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Evaluating the effects of sustainable intensification practices in smallholder farming systems: A case study of the Nabdam district, Ghana

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ABSTRACT

The impact of sustainable intensification (SI) on food security in the developing world is substantial and cannot be overstated. The study was anchored on the theory of planned behaviour and the diffusion of innovation. This study contributes to the field by examining the effects of SI practices in smallholder farming systems in the Nabdam District of the Upper East Region of Ghana. A concurrent mixed-methods approach was employed, with primary data collected through self-administered questionnaires, face-to-face interviews, and direct on-farm observations. A total of 384 respondents were selected from 2,535 households for the survey using a simple random sampling technique. Two focus group discussions were held in each selected community alongside nine key informants. The quantitative data were analysed using the Statistical Package for Social Sciences (SPSS VERSION 27). The qualitative data were gathered via tape recordings and coded into themes and content for analysis. The findings indicate that awareness of SI alone is insufficient to generate meaningful outcomes. Effective and sustained intensification requires adequate technical knowledge, practical skills, and institutional support. Gendered differences in SI adoption were observed, with men primarily engaging in land-intensive practices (61%). At the same time, women relied on labour- and knowledge-intensive approaches (62%), often supported by credit and extension services. Moreover, educated smallholder farmers were more likely to adopt SI practices than their uneducated counterparts. The study further demonstrates that adopters of sustainable intensification experience higher yields and increased income ($\beta = 0.365$, $t = 9.184$, $p < .001$) compared to non-adopters. Based on these results, the study concludes that, with sufficient institutional support, technical capabilities, and knowledge, sustainable intensification can substantially enhance smallholder farmers' livelihoods and food security. Enhancing adoption requires bolstering extension services, expanding credit availability, and encouraging gender-responsive interventions to maximise productivity and income gains.

Keywords: Ecological Integrity, Climate, Resilience, Smallholder, Sustainable Intensification

I. INTRODUCTION

Sustainable intensification (SI) has emerged as a leading paradigm in international efforts toward solving food insecurity, environmental degradation, and climate change (Jain et al., 2023). Awoonor et al. (2023) stated that food production needs to increase because the population will surpass 9.7 billion by 2050 while maintaining ecological and climate protection. Agricultural land expansion through traditional methods has become unsustainable because it leads to biodiversity loss and forest destruction and increases carbon emissions (Gupta et al., 2024). The world now recognises that people should adopt agricultural methods that increase existing farmland productivity through sustainable, socially acceptable, and economically sustainable methods (Wang et al., 2023). SI fulfils its purpose by combining better farming methods, soil fertility techniques, and climate-resilient concepts, which enable farmers to produce more while protecting the environment (Nord et al., 2023).

Africa experiences great difficulties in agriculture because its farming practices depend on small farmers who rely on natural rainwater but face problems from changing weather patterns. The erratic agricultural productivity in the area suffers from multiple challenges, which include decreasing soil fertility, unpredictable rainfall patterns, insufficient input access, weak agricultural support systems, and socioeconomic disparities (Cook et al., 2022). Nwokolo et al. (2023) reported that African governments and their development partners have strengthened their support for SI methods, which function as effective tools to boost food security and improve resilience for rural communities through integrated soil fertility management and conservation agriculture, enhanced seed varieties, agroforestry, and water harvesting methods, and diversified cropping systems. Farmers' adoption of agricultural technologies shows big differences because multiple social factors, cultural traditions, resource limitations, knowledge systems, gender dynamics, and farmers' abilities to assess potential dangers (Nwokolo et al., 2023) create diverse adoption patterns.

The assessment of drivers helps one to understand why different farming communities in Africa select particular practices for adoption, adaptation, or abandonment. The practice is gaining traction in Ghana as the country strives to strengthen its food systems and reduce its vulnerability to climatic shocks, especially in the Northern Savannah ecological zones (Kotu et al., 2022). The study provides essential information about how SI practices affect agricultural productivity and household resilience in areas with extremely harsh weather conditions, delicate soil, insufficient irrigation systems, and widespread poverty (Issaka et al., 2024). The climatic zone supports low-input farming among most smallholder farmers, but they encounter land degradation, shortened fallow periods, and unpredictable weather patterns (Ekka et al., 2023). The Ministry of Food and Agriculture, together with non-governmental organisations and international development agencies, has promoted SI technologies which include composting and Zai pits and improved seeds and crop rotation and mulching and integrated nutrient management but different communities and social groups hold diverse views about the technology's effectiveness and its adoption rate (Osei-Kofi et al., 2023). The field of sustainable intensification contains multiple existing studies that have explored the domain, but researchers still lack a complete understanding of how to implement these practices in the Nabdam District's specific socio-ecological environment.

