UNIVERSITY FOR DEVELOPMENT STUDIES

ADOPTION INTENSITY OF SUSTAINABLE LAND MANAGEMENT PRACTICES AND WELFARE OUTCOMES OF SMALLHOLDER FARMERS IN NORTHERN GHANA

ADAM MOHAMMED BAWAH

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FACULTY OF AGRICULTURE, FOOD AND CONSUMER SCIENCES

DEPARTMENT OF AGRICULTURAL AND FOOD ECONOMICS

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DECLARATION

I, hereby declare that, this thesis is the result of my original work and that no part of it has been presented for another degree in this University or elsewhere:

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ABSTRACT

The study investigated the impact of adoption intensity of sustainable land management practices on the welfare outcomes of smallholder farmers in northern Ghana using secondary survey data from the JIRCASUDS/SARI, TERRA Africa research project. The study first estimated the determinants of the intensity of SLM adoption among farm households, followed by estimating the effect of SLM adoption intensity on the welfares of smallholder farmers and lastly, identifying the constraints farmers face in adopting SLM practices. Results from the Standard Poisson Model revealed that, agricultural subsidies, number of household workforce, and household head income all had significant impacts on farmers' ability to intensify the adoption of SLMs. Also, the control function results indicated that farmers basic educational levels, household head workforce, household head income, household head savings amount, household head farm size, Village Savings and Loans Association (VSLA) group, distance to cooperative center were all significant in both adoption intensity levels and subsequently on the general welfare outcomes of smallholder farmers in the two regions. Meanwhile, the Kendall's coefficient revealed that, farmer awareness and understanding of SLMs, land tenure security, and extension services was ranked as the most consistent constraints of SLM adoption in the northern and savannah regions of Ghana. The study thus recommended that, government and NGOs need to expand their subsidy programmes, as well as build farmer field schools and mobile-based advisory services to intensify the dissemination of SLMs and the need to intensify their adoption levels. Secondly, the non-linear relationship between SLM adoption and welfare outcomes suggest that, policies should encourage comprehensive adoption of multiple

complementary practices rather than piecemeal implementation in order to fully maximize the benefits of SLM practices. Finally, government should introduce and implement sustained educational initiatives that will engage farmers in SLM training to deepen their understanding of SLM adoption intensities whiles charging extension agents to intensify its extension services during farming and non-farming seasons.

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"...Exalted are You; we have no knowledge except what You have taught us. Indeed, it is You who is the Knowing, the Wise." (Qur'aan 1:32)

"And [remember] when your Lord proclaimed, if you are grateful, I will surely increase you [in favor]; but if you deny, indeed, My punishment is severe." (Qur'aan 14:7)

"...God will raise those who have believed among you and those who were given knowledge, by degrees. And God is Acquainted with what you do." (Qur'aan 58:11)

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DEDICATION

I dedicate this work to Allah the Almighty, and to my noble family especially to my ever-inspirational Dad, Alhaji Bawah M. Ford, and my two lovely Mothers, Hajia Katumi Idris and Hajia Kuburah Idris, and also my ever-supportive Senior brother, Mr. Adam Abdur-Rahmaan whose shared responsibility has made this academic dream a reality.

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LIST OF ACRONYMS

AGRA	Alliance for a Green Revolution in Africa
AIC	Akaike Information Criterion
BIC	Bayesian Information Criterion
CSIR	Council for Scientific and Industrial Research
CSA	Climate Smart Agriculture
CA	Conservation Agriculture
CI	Care International
DFID	Department for International Development
FAO	Food and Agriculture Organization
FFBS	Farmers Field and Business School
GLRSSMP	Ghana Landscape Restoration and Small-Scale Mining Project
GIS	Geographic Information Systems
GSGDA	Ghana Shared Growth and Development Agenda
GPSNP	Ghana Productive Safety Net Project
GCAP	Ghana Commercial Agriculture Project
GLSS	Ghana Living Standards Survey
GDP	Gross Domestic Product
GoG	Government of Ghana
GSS	Ghana Statistical Service
ISFM	Integrated Soil Fertility Management
IoT	Internet of Things
JIRCAS	Japan International Research Center for Agricultural Sciences
LDN	Land Degradation Neutrality

MoFA	Ministry of Food and Agriculture
NBM	Negative Binomial Model
NDA	Northern Development Authority
NCCP	National Climate Change Policy
NGO	Non-Governmental Organization
PFJ	Planting for Food and Jobs
RESULT	Resilient and Sustainable Livelihoods Transformation
SARI	Savannah Agricultural Research Institute
SPM	Standard Poisson Model
SLM	Sustainable Land Management
SLWMP	Sustainable Land and Water Management Project
SOC	Soil Organic Carbon
SRI	System of Rice Intensification
UDS	University for Development Studies
USAID	United States Agency for International Development
UENR	University of Energy and Natural Resources
VSLA	Village Savings and Loans Association
WB	World Bank

CHAPTER ONE

INTRODUCTION

1.1 Background and Context

Feeding a surging world population which is expected to double by 2050 (close to 2.3 billion) emerges as a major agricultural research, development, and policy challenge in Sub-Saharan Africa (Doering and Sorensen, 2018). Adoption intensity of Sustainable Land Management Practices (SLM) has appeared increasingly essential for smallholder farmers in Ghana. The area, noted for its unpredictable rainfall, poor soil fertility, and consistently vulnerable to climate change, depend heavily on agriculture for livelihood. In recent times, governmental and non-governmental organizations have made significant efforts to intensify the adoption of Sustainable Land Management (SLM) practices among smallholder farmers, acknowledging their potential to increase agricultural productivity, enhance food security, and improve the welfare outcomes of communities. For instance, multiple agricultural initiatives have been launched by the government of the day through its Ministry of Food and Agriculture (MoFA) to promote the adoption of SLM practices in Ghana. In 2017, an agricultural cross-cutting policy like the Planting for Food and Job (PFJ) program was introduced, which remains a flagship initiative that seeks to promote as well as intensify SLM adoption by providing subsidized inputs and extension services to smallholder farmers in Ghana (Okolie et al. 2023). As a result of this policy, much emphasis has been placed on SLM adoption practices today and seeking to create a conducive environment in which farmers have been able to invest in enhanced farming methods like soil conservation and climate-smart agriculture. For example, the Ghana Landscape Restoration and Small-Scale

Mining Project (GLRSSMP) which was initiated in 2022 and funded by the World Bank to ensure maximum agricultural benefits to target both the savannah and forest zones in the country. Notably, the project included components devoted to promoting SLM adoption practices such as improved agroforestry systems and other agricultural practices that sought to reclaim the abandoned arable lands as well as restoring its fertility status. Furthermore, Non-Governmental Organizations (NGO's) such as the Alliance for a Green Revolution in Africa (AGRA) through its Soil Health Program has also committed to the promotion and proper implementation of the Integrated Soil Fertility Management (ISFM) practices across Africa where Ghana is one the beneficiaries among several African nations. Through this wonderful intervention, proper sustainable agricultural practices are taught to farmers on how to use fertilizers, crop rotation, and organic matter in the soil appropriately and thus seeking to tackle the core problem of soil fertility loss, which directly affects farm productivity in these pronounced regions (Zougmoré et al. 2018). Apart from this intervention, the Canadian Feed the Children Group has engaged local groups within the rural settings of northern Ghana in introducing the Resilient and Sustainable Livelihoods Transformation (RESULT) project, that seeks to improve climate-resilient agriculture and sustainable land use among smallholder farmers in northern Ghana. In addition, the current phase of the (RESULT) project (2020-2025) targets the complete adoption of agroecological innovations like water harvesting, conservation agriculture, and forestry management practices (Dzanku, 2024). It is important to know that, soil fertility, water conservation, and productivity of land are few among numerous sustainable land management practices which can be implemented to avoid the consistent land detoriation menace in order to establish a well-developed ecological equilibrium. Thus, in effect the promotion of sustainable agricultural practices such as crops, livestock and afforestation systems is commonly referred to as agroforestry which further enhances biodiversity, soil fertility, and other agricultural revenue enhancements (Sanou et al. 2019).

Moreover, SLM practices entails a number of practices that maintain the use of land resources, thereby promoting agricultural productivity and ecosystem health. Practices such as crop rotation, inter-cropping, relay cropping, rhizobium usage, crop bonding, inorganic fertilizer use, mulching, improve seeds, row planting, crop residue, zero tillage management, agroforestry, integrated pest management, conservation of soil water, and organic fertilization play a significant role in addressing soil erosion issues as well as increasing soil fertility and water holding capacity of agricultural lands. Smallholder farmers who usually have limited access to new agricultural inputs, stand to gain from SLM practices since they lower costs and increase yields. In addition, owing to the uncertainty in rainfall and the high potential for soil erosion, agroforestry and soil conservation activities have been greatly advised to keep these issues in check whiles offering adequate platforms for farmers to increase their SLM adoption levels in the northern and savannah landscapes of the country. These practices are crucial in tackling soil fertility losses due to severe soil erosion issues, as well as boosting soil water holding capacities, and productivity of the soil, and thus resulting to an increase in crop yields and rural food security (Issahaku and Abdulai, 2020). In addition, SLM practices improves the sustainable productivity of agricultural lands which allows the farm systems within these regions to respond to climate shocks. Organic rainfall-based farms with small irrigation schemes are vulnerable to climatic shocks, which in most cases result into crop failure and lower incomes of farm households in the regions. This is the reason why SLM practices need to be implemented in order to improve farm productivity and household economic stability and guarantee food security levels of farm households. Empirical research has indicated that SLM-based farms are technically more efficient and environmentally more sustainable compared to non-SLM-based farms (Issahaku et al., 2019). This is partly due to the fact that SLM adopters have improved management of their natural resources, leading to increased agricultural production and lower input costs (Issahaku and Abdulai, 2020). Again, the worth of credit and extension service access in determining such practices has been highlighted as an indicator of policy interventions through the availability of financial and technical assistance, which would have substantial impacts on the well-being of smallholder farmers. Also, SLM practices like crop diversification would lead to more stable and diversified incomes which therefore, allows the smallholder farmers to diversify their agricultural investments in crops, thus by growing a variety of crops without exposing them to a complete crop failure, and again allowing farm households to sell their surplus in the local market to avoid food wastages (Moomen et al., 2024). Again, SLM practices has significant environmental advantages to the northern and savannah regions where deforestation and land degradation are frequent and thus calls for sustainable agricultural practices such as agroforestry and other conservational agricultural practices to restoring the healthy status of degraded land along with maintaining the ecological balance within the regions. To further elaborate on this, incorporating trees into farms further improves the fertility status of the soil as well as reduce soil erosion problems to a larger extent whiles generating additional incomes from timber as well as non-timber forest product sales for agricultural households at the same time mitigating climate change by enhancing carbon sequestration within the country (Partey et al., 2018). Furthermore, climate change poses a great threat to the agricultural productivity in northern Ghana, and as such environmental and soil fertility gains are needed to promote sustainable agriculture in order to combat the growing menace of soil degradation (Moomen et al., 2024). Likewise, the advantages of SLM adoption intensities are usually underappreciated by smallholder farmers who do not have the required resources and technical knowledge such as extension services and farmer training programs which are required for SLM adoption promotion (Nyagango et al., 2023). Furthermore, economic limitations are a great drawback to the practice of SLM adoption intensities in the sense that organic manure or soil conservation structures are generally beyond the financial limits of farmers and thus limits their chances of adopting these sustainable agricultural practices. In addition, rural farmers are not able to attain sustainable credit to adequately invest in these agricultural practices, and this has a humongous negative effect on their productivity levels and further corresponds to the general decline of the well-being of farmers every year. Therefore, in order to address these challenges, it is necessary to develop an agricultural policy intervention that are particularly tailored to provide financial support, technical expertise, and market linkages to smallholder farmers.

Further studies from (Sanou et al., 2019) shows that adoption intensities of SLM practices has the potential to improve the well-being of smallholder farmers in northern and savannah regions of Ghana by enhancing agricultural productivity, environmental sustainability, or household income. However, to optimize these services, investment in extension services and credit support needs to be enhanced, and further policy frameworks needs to be formulated to promote the adoption intensity levels of SLM practices. Therefore, tackling these issues will help position the Ghanaian smallholder farmers well enough to overcome the adaptational hurdles of the changing climate and keep guaranteeing the food basket of the nation and its overall economic development.

1.2 Problem Statement.

Ghana and other developing nations in Africa are constantly faced with critical challenges in establishing a more resilient sustainable agriculture development, whiles ensuring food security and enhancing the livelihood of smallholder farmers in the country. The northern regions of the country are exposed to semi-arid climatic conditions, unstable rainfall, and vulnerable ecosystems. These areas constitute the majority population of smallholder farmers in Ghana who depend solely on rain-fed farming systems. However, these regions are severely hit by land degradation, soil erosion, and declining soil fertility, which are further exacerbated by rapid climate change and unsustainable agricultural practices. The GSGDA III policy framework acknowledges these pressing concerns as critical to addressing food security, poverty reduction, and regional sustainable development objectives (Acheampong et al., 2022). It is in light of these assertions from this policy framework that informed the government to implement the various SLM adoption initiatives such as the ongoing Planting for Food and Jobs (PFJ) program, which was implemented in 2017 to boost the country's efforts in championing the course of sustainable agricultural practices (Issahaku et al., 2020). This agricultural initiative also seeks to enhance agricultural productivity by reinforcing innovative soil regenerative techniques that seeks to promote the adoption of SLM practices in order to generate employment opportunities for smallholder farmers as well as the ever-growing unemployed youth. While not exclusively SLM focused, it incorporates elements promoting improved agricultural inputs and extension services. An extensive research studies from Issahaku and Abdulai (2020) documented that, the PFJ participation correlated with a 15% increase in climate-smart agricultural practice adoption among smallholder farmers in northern Ghana. However, despite the implementation of this wonderful policy by the government in establishing the significance of SLM practices and as a sustaining remedy to these menaces in the country’s agricultural sector, SLM adoption intensities among smallholder farmers in these regions remain substantially very low (Kansanga et al., 2023). Additionally, their findings validate that, although SLM practice awareness levels are high, their uptake is limited by several barriers, such as limited economic resources, weak agricultural extension services, and insecure land rights. This difference of knowledge and adoption intensities even validates the need for particular interventions aimed at surmounting such barriers. In addition, in the fight against the menace of soil fertility and unfavorable climatic factors, NGOs have played central roles in SLM practices for Ghanaian smallholder farmers. For instance, AGRA has led efforts to support soil fertility improvement and agricultural sustainability in the northern part of the country. Their Soil Health Programme has effectively trained 3,000 agro-dealers and 1,500 extension agents in integrated soil fertility management to more than 500,000 smallholder farmers across the entire northern region of Ghana (Khanal et al., 2024). The programs have resulted in increased adoption of improved seeds, fertilizers, and other SLM practices. Likewise, the Sustainable Land and Water Management Project (SLWMP), implemented under the World Vision in collaboration with the Ministry of Food and Agriculture (MoFA) has been dedicated to enhancing climate-resilient agriculture, agroforestry, and water management in northern Ghana (Kansanga et al., 2019). Interestingly, their empirical study showed that participating farmers in the project achieved 30% more crop yields and 25% reduced soil erosion compared to non-participating farmers. Also, the GPSNP supported by the World Bank (2019-2024) is also a government scheme which is responsible for subsidizing SLM practices indirectly through climate resilience and social protection (World Bank, 2022). Also, further studies from (Alare et al., 2018) illustrated that even though SLM adoption intensity is aimed at yield increase, realizing such an increase in household welfares relies considerably on market access and other secondary sources of off-farm livelihoods. SLM intervention impacts are difficult to evaluate in terms of time needed for one to feel the effects, especially in activities such as land conservation and agroforestry (Issaka et al., 2021). Again, environmental conditions, resource endowment, and market access heterogeneity across smallholder farmers in these regions means that, there is variability in the impacts of an intervention. Empirical research studies by Abdulai and Huffman (2014) argued that the uptake of soil and water conservation technology had more welfare impacts among wealthier farmers who were reached by extension agents and markets. Moreover, gender status of farmers is another important issue in SLM adoption intensity and performance such that, women farmers within the northern belt are most likely to encounter SLM adoption intensity barriers in various forms. For example, studies from Nasare et al. (2023) shows that, although women-headed household in the northern sector are often rare, their rate of willing to adopt as well as intensify the uptake of SLM technology had more significant impact on their household food security levels as against their male counterparts.

