



## Assessing the influence of farmers' socio-economic orientation on the adoption of recommended soil fertility management practices

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### ABSTRACT

This study examines how the socio-economic orientation of smallholder farmers influences their soil fertility management decisions. Smallholder farmers, numbering 100 from the Sekyere South District in the semi-deciduous forest and the Komenda-Edina-Eguafo-Abirem (KEEA) District in the coastal savannah agroecological zones of Ghana, respectively, were involved in the study, which adopted the mixed-methods approach to assess their knowledge and awareness of the 4R Nutrient Stewardship (4RNS) and Integrated Soil Fertility Management (ISFM) strategies. A semi-structured survey instrument was used to explore how socio-economic factors such as level of education, age, land tenure, and access to technical and financial support influence the farmers' soil fertility management decisions. The results revealed that 57.9% of farmers were aware of the ISFM, while 43.2% were aware of the 4RNS, indicating an information deficit. Nonetheless, about 77.6% of the farmers expressed the willingness to implement both soil fertility management approaches, contingent upon receiving sufficient technical training and financial assistance. The results confirmed that inadequate financial resources, limited access to technical expertise, educational attainment, and land tenure insecurity constrained, especially youthful and female farmers, from adopting recommended soil fertility management practices. Thus, farmers with higher levels of education were more likely to implement recommended soil fertility practices, while those without stable land tenure were less motivated to adopt the recommended soil fertility management strategies. The study demonstrated that the socio-economic orientation of smallholder farmers greatly influenced their adoption and investments in soil fertility management practices.

**Keywords:** Soil fertility management, Smallholder farmers, 4R Nutrient Stewardship, Integrated Soil Fertility Management, Ghana, Socio-economic factors

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### Introduction

Crop production in sub-Saharan Africa (SSA) faces myriad challenges, including low and declining soil fertility (Stewart *et al.*, 2020; Wawire *et al.*, 2021; Yeboah *et al.*, 2024), and high nutrient imbalances due to the inherently fragile nature of SSA soils (Agegnehu *et al.*, 2021; Tully *et al.*, 2015). Continuous cropping and leaching of easily



soluble salts from these soils lead to nutrient deficiencies and negative nutrient balances (Kartini *et al.*, 2024; Tan *et al.*, 2005; Zeeshan Ul Haq *et al.*, 2023). Studies have shown that low and declining soil fertility often causes low crop yields and low farmers' incomes in the region (Mateete *et al.*, 2010; Bjornlund *et al.*, 2020; Vanlauwe *et al.*, 2015). Inorganic fertilizers are scarcely used in SSA countries like Ghana due to high costs for smallholder farmers, unreliable supply, and poor technical knowledge about fertilizer quality and application rates (Ricker-Gilbert, 2020; Yeboah *et al.*, 2024). In Ghana, blanket fertilizer application rates are often recommended for most crops regardless of the agroecological zones (AEZs) where they are being applied. For instance, a blanket application rate of 4 bags of NPK 15-15-15 and 2 bags of urea per acre is recommended for maize regardless of the AEZ (Ojeniyi *et al.*, 2024). This blanket application rate often results in lower-than-expected yields and negative environmental effects. It is therefore imperative that synergies between the use of improved crop cultivars, complemented with sound soil fertility and plant nutrition strategies, are adopted by farmers. Soil fertility management research has not yielded the expected success in Ghana because these studies have largely been done on-station without much farmer participation. Thus, most soil fertility research activities rarely consider farmers' perceptions and socio-economic orientations during their implementation stages (Akinbode *et al.*, 2024; Becx *et al.*, 2012; Tesfahunegn *et al.*, 2021). The roles of extension officers, nongovernmental organizations (NGOs), and other institutions that provide support for implementing soil fertility management practices should also be recognized. Studies have demonstrated the critical contribution of outreach in innovation adoption within SSA farming communities (Oyetunde-Uzman, 2022; Rosário *et al.*, 2022; Sturdy *et al.*, 2008; Wellard *et al.*, 2013). The 4Rs of nutrient stewardship (4RNS) advocate the application of best nutrient management practices (BMPs) in an economically feasible, environmentally friendly, and socially acceptable manner to maximize nutrient uptake while minimizing field nutrient loss for increased crop yields in various cropping systems (Fixen, 2020). Integrated Soil Fertility Management (ISFM) is a paradigm aimed at improving soil fertility by combining indigenous and novel technologies and adapting them to local climatic and socio-

economic conditions (Ngetich *et al.*, 2019; Vanlauwe *et al.*, 2006; Yeboah *et al.*, 2024). Given the widespread acceptance of the potential of the 4RNS and the ISFM strategies to improve soil quality in SSA and the limited prioritization of plant nutrition and soil fertility management by most of SSA's smallholder farmers, an African Plant Nutrition Institute (APNI) outreach funding was solicited to bring purposely selected smallholder farmers together in two workshops at Agona in the Sekyere South. The Komenda-Elmina-Edina-Eguafo districts of Ghana, respectively, to assess their perceptions and knowledge about the two soil fertility management approaches, and investigate how their socio-economic orientations could affect the implementation of the 4RNS and ISFM strategies in the smallholder cropping systems.

Specifically, the study aimed to:

- i. Assess the knowledge and awareness of smallholder farmers in the target communities of the 4R nutrient stewardship and the Integrated Soil Fertility Management (ISFM) approaches; and
- ii. Gather evidence-based data and information about how their socio-economic orientations can affect their adoption of fit-for-purpose soil fertility interventions such as the 4RNS and the ISFM.

## Materials and Methods

This paper is a deliverable from an outreach that aimed to improve smallholder farmers' livelihoods through increased sustainable soil fertility management to improve crop yields and farmer incomes. To obtain the necessary data for this activity, an outreach program was carried out as part of an innovative and sustainable strategy to generate evidence-based data to support comprehensive policy discussions and targeted capacity building for smallholder farmers in Ghana. During the study, smallholder farmers were engaged in the target districts, specifically focusing on their understanding of how declining soil fertility affects crop yields in their areas.

The study was conducted in two strategically selected communities representing different agroecological zones in Ghana: Agona in the Sekyere South district of the Ashanti region, situated within the semi-deciduous forest zone, and Komenda in the Komenda-Edina-Eguafo-Abirem District of the Central Region,

located in the coastal savannah zone. These locations were chosen based on their contrasting farmer characteristics, varying farming systems, and distinct fertilizer requirements. Farmers in Agona-Ashanti typically practice mixed cropping of maize and cassava alongside cocoa production, while those in Komenda mainly practice monocropping of okra and pineapples.

The outreach was facilitated by the lead author, an expert in soil fertility, with support from specialists in agricultural extension and gender studies, along with graduate students and interns. The research team employed a multi-criteria analysis approach (Aenishaenslin *et al.*, 2013; Dean, 2020) to assess how factors such as education, land ownership, financial support, and technical support influence the adoption of the ISFM and 4RNS technologies. The participatory and utilization-focused approach was adopted to ensure effective engagement of all the smallholder farmers (Dorward *et al.*, 2003; Mponela *et al.*, 2023). In each district, a diverse group of 50 farmers was purposively sampled to include at least 50 percent women and youth.