1.2 Research Objective (s)

The objectives of the current study include the following:

(i) Determine the level of knowledge and awareness of Sustainable Intensification among smallholder farmers,
(ii) Ascertain the perception of smallholder farmers on gender accessibility to Sustainable Intensification,
(iii) Assess the adoption patterns of Sustainable Intensification among smallholder farmers
(iv) Evaluate any significant difference(s) in crop yield between smallholder farmers who employ Sustainable Intensification as against those who do not

1.3 Based on the objectives, the following hypotheses are tested:

Ho_1: There is a significant association between gender perception and accessibility to the adoption of sustainable intensification (SI) practices.
Ho_2: There is a positive relationship between the yield of adopters of sustainable intensification (SI) and non-adopters of SI practices.
Ho_3: An association exists between the income of adopters of SI and non-adopters of SI practices.

II. LITERATURE REVIEW

2.1 Theoretical framework

The study was based on the Diffusion of Innovation Theory developed by Everett Rogers in 1962 and the Theory of Planned Behaviour proposed by Icek Ajzen in 1985.

2.1.1 Theory of Diffusion of Innovation

The Diffusion of Innovations Theory, which Everett Rogers created in 1962, serves as an effective theoretical framework (Alves & Morrill, 1975) to study how smallholder farmers adopt sustainable intensification methods (Rosário et al., 2022). The theory demonstrates how social systems adopt new agricultural practices through seed variety improvements, integrated soil fertility management, conservation agriculture (Yussif, 2019), efficient water management, and the communication channels and social interactions used for information dissemination (Forero et al., 2025). According to the theory, farmers will decide to adopt sustainable intensification methods based on their assessment of the innovation's advantages and its ability to integrate into current farming systems, its level of difficulty, and its capacity for testing and showing results (Savari et al., 2025). Smallholder farmers in the Nabdam District of Ghana will decide whether to adopt the new practices based on their evaluation of economic and environmental advantages, the availability of extension services, their participation in farmer groups, their connections with peers, and their adherence to local social norms (Ncube et al., 2025). The theory identifies different adopter groups of farmers who demonstrate distinct rates of adoption through their progression from innovators to laggards (Rosário et al., 2022; Savari et al., 2025). This theory plays a vital role in the research by showing how factors and processes decide how farmers implement sustainable intensification practices, which establishes essential base information for the investigation of differing adoption patterns that impact productivity and income, and environmental sustainability results in smallholder farming households.

2.1.2 Theory of Planned Behaviour (TPB)

The study employed the Theory of Planned Behaviour (TPB) as developed by Icek Ajzen in 1991. It functions as a behavioural theory that shows how personal intentions impact actual behaviour. The theory states that people will behave according to their intention to execute a particular action (Sarma et al., 2025), which results from three main influences: their *attitude* about the behaviour, the *subjective norms* that control their actions, and the perceived ability to control their actions. TPB explains to researchers which factors influence Ghanaian farmers to accept sustainable intensification methods that include improved seed varieties, integrated soil fertility management, conservation agriculture, and efficient water management. Farmers will adopt these practices when they hold positive attitudes about their benefits which include increased yield or income and they perceive social pressure from extension officers and they perceive encouragement from extension officers (Waiswa et al., 2024) and farmer groups and community leaders (subjective norms) and they believe they possess all essential resources and knowledge and capacity to execute the practices (perceived behavioral control). The theory presents a structured framework for the study to assess psychological and social factors that impact adoption decisions, which leads to differences in uptake and resulting productivity, income, and environmental sustainability outcomes among smallholder farmers.

2.2 Empirical Review

Recently, there has been a real surge in research on sustainable intensification (SI) in smallholder farming across developing countries. The idea behind SI is simple: boost farm productivity without wrecking the environment, and use resources wisely. Researchers have looked closely at what farmers know about sustainable practices, how gender shapes access to new technology (Ofori et al., 2023), who actually adopt these innovations, and what happens to productivity as a result. It turns out that what farmers know makes a big difference. Pretty et al. (2011) claimed that farmers who have had more training are much sharper on practices like soil management and pest control. Marenya and Barrett (2007) backed this up when they asserted that when farmers get good information, they are quicker to adopt soil fertility technology. According to Abdulai and Owusu (2018), just having access to extension services pushes more farmers to try improved technologies.

