Integrated Nutrient Management and Food Security in Nigeria: Evidence from Farm-Level Data[1]

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Abstract

Integrated Nutrient Management (INM) is increasingly recognized a sustainable pathway for enhancing soil fertility and improving food security. However, empirical evidence on its level of adoption and implications for food security remains limited in Nigeria. This study explores the relationship between INM adoption and household food security using panel data from the General Household Survey Panel for 2018/2019 and 2023/2024. The analysis combines descriptive statistics and panel fixed effects model to provide robust empirical evidence. The results reveal a decline in food security status from 87.9% in 2018/2019 to 79.4% in 2023/2024, indicating the growing vulnerability among farming households. The level of INM adoption remains very low among agricultural households in Nigeria, declining from 17.8% to 11% over the same period. The exclusive use of inorganic fertilizers decreased slightly from 24.2% to 21.1%, while the share of farmers using only organic fertilizers increased from 7.5% to about 10%. Notably, nearly half of the farmers (≈49%) did not apply any fertilizer. Despite these trends, the Fixed-effects regression results show that increase in INM adoption is associated with 4.8% improvement in food security. These findings highlight the importance of integrated soil fertility management practices in enhancing agricultural resilience and household welfare. Policy efforts should therefore prioritize gender-sensitive interventions, strengthen extension delivery systems and promote climate-smart strategies to support INM adoption and enhance sustainable food security outcomes in Nigeria.

Keywords:

INM, Soil Fertility, Food security, Adoption, Sustainable Agriculture

JEL Codes Q16: Q18, Q56

1. Introduction

Global challenges such as climate change, population growth, and diminishing natural resources have made ensuring food security and building resilient communities critical objectives for sustainable development. Human activities are exerting unprecedented pressure on Earth's ecosystems, increasing environmental risks and emerging as the largest driver of planetary change

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(Rockström et al., 2017). As the global population continues to grow at an unprecedented pace, resources are becoming increasingly scarce, threatening the ability of future generations to access adequate food and a stable environment. Projections estimate that the world's population will reach 9 billion by 2050, with Africa accounting for over 25% of this growth. Notably, Nigeria is expected to experience the largest population increase on the continent (IMF, 2023; Statista, 2023).

Addressing the food demands of this expanding population requires a transformation in agricultural systems. Agriculture must become more productive, efficient, and sustainable while minimizing waste to meet the needs of current and future generations (Umesha et al., 2018). The challenge lies in achieving agricultural transformation that simultaneously ensures food security and mitigates environmental risks. Recognizing this, international frameworks such as Sustainable Development Goal 2 (SDG 2) emphasize the importance of sustainable agricultural practices to end hunger. Nigeria's pledge alongside 141 other countries at Conference of Parties 26 (COP26) to adopt eco-friendly land-use mechanisms and sustainable agricultural systems also emphasizes the need for strategies that reconcile food security with environmental protection (NCCC, 2023).

Integrated Nutrient Management (INM) has emerged as a viable pathway to address these challenges. INM optimizes nutrient use by aligning nutrient application with crop requirements and soil conditions. It integrates organic, inorganic, and biological fertilizers with sustainable practices such as mulching and crop rotation (Lamessa, 2016). This approach not only enhances crop productivity but also reduces environmental risks, preserves soil health, and ensures long-term agricultural sustainability (Chen et al., 2011). Its relevance is particularly important in developing countries like Nigeria, where agricultural productivity is constrained by critically low fertilizer use. Inorganic fertilizer use in Nigeria averages 18 kg per hectare, significantly below the global average of 100 kg per hectare (FMARD, 2020). Available evidence also shows that Nigeria's soils are increasingly deficient in organic matter, compounding the challenges of declining fertility (Abdulkadir et al., 2021). Organic fertilizer-use averages about 0.2 kg/ha, 2016, far below the 50 kg/ha commitment set by the Abuja Declaration on optimal fertilizer usage. INM offers a practical solution by integrating locally available organic inputs with inorganic fertilizers to enhance soil fertility and improve crop yields.

Despite the importance of Integrated Nutrient Management (INM) for sustainable agriculture, there is a paucity of empirical studies directly linking INM adoption to household food security. This study seeks to fill this gap by analyzing the effect of INM adoption on household food security in Nigeria. By identifying the pathways through which INM influences household food security, the study sees to deepen understanding of sustainable agricultural practices that can be scaled up to meet national food security objectives. The study will contribute to ongoing policy discussions on sustainable agriculture, input support programs, and strategies for building climate-resilient food systems in Nigeria.