Although SLM practices have enhanced climate shock resilience, they are eventually undermined in the long run due to other dynamic environmental conditions. According to Kansanga et al. (2019) who argues that, it is critical to adapt SLM strategies that will suit new climatic conditions in order to benefit agricultural households in the rural communities in general. In addition, land tenure insecurity still hinders the large-scale and intensity of SLM adoption in the northern and savannah regions of Ghana. The dominance of customary land systems with unclear ownership rights discourages farmers from investing in long-term land enhancements. Although the Ghana Land Administration Project has recorded some success in improving land management, there are still major challenges that is hampering the progress of these agricultural practices. A study from Issahaku and Abdulai (2020) concluded that farmers with secured land rights were 30% more likely to intensify the adoption of SLM practices more than those lacking such rights, which further underlines the importance of a more effective land governance reforms. Also, the accessibility of technology and inputs remains essential to the efficient utilization of SLM practices because, subsequent projects like the Planting for Food and Jobs has such vast potential in expanding access to improved seeds and fertilizers, but smallholder farmers barely receive such holistic inputs necessary for total SLM adoption and implementations, such as mechanization services and irrigation kits. Also, enhancing agricultural supply chains and driving local organic input manufacturing can greatly reinforce the effect of SLM adoption intensity and practices (Okolie et al., 2023). Once again, access to the market has a vital role to play in promoting and intensifying the adoption of SLM which directly has the potential to improve farm productivity and enhance welfare status of farmers within these regions. Although the intensity of SLM adoption practices brings about improve productivity, farmers normally find it challenging to sell their food surplus at decent prices in the local market. Thus, substantive program interventions aiming to enhance only crop productions with no focus on market accessibility could result to further decline of welfare status of smallholder farmers in these regions. According to Nyagango et al. (2023) interventions that combine the intensity of SLM adoption promotion and market development and accessibility are more effective in achieving higher sustainable welfare gains among farmers. The promotion of SLM adoption intensity as well as improving the welfare outcomes of smallholder farmers in the northern and savannah zones is an emerging area of research that needs more attention. Despite the tremendous progress made in areas such as awareness and knowledge dissemination of these practices by various interventions from previous and current government, adoption intensity and implementation levels still remain extremely low, and thus inhibiting the very welfare gains of smallholder farmers especially in regions under study. While SLM practices hold great promise for a good future of combating land degradation and farm productivity, their success is still hindered by a group of socio-economic, institutional, environmental, and cultural limitations.

Overcoming such obstacles requires a combined approach through technological innovation, policy reform, and institutional strengthening. This, thus requires a sustained and improved agricultural extension services, better access to resources, land tenure improvement, and the application of gender-responsive SLM measures. More importantly, participatory research through farmer, policymaker, and stakeholder involvement in context-specific SLM solution formulation is greatly required to successfully promote and implement this important agricultural initiative. By bridging these adoption intensity and implementation gaps, Ghana can transition towards a more resilient and more sustainable agricultural system that enhances the well-being of smallholder farmers and preserves the nation's natural resource for generations to come.

1.3 Research Questions

1.3.1 Main Research Question

What are the determinants, welfare implications, and constraints associated with the adoption intensity of sustainable land management practices among smallholder farmers in the northern and savannah regions of Ghana.

1. What are the factors influencing the intensity of adoption of sustainable land management practices of smallholder farmers in the northern and savannah regions of Ghana?
2. What are the effects of the intensity of adoption of sustainable land management practices on the welfare outcomes of farm households in the northern and savannah regions of Ghana?
3. What are the constraints farmers face in adopting sustainable land management practices in the northern and savannah regions of Ghana?

1.4 Research Objectives

1.4.1 Main Research Objectives:

The main objective of this study is to assess the determinants, welfare implications, and constraints associated with the adoption intensity of sustainable land management practices among smallholder farmers in the northern and savannah regions of Ghana.

1.4.2 The specific objectives are;

1. To estimate the determinants of the intensity of adoption of sustainable land management practices of smallholder farmers in the northern and savannah regions of Ghana.
2. To estimate the effect of the intensity of adoption of sustainable land management practices on the welfare outcomes of farm households in the northern and savannah regions of Ghana.
3. To identify the constraints that hinder farmers to intensify the adoption of sustainable land management practices in the two regions.

1.5 Research Justification

The northern and savannah regions of Ghana are faced with the imperative issues of land degradation, climate change, and persistent poverty among farm households, and thus this research becomes very pertinent and inevitable. These regions are characterized by a semi-arid climatic condition and increasingly less reliable rain-fall patterns, and constantly experiencing rapid soil degradation, soil fertility decline, and mounting losses of its farm output. These are exacerbated by the speeded effects of climate change, threatening food safety and farm revenues of the smallholder farmers, who dominate the farm labor in these nations. Recent statistics from Ghana's Ministry of Food and Agriculture indicate that agricultural productivity in the northern parts of the country has reduced by approximately 15-20% over the past decade primarily because of the mismanagement of land and environmental degradation. The trend will also have future implications regarding local food security and for the nation's agricultural production as a whole, as the areas are key to the nation's cereal crop production in the form of millet, sorghum, and legumes. Similarly, government initiatives like the "Planting for Food and Jobs" initiative and the "Ghana Agricultural Sector Investment Programme" (GASIP) are more focused on sustainable agriculture. This research aligns closely with these policy priorities, making it especially pertinent for supporting effective implementation and evaluation.

First, investigating the factors that drive and influence the adoption intensity of sustainable land management practices is critical, particularly in light of the global push towards climate-smart agriculture and environmental sustainability. Understanding the socioeconomic dynamics behind adoption decisions can help government bodies and non-governmental organizations (NGOs) create effective programs and policies. This research will seek to address an important gap and further expand the conversation in promoting sustainable agricultural practices specifically in SLM adoption rates which remains a re-occurring challenge in meeting the country’s soil regenerative techniques agenda, bearing to the fact that, only 30-40% of farmers are consistently implementing these practices in the northern part of the country. Secondly, evaluating the impact of SLM adoption intensities on welfare is crucial, given Ghana’s commitment to Sustainable Development Goals (SDGs) like SDG 1 (No Poverty) and SDG 2 (Zero

Hunger). Poverty levels in northern Ghana remain considerably higher than the national average, roughly 45% compared to a national rate of about 23%. Understanding how sustainable land management affects household welfare will be key to developing evidence-based policies that can effectively address these disparities. This research is expected to provide vital insights into how sustainable practices can boost farmer livelihoods, aiding in the optimization of resources allocated to agricultural development. Lastly, the study also seeks to investigate the various barriers hindering the adoption intensity of sustainable land management practices whiles seeking to address the critical gaps in the current agricultural policy of promoting sustainable agricultural practices in the country. Also, recent agricultural extension surveys indicate that despite a growing awareness of sustainable methods, adoption is hindered by various challenges. The identification and investigation of these constraints are essential to inform policy formulation and program design. These results will be invaluable to NGOs within the agricultural industry, allowing them to design more successful strategies to overcome these challenges and enhance adoption rates. Additionally, Ghana's updated Nationally Determined Contributions (NDCs) under the Paris Agreement underscores the agricultural sector's role in climate adaptation and mitigation. This research will provide valuable information on how adoption intensities of sustainable land management practices can support these national climate goals while enhancing farmers welfare. Moreover, given the increasing interest from international development partners in climate-resilient agriculture, this study will supply crucial evidence to guide investment choices and program design for non-Governmental Organizations operating actively in Ghana's agricultural sector by offering essential insights to inform program development and execution. Although many NGOs are actively promoting sustainable practices, their interventions often lack data that is specific to the northern and savannah regions. Hence, findings from this study will allow these organizations to better target their efforts, enhance effectiveness, and maximize impact on farmer welfare. Furthermore, the research will promote improved coordination between government agencies and NGOs by establishing a shared understanding of the challenges and potential pathways for advancing sustainable land management practices within the agricultural landscape of the country.

1.6 Organization of the Study

The rest of the study comprises of four chapters. Chapter two reviews the related and available relevant literature on sustainable land management (SLM) practices and welfare outcomes. At the same time, the methodology of the study is well elaborated in chapter three, where the research design, data source, the conceptual framework, as well as the analytical framework of the study are unraveled. It also includes the empirical model used; definitions of variables used in the econometric models as well as their a priori expectations. In chapter four, results and discussions of the findings are presented and finally, chapter five outlines the summary findings, conclusions and recommendations prescribed for policy makers and various stakeholders alike.

CHAPTER TWO

LITERATURE REVIEW

2.1 Chapter Outline

This chapter reviews the relevant and related literature on the adoption intensity of sustainable land management practices and their potential impact on smallholder welfare outcomes. The concept and importance of SLM practices in Ghana is reviewed in section 2.2. A comprehensive review of the background of agriculture and challenges in the northern and savannah regions of Ghana is captured in section 2.3. A thorough review of the various SLM practices in northern Ghana takes center stage in section 2.4. The impact of SLM adoption intensity on the welfares of smallholder farmers in the northern and savannah regions is empirically reviewed in section 2.5. Whiles section 2.6. will look at the various and potential challenges hindering farmers in these regions from intensifying their level of adoption of SLM practices. An important look at the various non-Governmental Organization as well as Governmental initiatives and interventions in aiding smallholder farmers to intensify their levels of adoption of SLM practices in these regions of study as well as the country at large in section 2.7. Section 2.8. will seek to suggest as well as project future directions and the potential research gaps that could be taken up by the research community to further continue the conversation, and arriving at the minute details of intensifying SLM practices and the potentials it has for the Ghanaian agricultural sector in the near future. Finally, Section 2.9. will conclude the literature review by giving us the synthesis of key findings on adoption intensities of SLM impacts and challenges, the implications for policy and practice and finally, a call for continued research and support for smallholder farmers in northern Ghana.

2.2 The Concept and Importance of Sustainable Land Management (SLM) in Ghana

Sustainable Land Management (SLM) is one of the means to forestalling the connected challenges of global climate change, land degradation, and food safety problems in northern and savannah zones of Ghana. SLM are practices that seeks to enhance land, water, biodiversity, and environment management to adapt with mounting food and fibers demands along with sustaining livelihood and ecosystem function (The World Bank, 2005). In Ghana, whose economy is still agriculture-oriented, and with a contribution of a percentage of nearly 20% of national GDP and a workforce of over 30% within the agricultural sector, the adoption of SLM practices continues to be of particular importance (Nyamekye et al., 2021). It is also referred to as land resource application, for example, soils, water, animals, and plants, are essentially needed to produce products that will meet the changing human demands while at the same time, preserving the long-term productive potential of the land resource and their environmental role within the agricultural space (Nkegbe and Shankar, 2014). Many research studies in the past few years have estimated the pressing need of SLM adoption intensity in Ghana due to increasing land degradation, soil erosion, and climatic effects on crop yields. For instance, Issahaku et al. (2020) report that SLM technologies such as conservation agriculture, agroforestry, and integrated soil fertility management and water harvesting options are effective measures against such issues. They concluded that SLM practices can yield about 15-20% increase in crop production and improve soil health by 25-30% within five years. Again, Nkegbe et al. (2014) are of the opinion that SLM adoption intensity is not only a green resource need but an economic tool for Ghana to improve and sustain its agricultural sector. Their empirical econometric estimations indicate that the widespread adoption of SLM practices has the potential to increase the agricultural GDP on average by 5-7% annually, which is an unmistakable indicator of the massive economic benefits in sustainable land use practices. Relevance of SLM adoption intensity practices to Ghana cannot be exaggerated especially in view of the current status of the agricultural sector in Ghana. Another reliable Okolie et al. (2023) argue that, SLM adoption practices is significant to maintain and promote agricultural productivity, promote food security, and achieve resilience against the impacts of climate change. In response to the looming threat of increased environmental challenges and in support of sustainable development, SLM practices has emerged as a focus area for policymakers, researchers, and development actors in Ghana. The practice of SLM has been put at approximately estimated one mechanism used to increase, not only productivity in farming, but well-being of most Ghanaian farmers based on major representation in its agricultural sector (Nkegbe and Shankar, 2014).