Gender, though, is still a huge factor. Studies keep showing that women face bigger barriers—less access to land, credit, and training (Kassie et al., 2015). Doss (2018) spells it out: women farmers just do not have the same opportunities. Quisumbing et al. (2014) further argued that women’s limited access to assets slows down how quickly they can adopt new technology. Meinzen-Dick et al. (2011) point out that cultural norms often restrict women even further (Doss, 2018). Men generally adopt innovations faster because they have more resources, but when women get the same support, their adoption rates catch up (Doss, 2018). When it comes to adoption, there are a bunch of factors at play, farm size, education, credit, and access to markets all matter. In the opinion of Rogers (2003), the Diffusion of Innovation theory helps explain how new ideas spread among farmers. Kassie et al. (2015) found that farmers often pick up several sustainable practices at once, since combining them usually brings better results. In the view of Asante and Amuakwa-Mensah (2014), climate-smart agriculture and soil management show that farmers tend to start with the cheapest, easiest changes and build from there.

All this research points to a clear trend: sustainable intensification lifts yield and protects the environment at the same time (Asante & Amuakwa-Mensah, 2014). Tilman et al. (2011) showed that better crop management—like smarter fertiliser use, crop rotation, and integrated pest management- really pays off. Research across sub-Saharan Africa agrees: conservation agriculture and integrated soil fertility management boost smallholder yields. In Ghana, farmers who mix improved seeds, fertilisers, and soil conservation practices see better harvests than those sticking to traditional methods (Ofori et al., 2023). How much yields improve depends on things like local conditions, how skilled the farmers are, and whether they can get the right inputs (Ofori et al., 2023).

Even with all this progress, there are not enough studies looking at how much farmers actually know about the bigger picture of sustainable intensification—not just single technologies. There is also not much work on how smallholder farmers themselves see gender barriers to adopting SI, especially at the local level. A lot of studies focus on why farmers adopt certain practices, but few really dig into how they combine different SI methods on their farms. And while we know SI can boost productivity, there is still a lack of direct comparisons between farmers who adopt SI and those who do not, within the same area. Filling these gaps matters if we want to truly understand how knowledge, gender, and adoption choices shape sustainable farming for smallholders.

III. METHODOLOGY

3.1 Profile of the Nabdam District

The study was conducted in the Nabdam District of the Upper East Region. It is positioned between latitudes 10° 47' and 10° 57' North and longitudes 0° 31' and 1° 15' West. According to (Nborah et al., 2026), the district has a population of 51,861, comprising 25,552 males and 26,309 females, and covers a land area of 251 km². It shares borders with the Bongo District to the north, the Talensi District to the south, the Bawku West District to the east, and the Bolgatanga Municipality to the west. The landscape is characterised by relatively undulating lowlands and gentle slopes with gradients ranging from one to five per cent, interspersed with isolated rock outcrops and upland slopes. The district is part of the Birimian, Tarkwaian, and Voltarian rock formations in Ghana. A significant 95.7 per cent of households engage in smallholder agriculture, with 98.1% involved in crop farming. Poultry, particularly chickens and guinea fowl, are the most commonly reared animals in the country. The climate is tropical, with two distinct seasons. Erratic rainfall, from May to October, whereas the dry season starts from October to April, is characterised by warm and hazy weather with minimal or no rainfall. The average rainfall ranges from 88mm to 110 mm, with an annual total of approximately 950 mm. Temperatures can soar to 45 °C in March and April and drop to approximately 12 °C in December (Agyekum et al., 2024).

3.2 Research Approach and Design

A pragmatist research philosophy guided this study and underpinned the choice of a concurrent mixed-method approach to assess the effectiveness of sustainable intensification practices in smallholder farming systems within the Nabdam District of Ghana. Pragmatism emphasises the use of multiple methods, tools, and perspectives in understanding complex real-life problems and, as such, is suitable for studies on sustainable Intensification practices, where both measurable outcomes and contextual experiences are important. Pragmatism supports methodological flexibility, quantitative and qualitative, that allows varied means of gathering evidence without being constrained by a single epistemological position.

The research used a concurrent mixed-methods design to collect and analyse both quantitative and qualitative data at the same time, which enabled researchers to create a complete understanding of sustainable intensification adoption and its effects through the triangulation method. The quantitative component includes a cross-sectional household survey through which empirical data on adoption levels, gender participation in and accessibility to SI, yields, labour dynamics, resource efficiency, and socio-economic characteristics of smallholder farmers are gathered. The qualitative component makes use of in-depth key informant interviews and focus group discussions with farmers, extension agents, and community leaders in order to explore such factors as behavioural and informational, gendered, and sociocultural influences that shape adoption and perceived benefits.

