shaped by socio-economic and institutional factors, with fragmented adoption of practices characterized by heavy reliance on chemical fertilizers while underutilizing complementary soil health practices. Strengthening extension systems, improving input accessibility, enhancing farmer capacity through targeted training, and promoting integrated approaches that combine organic and inorganic nutrient sources are recommended to promote sustainable soil fertility management among smallholder maize farmers in the study area.

Keywords— *Integrated Soil Fertility Management Practices, adoption, soil fertility strategies, smallholder farmers.*

I. INTRODUCTION

Agriculture remains the backbone of many developing economies, and its role in food security, poverty alleviation, and economic growth has been emphasized in countless policy documents and academic works over the decades. In sub-Saharan Africa (SSA), smallholder farming systems dominate agricultural production, accounting for nearly 80 percent of food supply (Ademola & Musa, 2021). However, the sector faces multiple structural challenges, among which soil fertility degradation stands out as one of the most critical. Declining soil quality threatens not only crop productivity but also the livelihoods of millions who depend on agriculture for subsistence and income. The Food and Agriculture Organization has repeatedly stressed that soil nutrient depletion is a fundamental constraint undermining agricultural resilience in SSA (FAO, 2020).

Maize, one of the most widely cultivated cereals in Africa, has been particularly affected by soil nutrient depletion, with yields in many regions stagnating at 1.5–2.5 tons per hectare against a potential of 5–7 tons under improved soil fertility

management (Kwara & Yusuf, 2020; Yakubu & Ibrahim, 2024). Despite the availability of innovative approaches such as Integrated Soil Fertility Management (ISFM), which emphasizes the combined use of organic and inorganic inputs alongside good agronomic practices, adoption across Africa has remained uneven due to knowledge gaps, institutional weaknesses, and resource constraints (Ajayi & Usman, 2021).

In Nigeria, these continental challenges are vividly mirrored, with soil fertility decline continuing to undermine the productivity of major staple crops. Agriculture remains central to the Nigerian economy, employing over 60 percent of the population and contributing significantly to household food security, yet low soil fertility, poor extension services, and weak access to inputs have constrained productivity growth (National Bureau of Statistics, 2022; Bamigboye, 2022). Maize stands out as both a staple and a commercial crop in the country, grown widely across ecological zones and consumed by nearly all households either directly or indirectly through livestock feed and industrial uses (Lawal, Ibrahim & Odey, 2020). However, national average maize yields remain at 2 tons per hectare, far below the achievable 5 tons under proper soil fertility management (Adamu & Sanni, 2023).

In Nigeria, 90% of farmers are subsistence farmers who have little access to outside assistance for boosting soil fertility (Kumwenda et al., 2019). Low soil fertility in smallholder agriculture has frequently resulted in more than 60% of smallholder farmers producing insufficient crops to meet their household food needs, compelling them to engage in casual labor or off-farm wage work in order to obtain food (Kumwenda et al., 2019). Generally, most studies on soil fertility management technologies have focused on other regions of sub-Saharan Africa, with limited emphasis on Nigeria. In countries such as Kenya and Uganda, empirical research has examined factors influencing farmers' adoption of inorganic fertilizers and selected soil fertility innovations (Nambiro & Okoth, 2023; Ariga & Jayne, 2024; Okoboi & Barungi, 2022).

Several studies on Nigeria have concentrated on the use of chemical fertilizers and organic manure in maize and rice systems (Chude, Olayemi & Daudu, 2018; Ayoola & Makinde, 2021). While these studies provide valuable insights into input use, they rarely capture the holistic framework of ISFM—which integrates organic and inorganic nutrient sources, improved germplasm, and sound agronomic practices in a complementary manner (Vanlauwe, Coyne & Chianu, 2020). Evidence from Nasarawa State Ministry of Agriculture (2021) indicates that maize farmers in the state still depend heavily on single fertility practices such as NPK fertilizer application or farmyard manure, with little integration of improved seeds, residue management, and crop diversification. This piecemeal approach has limited effectiveness in reversing soil nutrient depletion, reducing environmental degradation, and achieving sustainable productivity.