2.3 Overview of Agriculture and Challenges in the Northern and Savannah Regions

The northern and savannah regions are completely central to Ghana's agriculture sector. Semi-arid climatic regimes, one rainy season, and extensive dry seasons mark these regions with unique challenges and opportunities to advance as well as improve their agricultural sector (Gyampoh et al., 2021). Rain-fed cropping and smallholder agricultural farming systems is characterized by these regions with sorghum, millet, maize, rice, and legumes being their dominant crops. Livestock production such as cattle, goats, and sheep is a large business in these regions, domestic animals. Despite these challenges, the two regions still contributes largely in terms of feeding the Ghanaian populace as well as cushioning the food security status of the country (Adams et al., 2021). Although occupying around 41% of Ghana's geographical landscape, the regions have never lagged behind when it comes to economic growth and agriculture production. Nonetheless, there is the recent work of Wood (2013) placing into perspective the huge potential benefits for these regions to intensify as well as expand their agricultural activities. It again shows that the northern and savannah regions contain over 50% of arable land in Ghana but yet, only 40% of the land are utilized in agricultural production and thus possess immense potential for expansion and growth. The role of these regions cannot be under estimated as they are also considered to aid in the alleviation of poverty as well as combating food insecurity. Furthermore, empirical studies from Dittoh et al. (2012) observe that the smallholder farmers in such regions account for over 70% of Ghana's staple food crops like millet, sorghum, and groundnuts. Again, their study concludes that agricultural development in such regions has a higher contribution to poverty reduction compared to other regions of the country, where an increase in agricultural productivity by 1% will lead to poverty reduction by 2-3%. Unfortunately, the agricultural sector in northern Ghana also encounters soil erosion, erratic rainfalls, and increasing temperatures due to rapid climatic conditions. This is further compounded by the inadequate exposure to high-technology farm inputs and machinery, resulting in poor yields and perpetual poverty among smallholder farmers

(Okolie et al. 2023). Some of the issues that have hindered the development of this sector are elaborated below.

2.3.1 Climate and Environmental Factors

The agricultural sector in northern Ghana is also more vulnerable to the impacts of climate change, which are of numerous forms that are very determinative of crop yields, animal performance, and overall sustainability of agricultural practices. The smallholder farmers in the region, according to Antwi-Agyei et al. (2014), have experienced improved drought, unpredictable rainfall patterns, and increased temperature. These climate changes are resulting in declining growth seasons, greater crop losses, and elevated rates of pests and diseases. Their research revealed that more than 80% of the farmers indicated they have experienced climatic pattern alterations over the past two decades, 75% have observed diminished yearly rainfall, and 68% have observed irregular temperature patterns and thus leading to the production of some of the major staples like maize and sorghum going down and to others experiencing 40% yield losses (Baffour-Ata et al., 2022). Some of the severe farming hazards smallholder farmers encounters in the northern and savannah regions includes desertification and soil erosion which are at very high rates as documented by (Antwi-Agyei et al., 2021). Again, they highlighted the severe rate at which some of the areas were losing between 50 tons of topsoil per hectare annually which reduced the soil fertility, water-holding capacity status and renders them vulnerable to drought. Furthermore, slash-and-burn agriculture, deforestation, and overgrazing have sped up such degradation processes, which are in a vicious circle worsening the effects of climate change. According to Antwi-Agyei et al. (2021), they estimated that close to 35% of agricultural land in northern Ghana is extremely vulnerable to desertification, which poses a threat to the livelihoods of close to 35 million smallholder farmers. Additionally, reduction of soil degradation by the adoption of sustainable land management (SLM) practices is effective as per findings of Kansanga et al. (2019) that 60% loss of soil and 25-30% loss of soil organic matter in five years was guaranteed by following conservation agriculture practices such as minimum tillage and crop rotation. Surprisingly enough, such farming systems not only play a role in preventing soil erosion but also serves the essential role of enhancing stability and productivity of the farming systems in the area. Furthermore, water shortage and unreliable rainfall, are some of the other problems that confront the farming communities in northern Ghana. Again, a research study by Aniah et al. (2016) revealed that over 60% of the regions' smallholder farmers solely rely on rain-fed agriculture and are therefore under a high risk of rainfall variability and drought. The survey indicated a whopping decline in yearly rain in the past three decades, and in some areas, there was up to a reduction of 150mm in average annual precipitation. Apart from this, rain has also become more sporadic, with drier spells at crucial growth phases of the crop and intense but frequent rain leading to flooding and erosion. This diversification has therefore caused crop loss and lower production, with farmers noting losses in yields up to 50% in the case of drought. Also, Gyampoh et al. (2016) further examined the impacts of water scarcity on livelihood and adaptation by smallholder farmers, further adding that competition between agriculture, household, and other uses is increasing. Farmers in Northern Ghana had 15% access to irrigation facilities, which decreased their ability to adapt to rainfall variability and extend their growing seasons considerably. However, there have been other investigations that have come up with successful interventions where water use efficiency in the area can be improved. Nonetheless, counter evidence by Azumah et al. (2023) documents that there are alternative water harvesting and conservation techniques for the same purposes, and concluded that input-constrained and low-technology systems like zai pits and contour bunding can raise availability of water to crops by 30-40% and production by 20-25% where water scarcity is the situation. Such techniques have tangible channels through which farm productivity is improved despite water scarcity.

To summarize, the agro-ecologies of the northern and savannah regions of Ghana are going through a series of issues ranging from climate change to land degradation and then water scarcity. These issues are inter-related and have implications at the national level for long-term livelihood and food security of smallholder farmers. There has to be an integrated strategy for policy intervention, climate-smart agriculture, and sustainable land management that needs to be developed to enhance the resilience, productivity, and food security of these regions.

2.3.2 Socioeconomics Context of Smallholder Farmers

The northern and Savannah regions of Ghana are extremely food insecure and poor income earners, especially smallholder farmers. A research study from Ummah (2019), established that the two regions have a higher poverty incidence rate compared to the national average of 61.1% for Savannah and Northern versus the nation's 23.4%. Another research findings from Kansanga et al. (2019) established that 67% of farmers in northern Ghana were moderately to severely food insecure, and the most difficult period was the lean season (May to August). Moreover, climate uncertainty has also been deepened by food insecurity, where uncertain rainfall and rising temperatures resulted in a 15-20% reduction in crop yields over the past decade (Asante et al., 2024). Despite such limitations though, the farmers in the region have been able to devise adaptive measures as Antwi-Agyei et al. (2021) recorded the application of zai pits, a water and soil conservation technique that had raised the yields of millet and sorghum during periods of drought by 30%. Furthermore, smallholder farmers in the savannah and northern zones remain beset by enormous bottlenecks hindering access to minimum inputs and access to markets, a finding that limits productivity as well as their economic growth. Empirical research from Kotu et al. (2022) report that 73% of the farmers interviewed reported that insufficient access to credit was the greatest hindrance to embracing innovative farming technology. The formal financial institutions only covered 18% of the farmers, and others accessed informal credit groups or borrowed nothing. Again, land tenure insecurity is again at the center of the problem as 62% of smallholder farmers, women, and youth have insecure land rights (Kansanga et al., 2019). Also, water supply is another limitation on its own, according to Azumah et al. (2023), who explain that only 23% of smallholder farmers covered under the study possess irrigation facilities, and the majority of them are exposed to rainfall variability. Furthermore, market access is also a tough restriction due to the poor infrastructure and storage capacity, which contribute to up to 40% post-harvest loss of perishables (Awafo et al., 2024 ; Gideon et al., 2021). Again, the smallholder farmers are only receiving a small portion of the market price for their crop produce due to their involvement in various intermediaries. Despite these obstacles, there are few positives that have been achieved in this regard. Again, Issahaku et al. (2020) determined that there was a utilization of mobile phone technology in the provision of market access expansion where farmers utilized market information services through the use of mobile phones in an attempt to push farm gate prices up by 10-15%. Moreover, gender disparities still persist in the agricultural sector as women continue to experience a series of challenges. According to studies, female farmers of about 23% are less probable to use the agricultural extension services and 35% less likely to use credit facilities compared to their male counterparts. Also according to Pealore (2022), male-headed families are also 1.5 times more food-insecure compared to female-headed families. The customary land tenure institutions in northern Ghana also formalize gender inequities in such a way that women own exclusive rights over only 9% of land that is cultivable despite them being more than 50% of farm workers (Antwi-Agyei et al., 2015). This excludes women from land access for investing in conservation agriculture and other formal credit and sustainable land use. Attempts have been made to bridge these gaps. A study from Baffour-Ata et al. (2022) confirmed that extension services improved the agricultural productivity of women farmers by 25% over a period of three years. Furthermore, Antwi-Agyei et al. (2021) and Ankrah et al. (2020) have also acknowledged the important role played by women in agro-biodiversity conservation in the region because they are the main custodians of their indigenous seed crops and therefore ensure household food security and climate variability resilience. As much as this has been constructed, structural problems still linger, particularly for women. Empirical studies from Boudalia et al. (2024) also believed that women are occupied in low-value agriculture and have few decisions to make at the value chain level. They called for enforcing strict policy interventions to handle deeply rooted system bottlenecks to remove gender imbalances in agriculture.

The agricultural sector of the northern and savannah regions of Ghana is faced with numerous challenges which hinders economic growth, food security, and climatic resilience. They include poverty, food insecurity, scarcity of resources, climate change, water scarcity, and gender inequality. The reaction to the implication of the challenges calls for an intervention that entails expanding access to credit, land tenure security, irrigation, market information, and gender-sensitive support systems for agriculture to foster more sustainable agro-development and sustainable livelihood in the area.

2.4. Sustainable Land Management Practices in Northern Ghana

2.4.1 Conservation Agriculture

Conservation Agriculture (CA) is a basic land management technique that has been instrumental in alleviating soil erosion and low crop yields in northern Ghana. Low tillage of soil, year-round soil cover, and diversification of crops by rotation or intercropping were the primary CA principles. According to (Kermah et al., 2018) the practices are aimed at improving soil fertility, water level, and farm sustainability. Smallholder farmers in the northern and savannah regions SLM adoption rates have been slow and farmers have resorted to other alternatives that suit the local conditions. According to Kermah et al. (2018), they affirm that minimum tillage or no-till technology is being adopted more and more with the cover planting of crops like mucuna or lablab. Leguminous cover crops alike maintain the soil intact as possible to prevent erosion as well as soil fertility enhancement through nitrogen fixation. Crop rotation, particularly cereals like maize and sorghum to legumes like cowpea and groundnut and intercropping, particularly maize-legume intercropping, is also are all practiced in these regions (Kermah et al., 2018). A study by Adolwa et al. (2019) survey that, only 27% of the smallholder farmers had fully adopted CA practices. A considerable number of determinants influence their adoption levels, including information accessibility, endowment with resources, and perception of benefit for Conservation Agriculture. The most pronounced challenge is labor availability during the early stages of cultivation, especially weed control in no-till farming. Further study enquiry from Adolwa et al. (2019) estimated that the majority of farmers encountered increased in weed pressure at the beginning of CA adoption, which would discourage them from pursuing the practice further. Secondly, the lack of proper machinery such as no-till planters is also a discouraging aspect as well as socio-economic conditions, such as level of education and availability of extension services, are also among several factors. Moreover, land tenure insecurity, particularly in northern Ghana, is also a discourager to individuals involved in long-term investment in sustainable land use. Despite all these problems, CA has managed to improve the soil fertility and farm yields of the area. An empirical study from Okolie et al. (2023) compared CA with conventional farming for three years under the savannah climate. The findings indicated that there were significant improvements in the soil in CA, including water infiltration rates, reduced bulk density, and improved Soil Organic Carbon (SOC) content. Empirical research by Okolie et al. (2023) verifies that, there was a three-year average increase of 15% in SOC in CA plots compared to conventional farming. Moreso, soil organic matter accumulation facilitates improvement of soil structure, water holding capacity, and nutrient storage that are essential for production under sustainable agriculture. With regard to crop production, Okolie et al. (2023) delivered different but otherwise positive results during the initial few years, where CA yields were either equal to or lower than conventional agriculture. But after the third year, CA systems were consistently greater than conventional systems, and maize yield increased by 20-30%, this is because there were better soil moisture conservation and higher availability of nutrients in CA plots. However, Okolie et al. (2023) also cite that the CA yields will never be immediate within the first year and even extend to 2-3 years of sustained uptake before gains can begin to emerge, however the gap may be frightful to low-resource farmers that are likely to feel the yield losses in the short-run brutally. Although adoption intensity is still constrained by the constraining factors like labor requirement, lack of machinery, and socio-economic constraint, the evidence for the merit of CA in improving soil fertility and sustainable agriculture production is comforting. In order to attain wider adoption intensity, there will be more policy intervention and research to resolve these challenges and thus farmer support in terms of information availability, machinery availability, and land tenure will be critical to attain wider adoption of Conservation Agriculture and its long-term agricultural benefits in northern Ghana.

2.4.2 Agroforestry Systems

Agroforestry systems continue to be among the fundamental components of the northern and savannah region sustainable land management with many economic, environmental, and social advantages. Agroforestry systems consist of trees and shrubs incorporated into a combination of animals or crops with a specific purpose of ecological balance, improved soil, and sustained farmers' income levels aside from maintaining the environment in order. Other agroforestry systems have also been developed in northern Ghana that are adapted to local conditions and farmers' preferences. An extensive research from Bayala et al. (2020) explain some of the predominant systems in northern Ghana like alley cropping, whereby crops are planted between tree or shrub rows is properly practiced and as result the soil fertility levels are enhanced by adding organic matter and provides protection to crops from wind and soil erosion. Parkland systems, characterize by the intentional retention of scattered trees within farmlands are also common. These methods are traditionally important with trees such as Shea (Vitellaria paradoxa) and (Parkia biglobosa) or parkland (or agroforest) planted in fields at large spatial scale which renders ecological and economic gains. Large-scale agroforestry systems or home gardens, are tree and shrub specimens that are established in and about homesteads and comprise a key element in household nutrition and food security. However, live fences and windbreaks are increasingly being employed, particularly in desertification-susceptible areas, for the protection of crops against erosive winds and soil erosion (Fané et al., 2024). Agroforestry systems in northern Ghana were discovered to provide a valuable fertility input to soil as well as conservation of biodiversity. Organic soil matter quality, nutrient cycling, and soil structure are improved by agroforestry land use compared to normal monoculture land use, as stated by Asante et al. (2024). Tree cultivation with nitrogen-fixing characteristics such as Faidherbia albida has been of immense advantage to improve the fertility of soils and reduce the application of chemical fertilizers. Biodiversity has also been found to be positively affected by agroforestry land use. From the studies of Yahaya et al. (2024) who confirmed that agroforestry systems enhance more bird and insect species diversity compared to the conventional farm system. Higher diversity facilitates pollination and organic pest control, and chemical pesticides are therefore minimized while the yield of the crop increases. The economic advantage has also led to the uptake of agroforestry. Again, from Asante et al. (2024) who also compared the economic benefit of agroforestry in northern Ghana and concluded that cashew, mango, and moringa tree crops cash-generating huge off-season supplemental revenue. Shea tree has proven to be very profitable because shea butter business throughout the whole world has encouraged economic development in the region. Shea nuts collection and production according to Dzanku (2024), have been a primary source of revenue, under the leadership of women which has aided in improving household well-being, and economically empowering them as well. Besides these benefits, carbon market development has spurred agroforestry activity even more further according to (Essegbey et al., 2020). Therefore, agroforestry systems in northern Ghana offer a holistic approach to the adoption and intensification of sustainable land management practices. Agroforestry is responsible for the improvement of soil fertility, diversification, farmers' income diversification, and contributing to the general environmental conservation. Notwithstanding challenges such as high initial capital and technical support requirements, the different returns of agroforestry in the soil, biodiversity, and economic empowerment dimensions indicate that it has enormous potential for scaling up, particularly with further research, policy support, and access to markets.