3.3 Sample Frame and Sample Size Determination

This study focused on selected households within Kongo, Pitanga, and Dasobligo in the Nabdam District. In establishing the total study population of smallholder farmers, a sequential door-to-door listing was done within the selected communities to validate the rate of intensification and adoption. The listing identified about 2535 smallholder farming households in the study communities (see Table 1). This had to be done because no records existed on households involved in small-scale intensification in the selected study communities. Small-scale farming is dynamic in the district, and its current phase of intensification and sustainable practices is different from one household to another within the district. The listing exercise provided the researcher with an accurate number of smallholder farmers within the selected study areas and helped confirm household eligibility. The formula for determining sample size by Cochran (1977) was used to select 384 participants for this study.

$$n_o = \frac{z^2 . p.(1-p)}{e^2} \quad \text{………Eqn (1)}$$

Where: n_0= initial sample size, Z= Z-score corresponding to the confidence level, p= estimated proportion of the population, e= desired margin of error

$$no = 384/(1 + (384 - 1)/2535) = 384/(1 + 383/2535) \quad \text{………Eqn. (2)}$$

$$n_o = 384/ 1.151=384 \quad \text{………Eqn. (3)}$$

The sample size was apportioned equitably and proportionally among the study communities: Kongo, Dasobligo, and Pitanga. The distribution considered the level and severity of smallholder farming intensification in the study areas.

Table 1
Sample Size Distribution of the Participants

	Names of communities and the total number of households			
Categorisation	**Kongo (HH = 1,350)**	**Dasobligo (HH = 435)**	**Pitanga (HH = 750)**	**Total Households Sampled**
Low	32	24	26	82
Moderate	47	43	36	126
High	79	55	42	176
Total	**158**	**122**	**104**	**384**

3.4 Sampling and Data Collection Techniques

This study adopted both probability and non-probability sampling strategies, in line with the mixed-methods research design. A simple random sampling procedure was adopted to select smallholder farming households in the quantitative component by first listing. The number of households listed from the three communities, namely Kongo, Dasobligo, and Pitanga, was 2,535, from which a sample size of 384 households was gleaned. The lottery method was subsequently applied in selecting the households for participation in the survey process. Numbers were written on papers and rolled for members to pick from a basket. Any member who picked an even number was allowed to participate in the study. The process was repeated until we reached 384 respondents. This method was applicable as it gave equal chances to every eligible household, thus making the data representative.

Quantitative information was gathered through a cross-sectional household survey because this approach has proven most efficient in acquiring structured data from a large number of respondents. A face-to-face personal interview was also conducted to solicit information from the respondents. This was necessary because it involves direct contact between the enumerator and the respondent, allowing the interviewer to probe for clarification whenever there is any misunderstanding of the questions. The questionnaires targeted household heads, spouses, or any other senior member who had an in-depth understanding of smallholder farming and sustainable intensification practices. A structured questionnaire implemented through Computer-Assisted Personal Interviewing (CAPI) on the Google Forms platform facilitated data collection. This platform reduced time and cost and increased the accuracy of the data.

For the qualitative component, purposive sampling was employed using key informant interviews. This approach targeted persons with extensive experience in local farming systems; three (3) personnel of the Ministry of Food and Agriculture (MoFA), ten (10) local farmers in Kongo, Dasobligo, and Pitanga, and four (4) officials of the Ministry of Food and Agriculture in the Nabdam District. They provided information on sustainable intensification practices, the ecological integrity of intensification practices, and climate-smart agronomic practices relevant to smallholder farmers. In the Nabdam Data collection, this phase utilised semi-structured interviews. With the aid of interview guides and checklists, the researchers explored farmers' adoption of sustainable intensification practices and their climate change adaptation strategies.

Furthermore, focus group discussions were held for each community. In all six (6) focus group discussion sessions, were held for the three communities. In each community, a focus group discussion session was held separately for each gender to enable women to express themselves freely without influence. Membership of the FGDs was twelve (12). Non-participant observation was conducted to document visual evidence of farming practices, including soil and water conservation practices. The researchers hired a literate person to assist in the translation and interpretation of self-administered questionnaires from English to the Nabt language to enhance the understanding of respondents. The multiple data collection methods were employed in the qualitative phase to facilitate data triangulation and enhance the validity of the findings.