Semi-structured questionnaires (Heve *et al.*, 2023; Obour *et al.*, 2020) were administered before the outreach to establish baseline data about farmers' knowledge and willingness to accept the 4R nutrient stewardship approach. The team used modern, effective, and socially acceptable communication tools, combining both quantitative and qualitative methods in a concurrent nested design to gather comprehensive primary and secondary data. In each district, two focus group discussions (FGDs) were conducted first at the start, and subsequently, at the end of the outreach to understand existing indigenous soil management approaches, stakeholder perceptions, and socio-economic incentives that might motivate smallholder farmers to adopt the 4RNS and the ISFM strategies. These discussions yielded responses about the farmers' ages, farming experience, education levels, current soil

fertility management strategies, and their awareness and knowledge levels regarding 4RNS and ISFM technologies.

The study maintained high ethical standards throughout its implementation. Faculty members experienced in social science research reviewed the study protocol and survey instruments for ethical suitability and methodological soundness. Verbal and written consents were obtained from all respondents as applicable before the data collection. To ensure privacy and confidentiality, field assistants received thorough orientation and training to maintain professional standards and avoid judgmental or biased approaches to questioning during the data collection process. All interviews were documented contemporaneously, and the documents were thoroughly reviewed to ensure familiarity with the data.

The Statistical Package for Social Sciences (SPSS) version 23 was used to analyse the quantitative data obtained from the study, with the results presented as means in bar charts or frequency tables. SPSS was considered as one of the most important and influential statistical tools for quantitative data analysis (Rahman and Muktadir, 2021). The qualitative data were analysed using the thematic approach with the documented responses, which were organized and coded.

## Results and Discussion

### **Awareness and willingness to adopt improved soil management practices**

The study revealed varying levels of awareness and willingness to adopt improved soil management practices. While 57.9% of farmers were aware of Integrated Soil Fertility Management (ISFM) practices (57.1% Sekyere South, 58.8% KEEA), only 43.2% were familiar with 4R Nutrient Stewardship (39.3% Sekyere South, 47.1% KEEA) (Table 1).

Table 1. Awareness of soil amendment practices.

	Sekyere South	KEEA	Chi-square value
	Freq. (%)	Freq. (%)	
ISFM			0.024
No	24(42.9)	14(41.2)	
Yes	32(57.1)	20(58.8)	
4R			0.524
No	34(60.7)	18(52.9)	
Yes	22(39.3)	16(47.1)	

\**p-value* <0.05

The study reveals key insights into the adoption of two agricultural practices—Integrated Soil Fertility Management (ISFM) and 4R nutrient stewardship—across two districts, Sekyere South and KEEA in Ghana (Table 1). Regarding the adoption of ISFM, the results show a significant difference between the two districts, indicated by a Chi-square value of 0.024. Conversely, the willingness to adopt the 4RNS was not significantly different (Chi-square value of 0.524) between the two districts.

Given that ISFM adoption varies by district, district-specific approaches are needed that consider local conditions such as soil quality and climate, which impact the effectiveness of nutrient management, organic matter, and soil and water management practices. On the other hand, the consistent adoption of 4R practices across both districts indicates that a unified, broad-based approach could effectively promote 4R practices without the need for district-specific adjustments. A general educational campaign and training program focused on nutrient management principles could be an efficient way to promote these practices in both districts.

Both ISFM and 4R aim to improve soil health, increase crop yields, and promote environmental sustainability. Adopting both practices could yield synergistic benefits, including better soil structure, enhanced nutrient availability, and reduced environmental degradation. However, while ISFM adoption may require more localized and tailored interventions, 4R adoption can be supported through broad-based strategies applicable across various contexts.

This view that knowledge about ISFM and 4RNS is useful to the farmers was affirmed during a KII with a 45-year-old female farmer from KEEA as follows:

*“I regret that we have not had this kind of information in the past. I think that if we had known about proper soil fertility management, our livelihoods would have improved greatly by now”*

A female farmer, KII.

To comprehensively support sustainable agriculture, extension services, public-private partnerships, and local government initiatives must collaborate to facilitate the adoption of both ISFM and 4R practices. Offering subsidies or incentives for inputs related to these practices could further enhance adoption rates, particularly among resource-constrained farmers. The study suggests a dual approach: localized promotion of ISFM based on district-specific

conditions and broad support for 4R nutrient stewardship across the regions. This combined strategy can enhance productivity, improve soil health, and build climate resilience in both districts.

Ultimately, this approach could serve as a model for other regions in Ghana and similar agroecological zones. By addressing both district-specific challenges in ISFM adoption and providing consistent support for 4R practices, agricultural programs can improve sustainability, strengthen resilience to climate change, and ensure food security. This integrated strategy is crucial in promoting sustainable agricultural systems, particularly in vulnerable regions facing climate risks.

Another male participant from KEEA described the outreach as both “interesting and exciting,” particularly because of the potential impacts of the ISFM and 4RNS on crop yields and farm incomes (FGB, KEEA).

A female farmer opined that training the farmers in a non-discriminatory, customized manner will rapidly transform agricultural production by incentivizing males and females alike to practice sustainable soil fertility management (Female farmer, KII)

Another female farmer supported this assertion as she remarked that:

*“It’s been an interesting and exciting discussion as the impacts of ISFM and 4RNS on crop yields have been demonstrated to males, females, and young or old farmers in this outreach”*.

A female farmer, KII.

The adoption of Integrated Soil Fertility Management (ISFM) practices among smallholder farmers in Ghana is influenced by various factors. These include agroecological zones, land ownership, access to credit, and distance to input shops (Kwadzo and Quayson, 2021; Yeboah *et al.*, 2024). Adoption rates vary significantly across regions, with only 26.7% of farmers adopting the full set of ISFM technologies in some areas (Kwadzo and Quayson, 2021). Factors such as non-farm income, livestock ownership, and participation in field demonstrations also play crucial roles in the adoption of sustainable agricultural practices (Ehiakpor *et al.*, 2021). The availability of improved seeds is a major determinant of ISFM adoption, with significant differences observed between regions like Tamale (Ghana) and Kakamega (Kenya) (Adolwa *et al.*, 2019). Plot-level variables, including soil carbon, texture, and slope, consistently affect

ISFM adoption across different locations (Adolwa *et al.*, 2019). To promote ISFM adoption, policies should target institutional and plot-specific characteristics (Ehiakpor *et al.*, 2021; Hörner and Wollni, 2022).

However, encouragingly, 77.6% expressed willingness to adopt both practices with proper support (Table 2), indicating the potential for expanding sustainable soil management practices.

Table 2. Willingness to adopt soil amendment practices.