2. Literature Review

2.1 INM Adoption and Household Food Security

INM practices are linked to several farming households' outcomes, influencing various aspects of their livelihoods and well-being. INM plays a crucial role in enhancing food security through multiple pathways. By increasing food availability (through higher agricultural yields), improving food access (via increased income and dietary diversity), and promoting sustainable food production systems, INM practices enhance food security of households (Khalid et al 2022; Antil and Raj, 2019; Chen et al, 2011). Accordingly, INM can lead to significant increases in crop yields while increasing nutrient use efficiency and reducing environmental risk.

Several empirical studies provide evidence of INM's effect on different food security components. Mangaraj et al. (2022) studied the effect of INM on the growth and yield of intercropped Rice and Green gram under Coastal Plan Agro-climatic conditions in India. Their findings showed that the INM treatment, which includes 50% RDF inorganic fertilizer and 50% farmyard manure (FYM), increased leaf area and duration, height, tillers, dry matter accumulation, and yield parameters in short-grain aromatic rice. Similarly, an INM treatment consisting of 50% fertilizer and 50% FYM applied to rice and 75% RDF, Rhizobium, and phosphate-solubilizing bacteria for Green gram led to a significant increase in the productivity of the rice-green gram intercrop. Similarly, Odedina et al. (2012) assessed the performance of INM in cassava cultivation in Southwest Nigeria and found that integrating inorganic and organic fertilizers outperformed single-application treatments. The combination led to improved soil nutrient balance and greater cassava yield, underscoring the relevance of INM in staple food crop systems common among smallholder farmers in Nigeria. Chauhan et al. (2017) also provided evidence of INM's impact in horticulture, revealing that chilli plants treated with both vermicompost and chemical fertilizer had the shortest time to first flowering, the highest number of fruits per plant, fruit girth, fruit length, and fruit yield per plant.

Beyond yield improvements, INM also plays a vital role in enhancing food security by increasing farmers' income and promoting sustainability. Zhang et al. (2012) conducted a large number of on-site demonstration experiments and found that reducing nitrogen fertilizer to accommodate INM practices increased net farm income for fruits by $775, vegetables by $397, rape by $196, and cotton by $164. Integrated Nutrient Management (INM) contributes to long-term sustainable production, nutritional security, pollution reduction, and enhanced soil health, thereby contributing to a sustainable food system (Sharma et al., 2022).

While existing studies provide valuable insights into the agronomic and economic benefits of INM, such as increased crop yields, improved soil health, and enhanced farm incomes, most of these studies only focused on pathways to food security. Studies that explored the direct impact of INM adoption on the food security status of households, using validated and experience-based indicators, particularly in the Nigerian context, are limited. This study fills this gap by linking INM adoption directly to household food security as measured using Food Consumption Score (FCS) Unlike proxy measures such as yield or income, the FCS represents standardized consumption-based measure which captures food consumption frequency, dietary diversity and nutritional importance of foods consumed by households. By doing so, the study offers a more nuanced understanding of how sustainable agricultural practices such as INM affect household well-being beyond productivity gains.

3. Methodology

3.1 Data Source

This study employs secondary data from the General Household Survey Panel (GHS-Panel), which is part of the Living Standards Measurement Study-Integrated Surveys on Agriculture (LSMS-

ISA). The study used the panel data from the two most recent waves (2018/2019 and 2023/2024[2]) to examine the association between INM adoption on food security.

3.2 Analytical Techniques

Statistical and econometric techniques were employed in the estimation of the study objectives. These include descriptive statistics, food security measure, and Panel Fixed Effects model.

3.2.1 Food Consumption Score

The Food Consumption Score (FCS) is a widely used method of food security developed by World Food Programme (2008) to calculate a composite score based on the frequency, diversity and nutritional importance of food groups consumed by households. This approach aligns with the pathways through which INM influences food security. Hence, the choice of FCS as the measure of food security adopted in the study. In computing FCS, the consumption frequency of each food group was multiplied by its respective weight[3] with the resulting weighted scores summed up to generate the FCS for each household. Households are considered to have acceptable food security, if the FCS value is greater than 35.