3.5 Data Analysis and Presentation

The quantitative data were initially processed for analysis by assigning codes using the Statistical Package for Social Sciences (SPSS), version 27 (Osumanu et al., 2019). Further, descriptive data were analysed based on frequency and percentage. Later, cross-tabulation tests were conducted on data related to key variables in the research.

A linear regression model Income = $\beta0+\beta1i+\varepsilon i$……………………………………………………………………eqn. 1,

Where: Income = dependent variable, SI Adoption = independent variable (adopters, non-adopters). β_1= income differences due to SI adoption (Jones-Garcia & Krishna, 2021). The mathematical model was used to establish the differences in income between adopters and non-adopters. More so, an inductive research approach was used in this part of the qualitative research. All interviews were transcribed in English; the data are structured around significant themes, aligned with the aims and objectives of this study. This study used a thematic content analysis framework, which incorporates the use of grounded theory principles to identify recurring patterns in the data, which then allowed for a harmonisation of the gained results in terms of the insights into the farmers' adoption of aspects of sustainable intensification. This was later described in terms of quotations from smallholder farmers in the sample communities**.**

IV. FINDINGS & DISCUSSION

4.1. Findings

4.1.1 Knowledge and Awareness of Sustainable Intensification by Smallholder Farmers

The five-item Likert scale results shown in Table 2 demonstrate that smallholder farmers know sustainable intensification (SI). The extension agents and NGOs successfully sensitised 252 out of 384 respondents who confirmed their understanding of SIs. Farmers demonstrated their knowledge of major SI practices through their soil fertility management and improved seed use agreement, which 228 farmers confirmed. The neutral responses indicate that farmers need more training because they did not complete their required training. Environmental benefits of SI were well understood, with 244 respondents believing SI promoted environmental sustainability, reflecting farmers' recognition of conservation needs due to climate risks. Communities experienced barriers to information access because only 201 people understood SI information, while 88 people remained neutral about their ability to access SI information. The 204 respondents who understood SI practice applications overlapped with 92 neutral respondents who demonstrated their need for additional training before they could implement SI practices.

Table 2

Knowledge of Smallholder Farmers on Available SI Practices (Five-point Likert Scale)

ITEMS	**Strongly disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**
I understand what sustainable intensification means	22	38	72	168	84
I know the key SI practices (soil, seeds, water).	26	46	84	160	68
I understand the environmental benefits of SI.	20	43	77	172	72
I know where to access SI information/support	33	62	88	147	54
I understand how to apply SI practices on my farm	30	58	92	146	58

4.1.2 Gender Perception of Smallholder Farmers Accessibility to Sustainable Intensification

The gender-based analysis of agricultural resource accessibility shows how different perceptions between male and female farmers affect sustainable intensification results. The results in Table 3 show that male farmers reported greater access to land (61) than female farmers (43), reflecting long-standing traditional norms in northern Ghana, where land ownership and control are predominantly male-dominated. The study results show that women who work on temporary land arrangements will not invest money into sustainable agricultural methods that need permanent land rights. Female farmers accessed labour resources at a higher rate (62) than male farmers, who accessed them at a lower rate (25). The communal labour systems and social networks, such as “nnoboa” that women use to access work, create an advantage that helps them obtain more labour resources.

The study indicates that male farmers experience labour deficiencies because workers opt to migrate or choose to engage in economic work that is not related to farming. Similarly, female respondents reported greater access to credit (60) compared to males (42). This finding reflects the proliferation of microcredit and village savings and loans associations (VSLAs) targeted at women in the district, as well as development programmes that prioritise women’s financial inclusion. Access to extension support also appeared to favour female farmers (51) over male respondents (40). This may be due to targeted capacity-building interventions by NGOs and agricultural development projects that intentionally engage women to improve agricultural knowledge and decision-making. It also highlights that women may be more available or willing to attend training programmes. Overall, the total distribution shows more female (216) than male (168) responses, and across three of the four resource categories-labour, credit, and extension support. Women reported better access than men.

Table 3

Gender Perception of Smallholder Farmers' Accessibility to SI Practices

Productive Resources		Land	Labour	Credit	Extension support	Total
Gender of respondent	Male	61	25	42	40	168
	Female	43	62	60	51	216
Total		**104**	**87**	**102**	**91**	**384**

As shown in Table 4, a chi-square test was performed to confirm the observations. It was noticed that the differences in access to productive resources by gender are statistically significant ($\chi^2 = 17.633$, df = 3, p = 0.001), indicating that gender and perceived access to resources are not independent in the Nabdam District. Thus, the null alternative hypothesis (H_a), 'there is an association between gender influence and participation in smallholder SI practices', was therefore accepted. As a result, gendered disparities in access to productive resources continue to undermine women's engagement in agricultural intensification in the area.