	Sekyere South	KEEA	Chi-square value
	Freq. (%)	Freq. (%)	
ISFM			0.054
No	12(21.4)	8(23.5)	
Yes	44(78.6)	26(76.5)	
4R			0.054
No	12(21.4)	8(23.5)	
Yes	44(78.6)	26(76.5)	
Capacity Building			2.542
No	4(7.1)	0(0.0)	
Yes	52(92.9)	34(100.0)	
Capacity Building			0.386
No	21(37.5)	15(44.1)	
Yes	35(62.5)	19(55.9)	

\**p-value* < 0.05

Table 2, comparing Sekyere South and KEEA on agricultural practices, reveals important insights into the adoption of different farming systems. In both regions, the adoption of Integrated Soil Fertility Management (ISFM) and the 4R approach (Right Source, Right Rate, Right Time, and Right Place) is notably similar, with Sekyere South showing 78.6% adoption for ISFM and 78.6% for 4R. In comparison, KEEA has slightly lower adoption rates of 76.5% for both practices. The Chi-square values of 0.054 for both ISFM and 4R indicate that the adoption of these practices is not significantly different between the two regions. This suggests that both Sekyere South and KEEA are implementing similar soil fertility management techniques, due to similar access to resources and agricultural extension services. However, the capacity-building programs show some differences. In the first capacity-building category, Sekyere South had 92.9% of farmers receiving training. In comparison, KEEA had 100% participation, resulting in a Chi-square value of 2.542, which indicates a significant difference between the two regions. This suggests that KEEA has more widespread access to capacity-building programs compared to Sekyere South. In the second capacity-building category, the Chi-square value of 0.386 indicates no significant difference between the two regions, with Sekyere South having 62.5% participation and KEEA 55.9%. This minor difference suggests that once training opportunities are available, the uptake is similar across both regions. Overall, while both regions show similar adoption rates for agricultural

practices, the access to and impact of capacity-building programs vary, with KEEA having a slight advantage in the first category. These findings highlight the need for targeted interventions to ensure equitable access to training and resources, particularly in regions like Sekyere South, where access to capacity-building programs may need improvement.

The adoption of Integrated Soil Fertility Management (ISFM) practices varies across regions in Africa. In Ghana, adoption rates are relatively low, with only 26.7% of farmers fully adopting ISFM technologies (Kwadzo and Quayson, 2021). Factors influencing adoption include agroecological zones, land ownership, access to credit, and distance to input shops (Kwadzo and Quayson, 2021). In Kenya, adoption rates are higher, with 36% of farmers in Kakamega fully adopting ISFM practices compared to only 3% in Tamale, Ghana (Adolwa *et al.*, 2019). Determinants of adoption include soil characteristics, plot area, family labor availability, and access to improved seeds (Acheampong *et al.*, 2021; Adolwa *et al.*, 2019; Oyetunde-Uzman, 2022). In semi-arid areas of Kenya, factors such as group membership, access to credit, gender, age, and extension services significantly influence ISFM adoption (Mutuku *et al.*, 2017). To enhance adoption, policymakers should focus on improving access to credit, farm machinery, information, and markets (Mutuku *et al.*, 2017).

Several factors influenced soil fertility management practices across the districts. While 59% of farmers reported that lack of information had a minimal impact on their soil fertility management, 34% indicated

significant impacts from information shortage. Financial constraints emerged as a crucial factor, with 47% of KEEA farmers strongly agreeing that inadequate finance affected their practices, compared to 36% in Sekyere South.

### **Demographic characteristics of farmers**

The demographic data from the two districts involved in the study are presented in Table 3.

Table 3. Farmer Characteristics (Continuous Variables).

Farmer Characteristics	Sekyere South	KEEA	t-value
	Mean (SD)	Mean (SD)	
Age	49.59(14.299)	38.44(11.789)	3.823*
Number of spouses	0.88(0.764)	0.75(0.508)	0.826
Household Size	9.21(6.011)	5.59(3.322)	3.226*
Years of education	10.10(6.554)	10.76(5.269)	-0.498
Income Level	19603.57(13041.500)	20885.29(20023.140)	-0.368
Years of farming	20.71(14.599)	12.26(10.064)	2.970*
Acres of land	9.027(7.887)	7.676(7.171)	0.814

\**p-value* < 0.05

The study revealed that farmers in Sekyere South were significantly ( $p < 0.05$ ) older, with a mean age of 49.59 years, compared to 38.44 years in KEEA (Table 3). This observation suggests that farmers in Sekyere South are probably more experienced, and possibly more risk-averse, relying on traditional practices, while the relatively younger farmers in KEEA are more open to adopting new agricultural technologies and innovations. This age disparity also points to the need for customized soil fertility management strategies to meet the preferences of the farmers in the two districts. The results further showed that farmers in the Sekyere South have significantly more years of farming experience (20.71 years) than those in KEEA (12.26 years), with a t-value of 2.970 ( $p < 0.05$ ). This difference in experience may influence the farmers' adoption of agricultural innovation. Thus, farmers in the Sekyere South may readily adopt approaches that integrate modern soil fertility management strategies with indigenous methods, while the farmers in KEEA are likely to adopt more scientific soil fertility technologies that are tailored for adoption by younger farmers.

Although the average number of spouses of the farmers in the two districts was not statistically different (t-value = 0.826), farmers in the Sekyere South district have significantly larger average household sizes (9.21) compared to KEEA (5.59), (t-value of 3.226,  $p < 0.05$ ), which suggest a potentially greater labor availability in Sekyere South to support labor-intensive farming practices to increase productivity even in the absence of mechanization. [Miine \*et al.\* \(2023\)](#) and [Brown \*et al.\* \(2019\)](#) opined that younger farmers are

more open to new technologies and long-term investments, unlike older, risk-averse farmers. However, the larger household size also implies increased food and financial demands that could put a strain on available financial resources, limiting farm investments.

The smaller family sizes in the KEEA district also indicate the possibility of less family labour availability compared to the Sekyere South. This will potentially drive a greater reliance on hired labor or encourage the adoption of less labor-intensive methods in the KEEA. Thus, the household size difference between the two districts is indicative of the need for district-specific policies that address labor dynamics, such as labor-sharing arrangements in Sekyere South and support for mechanization or other labor-saving technologies in KEEA. Age plays a significant role in technology adoption, with older farmers generally being more conservative and resistant to change ([Brown \*et al.\*, 2019](#); [Olum \*et al.\*, 2020](#)). Marital status differs notably between the districts. Sekyere South has a higher proportion of married farmers (73.2%) compared to KEEA (55.9%), but this did not reflect in a significant difference in family sizes. The similarity in farmers' farm sizes in both districts (t-value = 0.814) suggests that the productivity potential at both agroecological zones may be similar if other factors like input access and technology adoption do not vary between the two districts. Thus, soil fertility management decisions of farmers in the 2 districts may not be affected by land size. However, studies have shown that farm size and household characteristics influence technology adoption and that farmers with larger farms are more

likely to adopt new practices (Adams and Jumpah, 2021; Hu *et al.*, 2022; Ruzzante *et al.*, 2021).