2.4.3 Integrated Soil Fertility Management

Integrated Soil Fertility Management (ISFM) has gain enormous attention so far as the adoption sustainable agricultural land management practices in the northern and savannah regions are concern. ISFM aims to enhance soil fertility, raise crop yields, and change the smallholder farmer's livelihood through the integration of improved crop varieties, better agronomic management, and inorganic and organic fertilizers.

Most importantly, organic-inorganic fertilizer blended with inorganic fertilizer is the key to success in ISFM. Evidentially, Yeboah et al. (2023) in their research on the impact of blending on maize yield and soil fertility in Guinea savannah agro-ecological zones concluded that sole or combined application of organic amendments such as crop residues and animal manure with balanced ratio of inorganic fertilizer greatly improved soil organic matter, structure, and nutrient status. Synergistic management provided 25-30% additional maize in three years. ISFM was also suggested to utilize local available organic materials such as rice husk and neem leaves as low-cost substitutes for the use of expensive imported inorganic fertilizers. Another study by Boansi et al. (2024) who confirmed that, long-term effects of ISFM on soil health indicators for five years of sustained use of organic and inorganic fertilizers resulted in enhanced microbial biomass in soil, enzymatic activity, and general overall soil diversity richness, which reflects the environmental advantages of ISFM. Exposure to ISFM management practices suitable for crops and prevailing conditions within local agroecology is just as crucial to guarantee success. Also, further studies from Essegbey and Maccarthy (2020) carried out on-farm trials for nutrient management optimization in staple cereals such as sorghum, millet, and cowpea where their results showed that ideal fertilizer placement and timing had the potential to increase nutrient use efficiency and yield considerably. Split application of nitrogen fertilizer in sorghum, for instance, where one-third at planting and two-thirds at jointing, realized a 15-20% grain yield increase. For instance, microdosing technologies in which minute quantities of fertilizer are placed directly on plant roots prevented loss of fertilizer and improved nutrient absorption. The use of ISFM has been further promoted with the implementation of precision agriculture technologies such as soil test kit and cell phone applications. Again, studies from Kansanga et al. (2019) showed how the low-tech options were able to reduce application of fertilizer by 10-15% without any cost to the yield levels of the crop or even enhancing the yields. This proved not only to reduce input cost but also to add to the profit margins of the smallholder farmer. Nonetheless, even though the advantages of ISFM have been confirmed, it has low adoption rates due to a large series of barriers hindering their promotion. Further research studies by Kansanga et al. (2019) established that among the barriers to the adoption of ISFM were the cost of fertilizer and seed quality when buying, limited access to institutions providing credit, and poor extension services. Thereafter, there are cultural matter where the farmers simply will not use animal dung to be used on human-fertilized crops for cultural or safety reasons. Gender disparities in access are also a factor that brings about such challenges, with additional challenges to the women farmers for adopting the ISFM process. It was because of such issues that Essegbey and Maccarthy (2020) suggested the use of a multi-stakeholder framework in order to foster ISFM uptake where they advised farmer-based capacity development agents, public-private partnerships for inputs supplies, and innovative financial instruments through the pipeline of input credit systems. Furthermore, participatory training techniques, such as farmer field schools, showed the prospect of bridging culture gap and facilitating wider spreading of information around ISFM techniques. Although ISFM can potentially increase the fertility of the soil, increase the productivity of the crops, and increase the stability of the farm systems of northern Ghana, there are socio-economic, cultural, and logistics-based constraint factors to its adoption, and these are going to have to be addressed if it is going to be adopted at a large landscape. The collective efforts of farmers, researchers, and policymakers will play a crucial role in realizing the full potential of ISFM in the nation.

2.4.4 Water Management Techniques

Semi-arid areas such as northern Ghana have seen increasing adoption of rainwater harvesting technology as a low-cost water management system. An empirical study from Balana et al. (2020) outlined some of the rainwater harvesting techniques that were scaled up by smallholder farmers with in-situational systems such as tied ridges and contour bunds that were trailblazing. These practices enabled 15-20% yields in maize and sorghum as a result of the fact that they significantly enhanced water-holding capacity of soil, thereby leading to minimal crop loss during dry periods. The practitioners also experienced a 25% increment in household incomes, evidence of the overall advantage of rainwater harvesting to the prosperity and economic security of farmers. Moreover, minor irrigation is one of the most crucial water management systems in northern Ghana. From a systems effects survey by Owusu et al. (2018) the irrigating farmers registered 30-40% farm yield increases compared to rainfed farmers. The irrigating farms, apart from value farming all year round, with regular cash flows, particularly during the dry season. The research also established that, to a significant degree, small irrigation helped women farmers in the sense that it allowed them to grow value vegetables that helped to improve household income and food diversification. To determine crop diversification and climatic resilience. Another research findings from Baffour-Ata et al. (2022) applied a longitudinal study whose objective was to identify the practice's contribution toward water management in the respect of impacting farmers' capacity for crop diversification as well as bouncing back from climatic shocks.

From the observations, they inferred that rainwater-harvesting farmers practicing small-scale irrigation were able to grow diversification of crops that encompassed drought crops alongside high-value horticultural crops. Not only did enhanced diversification enhance the food security, but also made the farmers more financially resilient as they were 40% less vulnerable to catastrophic income declines during the drought years compared to conventionally farmed farmers. Furthermore, rainwater harvesting and small irrigation schemes are thus still vital to Agri-production, economic resilience, and climate risk in northern Ghana. They are of extremely high significance to the farmers and specifically women farmers as well as crop diversification with attendant additional food security and livelihood.

2.4.5 Climate-Smart Agriculture

Introduction to CSA Climate-Smart Agriculture (CSA) is the universal clarion that climate change mitigation and food security are twinning for substitute problems. A study by Zougmoré et al. (2018), as a whole, CSA has farm practice toward improving productivity sustainably, shock resilience through response to climatic shocks, and low emissions of greenhouse gases. To northern agriculture and the Ghana savanna, most vulnerable to climate change, CSA is a green approach to development to greater agricultural productivity and a livelihood. According to them, Zougmoré et al. (2018), they believe climate-resilient crop improvement, water-saving agriculture, and conservation agriculture are the three legs of CSA. These are fundamental practices in north Ghana whose climate is unstable as regards rainfall and whose land quality is low grade. These producers were able to achieve the level of maximizing their productions, improving the quality of sources of their revenues, and improving climate adaptation through application of CSA. Successful implementation of such CSA in areas like these needs to be successfully integrated into the regional agrifood system. A collaborative research between Antwi-Agyei and Nyantakyi-Frimpong (2021) also observe that indigenous knowledge systems need to be researched so that CSA practice can be scaled up. For instance, indigenous agroforestry systems in which trees and shrubs are combined with animals and crops have immense flexibility in utilizing CSA. The systems create other sources of income from forest products, enhance fertility in the land, and enhance carbon stock. The local systems can be incorporated into the already existing CSA practice to help change the industry to climate-smart and climate-resilient. With severe barriers to adoption, the adoption has encountered challenges even when the potential in CSA is present. Barriers such as tenure, gender relations, and culture are some of the factors which can influence application in new agriculture, highlight participatory practice with farmers, especially women and youth, to establish economically and culturally suitable CSA interventions together. Policy Support for CSA Strong adoption and policy support of the strategies are necessary in order to upscale CSA in northern Ghana and the savannah effectively. According to Partey et al. (2018) who employ the policy environment of CSA in Ghana and observe that some of the challenges are poor coordination among government institutions and non-governmental stakeholders that work in the agriculture and climate change area. This results in wastage of resources and repetition of efforts. They suggest the use of multi-stakeholder platforms as the future approach whereby coordination is improved and sharing of information is facilitated. The second root problem is restricted access to finance and technology by smallholder farmers. CSA would be capital- and technology-driven in the form of new strategy and technology that poor farmers barely have the resources to invest in. Zougmoré et al. (2018) are of the view that new financial products, e.g., climate-smart credit systems, would be needed to increase application of CSA. In scaling up CSA to local scales due to agro-ecological variability in northern Ghana, there must not be homogeneous CSA interventions and thus employing the R&D technology will be needed at the local levels on a participatory mode so that CSA interventions can be formulated based on the changing requirements of various farm communities. Again, Partey et al. (2018) recommend that, although CSA holds vast potential to contribute meaningfully to the livelihoods of Ghana's northern belt and savannah zone smallholder farmers, it must be promoted in an integrative manner in a way that effective use can be leveraged. This could potentially entail an inter-linkage between policy support, local knowledge, and site-based intervention that is accessible, equitable, and effective. With coordination, extra resources, and cooperating with all the concerned parties, CSA can be a significant intervention in food safety and climate variability resilience.

2.5. Impact of SLM Adoption Intensity on Smallholder Farmers' Welfare in the Northern and Savannah Regions of Ghana

Sustainable land management (SLM) practices are currently a key intervention to boost farm productivity and household livelihood of farm households operating in the northern and savannah regions of Ghana. The current review takes into account the welfare impacts of the intensity of SLM adoption, with emphasis on how intensities of SLM adoption have direct effects on improving household total income and household's food security levels.

2.5.1 Household Total Farm Income

The implementation of SLM adoption intensity practices and their spectacular returns have brought about unprecedented agriculture productivity advancement and smallholder farmers' incomes in northern Ghana. According to Nasare et al. (2023) who conducted a detailed study in the region's districts and found that the farmers who implemented the practice of implementing the soil conservation practices, i.e., contour bunding and mulching, indicated that their level of yield improved by 15-20% on average for maize and sorghum, which are the preferred foods in the region. This also positioned it such that there were significant rises in farm incomes where adopters were 18-25% more income households than the non-adopters. There were income gains as a result of enhanced water retention and fertility of the soil, which under semi-arid conditions encountered in northern Ghana are exactly needed. Also, Nketia et al. (2018) also agree that SLM adoption intensity aids smallholder farmers to broaden their revenue sources which serves as a catalyst for the diversification of their income through the proper implementation of SLM practices. Again, from their research, they establish the fact that, farmers' agricultural intensification with complementary practices such as agroforestry and cropping and livestock integration were more likely to diversify into other off-farm business that would bring income. The two drivers of diversification were increased availability of time due to increase in land use efficiency and increased financial capability to invest in other productive activities. More generally, the most prevalent SLM adoption intensity practices that were practiced by farmers showed 30% chances of undertaking petty trade or small business, an and other enterprise that contributed to both household income elasticity as well as enhancing their economic well-being. Therefore, SLM adoption intensity practices have robust evidence of the positive economic effect of SLM adoption intensity on household farm income among smallholder farmers in savannah and northern agro-ecological zones.

2.5.2 Household Food Security

SLM intensification programme is highly welcome in support of the value addition of diets and food security of smallholder farmers of northern Ghana. The current review takes into consideration the role played by SLM intensities to facilitate achievement in making homes seasonally secure, food-insecure-free, and diet-diverse to scale up SLM practice towards diversified and enhanced food systems. Improved Food Availability SLM practice adoption has been of great importance in improving food availability at the household level. According to Antwi-Agyei and Nyantakyi-Frimpong (2021) implemented a systematic review in Northern Ghana where agroecological innovation like zai pits and contour bunding received utmost priority. The evidence showed that there was a 25-30% increase in cereal productivity among adopters in comparison to non-adopters. This enhanced productivity safeguarded months of autumn in off-seasons when food was scarce, hence improving food availability in such households. These habits have been revealed to improve food production and availability throughout the year and thus food security at household level. Beyond the production of additional food, food quality and quantity supplied are important in further improving nutritional content. Again, empirical studies from Acheampong et al. (2022) outlined the association of SLM adoption and dietary diversity in the Upper East Region. The authors established that crop diversification and integrated soil fertility management were the characteristics of adopter farmers with greater dietary diversity score.

Agricultural adopter households consumed 1.5 more daily food groups than non-adopters which was largely due to increased production at the farm level of more intensive mixed and higher income that was able to be shifted to spending on diversified diet consumption. It also confirmed that female-headed households were more transformed, that is, SLM can also be used as an instrument for supplementing nutrition in a gender context. This region is central to challenging the possibility of higher levels of SLM adoption intensity as a means of enhancing food accessibility and the sustenance of nutrition equilibria for farmers. In addition, seasonality of food shortage, process climate change has the potential to worsen this in most environments, is an entrenched issue for northern Ghanaian small-scale farmers. Again, Antwi-Agyei et al. (2015) analyzed the role of the adoption of SLM practices toward food security seasonality. In their three-year longitudinal study, they determined that farmers who escalated the extent to which they used water-saving technology and drought-resilient crops to reduce the harshness of shortage in the hunger season, which traditionally begins from June through to August. Interestingly, SLM-adopting farm households in 40% fewer cases experienced a severe food shortage compared to non-adopters in such peak months. These implications indicates that, SLM adoption practices has positive impact on seasonal reduction of food security, especially with increased climate variability. Whiles SLM adoptions enhances nutritional richness as well as contributing to the general improvement of food security levels of farm households. However, Kansanga et al. (2019) warned that nutritional status SLM adoption levels and trends are of a nonlinear character hence from their evidence in the Upper West, they were able to conclude that, even though food availability had improved due to SLM practices, it did not always translate to improved nutrition, especially among children aged below five. They also recommended that complementary interventions like nutrition education and gender-sensitive interventions need to be intensified in order to achieve the respective nutritional benefit of SLM practice. In other words, nutrition education and SLM practice should be complemented with each other in a way that the increase in food availability has other beneficial health effects, especially on the more vulnerable such as young children. A study from Alare et al. (2018), indicates that SLM adoption intensities and their impacts on dietary diversification are also very well-known in terms of their impacts on fruit and vegetable dietary benefits among households in northern Ghana. What the authors were successful in doing was that from their experiment farms whose agroforestry intensification was being implemented as part of their SLM promotional strategies, where there was a 30% increased vegetable and fruits intake in their respective homes compared to other participants regarding nonconventional farm practices. Increased consumption was done through enhanced quality micronutrient, i.e., iron and vitamin A, which aided in controlling malnutritional deficiencies in the regions. These facts render the viability of the agroforestry institution in the elimination of micronutrient and stealth hunger, and generally improving the general welfare outcomes of smallholder farmers in northern Ghana.