> *This claim is supported by insights from female key informant interviewees in Pitanga, who expressed deep concern about women's participation in and access to smallholder intensification practices. "Access to essential farm inputs—particularly fertiliser-remains extremely limited for us, the women farmers, thereby constraining our ability to adopt intensification practices. In contrast, male farmers possess greater financial resources and stronger social and institutional networks, which enable them to acquire such inputs more easily" (Pitanga, 18th October, 2025)*

Table 4

Chi-Square Tests of Association

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	17.633[a]	3	.001
Likelihood Ratio	17.890	3	.000
Linear-by-Linear Association	2.629	1	.105
N of Valid Cases	384		

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 38.06

4.1.3 Adoption Patterns of Sustainable Intensification by Smallholder Farmers

The adoption of Sustainable Intensification (SI) practices by farmers depends on their education level, according to the cross-tabulation results between their education levels and SI practice adoption. The majority of farmers without formal education (55.6%) remained in the low adoption group, while 33.3% adopted a moderate number of practices, and no farmers reached the high adoption level. Farmers without formal education face difficulties in adopting multiple SI practices because they lack access to information, which prevents them from learning and applying advanced technical skills. Primarily educated farmers adopted practices at all levels because they distributed their adoption across different categories, which included low adoption at 33.3%, moderate adoption at 50%, and high adoption at 11.7%. Basic education allows farmers to read and understand enough information, which enables them to use multiple SI practices, although their usage of these practices remains low.

At the JHS level, moderate adoption was the dominant category (56.3%), followed by high adoption (16.2%) and low adoption (25%). Junior high school farmers developed better knowledge, which helps them achieve multiple SI practice implementations through their improved information access. SHS-level farmers show greater capacity to adopt multiple SI techniques since 35.7% of them reached high adoption, while 50% achieved moderate adoption, and 14.3% stayed at low adoption, according to their agricultural knowledge base and problem-solving abilities.

Tertiary-educated farmers had the largest share in the high adoption category, representing 67.9%, followed by the moderate adoption category, 27.5%, and the low adoption category, 4.6%. It is evident that the higher the educational attainment of farmers, the greater their capacity to understand, evaluate, and comprehensively adopt many SI practices, with education thereby serving as an enabler of sustainable intensification within the district. Farmers' level of education and the adoption of SI practices were assessed using a chi-square test of independence. The results show there is a statistically significant association ($\chi2$=X, df = 12, $p < 0.001$), which suggests that the intensity of adoption varies with educational attainment. For instance, the higher-educated farmers (SHS and Tertiary) were more likely to fall within the multiple adoptions category, while farmers with no formal education were concentrated within the low or non-adoption category.

Table 5

Adoption Patterns of Smallholder Farmers

Level of Education	Non-Adopter (0)	Low Adoption (1–2)	Moderate Adoption (3–4)	High Adoption (5–6)	Total
No formal education	5	25	15	0	45
Primary	3	20	30	7	60
JHS	2	20	45	13	80
SHS	0	10	35	25	70
Tertiary	0	5	30	74	109
Total	**10**	**80**	**155**	**119**	**384**

4.1.4 Comparison of Yield between Adopters and Non-adopters

An independent sample t-test was performed to compare the yield of adopters of sustainable intensification practices to non-adopters. The analysis indicates that adopters of sustainable intensification practices experience more yield (M=1.56 SD= SD=0.499) than Non-adopters (M=1.38, SD= 0.488), t(166) = 2.291, P< 0.05

> *"This observation is further reinforced by the views of focus group discussants, who indicated that the adoption of intensification practices, such as the use of chemical fertiliser, crop rotation, and improved water management, has led to significantly higher production levels compared to those of non-adopters. Participants attributed these positive outcomes largely to the higher educational attainment of adopters, which enhances their understanding, awareness, and effective application of sustainable intensification practices" (15th June, 2025).*

Table 6a

Group Statistics

	SI Categories	***N***	***Mean***	***Std. Deviation***	***Std. Error Mean***
Gender of respondent	Adopters	79	1.5570	.49992	.05625
	Non-adopters	89	1.3820	.48863	.05180