The farmers' years of education (Sekyere South: 10.10 years, KEEA: 10.76 years) were not significantly different between the 2 districts (t-value = -0.498). This similarity in the level of literacy and skills among the farmers suggests that similar training approaches and extension services may be used in both districts to facilitate technology adoption. Oli *et al.* (2025) and Benoit (2022) argued that education levels and farming experience influence technology adoption rates in that more educated farmers show higher adoption tendencies. The income levels of farmers in the Sekyere South (19,603.57) and KEEA (20,885.29) districts are also not significantly different (t-value = -0.368). This indicates that the farmers had similar economic opportunities and challenges, including financial constraints that influenced their investment and technology adoption decisions. Therefore, providing financial support policies and credit programs or input subsidies will similarly benefit the farmers. According to Branca *et al.* (2022), access to financial services, stable markets, and extension services is crucial for promoting sustainable practices.

The gender distribution of farmers in the Sekyere South and KEEA districts is similar (chi-square of 0.143), with a slight male majority in both districts (51.8% in Sekyere South and 55.9% in KEEA). Gender disparities in access to agricultural resources persist in developing countries, affecting productivity and economic outcomes. Access to resources such as land, extension services, and information remains gendered, while access to credit, ICT, and labor is less influenced by gender (Ankrah *et al.*, 2020). However, studies in Ghana and Ethiopia revealed that male-headed households generally have greater access to land, livestock, labor, and inputs compared to female-headed households (Abdisa *et al.*, 2024; Gebre *et al.*, 2021; Kpoor, 2019). However, when given equal access to resources, female farmers can be more efficient and productive (Ankrah *et al.*, 2020; Dwomoh *et al.*, 2023). Interventions to address this disparity include prioritizing agricultural advisory services for women with low educational backgrounds, especially in patriarchal societies, introducing technologies to reduce women's workload, and improving access to productive inputs for female-headed households (Ankrah *et al.*, 2020; Dwomoh *et al.*, 2023). In another

study, Ankrah *et al.* (2020) found that education, age, and socio-cultural norms can mitigate the gendered access and control of resources.

The results revealed that the majority of the respondents in both districts are heads of their households (63.6% in Sekyere South and 57.6% in KEEA), with no significant difference (chi-square value of 0.320), suggesting similar household structures across the two districts. Sekyere South has a higher percentage of farmers with secondary income sources (25%) compared to KEEA (14.7%). This suggests that farmers in the Sekyere South show greater economic diversification opportunities. Many of the farmers' partners are also involved in farming, but some of them were engaged in local government and petty trading, indicating complementary income sources within households. Off-farm income and affiliations with farmer organizations positively correlate with sustainable agriculture adoption (Anang *et al.*, 2024; Anang *et al.*, 2020; Ma *et al.*, 2023). These findings suggest that promoting sustainable agricultural systems requires tailored approaches that consider farmers' socio-economic characteristics, attitudes, and beliefs, as well as region-specific factors affecting technology diffusion.

Land tenure arrangements differ significantly between the two districts (chi-square value of 13.008). Sekyere South has a higher proportion of farmers using family land (39.3%) or owning land (33.9%), while those in KEEA rely more on cash rental land (35.3%). This difference could affect land security, long-term investment in land improvements, and overall productivity (Antwi-Agyei *et al.*, 2015; Bannor *et al.*, 2022). Additionally, both districts rely heavily on personal savings for financing their farms. However, Sekyere South shows a slightly higher reliance on loans (23.2%) compared to KEEA (11.8%), suggesting a greater need for access to credit or a higher willingness to utilize credit in Sekyere South. The basis for selecting the two districts was the differences in the dominant crops cultivated by their farmer; the results showed that cocoa was the most prevalent crop in both districts. However, Sekyere South showed a more diversified crop profile, with a significant proportion of farmers cultivating cassava (30.4%) and maize (21.4%). This crop diversification in Sekyere South could provide greater resilience to market or environmental shocks, particularly those that affect monocrop farming like cocoa.

Table 4. Farmer characteristics (categorical variables).

Farmer Characteristics	Sekyere South Freq. (%)	KEEA Freq. (%)	Chi-square value
Sex			0.143
Male	29(51.8)	19(55.9)	
Female	27(48.2)	15(44.1)	
Marital Status			3.254
Married	41(73.2)	19(55.9)	
Single	13(23.2)	14(41.2)	
Widowed	2(3.6)	1(2.9)	
Head of Household			0.320
No	20(36.4)	14(42.4)	
Yes	35(63.6)	19(57.6)	
Highest Education			6.987
No Formal Education	5(8.9)	0(0.0)	
Primary	8(14.3)	2(5.9)	
Junior High School	22(39.3)	13(9)	
Senior High School	11(19.6)	9(26.5)	
Diploma	5(8.9)	3(8.8)	
University	5(8.9)	7(20.6)	
Main Occupation			0.614
Farming	55(98.2)	34(100.0)	
Teaching	1(1.8)	0(0.0)	
Occupation of Partner			2.925
Farming	35(62.5)	22(64.7)	
Local Government	8(14.3)	5(14.7)	
Petty trading	11(19.6)	6(17.6)	
Masonry	1(1.8)	0(0.0)	
Catering	1(1.8)	0(0.0)	
Driving	0(0.0)	1(2.9)	
Main source of income			0.000
Farming	56(100.0)	34(100.0)	
Additional source of income			4.547
None	42(75.0)	29(85.3)	
Money lenders	8(14.3)	3(5.4)	
Salary	3(5.4)	1(2.9)	
Carpentry	1(1.8)	0(0.0)	
Driving	0(0.0)	1(2.9)	
Catering	2(2.6)	0(0.0)	
Own Livestock			0.764
No	25(44.6)	12(35.3)	
Yes	31(55.4)	22(64.7)	
Land Tenure			13.008*
Family land	22(39.3)	5(14.7)	
Cash Rental	6(10.7)	12(35.3)	
Own land	19(33.9)	9(26.5)	
Lease	7(12.5)	5(14.7)	
Sharecropping	2(3.6)	2(5.9)	
Government	0(0.0)	1(2.9)	
Farm Finance			2.277
Own savings	40(71.4)	29(85.3)	
Relatives	3(5.4)	1(2.9)	
Loans	13(23.2)	4(11.8)	
Main type of crop			4.827
Maize	12(21.4)	5(14.7)	
Cassava	17(30.4)	10(29.4)	
Cocoa	22(39.3)	19(55.9)	
Plantain	1(1.8)	0(0.0)	
Vegetables	4(7.1)	0(0.0)	

\**p-value* < 0.05

Education levels varied significantly across districts (Table 4). While 34% of farmers completed Junior High School (JHS), with 24% from Sekyere South, only 14% had a university education (8% from KEEA, 6% from Sekyere South) (Fig. 1). Thus, a higher percentage of farmers in the KEEA district have completed senior high school or university education compared to Sekyere South, which has a larger proportion of

farmers with lower levels of education (chi-square value of 6.987). This difference may affect technology adoption, the use of agricultural information, and overall productivity. According to [Chankseliani \*et al.\* \(2021\)](#); [Žalėnienė and Pereira \(2021\)](#), higher education is often associated with better resource access and an increased ability to adopt new technologies.