Nasarawa State, located in the north-central region of Nigeria, epitomizes this paradox of high agricultural potential constrained by soil degradation. The state is predominantly agrarian, with maize as one of its most important food and cash crops, cultivated mainly by smallholder farmers on average farm sizes of 1–3 hectares (Isaac & Ojo, 2023). Farmers in Nasarawa consistently report declining yields due to continuous cultivation, poor fertilizer access, and limited adoption of ISFM practices, despite the availability of fertile lands and favourable climatic conditions. The broad objective therefore is to assess the use of ISFM practices among smallholder maize farmers in Nasarawa State. The specific objectives are to:

- determine the effect of households' socio-economic factors on farmers' uptake and use of ISFM technologies.
- ascertain the various soil fertility management strategies employed by smallholder farmers

II. LITERATURE REVIEW

2.1 Theoretical Framework: Diffusion of Innovations Theory (DOI):

This study is based on the Diffusion of Innovations Theory (DOI) as the primary theoretical framework. The theory was originally propagated by Everett M. Rogers in 1962, who defined diffusion as "the process by which an innovation is communicated through certain channels over time among the members of a social system." Rogers identified four core elements of diffusion: the innovation itself, communication channels, time, and the social system. Central to the theory is the proposition that individuals' decisions to adopt an innovation are influenced by their perceptions of five key attributes: relative advantage, compatibility, complexity, trialability, and observability. The theory assumes that individuals are influenced not only by personal evaluation of an innovation but also by social interactions and peer influence, making it

particularly relevant for understanding technology adoption in rural and communal settings (Rogers, 1962; Rogers, 2003). In applying this theory to the study, the use of Integrated Soil Fertility Management (ISFM) practices among smallholder maize farmers is conceptualized as an innovation adoption process shaped by farmers' perceptions, social interactions, and institutional support systems. By employing DOI, this study explains variations in ISFM use as outcomes of differential access to information, perceptions of innovation attributes, and positions within the social system (Feder, Just, & Zilberman, 1985; Rogers, 2003).

2.2 Conceptual Framework:

The conceptual framework for this study illustrates the interaction between independent, intervening, and dependent variables in shaping ISFM adoption among smallholder maize farmers. The independent variables comprise social, economic, and institutional factors that influence farmers' decisions to adopt soil fertility management practices. Social factors include age, gender, educational level, farming experience, and household size. Economic factors encompass availability of credit, cost of technology, farm size, farm income, and climatic conditions. Institutional factors include access to extension services and membership in farmer associations. The intervening variables represent the specific Integrated Soil Fertility Management practices that farmers may adopt as part of their soil management strategies. These include improved crop varieties, crop rotation, organic manure application, fertilizer use, composting, crop protection measures, agro-forestry practices, and general soil fertility enhancement techniques. The dependent variable focuses on two key outcomes: farmer's uptake of ISFM technologies and farmer's use of ISFM practices. Adoption is measured as the farmer's decision to incorporate ISFM practices into their production system, while use refers to the extent and intensity of application of these practices on their farms

III. METHODOLOGY

3.1 Study Area:

Nasarawa State, the focus of this study, is located in the North Central geopolitical zone of Nigeria. It lies between latitude 7°45'N and 9°25'N, and longitude 7°00'E and 9°37'E, sharing boundaries with the Federal Capital Territory (FCT) to the west, Benue State to the south, Kogi State to the southwest, Kaduna State to the north, Plateau State to the east, and Taraba State further southeast. The state covers a total land area of approximately 27,117 square kilometers, encompassing a mix of lowland plains, gentle undulating hills, and riverine valleys. This topographical diversity contributes to a wide variety of soil types and ecological conditions conducive to crop cultivation, including maize, which is one of the dominant staple crops grown by smallholder farmers across its local government areas. In terms of population, Nasarawa State is home to an estimated 2.9 million people according to the 2022 population estimates derived from the National Bureau of Statistics and projected based on the 2006 population census. The population is distributed across 13 Local Government Areas (LGAs), which include Lafia (the state capital), Doma, Keffi, Akwanga, Karu, Obi, Wamba, Nasarawa Eggon, Nasarawa, Keana, Awe, Kokona, and Toto.