Table 6b

Independent Sample t-Test

		Levene's Test for Equality of Variances								
		F	**Sig.**	**T**	**df**	**Sig. (2-tailed)**	**Mean Difference**	**Std. Error Difference**	**95% Confidence Interval of the Difference**	
									Lower	**Upper**
Gender of respondent	Equal variances assumed	2.225	.138	2.291	166	.023	.17494	.07636	.02418	.32569
	Equal variances not assumed.			2.288	162.685	.023	.17494	.07646	.02396	.32592

Simple linear regression was used to assess whether the adopters of sustainable intensification significantly predict income earned by non-adopters. The test revealed a significant difference in income between adopters and non-adopters of sustainable intensification practices. The model explained approximately 18.1% of the variance in farmers' income (R^2 = 0.181) and was statistically significant, F(1, 382) = 84.351, p < .001. The adoption coefficient was significant and positively correlated with income (β = 0.365, t = 9.184, p < .001), indicating that farmers who adopted sustainable intensification practices had significantly higher income compared to non-adopters.

Table 7a

Model Summary

Model	R	R Square	Adjusted R-Square	Std. Error of the Estimate
1	.425[a]	.181	.179	1.10163

Predictors: (Constant), Adopters, and Non-adopters

Table 7b
ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	102.368	1	102.368	84.351	.000[b]
	Residual	463.591	382	1.214		
	Total	**565.958**	**383**			

a. Dependent Variable: income, b. Predictors: (Constant), Adopters, and Non-adopters

Table 7c
Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.277	.146		8.768	.000
	Adopters and non-adopters	.365	.040	.425	9.184	.000

Dependent Variable: Income

Table 7d
Summary of Results

Hypothesis	Regression weights	β	T	p-value	Results
H₄	ASI ⟶ INLF	.365	9.184	.001	Supported
R	.181				
F(1, 382)	84.351				

Note: ASI = adoption of sustainable intensification practices, IFIL =Influence on farmers' income level.

4.2 Discussion

This section interprets the study's empirical findings, linking them to existing literature and examining their implications for smallholder farmers' adoption of sustainable intensification practices in Nabdam District, Ghana.

4.1.2 Knowledge of Sustainable Intensification and Implications for Smallholder Farming

The uneven understanding of sustainable intensification among smallholder farmers leads to negative consequences that affect the SI outcomes, both their achievement and long-term sustainability. The high level of SI concept awareness among people contrasts with their environmental awareness because people lack the technical expertise and knowledge resources needed to implement SI practices successfully (Anibaldi et al., 2021). SI practice occurs at multiple levels because people practice it as a basic activity or as an advanced activity to achieve both productivity and environmental sustainability and livelihood resilience. Farmers need better access to support services and practical knowledge to learn how to implement SI practices across all their agricultural operations (Jenkin et al., 2011), which forms the base of sustainable intensification.

The extension staff training program requires practical extension training to help farmers adopt complete agricultural systems instead of independent agricultural practices, which will result in lower agricultural productivity and minimal soil health improvements (Saka et al., 2020). The uncertainty farmers face about implementing SI practice leads them to choose between adopting practices or abandoning them because they see implementation as a risk, which affects their willingness to adopt SI practice. The extension agents need capacity building, while local farmers require timely access to relevant information, and farmers need to learn through practical experience, which all together will help them transform their knowledge into effective, sustainable intensification practices.

4.1.3 Gendered Perceptions of Access to Productive Resources and Implications for Sustainable Intensification

The study discovered that gender-based resource access restrictions negatively affect smallholder farmers' ability to achieve sustainable intensification (SI) results. The ability of men to access land gives them a structural benefit that enables them to implement long-term SI methods that depend on land because farmers with secure land rights will invest more in soil fertility and conservation efforts (Doss, 2001; Meinzen-Dick et al., 2019). The lack of both labour resources and extension services will prevent men from successfully implementing and maintaining these techniques. Women's land ownership limitations prevent them from making long-term SI commitments because they need secure tenure to practice soil enhancement methods, which require time to yield results (Quisumbing et al., 2014).

Women can use their improved access to labour and credit and extension services to find multiple ways to implement sustainable agricultural practices. Women use social networks to increase their labour force capacity, which allows them to implement resource-efficient and soil-enhancing SI methods that require intensive labour, such as mulching, composting, and intercropping (Kristjanson et al., 2017). Women can adopt SI practices, which depend on knowledge and agricultural inputs, because better access to credit and extension services enables them to do so. Extension agents help farmers develop technical skills and adaptive capacity through their training programs, while credit funding enables farmers to buy better farming materials and develop small-scale agricultural technologies (Ragasa et al., 2013; Doss et al., 2020). The resources will not provide their complete SI advantages because women do not possess secure land rights or decision-making power. The implementation of gender-responsive strategies must address women's land tenure restrictions while boosting men's access to labour and extension support to establish sustainable farming practices.