3.2.2 Panel Fixed Effects Model

To assess the impact of INM on food security, the study employed fixed effects panel data model. The decision to use a fixed effects model instead of a random effects model was based on the recognition that fixed effects models yield more robust estimates of treatment effects (INM adoption), especially when there are unobserved time-invariant factors that could confound the relationship between INM adoption and food security. Fixed effects estimators rely solely on variation within individuals, thus remaining unaffected by confounding due to unmeasured factors that remain constant over time (Lmlach et al., 2013). Following the approach outlined by Bollen and Brand (2010), the fixed effect model incorporating both household fixed effects and survey-wave fixed effects, is specified as:

$$K_{it} = \alpha_o + \beta_1 AGE_{it} + \beta_2 HHSZ_{it} + \beta_3 LIT_{it} + \beta_4 ASST_{it} + \beta_5 EXP_{it} + \beta_6 INM_{it} + \beta_7 EXT_{it} + \beta_8 SEC_{it} + \beta_9 IMP_{it} + \beta_{10} LAND_{it} + \beta_{11} TEMP_{it} + \beta_{12} FAM_{it} + + \beta_{13} ASST_{it} + \beta_{14} WAV_{it} + \varepsilon_{it} \qquad + \quad (4)$$

Where:
K_{it} is FCS for household *i* at time *t*.
INM_{It}: Indicator variable for INM adoption for household *i* at time *t*.
X_{it}: Vector of control variables (e.g., household income, education) that may influence food security.
μ_i: Entity-specific fixed effects capturing time-invariant heterogeneity.
ε_{it}: Error term capturing unobserved factors affecting food security.

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[2] Due to data attrition and the addition of new households in 2018/2019 and 2023/2024, the study only focused on these two recent waves to ensure comparability and consistency in the panel.
[3] Food group weights: Mainstaples-2; Pulses- 3; Vegetables-1; Fruit-1; Meat/Fish- 4; Milk-4; Sugar-0.5; and Oil- 0.5. Source: World Food Program (2008)

The definitions of the explanatory variables in equation 3 are presented in Table 1.

Table 1: Definition of the Explanatory Variables

Variable Code	Variable Name	Description/Measurement
AGE	Age	Age of the household head in years
HHSZ	Household size	Number of household members
LIT	Literacy rate	Dummy variable takes a value of 1 if *ith* household head is literate and 0 if otherwise
EXP	Expenditure	Total monthly household expenditure (₦)
EXT	Extension Contact	Takes a value of 1 if ith household has access, and 0 if otherwise
IMP	Improved Seeds	Dummy (1 if *ith* household head uses improved seeds and 0 if otherwise
SEC	Sector	Dummy (1 if *ith* household resides in urban and 0 if otherwise)
TEMP	Temperature	Annual temperature (^oC)
LAND	Land	Dummy (1 if household owns agricultural land, 0 otherwise)
FAM	Farm size	Farm size in hectares
ASST	Asset ownership	Number of assets owned
WAV	Wave variable	Wave fixed effect represented using a dummy variable which equals to 1 if household is observed in wave 2023/2024 and 0 if otherwise
Food Security (K_{it})	Food Security	As explained above;
INM (Y_{it})	Integrated Nutrient Management	Dummy equals to 1 if household applies both organic and inorganic fertilizer on the same plot, 0 otherwise)[4]

4. Results and Discussion

This section presents a detailed analysis of the sociodemographic characteristics of farmers, patterns of fertilizer use and their food security status. It also provides empirical evidence on the

4.1 Farmers' Characteristics and INM Adoption Patterns

The socioeconomic characteristics of farmers play a critical role in shaping their decisions to adopt new crops, farming practices or agricultural technologies. Table 2 profiles selected household characteristics by INM adoption across the period 2018/2019 and 2023/2024. Although the adoption level of INM is generally low, the adoption rate was higher among male-headed households than female-headed households in both periods. The observed gender disparities may be due to differences in access to resources, decision making, land ownership and extension services, as documented in earlier studies (Jerumeh 2024; Doss, 2018). The adoption rate was

[4] While INM can be measured based on intensity (e,g nutrient-adjusted application rates) and other soil fertility management indices, these alternatives require data on quantity and nutrient content which are not available in the GHS dataset. Thus, the study relies on the binary plot level use of INM.

however observed to decline in 2023/2024 for both sexes. Similarly, while adoption rate was much lower in the latter period, it tended to decrease as farmers advanced in age, particularly after 64 years**.** Younger farmers are generally less risk-averse and are more receptive to new technologies and practices than their older counterparts (Milikias and Abdulahi, 2018), suggesting a higher likelihood of adopting sustainable practices like INM.