Climatically, Nasarawa State experiences a tropical sub-humid climate, marked by two distinct seasons: a rainy season from April to October and a dry season from November to March. The mean annual rainfall ranges between 1,100 mm and 2,000 mm, with higher rainfall amounts recorded in the southern and central parts of the state. Agriculture constitutes the backbone of Nasarawa's economy, employing over 70% of the state's labour force, the vast majority of whom are smallholder farmers cultivating on plots averaging between 1 and 3 hectares (FAO Nigeria, 2021).

3.2 Population of the Study and Research Design:

The study employed a survey research design and utilized structured questionnaires administered to 300 smallholder maize farmers selected through a multi-stage sampling technique across six communities in three Local Government Areas of Nasarawa State, Nigeria. The population for this study comprises all registered and active smallholder maize farmers in Nasarawa State. These farmers cultivate maize predominantly for household consumption and local markets, using small-scale production systems that average between 1 and 3 hectares.

3.3 Sample Size and Sampling Techniques:

A multi-stage sampling technique was employed in this study to ensure a representative and methodologically rigorous selection of smallholder maize farmers in Nasarawa State. In the first stage, three LGAs—Lafia, Doma, and Nasarawa Eggon—were purposively selected. These LGAs were chosen because they have high maize production intensity, active participation in agricultural extension programs, and substantial involvement in soil fertility improvement initiatives. In the second stage, a total of six farming communities—two from each selected LGA—were randomly selected using a simple random sampling technique without replacement. The sampling frame at this stage was derived from community registers maintained by the Nasarawa State Agricultural Development Programme (NADP) and local extension offices.

In the third and final stage, systematic random sampling was employed to select individual farmers from the six chosen communities. A validated sampling frame of all active maize farmers was compiled using NADP community rosters, village extension agent records, and cooperative membership lists. The total population (N) of maize farmers across the six communities was 1,200. Using Yamane's formula (1967) to determine the appropriate sample size:

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

where n = sample size, N = population size, and e = margin of error (0.05), the calculation was as follows:

$$n = \frac{1200}{1+1200(0.05)^2} = \frac{1200}{1+3} = \frac{1200}{4} = 300 \quad (2)$$

Thus, a sample size of 300 respondents was obtained, representing a 5% margin of error and ensuring a statistically robust sample. To ensure proportional representation, 50 farmers were selected per community, providing even coverage across all six communities. The systematic sampling interval (k) for each community was calculated as $k = N/n$, ensuring every kth farmer on the updated list was selected until the required 50 respondents per community were reached.

3.4 Instrumentation and Data Collection:

To obtain relevant data for this study, a quantitative data collection approach was adopted, using a well-structured questionnaire as the primary instrument. The questionnaire was administered to selected smallholder maize farmers across six communities in three purposively selected Local Government Areas in Nasarawa State.

Data collection was carried out with the assistance of trained enumerators and local extension officers, ensuring language clarity and proper understanding of questions among respondents. All questionnaires were filled out face-to-face to minimize missing data and reduce ambiguity. Upon completion, the collected data were coded and prepared for analysis using SPSS software. The structured design of the instrument ensured that each research objective was fully addressed through targeted questions, allowing for comprehensive statistical analysis and interpretation.

3.5 Method of Data Analysis:

This study employed both descriptive and inferential statistical tools to analyze the data collected in accordance with the research objectives using the Statistical Package for the Social Sciences (SPSS Version 25). For Objective 1, a binary logistic regression model was employed to analyze the socio-economic factors influencing the adoption of ISFM practices, with adoption coded as 1 and non-adoption as 0. Descriptive statistics were used to analyze Objective 2, to identify the prevalence of different ISFM components among farmers.