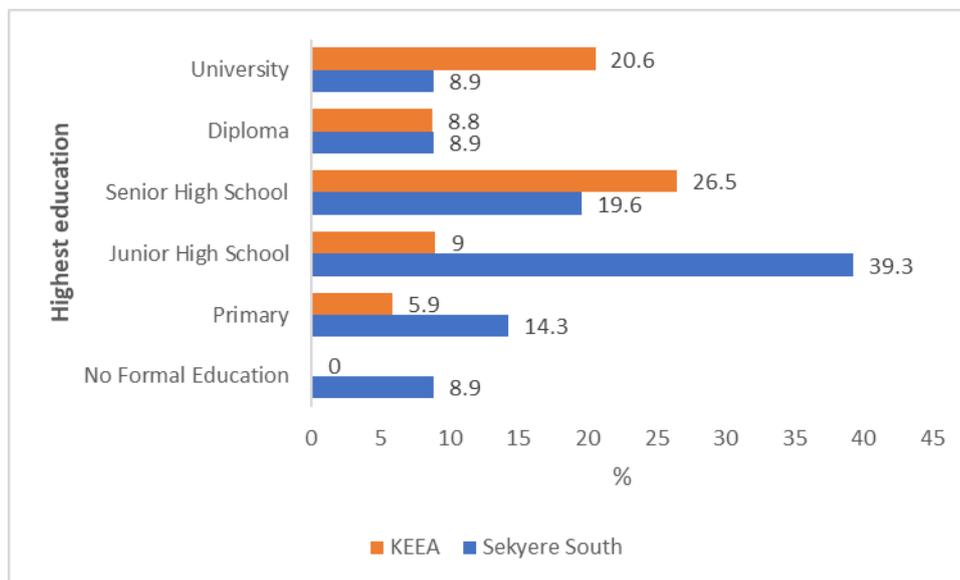


Fig 1. Highest education of Farmers from both districts.

This educational distribution aligns with findings from [Paltasingh and Goyari, 2018](#), who noted that educational levels significantly influence farmers' ability to adopt new agricultural technologies. The

farming experience between districts showed notable differences (Fig. 2). Revise this section to deal with repetitions.

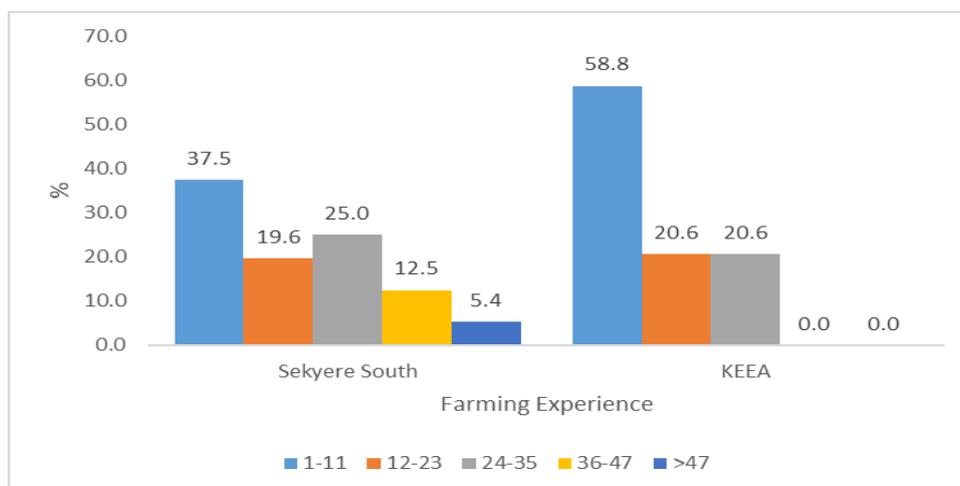


Fig 2. Number of years of farming from both districts.

About 46% of farmers had approximately 10 years of experience, equally distributed between both districts. However, long-term farming experience (40+ years) was found in

Sekyere South (3%), suggesting a more established farming community in this district.

### Farming systems

The study identified distinct patterns in farming systems between the two districts.

Mixed cropping dominated (63%), with a higher prevalence in Sekyere South (45%) compared to KEEA (18%) (Table 5).

Table 5. Cropping system and organic amendment application.

	Sekyere South	KEEA	Chi-square value
	Freq. (%)	Freq. (%)	
Cropping System			5.478
Monocropping	13(23.6)	16(47.1)	
Mixed cropping	38(69.1)	17(50.0)	
Intercropping	4(7.3)	1(2.9)	
Organic Amendment			1.708
No	20(38.5)	16(53.3)	
Yes	32(61.5)	14(46.7)	
Organic Input used			6.312
None	24(42.9)	20(60.6)	
Animal Manure	21(37.5)	9(27.2)	
Compost	4(7.1)	3(9.1)	
Manure and Compost	7(12.5)	1(3.0)	

\**p-value* <0.05

Table 5 comparing Sekyere South and KEEA reveals significant differences in cropping systems and organic amendments use, with deeper implications for agricultural practices and sustainability in these regions. The Chi-square value for cropping systems is 5.478, indicating a significant difference between the two areas. In Sekyere South, 69.1% of farmers practice mixed cropping, while 23.6% engage in monocropping and 7.3% in intercropping, whereas KEEA shows a higher proportion of monocropping at 47.1%, with mixed cropping at 50.0% and intercropping at only 2.9%. This suggests that farmers in Sekyere South prefer mixed cropping as a risk mitigation strategy, which is more sustainable and adaptable to changing climatic conditions, as it diversifies production and reduces the risk of crop failure due to pests, diseases, or adverse weather. On the other hand, the greater reliance on monocropping in KEEA may be due to economic factors such as market demand for specific crops or access to specialized resources for monoculture farming, reflecting a divergence in cropping systems that may impact the regions' resilience and sustainability. Regarding organic amendments, the Chi-square value of 1.708 indicates a moderate difference in practices between Sekyere South and KEEA, although not statistically significant. In Sekyere South, 61.5% of farmers use organic amendments, compared to 46.7% in KEEA, suggesting that Sekyere South has a higher proportion of farmers incorporating organic

practices into their farming systems, which are linked to improved soil fertility and long-term land sustainability. The lower adoption in KEEA may be due to factors such as limited access to organic inputs, lack of awareness, or a higher reliance on chemical fertilizers. In terms of organic input use, a significant difference is observed with a Chi-square value of 6.312. In Sekyere South, 42.9% of farmers use no organic inputs, whereas in KEEA, 60.6% do not use organic inputs, indicating that Sekyere South has a relatively higher adoption of organic practices, with animal manure being the most commonly used organic input in both regions, although Sekyere South shows greater use of both animal manure (37.5% vs. 27.2%) and compost (7.1% vs. 3.0%). These findings suggest that Sekyere South is more engaged in organic farming practices, potentially due to better availability of manure, stronger support for organic methods, or greater awareness of their benefits, while KEEA's higher percentage of farmers not using organic inputs could reflect a stronger reliance on synthetic fertilizers or insufficient access to organic alternatives. These differences highlight key factors such as resource availability, knowledge, and infrastructure that influence farming practices. Generally, Sekyere South seems to focus more on sustainable agricultural practices, particularly in mixed cropping and organic amendments, whereas KEEA's focus on monocropping and lower use of organic inputs may prioritize economic