INM adoption appears to increase with household size, with households having 11 members or more showing the highest rate of adoption in both agricultural seasons (31.6% and 19.4%, respectively). Larger household size may imply greater availability of family labour to implement labour intensive practices like INM. Education also plays an important role in INM adoption as households with literate heads consistently reported higher rates of INM adoption than their non-literate counterparts.

Households' economic condition also influenced their levels of adoption. Monthly expenditures increase with adoption rate, with households spending ₦40,000 or more showing a marked increase in adoption between 2018/2019 (21.95%) and 2023/2034 (32.1%). Similarly, households earning non-farm income and having access to credit reported a higher adoption rate, highlighting the centrality of liquidity in enhancing technology uptake. INM adoption was observed to be higher among households with access to extension services in 2018/2019 (22.5% versus 16.8%). However, a noticeable drop occurred in 2023/2024, which may suggest reduced access to extension services or changes in farmers' priorities.

Table 2: Distribution Socioeconomic characteristics of Farming Households by INM Adoption

Socioeconomic Characteristics	INM Adoption (%)	
	2018/2019	**2023/2024**
Sex		
Male	19.90	12.84
Female	5.36	4.21
Age(years)		
<30	18.40	12.00
30-49	20.17	11.92
50-64	16.36	12.74
≥65	14.38	9.06
Household Size		
<5	11.46	6.65
5-10	18.14	11.83
≥11	31.62	19.39
Literacy Level	**19.41**	**12.84**
Monthly Expenditure (₦)		
≤20,000	16.50	10.76
20,000-39,999,	21.83	11.14
≥40,000	21.95	34.13
Non-Farm Income	24.06	14.67
Access to Credit	18.01	11.24
Extension services	22.45	10.27

4.2 Trends in INM Adoption

Although INM is recognized as an effective pathway for ensuring long term food production, its level of adoption remains low in Nigeria. Figure 1 shows a clear decline in the adoption level of INM from 17.8% in 2018/2019 to 11% in 2023/2024. This downward trend is in sync with evidence showing that the sustained adoption of labour and knowledge intensive practices may decline if not adequately supported by extension services, incentives and necessary resources (Mponel et al, 2016; FAO, 2017). This concern is particularly important for the organic component of INM, which without adequate support, resources and proximity to nutrient sources, may discourage farmers from adoption, given the associated labour and transportation costs. High prices or unavailability of inorganic fertilizers or other nutrient sources can also contribute to decreased use of INM practices. Effective INM adoption therefore requires adequate access to both organic and inorganic inputs, the absence of which can make farmers revert to traditional methods which may lead to gradual degradation of the soil. Without broader uptake of INM, efforts to secure long-term food production and strengthen household resilience may be undermined (Umesha et al., 2018; Gezahegn, 2021).

The use of inorganic fertilizers by farmers remained relatively stable, with a slight reduction in its use from 24.2% to 21.1% in 2023/2024. However, although still low, the proportion of farmers relying on organic fertilizers alone increased from 7.5% to about 10%. This suggests a gradual shift towards organic fertilizers, given the rising costs of inorganic fertilizers and the increasing awareness of the benefits of soil health. Overall, the usage of either or both organic and inorganic fertilizer in Nigeria is generally low, with about half of the sampled farmers not using any method of fertilization in 2018/2019. Although it marginally decreased in recent years, the level of farmers in this category remains relatively high and concerning, given the implication of the continued use of degraded soils on productivity, vulnerability to shocks and deviation from global commitments to sustainable agricultural practices.