3.6 Model Specification:

3.6.1 Logistic Regression Model:

To achieve Objective 1, a binary logistic regression model was employed to analyze the socio-economic factors influencing the adoption of Integrated Soil Fertility Management (ISFM) practices among smallholder maize farmers in Nasarawa State. Logistic regression is appropriate for this analysis as it is specifically designed to model dichotomous outcomes—in this case, the adoption (coded as 1) or non-adoption (coded as 0) of ISFM technologies. The general logistic regression model is expressed as:

$$\text{Logit}(P_i) = \ln\left(\frac{P_i}{1-P_i}\right) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \dots + \beta_n X_n \quad (3)$$

Where:

- P_i = Probability that the i-th farmer adopts ISFM
- $1 - P_i$ = probability of non-adoption
- β_0 = intercept
- $\beta_1, \beta_2, \dots, \beta_n$ = regression coefficients corresponding to the independent variables X_1, X_2, \dots, X_n

The probability of adoption (P_i) is derived from the logit function as:

$$P_i = \frac{e^{\beta_0 + \beta_1 X_1 + \beta_2 X_2 + \dots + \beta_n X_n}}{1 + e^{\beta_0 + \beta_1 X_1 + \beta_2 X_2 + \dots + \beta_n X_n}} \quad (4)$$

Parameter estimation was carried out using the Maximum Likelihood Estimation (MLE) technique, and the estimated coefficients were interpreted using the Odds Ratio (OR), calculated as $OR = e^{\beta_j}$. Model performance was evaluated using the Hosmer-Lemeshow Test and Pseudo R-Squared measures including Cox and Snell R^2 , Nagelkerke R^2 , and McFadden's R^2 .

IV. RESULTS AND DISCUSSION

4.1 Effects of Socio-Economic Factors on ISFM Adoption and Usage:

The logistic regression analysis examined the influence of household socio-economic factors on the adoption of Integrated Soil Fertility Management (ISFM) among smallholder maize farmers in Nasarawa State. The model in Table 1 demonstrated a moderate fit, with a -2 Log Likelihood of 254.329, Cox and Snell R^2 of 0.298, McFadden's R^2 of 0.319 and Nagelkerke R^2 of 0.412, indicating that approximately 30–41% of the variation in ISFM adoption was explained by the socio-economic predictors included in the study. Among the ten predictors analyzed, five were statistically significant, namely age, education, annual income, extension contact, and association membership.

Age ($B = -0.025$, $p = 0.022$) was significant and negative, suggesting that older farmers are less likely to adopt ISFM due to risk aversion, shorter planning horizons, and preference for traditional practices (Tittonell et al., 2023). Education was highly significant ($B = 0.372$, $p = 0.001$); each additional level increased adoption likelihood by 45%. This underscores ISFM's knowledge-intensive nature and the role of education in enabling comprehension of technical recommendations and adaptive decision-making (Chianu et al., 2022). Annual income ($p = 0.032$) was significant, confirming that financial resources are essential for affording improved seeds and fertilizers, consistent with findings across sub-Saharan Africa (Kamanga et al., 2024). The strongest predictors were extension contact ($B = 0.973$, $p = 0.005$) and association membership ($B = 0.658$, $p = 0.033$). Farmers with extension contact were 2.65 times more likely to adopt, showing the importance of knowledge access and technical support (Tittonell et al., 2023). Association members were nearly twice as likely to adopt, highlighting the role of social capital, peer learning, and collective action in reducing adoption risks and improving access to inputs (Vanlauwe et al., 2019).