gains over long-term sustainability. To address these differences, targeted interventions could promote sustainable practices across both regions, such as increasing the availability and education on organic farming in Sekyere South and encouraging diversification of cropping systems and the integration of organic practices in KEEA to reduce vulnerability and enhance long-term agricultural

resilience. Gender analysis of land ownership revealed that 29% of farmers have their own land, with higher female ownership (18%) compared to males (11%) (Fig. 3). This finding contradicts traditional patterns of male-dominated land ownership in Sub-Saharan Africa (Chigbu, 2019; Slavchevska *et al.*, 2021).

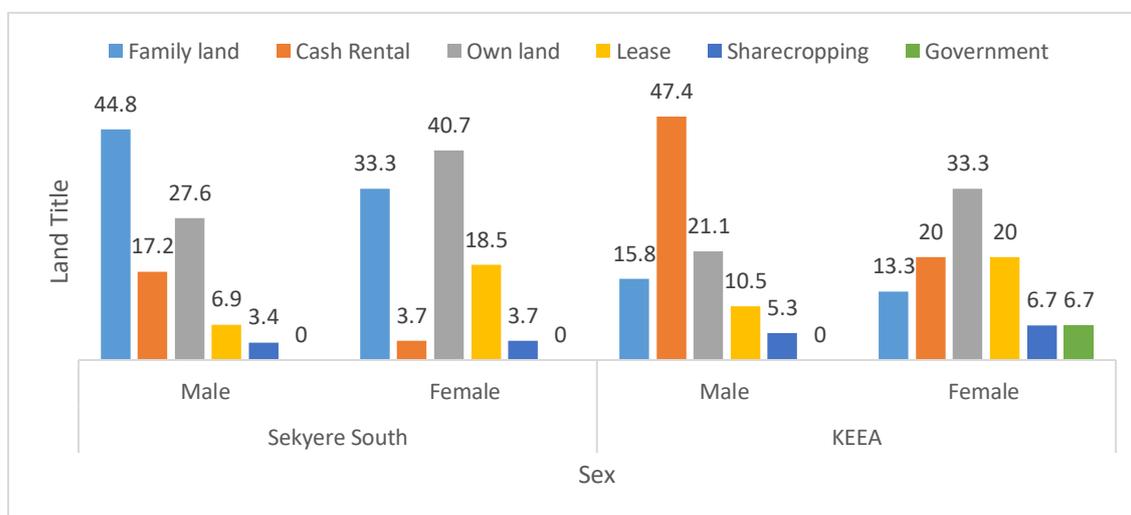


Fig 3. Sex and Farm land title.

**Soil fertility management practices**

The study showed that the farmers in the two districts use diverse soil fertility management practices. The majority (73%) of the farmers

applied animal manure, 13% of them used NPK fertilizers, and 11% utilized plant compost (Fig. 4).

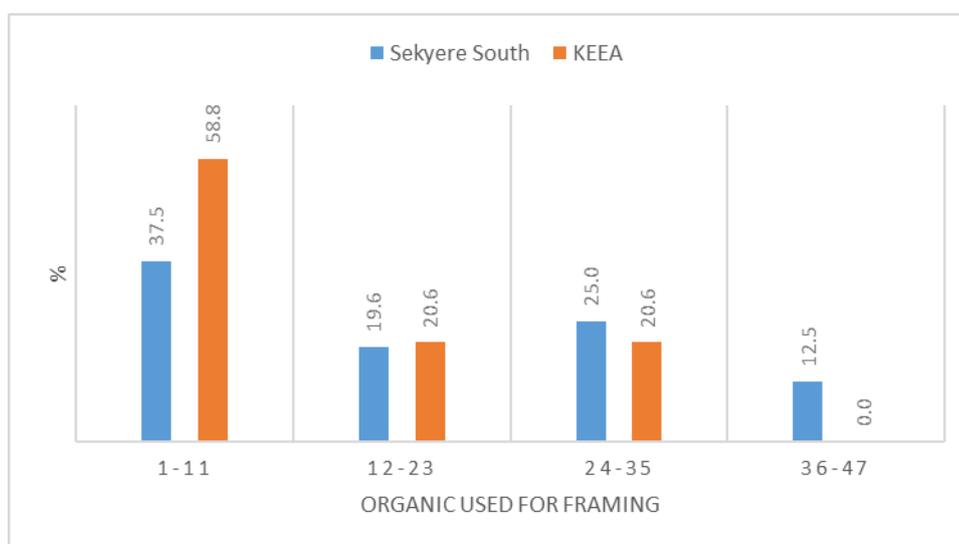


Fig. 4. Type of organic used for framing.

Most organic fertilizer users (51%) were from Sekyere South, suggesting the dominance of traditional farming practices in this district. Regarding technical support, 94% of farmers received assistance from MoFA, but only 34% accessed technical support from private

Agricultural Extension Agents. Notably, 5% of Sekyere South farmers reported receiving no technical assistance, highlighting potential gaps in access to technical support.

**Socio-demographic, awareness and willingness to pay**

Statistical analysis revealed significant correlations between various factors, including negative correlations between income levels and willingness to adopt ( $r=-$

0.189,  $p<0.05$ ), education and capacity building participation ( $r=-0.189$ ,  $p<0.05$ ), and land tenure and 4R awareness ( $r=-0.244$ ,  $p<0.05$ ) (Table 6).

Table 6. Relationship between socio-demographic, awareness and willingness to pay.

	Awareness		Willingness		
	ISFM	4R	ISFM	4R	Capacity
Sex	0.033	0.057	-0.036	-0.036	-0.014
Age	0.103	-0.129	-0.057	-0.057	0.051
Household Size	-0.008	0.075	-0.099	-0.099	0.133
Years of education	-0.014	-0.003	0.116	0.116	-0.189*
Income	-0.031	0.258*	-0.189*	-0.189*	-0.152
Farming Experience	0.073	-0.045	-0.121	-0.121	0.016
Land Size	-0.025	-0.091	0.104	0.104	0.029
Headship	0.033	-0.081	-0.096	-0.096	-0.061
Main crop	-0.046	0.305*	-0.324*	-0.324*	-0.081
Land Tenure	0.049	-0.244*	0.091	0.091	0.079

Food security implications were evident in the findings, with 76% of farmers reporting occasional food availability in the last 12 months. This was more pronounced in Sekyere South (50%) compared to KEEA (26%). These findings align with (Adjei-Nsiah *et al.*, 2022; Mateete *et al.*, 2010; Stewart *et al.*, 2020) studies highlighting the critical link between soil fertility and food production in Sub-Saharan Africa, suggesting that improved soil fertility management could enhance food security in these districts.