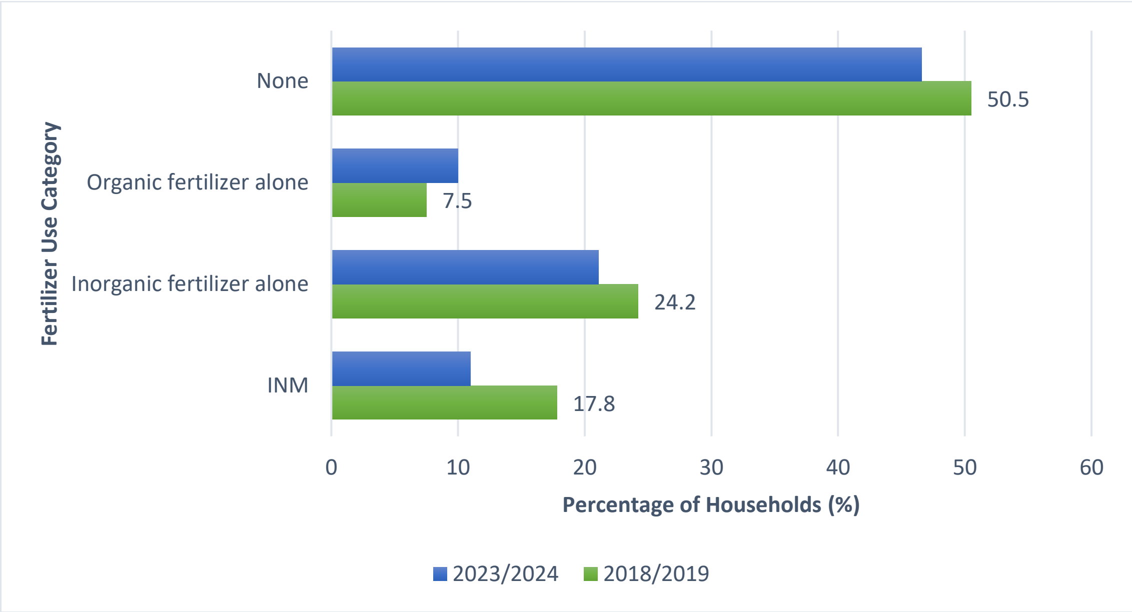

Figure 1: Distribution of Farmers by Fertilizer Use

4.3 Household Food Security Status

This section presents the results of the food security status of households using FCS. As shown in Figure 2, household food security declined from 87.9% in 2018/2019 to 79.4% in 2023/2024, indicating deterioration in the ability of households to consume healthy and nutritious diets. Although the number of food secured households reduced in 2023/2024, the relatively high share in this category, implies that most households can still maintain the frequency and consumption of diverse diets. According to FAO (2008), low income households with limited or no choice in reducing the diversity of their foods may respond to economic pressures by eating fewer meals per day or reallocating expenditure from non-food items, especially healthcare and education, to sustain food consumption.

Overall, while most households remained food secure in both periods, the downward trend suggests increasing vulnerability, particularly if the current pressures such as internal conflict, climate change, food inflation, and rising input costs persist.

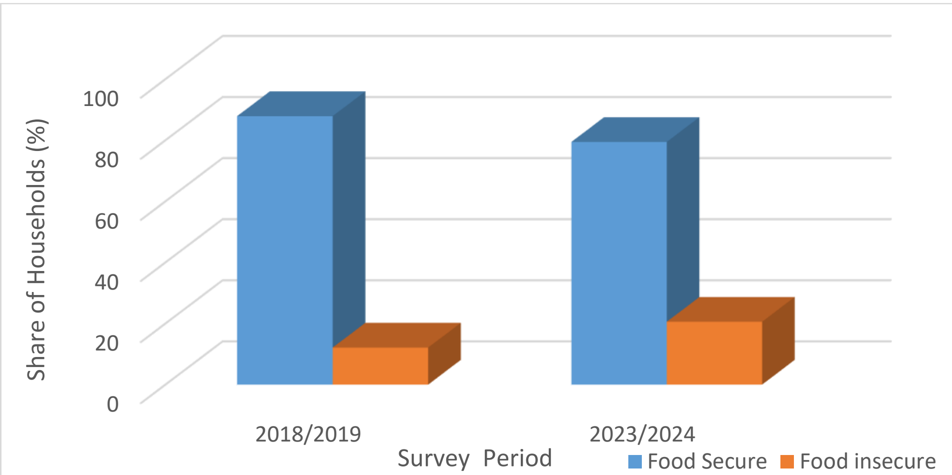

Figure 2: Distribution of Households by Food Security Status

4.4 Relationship between INM Adoption and Household Food Security

This section focuses on the effect of INM adoption on household food security. The diagnostics reveal the strong explanatory power of the estimated models (Table 3). The significant F statistics (19.32at $p < 0.000$) shows that model accounts for a considerable share of the variations in the food security status if the households.

The regression results indicate that INM adoption is positively associated with food security. Specifically, a unit increase in INM adoption is associated with a 5% improvement in household food security. This finding aligns with Sharma et al (2019), who established that the adoption of INM practices in rice-wheat cropping systems results in a significant increase in grain yield, ensuring food security for the population. Adopting INM in farming practices within ecological limits can help meet the increasing population's demand for food (Chaubey et al, 2023) by enabling more efficient nutrient management and sustainable farming practices.