Gender ($B = 0.413$, $p = 0.188$) was positive but not significant; males appeared 1.5 times more likely to adopt ISFM, though this gap has narrowed due to gender-inclusive extension (Chianu et al., 2022; Sanginga & Woomer, 2019). Household size ($B = 0.108$, $p = 0.061$) had a marginal positive effect, indicating that larger households with more labour are slightly better positioned to adopt labour-intensive ISFM (Ajayi et al., 2018). Farm size ($B = 0.144$, $p = 0.093$) and years of farming experience ($B = -0.072$, $p = 0.077$) were marginally significant, while marital status ($B = 0.271$, $p = 0.302$) showed no significant effect. In summary, ISFM adoption in Nasarawa State is shaped by a combination of demographic, economic, educational, and social factors, with younger, educated, wealthier farmers with access to extension services and associations most likely to adopt.

TABLE 1
LOGIT REGRESSION ESTIMATES OF SOCIO-ECONOMIC FACTORS INFLUENCING ISFM ADOPTION AND USAGE AMONG SMALLHOLDER MAIZE FARMERS

Variables	B (Coefficient)	Standard Error	Wald Statistic	p-value	Exp(B) (Odds Ratio)	Sig.
Gender	0.413	0.314	1.731	0.188	1.511	ns
Age (Yrs)	-0.025	0.011	5.269	0.022	0.975	**
Marital Status	0.271	0.263	1.063	0.302	1.311	ns
Household Size	0.108	0.058	3.502	0.061	1.114	*
Educational Level	0.372	0.117	10.089	0.001	1.451	***
Farm Size (Ha)	0.144	0.086	2.821	0.093	1.155	*
Years of Farming Experience	-0.072	0.041	3.12	0.077	0.93	*
Annual Income (₦)	0.000018	0.000008	4.622	0.032	1	**
Extension Contact	0.973	0.345	7.953	0.005	2.647	***
Association Membership	0.658	0.309	4.528	0.033	1.93	**
Constant	-2.315	0.987	5.509	0.019	0.099	**

Model Fit Statistics	
-2 Log likelihood	254.329
Cox and Snell R ²	0.298
Nagelkerke R ²	0.412
McFadden's R ²	0.319
Level of Confidence	95%

*Note: Significance levels are indicated as: ns = not significant ($p > 0.10$); * = $p < 0.10$; ** = $p < 0.05$; *** = $p < 0.01$.*

Source: Field Survey, 2025

4.2 Integrated Soil Fertility Management Practices Among Smallholder Maize Farmers:

The result in Table 2 revealed that chemical fertilizer use dominated ISFM practices among maize farmers, with 89% relying on NPK, urea, and other inorganic fertilizers due to their immediate yield effects and government-supported distribution programs. While effective in addressing nutrient deficiencies, sole reliance on inorganic fertilizers raises concerns about long-term soil health, environmental risks, and financial burdens on resource-poor farmers. A more sustainable approach was observed with 81.7% of farmers combining inorganic fertilizers with organic amendments such as manure, compost, and crop residues. This integrated practice aligns with ISFM principles, improving soil structure, biological activity, and long-term productivity (Vanlauwe et al., 2019).

Crop rotation was practiced by 78% of farmers, particularly with legumes, highlighting strong awareness of ecological benefits such as nitrogen fixation, pest control, and soil fertility improvement. Crop residue management (66%) and composting (62.3%) were also significant, reflecting farmers' recognition of recycling organic materials for soil enhancement despite labour and resource constraints. Intercropping was practiced by 58.7% of farmers, optimizing land use and diversifying outputs, though management complexities limit wider adoption. These findings are consistent with studies from other parts of sub-Saharan Africa where farmers combine multiple practices to manage soil fertility (Mango et al., 2019).

Other notable practices included mulching (55%), irrigation scheduling (47.7%), green manure (44%), cover cropping (40.3%), and minimal tillage (32.7%). The adoption of these practices demonstrates growing awareness of soil conservation techniques among smallholder farmers in Nasarawa State. However, the moderate adoption rates suggest that constraints related to labour, knowledge, and resource availability continue to limit widespread implementation of these practices (Tittonell & Giller, 2021).