The findings remain very influential to the level of adoption intensity of sustainable land management impacting the nutritional well-being and food security among smallholder farmers in northern Ghana. The implementation of Sustainable Land Management techniques such as conserving water, maintaining soil fertility, and planting varieties of crops have led to food availability and reduction of seasonal food insecurity together with dietary variety increase. Consequently, SLM practice has been found to improve nutrition performance in practitioners of agroforestry systems and female-headed households. To reach its optimum in the aspect of nutritional impacts on SLM adoption intensity, complementary interventions such as gender-responsive practice and nutrition education must be included. Therefore, SLM practices provide a general remedy to northern Ghana's food and nutrition security and climate change with a high degree of priority being accorded to the sustainability of agriculture. The findings measure the economic benefits of embracing intensities of SLM practices in actual agricultural productivity terms. The intensities of the adoption of SLM practices in northern Ghana depict long-term impacts on the health of soil, biodiversity, and climate. They not only render the farm sustainable but also human economic and environmental well-being in general.

2.6 Challenges and Barriers to Adoption Intensity of SLM Practices

Adoption intensity of SLM practices by Smallholder farmers in the northern and savannah regions of Ghana is also faced with a variety of major barriers and obstacles. In this current section, an attempt will be made to discuss some economic constraints that prevents the widespread implementation of SLM practices whiles concentrating on the initial farming costs, labor accessibility as well as market access.

2.6.1 Economic Constraints

Among the key challenges in intensifying the implementation of sustainable land management (SLM) practice is the heavy initial capital to be used. According to (Nkegbe and Shankar, 2014), who conducted a research in northern Ghana where they established the financial challenges encountered by smallholder farmers. They averred that initial investment costs of techniques such as contour bunding, stone lines, and small-scale irrigation can constitute between 15% to 40% of a farmer's yearly earnings. This cost of input discourages poor farmers despite the long-term rewards of SLM practices. Credit access was the focus of the study in its promotion of adoption of SLM practices. According to Nkegbe and Shankar, (2014), 62% of Farmers who were able to access formal credit were more likely to adopt SLMs as compared to according to the remaining 28% of farmers who could not access formal credit, and hence they were unwilling to adopt these practices. Interestingly, only 22% of the interviewed farmers used formal financial services, citing such challenges as high interest rates, collateral, and the availability of limited financial institutions in rural areas. As a response to these challenges, Dawuni et al. (2021) investigated alternative sources of funds, suggesting a revolving fund model based on a community approach. The model showed a likely 35% increase in the uptake of services in test markets, though as a proposal contingent upon facilitation by public policies as well as combined effort between public and private organizations. Another major economic barrier to the intensity of SLM uptake is the labor-intensive nature of most SLM practices. An extensive study from Kermah et al. (2018) who examined labor demands for most SLM practices in Ghana's Upper East, and they concluded that practices such as composting, mulching, and construction of soil and water conservation measures had the potential to raise the labor demand by 20-50% more than conventional cultivation, particularly in the early stages. Such families that had a higher number of working-age members were likely to embrace such practices, though rural-urban migration limited the available labor pool. Women-headed families were also more limited by virtue of time and cultural obligations. Another study from Sanou et al. (2019) analyzed the ability of mechanization to minimize the requirements for labor to counter such limitations. Their findings confirmed that small-scale mechanization could be used to bring labor inputs into certain SLM practices down to 40% or more, hence raising the adoption level. The research further raised the issues of context-targeted mechanization interventions and enhancing access to equipment via cooperative affiliation or subsidized lease plans. Also, farmers' market access and inclusion in the value chain is another important influence on the economic sustainability of adopting SLM practices. Furthermore, another study from Ummah (2019) examined market-based constraints that hinders farmers from intensifying the rate of SLM adoption in the savannah agroecological zone and found out that adopting farmers produced diversified and better-quality produce but could not take advantage of such advancements because market access was limited. Poor road infrastructure, no storage, and poor market information were some of the significant constraints. Farmers living over 15 km from large markets were 35% less likely to adopt improved SLM practices, as transport costs and post-harvest losses had a tendency to offset potential economic benefits. Farmers with long-term relationships with processors, exporters, or other value chain players were 40% more likely to adopt SLM practices, as these relationships had a tendency to provide price premiums and more stable markets. According to Yahaya et al. (2024) also expanded on these results, demonstrating that farmers in well-organized groups were 25% more likely to adopt SLM practices. Their collective bargaining power as a group, shared storage and transport facilities, and better access to market information through these groups were among the main drivers.

2.6.2 Knowledge and Information Gaps

The level of adoption of SLM practices in the savannah and northern regions of Ghana is dependent mainly on the information and communication. Extension services, farmers' experience, and integration of indigenous knowledge in these levels are determining factors here. An empirical study by Adolwa et al. (2019) used a survey in northern Ghana to establish the awareness of farmers towards various SLM strategies. Their study revealed significant disparities in the knowledge, where easy practices like crop rotation and intercropping were known, and advanced methods, e.g., integrated soil fertility management, were not known. Farmers' education levels were negatively related to SLM practice knowledge, and focused education programs were suggested as a result. According to Nkegbe and Shankar (2014) who also investigated further the dynamics of information exchange among agricultural communities. Social network analysis by them identified that farmers who were well connected and enjoyed positive social relationships with early adopters and community leaders were likely to understand as well as further disseminate the adoption of SLM practices. This is evidence of the way in which knowledge ids transmitted through formalized networks. Once more agricultural extension services are also involved in bridging this knowledge gap. Again, Moore et al. (2015) compared farmer-managed and participatory approaches with traditional top-down approaches in the northern and savannah regions of the country. From their evidence, they showed that farmers who were involved with participatory approaches such as farmer field schools and community demonstrations had 40% higher adoption of SLM practices. Notwithstanding the challenge with the extension system, e.g., funding constraints, lack of SLM training among extension agents, and transport infrastructure in rural areas. However, Antwi-Agyei et al. (2018) highlighted some of the issues that need to be raised in the extension system and as well recommended a multi-stakeholder public-private partnership and technology-based system for improvement of extension service delivery. Also, there must also be a balance between traditional and scientific approaches in the reinforcement of SLM promotion and scale-up. Moreover, Antwi-Agyei and Nyantakyi-Frimpong (2021) carried out research on the role of traditional ecological knowledge in the adoption of SLM practices by farmers in northern Ghana. The study established that adoption of SLM practice, which was made to fit into the traditional culture beliefs of the farmers and aligned with traditional agriculture, was adopted without challenges. For instance, agroforestry systems that utilized native trees used more than where exotic trees were used exclusively. Likewise, Kpotor et al. (2014) wrote about how adopting indigenous soil classification systems and scientific soil management practices affected the adoption of SLM. Based on their research, farmer adoption was 35% higher among those where extension officers utilized local terms and factors of management to train SLM compared to using the scientific method alone. It is a support for locally acceptable and culturally attuned ways to improve SLM practice.

2.6.3 Institutional and Policy Challenges

Policy and institutional drivers such as land tenure security, policy incoherence, and institutional coordination have a critical influence on the quality and coverage of implementation of sustainable land management (SLM) measures in northern and savannah regions of Ghana.

Second, land tenure security is one of the major drivers of farmers' investment in long-term SLM practice. According to Antwi-Agyei et al. (2018) land tenure and SLM adoption in northern Ghana and discovered that farmers who enjoyed secure land rights possessed formal titles or customary arrangements that were 35% more likely to adopt soil conservation practices and invest in agroforestry. This study reveals how permanent land tenure, statutory or customary, is the foundation on which farmers long-term invest in SLM. However, Kansanga et al. (2019) had also identified a concern, however, that increasingly commodification of land was diverting customary land systems, which would be challenging to SLM practice. They understand through their experience in the upper west area that fallows and soil fertility management have been disincentivized and lost with the fragmented land tenure systems and the fragmentation of communal lands. Policy interventions are their appeal to ensure and complement customary land rights with an incentive for sustainable land use practice. In addition, policy loopholes and inconsistency kill the application of SLM practice. Another study by Partey et al. (2018) critically analyzed the climate-smart agriculture policies in Ghana and their implications for SLM in the savannah agro-ecological zone. They observed that there was a huge gap between national policy formulation and local-level implementation. While the national policy had set the targets for SLM, SLM strategies had been integrated in just 30% of the districts' local study plans. This is attributed to insufficient local capacity, poor financing, and poor policy coordination across various levels of government. Similarly, Antwi-Agyei and Nyantakyi-Frimpong (2021) also explained the constraints in linking SLM policies to programs that can be implemented locally. Bureaucratic administrative red tape, sectoral goals conflicting with each other, and lack of authentic local participation were restrained as barriers to effective implementation by him. He advocates more responsive, flexible policy that will be able to address the changing agro-ecological and socio-economic conditions in which farmers will be operating. Second, for optimal application of SLM practices, proper coordination among stakeholders is also necessary. According to Zougmoré et al. (2018) who analyzed the institutional context of SLM in Ghana savannas through the examination of inter-connectedness among government institutions, research institutions, NGOs, and farmer organizations. They operated in an institutional fragmentation context with weak sharing of effort and information among themselves. Less than 25% of SLM practices had good multi-actor participation. Another study from Jinbaani (2016) also critically analyzed multi-stakeholder platforms for further enhancing the adoption rate of SLM. Evidence from the Upper East demonstrated that active district-level SLM forums raised coverage of farmers of SLM training by 40% and rates of adoption of soil fertility management inclusion by 30% over three years. The forums facilitated coordination of policy, research, and practice, as well. Again, Abass et al. (2018) advise against overdependence on institutional structure and believe that informal networks, together with traditional leadership, have substantive functions to drive and entrap the adoption levels of SLM practices. Their experience in the northern region highlighted the role of community leaders, i.e., elders and chiefs, to enable the adoption of SLM practices and interventions that follow local ecological rules and local values.

2.7 Government and non-Governmental Organization (NGO) Interventions

The Evolution in sustainable land management (SLM) practice in the northern and savannah regions has been driven by a range of government initiatives, policy, and nongovernmental organizations (NGOs). Adoption of SLM efforts by smallholder farmers has seen appreciable success thanks to these initiatives, but ongoing challenges related to equitable access, coordination, and sustainability issue continue to persist.

2.7.1 Government Policies and Programs

The Government of Ghana has recognized the importance of SLM as a climate change mitigation strategy and agricultural productivity improvement. The National Climate Change Policy (2021) is a general policy framework that puts climate change at the center of national planning, giving top priority to the promotion of SLM as an adaptation strategy in agriculture, with a focus on climatically exposed northern regions of the country. According to Essegbey and Maccarthy (2020) who evaluated the policy implementation and determined that it led to increased budgetary allocation in climate-smart agriculture, including SLM practices. Soil conservation practice had a 30% increase in adoption by those districts that had plans consistent with the national policy. One of the flagship programs of the Ministry of Food and Agriculture, the Planting for Food and Jobs (PFJ) program, was created to promote agricultural productivity and food security through improved access to quality seeds and fertilizers whiles integrating the SLM practices into the initiative along the implementation periods.

Again, Okolie et al. (2023) set up that, the PFJ beneficiaries in northern Ghana were 25% more likely to embrace soil and water conservation compared to their non-beneficiary counterparts. This is due to the fact that the program has an integrated approach, where subsidies are complemented with training in intensive agriculture. Disparities in program coverage, however, especially for hard-to-reach communities and women-headed households, continue to be a problem. Further, the Northern Development Authority (NDA) has been at the center of regional development and agricultural transformation in the northern part of the country. The NDA 2020-2025 strategy emphasizes sustainable land management and agriculture as drivers of economic development and poverty reduction. A study from Westerberg et al. (2021) researched NDA-backed SLM interventions in the savannah agroecologies and confirmed that over 5,000 hectares of degraded lands had been reclaimed by interventions like conservation agriculture and agroforestry. The model of the NDA on community-based natural resource management encouraged heightened sense of stewardship in community so that SLM interventions such as those came to be sustained. In spite of all these positive impacts, some of the constraining factors like political interference with project selection, poor long-term financing, and lack of adequate market linkages for SLM crops continue to exist. suggest a more integrated policy approach where promotion of SLM is incorporated into rural development policy as a whole. NGOs have also contributed significantly to the popularization of SLM practice beyond government efforts. Furthermore, Antwi-Agyei and Nyantakyi-Frimpong (2021) further examined the use of NGO-project interventions in northern Ghana and found that the interventions are mostly utilized as an experiment plot to pilot-test innovative SLM practices. The best-practice examples of NGO programs are, however, upscaled due to government initiatives in establishing big delivery platforms for SLM best practices. Government bureaus and NGO organizational coordination has also too often translated into duplicate effort and spastic messages to farmers. Initiatives like the government plans including National Climate Change Policy, Planting for Food and

Jobs, and NDA projects have served to shape up-take SLM practice development in Ghana's savannah and northern regions. Implementation of SLM strategy, and rehabilitation of land degradation have been enhanced by such operations. Poor access, coordination, political interference, and long-term sustainability issues are still the order of the day. In order to overcome such issues, concerted and coordinated efforts, facilitated by formal and informal institutions, need to be better rooted to guarantee the long-term achievement of SLM intervention.

2.7.2 Non-Governmental Organization (NGO) and International Organization Initiatives

These are NGOs and international agencies that have been pioneering the advancement of SLM practice in Ghana's savannah belts and northern belts. World Bank, USAID, and CARE International are some of the institutions that have been at the forefront. Such programs have had their effect reproduced through promotion of SLM uptake and enhanced livelihood for the smallholder farmer. This section presents the effect of such successful programs.