Several control variables also predict household food security. As shown in Table 3, total monthly food expenditure, a proxy for income, significantly improves ($p<0.001$) food security of households. This result reinforces the evidence that higher incomes improve the affordability of healthy and diverse diets (FAO, IFAD, UNICEF, WFP and WHO, 2022) and reduce liquidity constraints, providing greater access to resources needed to invest in modern agricultural inputs (Nabahungu et al,2025) and practices like INM.

Environmental conditions represent another factor driving the attainment of food security by agricultural households. Specifically, higher temperature is associated with lower food security, with a one unit increase in temperature linked to 59.0% decrease in the outcome. This result is in consonance with available evidence showing that higher temperatures, particularly during critical crop growth stages, can cause heat stress, reducing growth, impairing reproductive development and ultimately lowering yields (Sharma, 2025). Each degree rise in temperature poses a threat to life, the economy and food security (Rani and Reddy, 2023).

The wave dummy variable included to control for time-varying shocks such as price changes, inflation and seasonal variations across survey periods, shows a negative and significant effect on food security. This implies that food security worsened in 2023/2024 compared to 2018/2019, indicating a decline in the ability of households to afford healthy and nutritious diets. The worsening food insecurity in the country has been linked to different factors including internal conflict, climate change, economic difficulties, and rapid population growth (Ikhajiagbe, 2021; FEWSNET, 2024). Rising food prices remains a critical challenge, with food inflation increasing from 11.4% in December 2018 to 34.8% in December 2024. These issues are further exacerbated by underlying factors such as high cost of healthy diets, unhealthy food environment and deep-rooted inequality, which amplify their individual effects o of these challenges (WHO, 2024).

Table 3: Effect of INM Adoption on Food Security

Variables	**Coefficient**	**Robust Standard Error**	
Independent Variable-INM			
Age of Household Head	0.001	0.002	
Household Size	0.003	0.004	
Literacy	-0.021	0.017	
Number of Assets Owned	7.20E-06	3.58E-05	
Total Monthly Expenditure	1.1E-06***	1.10E-07	
INM Adoption	0.050*	0.026	
Extension Access	-0.021	0.026	
Sector	-0.652***	0.546	
Use of Improved Seeds	0.017	0.025	
Land Ownership	0.009	0.027	
Annual Temperature	-0.331***	0.062	
Farm Size	1.1E-05	4.50E-05	
Wave	-0.120***		
Constant	12.995	1.661	
sigma_u	0.514		
sigma_e	0.385		
Rho	0.641		
Diagnostic statistics			
F(13,2253)	19.32	Prob>F	0.000

Note: ***=p<0.1, ***=p<0.05 and *= p<0.1

5.0 Conclusion and Recommendations

This study examined the relationship between Integrated Nutrient Management (INM) adoption and household food security in Nigeria using the General Household Survey Panel (GHS-Panel) of 2018/2019 and 2023/2024. Findings reveal that household food security decreased from 87.9% in 2018/2019 to 79.4% in 2023/2024, underscoring the growing vulnerability of farming households. Results from the fixed-effects regression, however, show that INM adoption has a positive and significant effect on household food security, increasing it by 5%. INM contributes to improved food availability through higher agricultural yields, and enhances food access by increasing household income and dietary diversity, thereby reducing the risk of food insecurity. These findings underscore the importance of integrated soil management practices in improving agricultural resilience and household welfare. Policies targeted at improving access to organic and inorganic inputs alongside supporting knowledge dissemination are critical for scaling up INM adoption. Building on these findings, the study proposes the following recommendations:

1. Adoption of INM remains limited despite its contributions to food security. The Federal Government, through ADPs and state extension services, should intensify sensitization and farmer training. This should also involve engaging soil and crop management experts to provide context-specific guidance on INM practices, including appropriate nutrient combinations for different soils and crops.

2. Household age and expenditure also have significant effect on food security, Policies should focus on strengthening social protection programmes to support vulnerable households, particularly those with older heads and lower income.

3. Environmental conditions, such as temperature are major drivers of food security. Integrating INM promotion with climate-smart interventions, such as drought-resistant seeds, soil rehabilitation, and insurance schemes, will strengthen resilience and help promote food security under changing ecological conditions.

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