The findings in the study were reflected in the statements made by some farmers during the FGD and the KII as follows:

A 30-year-old female farmer from Sekyere south also indicated during a FGD that:

*"I would be glad if the training on ISFM and 4RNs would be done more frequently, and across the entire nation for farmers of all ages, academic backgrounds, and gender. The training can also be done as a top-up for the agriculture graduates to enable them to facilitate similar training programmes. However, adequate funding should be made available to promote this laudable training."*

A female farmer Sekyere south, FGDs.

Technical help is essential for effective soil fertility management. A primary technical proposal is to deliver specialised training on 4R Nutrient Stewardship (Right Source, Right Rate, Right Time, Right Place) and Integrated Soil Fertility Management (ISFM) (Johnston and Bruulsema, 2014). These frameworks provide scientifically grounded

recommendations for enhancing soil fertility while reducing environmental repercussions. Regarding the usefulness of technical training for the adoption of soil fertility management practices, a graduate farmer from Sekyere South District intimated that:

*"I regret the fact that I did not have this knowledge during my university education. Ten years after farming I am now better positioned to increase my yields through appropriate soil fertility management practices."*

A Graduate farmer from Sekyere south, KII. However, in terms of motivating the adoption of the ISFM and the 4RNS, a female farmer from the KEEA also indicated during a KII that:

*"I would be glad if the government would provide us with financial support to enable us to implement the ISFM and the 4RNS practices that we have been exposed to. Indeed, we also need further capacity building in this respect."* A female farmer from KEEA, KII.

The 4R framework underscores the necessity for accurate fertiliser application to minimise waste and enhance nutrient absorption, which is especially advantageous for smallholders who frequently encounter financial limitations. ISFM incorporates organic and inorganic soil amendments, crop management strategies, and soil conservation methods, proving to be highly effective across the many agro-ecological zones of Ghana. By deepening their

comprehension of these methods, smallholder farmers can make educated decisions that sustainably enhance soil fertility.

### **Soil management and agriculture extension advice**

Table 7 presents insights into soil management practices and agricultural extension advice in Sekyere South and KEEA, revealing some significant differences. In terms of "Other soil management" practices, Sekyere South has a slightly higher proportion of farmers using alternative techniques (52.7%) compared to KEEA (64.7%), though the Chi-square value of 1.232 suggests that this difference is not statistically significant. When looking at the "Main soil management" practices, Sekyere South shows a higher percentage of farmers using zero tillage (28.6%) compared to KEEA (14.7%), while KEEA has a stronger preference for mulching (23.5%) and cover cropping (20.6%) than Sekyere South, where mulching is less common (17.9%) and cover cropping is used by only 10.7%. The Chi-square value of 3.526 indicates a statistically significant difference between the two regions, suggesting that the regions differ in their main soil management practices, with Sekyere South favoring zero tillage and KEEA more inclined towards mulching and cover cropping. Regarding motivation, Sekyere South farmers are more likely to rely on training (64.3%) than KEEA farmers (50.0%), while financial support is more common in Sekyere South (35.7%) compared to KEEA (26.5%). However, KEEA farmers are more likely to receive both training and financial support (23.5%) than those in Sekyere South (0%), which is reflected in the Chi-square value of 14.471 and a p-value less than 0.05, indicating a statistically significant difference between the regions. This suggests that Sekyere South relies more on training as a motivator, while KEEA combines training and financial support to offer more comprehensive assistance to farmers. In

terms of agricultural advice, both Sekyere South (80.4%) and KEEA (82.4%) predominantly rely on extension agents for guidance, with a small proportion using radio as a source of advice (19.6% in Sekyere South and 17.6% in KEEA). The Chi-square value of 0.055 shows no significant difference between the two regions in terms of the source of agricultural advice, indicating similar reliance on extension services in both areas. In summary, while both regions share some common agricultural practices, significant differences in motivation strategies and soil management techniques highlight areas where targeted interventions could be beneficial. Strengthening financial support and expanding access to integrated advisory services could improve agricultural productivity and resilience in both regions.

This summary synthesizes findings from four studies on sustainable soil management practices in Africa and Asia. Adoption rates of integrated soil fertility management (ISFM) varied significantly between regions, with factors like seed availability, soil characteristics, and labor influencing uptake (Adolwa *et al.*, 2019). Socioeconomic factors, including gender, age, and access to extension services, were found to impact the adoption of conservation agriculture practices in Cameroon (Ngaiwi *et al.*, 2023). In Bangladesh, climatic factors, education, and access to information were crucial determinants of sustainable soil management adoption (Sharna *et al.*, 2022). The importance of extension services was highlighted across studies, with both farmers and extension agents in Nigeria demonstrating knowledge of soil and water conservation practices, though extension agents generally showed higher levels of knowledge and perceived importance (Danjumah *et al.*, 2024; Danso-Abbeam, 2022). These findings underscore the complex interplay of social, economic, and environmental factors in shaping agricultural practices across different regions.

Table 7. Soil management and agriculture extension advice.

	Sekyere South	KEEA	Chi-square value
	Freq. (%)	Freq. (%)	
Other soil management			1.232
No	26(47.3)	12(35.3)	
Yes	29(52.7)	22(64.7)	
Main soil management			3.526
None	24(42.9)	14(41.2)	

Mulching	10(17.9)	8(23.5)	
Zero tillage	16(28.6)	5(14.7)	
Cover cropping	6(10.7)	7(20.6)	
Motivation			14.471*
Training	36(64.3)	17(50.0)	
Financial Support	20(35.7)	9(26.5)	
Both	0(0.0)	8(23.5)	
Agriculture Advice			0.055
Extension Agents	45(80.4)	28(82.4)	
Radio	11(19.6)	6(17.6)	

\**p-value* <0.05

**Fertilizer observed changes**

Table 8 compares Sekyere South and KEEA in terms of agricultural practices and reveals significant differences, particularly in the use

of organic inputs, causes of changes, effects on productivity, and observed changes in vegetation cover.