Firstly, the USAID Feed the Future program has, in most cases, been a best-practice program in SLM adoption intensity practices and food security improvement in northern Ghana. The program is, as indicated by Rosenstock and Nowak (2022) at a point where it seeks to bring together climate-resilient agriculture and market-oriented methods to promote agricultural productivity sustainably. The peak of the program is the improvement of conservation agriculture practices such as minimum tillage, rotation, and cover crops. The implementation of the program has been reported with outstanding success. A research finding from Issahaku and Abdulai (2020) contrasted Feed the Future beneficiaries with non-beneficiaries and proved that farmers who participated attained 30% increase in maize production and 25% loss reduction in post-harvest. The beneficiaries also attained 20% increases in agricultural revenues yearly. Again, Antwi-Agyei and Nyantakyi-Frimpong (2021) noted that the women farmers from the Feed the Future program had 35% increased likelihood of taking up SLM practices than those who were not from the program. This was because there was gender-sensitive technology transfer and specialized training, and that empowered the women and improved their agriculture and gender-sensitive technology extension, which empowered women and enhanced their farm management. CARE International's FFBS approach has been conventionally another mandatory intervention in Ghana's savannah region, where market-friendly prudence and agroecosystem-consumable agrarian experience blended. The article from (Owiredu et al., 2024) acknowledges that FFBS approach is experience learning exposure of getting SLM skill acquisition and entrepreneurship skills training to smallholder producers. A research study by Asante et al. (2024) revealed that, impact evaluation had guaranteed FFBS members were 45% more likely to embrace diversified SLM practices, agroforestry, and integrated soil fertility management compared to non-members. FFBS strategy has recorded long-term business competence impacts from the participants as 60% of FFBS graduates attained improved market access and negotiation. The program performed optimally in improving women. A study from Owiredu et al. (2024) also found that women beneficiaries' autonomy to decide on land use and crop selection in the FFBS program was raised by 40%. There was increased empowerment, which assisted in raising SLM and household nutrition practice adoption, promoting the program's potentiality to alleviate agriculture inequalities. In pursuit of this objective, in addition to that, the Ghana Commercial Agriculture Project (GCAP), financed itself by the World Bank, has also been a trailblazer project in promoting coverage of SLM practice area in northern Ghana. With its emphasis on better water management and climate-resilient agriculture, the project has spurred. Moreover, Siakwa (2023) indicated an increased use of better irrigation techniques and improved drought-tolerant crop varieties among smallholder farmers. Again, Okolie et al. (2023) assessed the success of GCAP in Northern Regions and Upper West Region and concluded that the benefiting farmers had registered a 50% increase in the application of improved sets of irrigation and 35% increase in the application of drought-tolerant seeds. The increase boosted production of the dry-season crops by 40%. Value chain project development also enhanced market access because participatory project farmers experienced a 30% increase in farm gate prices through direct impacts of enhanced market linkages and value addition interventions Antwi-Agyei et al. (2018). Moreso, CARE International, World Bank, and USAID have all made contributions towards accelerating SLM practice and enhancing northern Ghana's smallholder farmers' well-being. These have been converted into agricultural productivity, market access, and reduction of gender imbalance in agriculture. Initiatives like Feed the Future, FFBS, and GCAP have achieved depth of penetration, yielding measurable outcomes in the form of yield and income rise and climatic resilient agronomic management. Scaling up these initiatives and sustainability of intervention is the challenge. Highest priority should be given to building local capacity, improving coordination among actors, and eliminating structural barriers to the dissemination of SLM practice.

2.8 Future Directions and Research Gaps

Substantial research has been carried out on adoption and implementation of SLM practices in Ghana's savannah and northern regions. Certain critical areas still require investigation in an attempt to improve the effectiveness of SLM interventions and enable us to have a better understanding of them. This part will address the most important future research areas and research needs in SLM, including long-term impact evaluation, digital technologies integration, and formulation of climate change impacts adaptation strategies.

2.8.1 Long-term Impact Assessment of SLM Practices

While numerous studies have documented the short-term impacts of SLM practices, there is a pressing need for systematic long-term impact assessments of the intensity of SLM adoption practices. An empirical studies from Nasare et al. (2023) meta-analyzed SLM in northern Ghana with a glaring lack of longitudinal studies that have been more than five years in duration. The authors argue that all the socio-economic and environmental impacts of most SLM interventions, particularly soil restoration and increased biodiversity, will be achieved in decades. Breaking this down, Nkegbe and Shankar (2014) presented a conceptual model for assessing long-term SLM impacts with emphasis on integrating direct and indirect impacts for smallholder well-being. Their approach is to integrate house surveys and remote sensing data in order to monitor long-term change in land productivity, ecosystem services, and livelihoods. It has the potential to be used in providing valuable information regarding the sustainability and resilience of SLM interventions during periods of environmental and socio-economic transformations. A research findings from Issahaku and Abdulai (2020) further state the importance of acquiring an understanding of the long-run economic viability of SLM ventures. Their own early findings of a decade's work in the Upper East Region indicate that while some SLM practices exhibit always-positive impacts, others may deplete or cease to be financially viable with passage of time through changes in prevailing climate patterns or market factors and thus making clear the imperative to employ adaptive management techniques and follow-up observation on SLM measures.

2.8.2 Integration of Digital Technologies in SLM

The potential of Digital technologies application to the promotion and observation of Sustainable Land Management (SLM) practice are a growing area of research in agriculture. Growing areas of application of digital technologies, i.e., remote sensing, mobile applications, and the Internet of Things (IoT), have been explored by some research interest focused on ease of uptake of SLM and farm practice.

Firstly, empirical studies from Alare et al. (2018) assessed the application of remote sensing and Geographic Information System (GIS) in evaluating SLM practice performance and adoption in northern Ghana. The study confirmed the capability in utilizing satellite imagery to spot the fields covered under specified SLM practice such as contour bunding and agroforestry. The method was discovered to be less expensive than the traditional field surveys that are extremely time-consuming and expensive. Remote monitoring of SLM practice uptake has the advantage of allowing for improved intensive and targeted cover and facilitating improved resource planning and improved targeted interventions. Also, Antwi-Agyei et al. (2018) also discussed the potential of mobile apps as a platform for SLM knowledge sharing among smallholder farmers. Their pilot in the Northern Region of Ghana showed that 30% more farmers embraced new SLM practices through a mobile app that is tailor-made for that specific intention than farmers who benefited from traditional extension services. The app was a platform for information sharing during the provision of real-time messages on climate-smart agriculture practice, market demand, and best land management practices. But the study emphasized especially the problem of taking mobile interfaces to low-literate farmers and local language and local knowledge-based mobile interfaces. By this, useability and appropriateness for more farmers to digital tools would be enhanced and technology in access and coverage would be brought within the reach of all farmers. Most importantly, Nketia et al. (2018) proposed a new method based on IoT sensors and machine learning models to provide real-time soil health status monitoring and site-specific SLM recommendation. The proof-of-concept experiment showed promising results to improve resource use efficiency, e.g., water and nutrient optimization. Their application in the fields allows the farmers to receive real-time data-driven information about the soil, which can be matched by smart irrigation, fertilization, and management. Large-scale deployment of the same is a tall order, the authors argue, in view of rural infrastructure, with internet penetration and electricity sometimes not assured. Large-scale training of the farmers in deploying such new technologies is another hindrance to rapid deployment. It will be of critical significance that these new internet-based technologies in the farm thrive if these are effectively trained and infrastructures well established. The application of digital technology, including remote sensing, mobile apps, and IoT sensors, has high potential to support SLM practice adoption and monitoring. These technologies augment more assessment of information, promote information presentation, and provide real-time information for purposes of direct guidance and all contributing to better use of resources and farm sustainability. Structural barriers to be overcome in order to attain the effect of these innovations are confinement by infrastructure, simplicity, and mass education of farmers. Further R&D on the subject, and on plural society integration of indigenous technology and knowledge strengthening in general, will become unavoidable to inform northern Ghanaian and global SLM digitalization.

2.8.3 Climate Change Projections and Adaptive SLM Strategies

Global warming has been in a rise in recent times which inevitably adds to the sufferings of farmers in their pursuit to revitalized the soil fertility status within the northern belt of the country. Adequate planning and including adaptation of sustainable land management (SLM) alternatives that will ensure the survival of the small-holder farmer from such occurrences is quite crucial. Studies of the SLM practice-climate change interface have come a long way, but some of the most important gaps that still exist to this day. Hence these strategies needed to address as well as achieve the long-term resilience of the agricultural systems in these exposed regions. For instance, Owiredu et al. (2024) conducted a general assessment of future climate change in savannah regions. Their prediction was concluded on warmer temperature increase and unpredictable rains, both of which have direct effects on agricultural yields. Climatic change needs to be tackled by the adaptation practices alongside environmental condition changes. The authors were worried about SLM practices and adaptations of these predictions which forces policy makers to introduce climate shock mechanisms aiming to facilitate climate resilience among smallholder farmers as well as enhance adaptation capacity in the event of climatic shocks. Again, Antwi-Agyei and Nyantakyi-Frimpong (2021) researched the practice of CSA as a means of reducing the impact of climate change in northern Ghana. Along with the smallholder farmer, she gathered many strategies most likely to counteract the impacts of climate change. Among such adaptation methods were drought-tolerant crops and harvesting water. Such practices also possessed the capability of enhancing the resilience of agricultural systems to climate change. The study, nonetheless, also established significant adoption challenges such as low availability of climate information, inadequate availability of resources, and inadequate extension services for facilitating the adoption of the practice. The study warrants positively the need for some policy intervention and better access to resources for ease in scale adoption of CSA. In addition to that, also investigated the potential of agroforestry systems to adapt and mitigate climate change for savannah ecosystems in northern Ghana. Based on their long-term experiments, they demonstrated that some trees have the potential to be utilized to increase water storage in soils and develop beneficial microclimatic conditions to improve crop drought resistance. The intercropping between the tree and the crop also increased the soil fertility as well as the water content in the soil, yielding more stable agriculture across various rainfall regimes. The authors did admit, however, that there were some areas calling for further work on the issue of the best combinations of tree and crop desirable as well as management practices to ensure success in various regimes of climate. Though the majority of findings were positive, there are still untapped knowledge gaps that relate to long-term ecological and socio-economic consequences of SLM practice in northern Ghana. Long-term assessment is required to adequately capture the livelihood and the environment impact of the SLM interventions. This will be necessary in an effort to develop and refine SLM interventions for the sake of making them endure in the long run. Hence, application of digital technology to SLM practice is very promising within the frame of large-scale adoption and monitoring. Yet, based on empirical evidence from studies conducted by many scholars, affordability and scalability within the rural setting of such technology is a topical issue. More study will nonetheless remain necessary to better investigate how new digital technologies like smartphone apps, remote sensing, and IoT sensors might be optimized for application within such an environment such as low-literacy groups.

To sum it all up, SLM adoption intensity practices is thus very important in the effort to manage the challenge of climate change in order to make smallholder production systems in northern Ghana sustainable in the long term. A collaborative research from Antwi-Agyei and Nyantakyi-Frimpong (2021), and Bayala et al. (2011) further mention the efficacy of practices such as CSA, agroforestry, and drought-tolerant crops towards managing the issue of climate change. But legitimate hindrances such as lack of information and access to resources must be considered. Secondly, information and communication technologies have the potential to be used as a useful tool to facilitate adoption and tracking of SLM practices but must continue to improve in order to overcome the scalability and accessibility hurdles. Closing the knowledge divides will play a critical role in achieving evidence-based policy and practice that will enhance Ghana's savannah and northern region farmers' well-being sustainably.

2.9 Conclusion

2.9.1 Synthesis of Key Findings on SLM Impacts and Challenges

Northern Ghana evaluation of SLM practice provides a challenge contrast that indicates the long-term challenges and favorable effects of practicing and adopting the measures. The favorable effects center on increased improvement in agriculture output, revenues, and food security with gender imbalance and knowledge constraint being excluded to discourage the potential of SLM practices. This sub-section places the dynamic, cumulative nature of SLM strength in context by listing the most relevant conclusions of recent studies and what these may mean for future interventions.

Among the advantages of SLM uptake, other scientists have also demonstrated food security and economic advantage of SLM uptake in northern Ghana. According to Nasare et al. (2023) who demonstrated that the enhanced productivity of major crops such as sorghum and maize by SLM adopting farmers such as agroforestry, conservation tillage, and water management techniques was boosted by 15-20%. Such increased yields counterbalance farmers' rise in production and additional food security. Again, Antwi-Agyei and Nyantakyi-Frimpong (2021) continued to state that SLM farm households had 25-30% fewer months of food shortages, a proxy for having higher year-round food sufficiency. All these show that SLM farm strategies provide food with increased security through tempering environmental shocks of erosion-induced loss of soils, water scarcity, and exposure to climate. As much as there are the advantages, gender inequality in adoption of SLM practices still exists. It discourages rural women to take part in SLM practice owing to forbiddance in acquiring access to land, low-quality training, and inhibiting cultural sentiment in taking part in farm decision-making, as delineated by Bardy et al. (2022) Gender-responsive protocols were applied by the research in providing a recommendation for what it needs in establishing a fair level ground between women and men in the way of securing identical results of SLM measures. Authors proposed gender-sensitive technology transfer and training as extension guidelines to empower the women farmers and to achieve higher SLM adoption equity as well Knowledge transfer and efficient extension are similar to SLM practice mass deployment issues. Moreover, Baffour-Ata et al. (2022) found that the majority of the smallholder farmers, particularly rural villagers, were poorly served by extension services and verifiable evidence on SLM practice. The study affirmed that extension services were decentralized with weak coordination at the local level among government ministries, NGOs, and farmers' associations. SLM practice adoption was thus uneven and farmers lacked technical backstopping for the successful practice adoption. Learning by participation and expansion of extension networks are suggested by authors as key interventions to ensure more efficient mechanisms of provision of knowledge and to promote SLM practice adoption. Integration of convergence of outputs born by discussed literature reaffirms the dynamic nature of the SLM effect under all economic, environmental, and social conditions. Effects of intensity of SLM adoption are heterogeneously dispersed across all farming communities and intervention thus has to be conducted at the group level. For instance, even though there could be producers who are advantaged by improved soil condition and water management, there are others who are adversely impacted by inadequate infrastructural facilities, limited resources, or inadequate technical support. To achieve maximum benefits from SLM uptake, there is clear need for adaptive management strategies that will be sensitive to interventions in responding to the needs and constraints of different farmer groups. whereas the economic, ecological, and social contribution of SLM practice rate is valuable, there are its knowledge transfer, mass scale, and accessibility equity problems. The economic advantage of higher crop yield with food security shows the capability of greater smallholder farmers' welfare through SLM intensity practice. With time, the need for more adaptive and context-adaptive sustainable agricultural practices is the answer to the issue as far as upscaling and maintaining SLM adoption intensities is concern in these regions under study.