4.1.4 Adoption Patterns of Sustainable Intensification by Smallholder Farmers

The study results demonstrate that the educational levels of farmers shape their ability to implement sustainable agricultural practices. The group without formal education showed low adoption rates because their lack of literacy and technical skills prevented them from understanding and using agronomic knowledge, which stopped them from implementing multiple SI methods. The group of farmers who completed senior high school and tertiary education systems showed much higher adoption rates because their educational background provided them with advanced cognitive abilities, which made them more open to new ideas and access to extension services and climate-related information systems. The study results match existing research, which demonstrates that educational attainment enables smallholder farmers to adopt climate-smart agricultural methods because it improves their access to essential agricultural information and technological resources (Atta-Aidoo & Antwi-Agyei, 2025). The evidence shows that educational attainment works together with other essential resources, which include access to extension services, credit, and information systems, to help farmers assess and implement different SI techniques for enhancing their productivity and resilience (Odoom et al., 2023). The process of acquiring higher education enables people to learn about SI innovations while also helping them make better decisions and manage risks effectively.

4.1.5 Comparison of Yield between Adopters and Non-adopters

The research provides strong evidence that smallholder farmers who use sustainable intensification (SI) methods achieve better crop yields and higher farm profits. The independent samples t-test shows that SI adopters achieve statistically higher yields than non-adopters (Fekadu et al., 2025), indicating that applying SI practices leads to measurable productivity gains through increased yield (Hussen, 2024). Farmers attributed higher yields to the combined use of chemical fertiliser application, crop rotation, and improved water management practices (Kiprotich, 2024). The practices create better resource allocation results and soil nutrient improvements while maintaining production stability during changing weather patterns, which serve as the main goals of sustainable intensification. Farmers who prioritise education show that yield improvements depend on both SI practice adoption and successful SI practice application and integration, which shows how human capital affects SI results. The income effects of SI adoption are equally pronounced, as the analysis showed that SI adoption significantly and positively predicts farm income, which accounted for substantial income differences among farmers (Hussen, 2024). The research demonstrates that SI benefits farmers through increased agricultural output and positive impacts on regional economies. Increased income levels result from higher production volumes and better resource allocation, which leads to larger marketable surpluses and higher profit margins.

V. CONCLUSIONS & RECOMMENDATIONS

5.1 Conclusion

The study shows that SI awareness does not lead to outcomes that have substantial value. Sustained effective intensification requires technical knowledge together with practical skills and available institutional resources, which include extension services and experiential learning opportunities. Gendered access to productive resources functions as a key factor that determines how farmers implement sustainable agricultural practices. Land-intensive activities receive support from men who possess better land access, whereas women use their access to labour and credit and extension services to execute knowledge-intensive and labour-intensive methods. The research shows that farmers need customised gender-sensitive solutions that solve their resource limitations and knowledge deficiencies to achieve sustainable SI practice adoption. The research demonstrates that farmers who use SI practices see improvements in their crop production and income and their overall way of life.

Farmers who use SI practices show better crop production and higher farm income than those who do not use SI practices, according to empirical evidence, which shows that SI helps farmers use their resources more efficiently while maintaining their production levels and achieving better economic results. The research shows that smallholder farmers can use SI as both a technical solution and an environmental strategy to boost their farming productivity and system resilience. The study demonstrates how human and institutional factors control the success of SI implementation. Educational attainment emerges as a key determinant of adoption intensity, with more educated farmers demonstrating greater capacity to integrate multiple SI practices, evaluate agronomic risks, and engage with extension services. The adoption of SI practices will increase through interventions that focus on enabling factors, resulting in better productivity and environmental sustainability for smallholder farmers.

5.2 Recommendation

The paper recommends that interventions meant to support sustainable intensification (SI) should go beyond raising awareness and instead focus on enhancing farmers' technical expertise, practical abilities, and access to institutional support, especially through well-funded extension services and experiential learning opportunities. Policies should adopt gender-responsive approaches that address disparities in access to labour, credit, land, and extension services to ensure inclusive participation and equitable benefits. Increased access to productive resources and specialised financial services, along with investments in farmer education and continuous capacity building, will boost the resilience, productivity, and income of smallholder farming systems.

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