Table 8. Fertilizer Observed Changes

	Sekyere South	KEEA	Chi-square value
	Freq. (%)	Freq. (%)	
Changes (Organic Input use)			15.807
No change	10(18.2)	11(32.4)	
Higher yield	25(45.5)	12(35.3)	
Green leaves	2(3.6)	0(0.0)	
Declining yield	0(0.0)	5(14.7)	
Bigger crop size	2(3.6)	2(5.9)	
Better growth	11(20.0)	4(11.8)	
Early maturity	5(9.1)	0(0.0)	
Cause of Change			8.897
None	15(26.8)	10(29.4)	
Low disease incidence	7(12.5)	6(17.6)	
Improve soil fertility	31(55.4)	11(32.4)	
Improved yield	0(0.0)	3(8.8)	
Poor soil fertility	3(5.4)	4(11.8)	
Effect of change			0.784
None	17(31.5)	8(40.0)	
Improve nutrient supply	30(55.6)	10(50.0)	
Lack of nutrients	1(1.9)	0(0.0)	
Improved plant health	6(11.1)	2(10.0)	
Changes in vegetation cover			0.729
No	15(26.8)	12(35.3)	
Yes	41(73.2)	22(64.7)	
Difference observed			6.172
Greener leaves	13(23.2)	13(38.2)	
Better growth	27(48.2)	8(23.5)	
None	14(25.0)	10(29.4)	
Yellowing of leaves	2(3.6)	3(8.8)	
			t-value
Duration of fertilizer use	2.41(2.078)	1.65(2.087)	1.687
Duration of observed changes	2.02(0.981)	1.82(0.673)	1.017

\**p-value* <0.05

The Chi-square value of 15.807 indicates a notable difference in the perceived impact of organic input use, with a higher percentage of farmers in Sekyere South (45.5%) reporting higher yields compared to those in KEEA (35.3%). Sekyere South also showed more diverse responses, including reports of green leaves, early maturity, and better growth, suggesting that organic inputs may be more effective or better implemented in this region. In contrast, KEEA had a higher percentage of farmers (32.4%) reporting no change, indicating a less positive outcome from organic input use. The Chi-square value of 8.897 for the causes of change highlights significant differences in how farmers attribute improvements in productivity, with Sekyere South farmers largely attributing changes to improved soil fertility (55.4%), while KEEA farmers are more likely to report poor soil fertility (11.8%). This suggests that Sekyere South may be better managing soil health, which is crucial for sustained agricultural productivity. Regarding the effects of change, both regions reported improvements in nutrient supply, with Sekyere South (55.6%) showing a slightly higher proportion of farmers noting benefits compared to KEEA (50%), which indicates that both regions recognize the positive impact of changes in agricultural practices on nutrient availability. The changes in vegetation cover, with a Chi-square value of 0.729, were similar in both regions, but Sekyere South showed more farmers reporting better growth (48.2%), suggesting that overall plant health and productivity may be improving more in Sekyere South compared to KEEA, where greener leaves (38.2%) were reported more frequently. The t-values for the duration of fertilizer use and the duration of observed changes indicate that Sekyere South has a longer history of fertilizer use (2.41 years) compared to KEEA (1.65 years), and the observed changes in Sekyere South have been more sustained over time, with a duration of 2.02 years, compared to KEEA's 1.82 years. These findings imply that Sekyere South has more experience with and longer exposure to agricultural innovations, leading to better outcomes. Overall, the data highlights that while both regions are adopting organic practices, Sekyere South seems to benefit more, potentially due to better soil fertility management and longer adoption of practices, whereas KEEA faces challenges like declining yields and poorer soil health, necessitating tailored interventions to improve agricultural productivity and resilience.

The study highlights the benefits of organic farming practices on soil fertility and agricultural productivity. Organic farms showed higher technical efficiency and potential for long-term productivity improvements compared to conventional farms (Issaka *et al.*, 2016). Farmers' perceptions of soil fertility aligned well with scientific indicators, emphasizing the importance of nitrogen in maintaining soil productivity (Dawoe *et al.*, 2012). Organic agriculture demonstrated better environmental performance, including improved soil organic matter content, water holding capacity, and biodiversity, despite lower yields (Gamage *et al.*, 2023; Sahu *et al.*, 2024; Schader *et al.*, 2012). In traditional farming systems, plots closer to homesteads received more organic inputs, resulting in higher soil organic carbon, cation exchange capacity, and nutrient content (Yakob *et al.*, 2023). Household characteristics, such as gender and wealth, influenced land management practices and soil properties. Overall, these studies suggest that adopting organic farming practices and increasing organic inputs can enhance soil fertility, agricultural productivity, and environmental sustainability in various contexts. This observation agrees with the remark made by a male farmer at the KII in the Sekyere South as reported below.

*"The training has brought great insight into why proper soil fertility management should be practiced by all farmers. Now we know that to manage our soil fertility properly, we need to use the right source of input at the right rate, placed at the right place, and at the right time."* A male farmer from Sekyere South, KII.

### **Recommendation and way forward**

Policymakers ought to formulate specialized support initiatives customized to the socio-economic characteristics of farmers (e.g., age, education, income, and resource accessibility) to address knowledge deficiencies and enhance execution. Land tenure reforms are essential to promote long-term investments in soil fertility. Public-private partnerships in agricultural extension services can deliver specialized expertise, innovative technology, and training, while technical support should emphasize frameworks such as 4R Nutrient Stewardship and Integrated Soil Fertility Management (ISFM). Recommendations for fertilizers tailored to individual locations, underpinned by soil analysis and the enhancement of

extension service capabilities, are crucial for optimal resource utilization. Financial limitations can be alleviated by accessible loan programs, new financing mechanisms (e.g., mobile banking, microfinance), and enhanced fertilizer subsidy initiatives aimed at at-risk farmers. These initiatives jointly seek to advance sustainable agriculture, bolster food security, and enhance rural livelihoods.

## Conclusion

The research underscores the fact that the socio-economic attributes of farmers, including education, access to technical resources, and land tenure security, significantly influence their readiness and capacity to implement sustainable soil fertility management strategies. Despite the varying farmers' understanding of the 4R Nutrient Stewardship and ISFM techniques, most of the farmers showed a readiness to adopt these approaches, contingent upon the provision of sufficient support systems. This signifies a significant opportunity for improved soil fertility management, targeted interventions that tackle knowledge deficiencies, restricted access to resources, and socio-economic obstacles, including financial limitations and tenure instability. The socio-economic barriers disproportionately affected young and female farmers, particularly in terms of difficulties in accessing resources and technical knowledge. Future interventions must be customised to address the specific requirements of various agroecological zones and the unique socioeconomic orientation of various farmer groups, ensuring the effectiveness of the solutions. Highlighting localised support could significantly increase adoption rates of soil fertility management practices, leading to sustainable agricultural productivity and enhanced livelihoods in Ghana's smallholder farming communities. The findings from the study will be used for advocacy and capacity-building for smallholders and as the basis for more holistic future soil fertility management research in Ghana and across other regions. The implementation of interventions based on the findings from the study will enhance the adoption and integration of more effective soil fertility management practices. This will contribute to achieving the Sustainable Development Goals of no poverty (SDG 1) and no hunger (SDG 2) through improved agricultural production, food and nutritional security, and job creation in SA.

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## Author contributions

All authors contributed to the study conception. Design for the article: KAF, ROD, SA, ANAA; Literature search and data analysis: KAF, ROD, SA, IB; Writing -original draft: KAF, ROD, ANAA, and all authors commented on previous versions of the manuscript; Review and editing: KAF, ROD, SA, IB. All authors read and approved the final manuscript.

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## Data availability statement

Data will be made available on reasonable request.

## Competing interests

The authors have no relevant financial or non-financial interests to disclose

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