Less common practices were taungya farming (29%), soil testing (25.3%), and biochar application (18%), mainly due to technical, financial, and infrastructural limitations. The low adoption of soil testing is particularly concerning as it prevents farmers from making informed nutrient management decisions, leading to inefficient fertilizer use (Chianu et al., 2022). Biochar adoption remains minimal due to limited awareness and technical knowledge required for production and application. About 8% of farmers engaged in unlisted, locally innovated methods, underscoring the importance of indigenous knowledge in ISFM.

TABLE 2
INTEGRATED SOIL FERTILITY MANAGEMENT (ISFM) PRACTICES USED BY SMALLHOLDER MAIZE FARMERS

S/N	Integrated Soil Fertility Management (ISFM) Practices Used	Frequency (f)	Percentage (%)
1	Crop rotation across different seasons	234	78.00%
2	Cover crop planting between growing seasons	121	40.30%
3	Mulching with plant materials (dry leaves, grasses, crop residues)	165	55.00%
4	Minimal tillage or no-till methods	98	32.70%
5	Soil testing before fertilizer application	76	25.30%
6	Controlled and scheduled irrigation	143	47.70%
7	Taungya farming system	87	29.00%
8	Compost production and application from organic waste materials	187	62.30%
9	Intercropping (planting two or more different crops simultaneously)	176	58.70%
10	Crop residue management (leaving on field or plowing into soil)	198	66.00%
11	Use of chemical fertilizers (NPK, urea, or other inorganic nutrient sources)	267	89.00%
12	Combined application of organic materials and inorganic fertilizers	245	81.70%
13	Biochar application	54	18.00%
14	Green manure cultivation	132	44.00%
15	Other methods not listed above	24	8.00%

Note: Multiple responses were allowed.

Source: Field Survey, 2025

V. CONCLUSION AND RECOMMENDATIONS

This study assessed the adoption and utilization of Integrated Soil Fertility Management (ISFM) practices among smallholder maize farmers in Nasarawa State, Nigeria, with specific focus on determining the effect of socio-economic factors on ISFM uptake and ascertaining the various soil fertility management strategies employed by farmers. The study concludes that while farmers adopt multiple fertility management practices, adoption remains fragmented, with chemical fertilizer use dominating at 89%, followed by combined organic and inorganic fertilizer application (81.7%), and crop rotation (78%). However, practices essential for long-term soil health such as soil testing (25.3%) and biochar application (18%) remain critically low, indicating a gap between current practices and comprehensive ISFM principles.

The regression analysis confirmed that age ($p=0.022$), education ($p=0.001$), annual income ($p=0.032$), extension contact ($p=0.005$), and association membership ($p=0.033$) significantly influence ISFM adoption, with younger, educated, wealthier farmers possessing strong institutional ties being most likely to adopt integrated soil management approaches.

Based on the findings of the study, here are well-structured, evidence-based recommendations:

1. Given the predominance of middle-aged farmers, moderate-to-large household sizes, diverse educational backgrounds, and limited income levels, ISFM promotion strategies should be context-specific and farmer-sensitive. Extension approaches should emphasize local languages, hands-on demonstrations, and participatory learning to accommodate farmers with low formal education.
2. Since education, income, extension contact, and association membership significantly influenced ISFM adoption, policies should prioritize human capital development and institutional support. Adult education initiatives, farmer field schools, and continuous capacity-building programs should be strengthened to improve farmers' understanding of ISFM technologies. Access to affordable credit and income-enhancing opportunities should be expanded to reduce financial barriers to acquiring complementary inputs.
3. Given the coexistence of traditional and improved soil fertility practices, ISFM promotion should emphasize the complementarity of organic and inorganic inputs rather than treating them as substitutes. Training programs should focus on appropriate combinations of organic manure, crop residues, inorganic fertilizers, and improved maize varieties to enhance soil productivity and sustainability.
4. The critically low adoption of soil testing (25.3%) calls for urgent intervention to establish accessible and affordable soil testing facilities. Mobile soil testing laboratories, public-private partnerships with agro-dealers, and simplified soil testing kits should be deployed to enable farmers to make informed nutrient management decisions.

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CONFLICT OF INTEREST

The authors declare no conflict of interest

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