2.9.2 Implications for Policy and Practice

The literature examined on the intensity of adoption of Sustainable Land Management (SLM) practices in northern Ghana and has established a number of research implications that extend and are far-reaching for policymakers and practitioners to deepen the intensity of SLM adoption and resilience of smallholder farmers. Implications relate to the delivery of finance products, local knowledge integration, empowering women, and reforming extension services, all of which are essential in enabling mass adoption of SLM practices. Some of the most obvious implications from literature are captured below:

Second, among the main challenges poor farmers have in upscaling SLM is the amount of initial capital for some of the SLM practices like agroforestry, water harvesting, and soil fertility management. An empirical review by Nkegbe and Shankar (2014) suggested the establishment of new finance instruments, e.g., subsidies, low-cost credit, or microfinance programs, to put such practices in the hands of poor farmers. By lowering the cost, policy-makers can encourage higher take-up of capital-intensive approaches that would result in productivity growth and long-term resilience. Moreover, financially incentivized policies facilitated to early adopters can create good feedback effects inspiring others to imitate. Another key finding from the literature is that indigenous knowledge blended with scientific SLM methods becomes imperative. Also, Awafo et al. (2024) reaffirmed that locally adapted extension services in conjunction with indigenous systems of agriculture and indigenous systems of soil classification led to a wider range of SLM methods' adoption. It concludes that policymakers should give due importance to documenting and incorporating indigenous knowledge in SLM extension work even more. With gratitude and understanding of farmers' local system and practice, policymakers can render the new SLM interventions more acceptable and acceptable. Aside from that, the approach could cause people to be more participatory due to the fact that farmers would be stimulated to foster a stronger attachment to more meaningful practices towards their traditional information. Apart from this, gender disparity in SLM adoption levels was also highlighted by Awafo et al. (2024), in its results and hence gender-sensitive policy is required. The literature extensively showed that women farmers, who are excluded from land, credit, and extension services, are disproportionately affected in scaling up the adoption intensity of SLM practices. Therefore, policy makers need to craft special support for women farmers in the package of gender-sensitive extension, land tenure reform, and access to credit facilities. By removing special constraints that hinder women farmers, intensity of SLM adoption can be made more equal and one where both men and women have equitable access to benefit of these technologies. Furthermore, strengthening the decision-making abilities of women and the ability of women can have greater socio-economic effects on societies and households. Lastly, literature has emphasized the importance of systems approach and integrated strategy in SLM promotion. For example, Essegbey and Maccarthy (2020) uncovered the advantage of farmer-led participatory extension over the conventional top-down extension practice. This implies that policy-makers are keen on restructuring agricultural extension services to facilitate interactive community-based learning and knowledge exchange. This places the farmer in control of choice and makes sure SLM interventions are context-dependent and responsive to local conditions. Apart from that, systems thinking would mean considering inter-relations among different farm system components, like animals, water, and soil, in a way that SLM indicators operate on several dimensions of farm sustainability.

2.9.3 Call for Continued Research and Support for Farmers in Northern Ghana

In light of this rigorous and extensive literature review on the intensity of SLM adoption in northern Ghana, there is promising evidence of the implications on potential benefits and limitations of SLM adoption intensity. Certain critical themes are to be discussed further in the hope of bringing about sustainability and long-term contribution of such practice. Such thematic research will not only lead to better SLM strategy but will also make strategies more compatible with changing issues, especially those issues resulting from climate change and socio-economic forces. The following overall research gaps were identified:

First, one of the most essential needs in SLM is long-term research that assesses the sustainability of SLM achievement for decades. This is particularly needed because environmental conditions are still undergoing changes due to climate change. Whereas Bayala et al. (2011) identified the probable synergy of adopting conventional and novel climate adaptation strategies, fewer studies have assessed the performance of such interventions in the long term. Longitudinal research is required to establish whether the advantages of SLM practices, including soil fertility and water holding capacity, can be sustained in the context of increasingly unstable climatic conditions, including more frequent floods and droughts. In addition, the diversity of landscapes and agricultural systems in northern Ghana is a challenge to the large-scale implementation of SLM practices. As noted in the literature, the region's multi-agro-ecological zones need zone-specific plans for the intensity of SLM adoption. Future studies will aim to tailor SLM practices for each zone based on soil types, rainfall regimes, and crop types. This would result in more context-specific advice that is more appropriate to the specific conditions of each agricultural zone. Research can be targeted on the ways in which SLM practice enhances not only farm output but also rural entrepreneurship, off-farm income diversification, and rural development. Again, Nketia et al. (2018) research suggested the potential of SLM practice to enhance rural entrepreneurship but more empirical research is required to identify ways in which the practices will stimulate new rural business activities as well as employment. Whereas technical SLM requirements are fundamental, it is equally important to resolve more generalized structural issues to smallholder farmers' capacity for adoption and take-off of SLM practices. Research in the future should aim at determining policy contexts and institutional reforms required for land tenure security to improve, which has a tendency to undermine farmers' investment incentives in long-term SLM practices. Moreover, integration of climate services with SLM strategies allows farmers to make the appropriate decision on planting dates, type of crops, and water allocation. Policy changes in these sectors would be guided by research that would allow farmers to overcome structural impediments for SLM intensity adoption. In conclusion, the broad literature offered a hopeful image regarding the ability of SLM to enhance the welfare of smallholder farmers in northern Ghana. But realizing that potential requires cooperation between policymakers, researchers, and practitioners to address existing issues, bridge knowledge gaps, and provide holistic support to farmer communities. Relying on the solid foundation of existing research, and bridging known gaps, stakeholders can work together towards a more resilient and sustainable agro-sector for northern Ghana, to improve livelihoods for smallholder farmers, and contribute towards overall rural development goals.

CHAPTER THREE

METHODOLOGY

3.1 Introduction

This chapter discusses the study area, data source, the sample size and sampling technique, the analytical framework as well as the definition of variables and a priori expectations. Section 3.2 discusses the study area, whiles section 3.4. will look at the sample size and sampling technique used in the study. Section 3.5 will discuss the analytical framework which will further explain how the various econometric models will be used to do the analysis. Lastly is the subject of variable measurements and a priori expectations form the concluding section 3.6. Additionally, this section captures both the theoretical and conceptual frameworks underlining the relationship between SLM adoption intensity and farmers welfare outcomes in the northern and savannah regions of Ghana.

3.2 Study Area

The study area encompasses 15 communities across the northern and savannah regions of northern Ghana, including Zowu, Kabilpe, Zaadanting, Laribanga, Kupoto, Biposu, Gushei, Chehidanyili, Yabogu, Tasundo, Chambe, Nangunkpang, Bandiyili, Tarikpaa, and Sabali. These communities are characterized by the predominance of smallholder farming and the promotion of sustainable land management (SLM) practices. Geographically, the regions are located between latitudes 8°30'N and 10°30'N and longitudes 0°30'W and 2°00'W, bordered by Burkina Faso to the north, the Upper East and Upper West regions to the north, and regions such as Bono East and the Eastern Region to the south. They experience a tropical savannah climate with distinct wet and dry seasons. The dry season, lasting from November to March, is marked by harmattan winds, creating arid conditions, while the wet season, from May to October, sees annual rainfall ranging from 80 to 150 mm, making the regions susceptible to land degradation and climate shocks. Agriculture is the backbone of the economy in these regions, with smallholder farming being the primary livelihood for most inhabitants. Farming in these regions are predominantly rain-fed and thus highly rainfall-dependent, and thus vulnerable to erratic weather and climate change. Crops such as maize, millet, sorghum, yam, cassava, rice, and groundnuts are some of the principal crops grown for subsistence and sale, with surplus sold in the local market. Also, animal husbandry is of great significance in the agricultural economy, with cattle, sheep, goats, chickens, and guinea fowls being prevalent. Moreover, mixed farming is also practiced by the farmers; wherein animal breeding is combined with crops in the field to develop immunity of the weather. Rotating farming with stock rearing, agro-pastoralism, is also a common practice, and transhumance wherein seasonally, the cattle are driven in search of grazing room when there is a dry season is followed in some. Furthermore, the regions are vast belts of agricultural cultivations, and they produce foodstuffs and livestock to be sold to national and local markets. Their sustainability is however, threatened by climate change, soil erosion, and low productivity. Hence their ability to adopt as well as intensify the various sustainable land management practices must thus be guaranteed for agricultural productivity and resilience and for enabling the well-being of the local population.

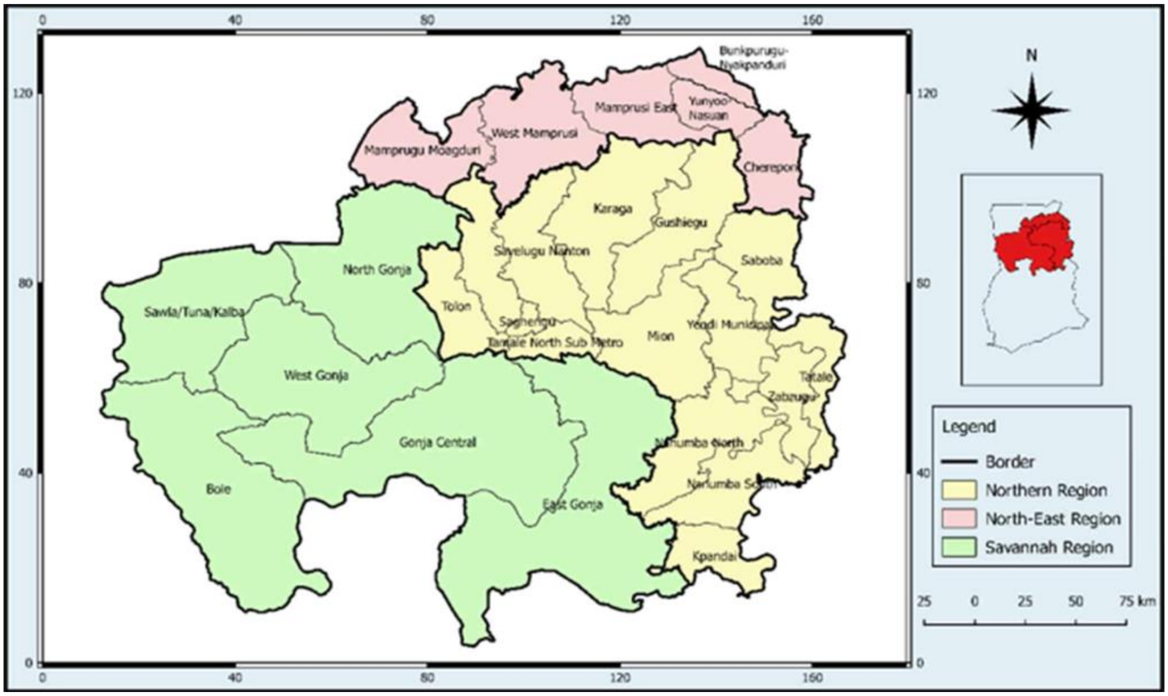


Figure 1: Regional Maps of the Northern and Savannah Regions, showing the Administrative Districts

Source: googlemaps.com

3.3 Data Source

The data used in this study is sourced from a collaborative research survey between the Japan International Research Center for Agricultural Sciences (JIRCAS), CSIR-Savannah Agricultural Research Institute and the University for Development Studies (JIRCAS/UDS/SARI, TERRA Africa Research Project). Titled "Sustainable Land Management in Ghana," the research was done with the aim of establishing efficient means of transferring soil conservation and rejuvenation techniques in Ghana. Conducted from 2022 to 2023, the survey generates descriptives and current information on intensity of SLM practices and their influence on smallholder farmers' welfare.

3.4 Sample Size and Sampling Technique

The sampling procedure used by the JIRCAS-UDS_CSIR Sustainable land Management in Ghana project was multistage sampling. First, fifteen communities were purposively selected base on different SLM practices engaged in the Savannah and Northern regions. A census was then conducted in these communities from which a simple random sampling was used to sample a total of 412 respondents from these communities. The table below presents the total number sampled from each community in the study area.

Table 3. 1 The Complete List of Communities and their Sampled Households in Northern Ghana

Region	District	Community	No. of Sampled Households
Northern	Savelugu	Gushei	30
	Kumbungu	Tarikpaa	34
	Mion	Yabogu	17
	Mion	Chahindanyili	37
	Nanumba South	Bandiyili	28
	Zabzugu	Tasundo	24
	Zabzugu	Sabali	32
	Karaga	Nangunkpang	17
Savannah			
	Central Gonja	Kabilpe	25
	Central Gonja	Zowu	25
	Central Gonja	Biposu	25
	Central Gonja	Chambe	33
	West Gonja	Zaadanting	31
	West Gonja	Laribanga	35
	Daboya Mankarugu	Kupoto	19
Total	9	15	412

Source: Adopted from JIRCAS-UDS_CSIR Consultancy Department, (2023)

The data contained modules of farm and household management, farm information, SLM adoption barriers, SLM adoption, perceived advantages, and welfare impacts like agricultural yields, income, climate resilience, and food protection. Enumerators were thoroughly trained in how to administer surveys to ensure accuracy and the quality of data obtained. Enumerators were trained in the SLM practice farm environments. Electronic data capture equipment was utilized during the interviews to reduce errors and conduct real-time checks on the data. Adding to this strong dataset, the study was able to analyze how SLM practices impact the health of Ghana's smallholder farmers in its savannah and northern savannah regions. The results will be able to give relevant information that can be used in developing specific interventions and policy measures towards advancing sustainable agriculture in the regions.

3.5 The Theoretical Framework on the relationship between SLM Adoption Intensity and farmers' Welfare Outcomes

The Conceptual framework is grounded on the production function theory that offers a mathematical model of analyzing the impact of the level of SLM adoption intensity and the well-being of smallholder farmers in the northern and savannah regions of Ghana whiles utilizing the sustainable livelihoods approach (Shiferaw et al., 2009). According to this model, agricultural production is a function of several inputs such as land, labor, capital, and technology (Coelli et al., 2005). The model also opines that, SLM adoption intensity is shaped by the complex relationships between farmer socio-economic, environmental, and institutional determinants (Issahaku & Abdulai, 2020). These determinants influence farm productivity, ecosystem service provision, and farmers' health. It is championed by the Land Degradation Neutrality (LDN) principle whose aim is to balance land productivity loss by restoration (Kansanga et al., 2019). SLM practices such as mulching, cover cropping, Integrated Pest Management, intercropping, relay cropping, green manuring, row planting, levelling, rhizobium inoculation, zero-tillage practice, crop rotation, inorganic fertilizer, bonding, improve seeds, organic fertilizer are the practices employed to deliver LDN, productivity, and climate change resilience (Okolie et al., 2023). The framework recognizes the influence of farmers' access to market, information, resources, policy and institutional support to the effectiveness and efficiency of SLM uptake (Abass et al., 2018).

To measure welfare impacts of SLM adoption intensity, a mathematical model of the production function is suggested with the integration of ecosystem services valuation and risk assessment.

The model is as follows:

$$Y = f(L, K, SLM, E, S) + \mathcal{E}$$

Where;

Y= Farmers' welfare (Which is measured as Total Household Consumption Expenditure)

L= Labour input

K= Capital input

SLM= Vector of Sustainable Land Management Adoption Intensity

E= Environmental factor (e.g. soil quality, rainfall etc.)

S= Socioeconomic factors (market access, access to information, extension services, level of education etc.)

Ɛ= Error Term

Econometric methods like the control function method or instrumental variables can be used to handle endogeneity (Issahaku and Abdulai, 2020), and stochastic frontier analysis can evaluate the efficiency gain due to SLM adoption intensity (Ankrah et al., 2020). Dynamic and long-term effects are also handled in the model through a multi-period framework. It is mathematically written as;

$$Y\_t = f(L\_t, K\_t, SLM\_t, E\_t, S\_t) + g(SLM\_\{t-1\}, E\_\{t-1\}) + \varepsilon\_t$$

Where g(.) stands for the lagged effects of SLM adoption intensity and environmental conditions on current welfare outcomes. It also enables the estimation of long-term and short-term effects of SLM intensity adoption on farmers' well-being while accounting for any possible time effect on benefit realization with enhanced land management (Azumah et al., 2023). Also, to add the ecosystem services aspect, the model can be extended with a valuation element. Therefore;

$$Y\_t = f(L\_t, K\_t, SLM\_t, E\_t, S\_t) + g(SLM\_\{t\text{-}1\}, E\_\{t\text{-}1\}) + h(ES\_t) + \varepsilon\_t$$

Where ES_t represents the value of ecosystem services like enhanced soil fertility, water holding capacity, and carbon storage (Dawuni et al., 2021). This comprehensive model allows for both short- and long-term analysis of the impact of SLM adoption intensity of highlighting the interconnections between agricultural productivity, ecosystem services, and socio-economic factors in the context of the northern and savannah regions of Ghana.

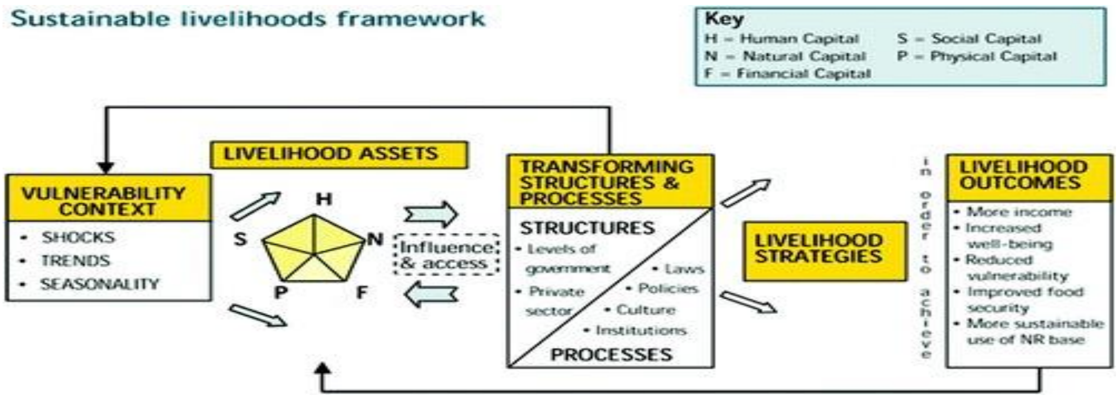


Figure 2: The Sustainable Livelihood Framework (SLF)

Source: Adopted from the modified version of DFID (1990)

3.6 Conceptual Framework on SLM Adoption Intensity and Welfare Outcomes

The conceptual framework is derived from the Sustainable Livelihood Framework (SLF) as presented in Figure 2 below. The (SLF) focuses on how people use livelihood assets (human, natural, financial, social, and physical) in a context of shocks, trends, and seasonality to diversify into other livelihood portfolio of activities geared towards the improvement of their standard of living. The choice of strategies is mediated by structures (e.g. Government, NGO's) and processes (e.g. Laws, policies, culture, institutions) and results in livelihood outcomes, such as income, food and livelihood security (Khatiwada et al., 2017). In contextualizing this, the (SLF) will serve as a structural guide to help us understand the complex relationships between different factors that affect the livelihoods of smallholder farmers through their choice of intensifying their level of SLM adoption based on the available assets. The five elements of the SLM framework are Vulnerability context, Assets, Livelihood Strategies, Institutions and Policies, and Welfare Outcomes. Adoption intensity of SLM practices will influence the welfare outcomes of smallholder farmers through several channels.

This theoretical foundation draws on the production function theory in the understanding that, the intensity of SLM adoption intensity will increase the productivity of farmers, and subsequently resulting in higher incomes and a better food security status of smallholder farmers in northern Ghana. This can be expressed mathematically as;

$$\frac{\Delta Y}{\Delta SLM} = \frac{\partial f}{\partial SLM}$$

Where $\frac{\Delta Y}{\Delta SLM}$ represents marginal change in welfare outcome as a result of the intensity of SLM adoption. Second, the intensity of SLM adoption should encourage smallholder farmers to adopt more sustainable livelihood strategies, e.g., crop diversification and livestock rearing, which reduce their exposure to external shocks. This can be mathematically written as;

$$SLM = g(X, Z, R)$$

Where g(.) is a function representing the correspondence between SLM adoption intensity and the numerous determinants affecting it. Third, SLM adoption intensity will grow smallholder farmers' stocks of assets, for instance, natural capital and social capital, and labor that are important to their livelihood success. Hence the mathematical expression will be;

$$A = h(SLM, K, Z, L)$$

Where A is a vector of assets and $h(.)$ is a function that represents the relationship between assets and the various factors that influence them. Finally, SLM adoption intensity is influenced by socio-economic factors, environmental, institutional and policy factors, such as rainfall patterns, government policies and market institutions, which can either support or prevent the adoption intensity of SLM practices. This can be represented mathematically as;

$$SLM = j(S, E, I, P)$$

Where S is a vector of socio-economic factors, E is a vector of environmental factors, I is a vector of institutional factors and P is a vector of policy factors. In conclusion, this integrated conceptual framework provides a comprehensive and realistic understanding of the relationships between SLM adoption intensity and welfare outcomes of smallholder farmers in the northern and savannah regions of Ghana. Based on the assets available, farm households are able to choose a livelihood diversification strategy in the context of factors either "pushes" or "pulls" them to intensify their level of SLM adoption which directly determines their livelihood income and general welfares outcomes.

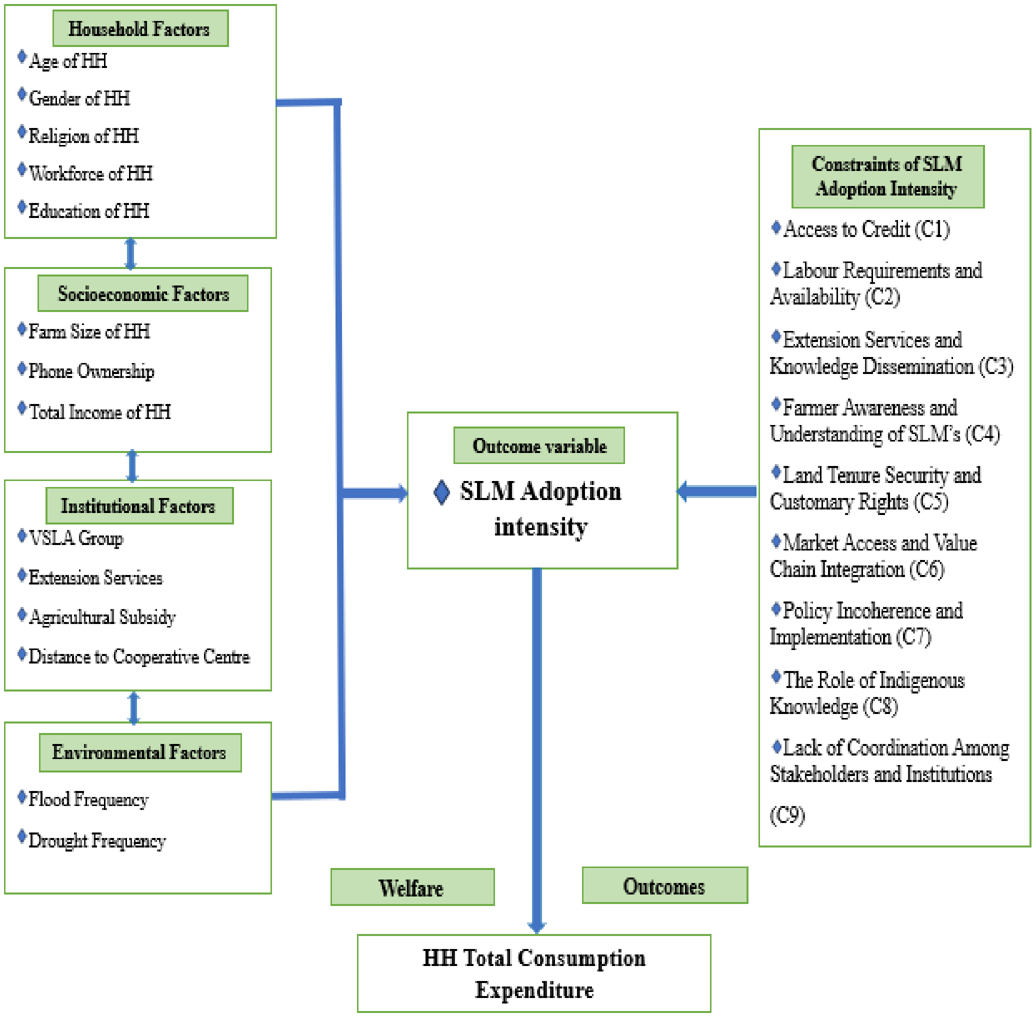


Figure 3: The Conceptual Framework on Adoption Intensity of Sustainable Land Management Practices and Welfare Outcomes of Smallholder Farmers in the Northern and Savannah Regions of Ghana.

Source: Author's conceptualization (2025)

3.7 Analytical Framework

This section used different econometric models and descriptive statistics to obtain the three primary research objectives. First, descriptive statistics of means, frequencies graphs and tables were employed to analyze the determinants, welfare implications, and constraints of sustainable land management practices adoption intensity among smallholder farmers in Northern and Savannah zones of Ghana. The subsection will also look at the estimation of the various determinants of SLM adoption intensity and the socioeconomic determinants of smallholder farmers in Ghana's northern and savannah belts in increasing their intensities of adopting sustainable land management practices (SLM), then estimating the impacts of SLM adoption intensity on farmers' welfare, using the total household consumption expenditure as a welfare measure and lastly determining the different constraints that deter smallholder farmers from increasing the adoption of SLM practices. The models to be utilized are the Standard Poisson Regression model to predict SLM adoption intensity, the Control Function model to predict the causal impacts of the intensity of SLM adoption on the welfares of smallholder farmers whiles correcting for the possibility of endogeneity and lastly, the Kendall's Coefficient of Concordance will be employed to determine as well as order the different constraints inhibiting the farmers from advancing their adoption levels of SLM practices in the northern and savannah zones of Ghana to greater levels.

3.7.1 The Standard Poisson Regression Model to Estimate Determinants of SLM Adoption Intensity

The Standard Poisson Regression is used to model the determinants of the adoption intensity of sustainable land management (SLM) among smallholder farmers. The level of adoption intensity, which measures the number of SLM practices a farmer adapts, constitutes count data with a perfect fit for the Poisson distribution. The aim is to analyze the socioeconomic determinants of the rate of SLM adoption intensity. Again, the model is used mainly due to the fact that strength of SLM uptake can be expressed as a count variable, i.e., the amount of SLM practice followed by one farmer. Furthermore, the strength of SLM adoption intensity is also discrete and non-negative outcome variable and satisfies the assumptions of Standard Poisson model. Second, the model uses the assumption that the variance and mean of the outcome variable are equal, which is generally a good assumption for count variables. Therefore, in the case of SLM adoption intensity, the variance and mean of the adoption intensity could be equal and therefore it is a better model for it. Additionally, the basic Poisson model can be estimated with the maximum likelihood estimation, which is a widely used and effective method. It can be generalized or extended to accommodate more complex data structures or relations. For example, the negative binomial model may be employed to handle overdispersion, while the zero-inflated Poisson model may be employed to handle excessive zeros in the data. In general, the Standard Poisson model is a suitable model to apply in estimating determinants of the intensity of SLM adoption by smallholder farmers in the northern and savannah zones of Ghana. For this purpose, its capacity to accommodate count data, non-negative and discrete outcomes as well as offering interpretable estimates makes it a suitable econometric measure for this type of analysis.

3.7.1.1 An Econometric Model Diagnostic Test and Comparison Using Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC)

Also, a model diagnostic test between the Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) was used to check the goodness-of-fit of statistical models, where lower values indicate a better model fit vs. complexity trade-off. In this case, the Standard Poisson Regression Model with AIC value of 1456.856 and BIC is 1505.108, while the Negative Binomial Model has an AIC of 1458.856 and BIC is 1511.130. Since the AIC and BIC values of the Standard Poisson Model are lower by a small amount compare to the Negative Binomial Model, what this implies is that the Standard Poisson Model is more adequately and marginally better fit to the data while been simpler (with 12 degrees of freedom compared to the 13 for the Negative Binomial Model). The implication of this is that the extra complexity of the Negative Binomial Model isn't properly improving the model fitness and hence not enough to justify its usage over the Standard Poisson Model. However, the AIC difference between the two models (2.0) is not large, and thus the two models are very similar to each other in fit. The rule is that if the difference in AIC is less than 2, it means both models are extremely close to each other and thus the Standard Poisson Model is ultimately better in this case. Conversely, though the BIC difference (6.022) is greater, punishing more the model complexity, and again validating the selection of the Standard Poisson Model as the simpler one. This suggests that the Standard Poisson Model would be most likely adequate in estimating the determinants of SLM adoption intensity without over-specifying the analysis. Finally, on AIC and BIC considerations, the Standard Poisson Regression Model seems to be the better one for this analysis. It fits equally well with the Negative Binomial Model but is simpler, which agrees with the principle of choosing the simplest model that fits the data best. Hence, the Standard Poisson Model can be considered adequate for determining determinants of SLM adoption intensity.

Table 3. 2: Model Diagnostic Test and Comparison Using AIC and BIC

Akaike's information criterion and Bayesian information criterion		ll(null)	ll(model)	df	AIC	BIC
Standard Poisson Model	412	-793.324	-716.428	12	1456.856	1505.108
Negative binomial model	412	-785.352	-716.428	13	1458.856	1511.130

Note: BIC uses N = number of observations

Table Source: Author's Calculation

The Standard Poisson Regression model can be specified as follows:

$$P(Y_i = y_i|X_i) = \frac{{\lambda_i}^{y_i} e^{-\lambda_i}}{y_i!}, \quad y_i = 1,2, \ldots$$

Where $Y_i$is the number of SLM practices adopted by farmer i, which follows a Poisson distribution with mean λ_i, where λ_i represents the expected number of SLM practices adopted;

The expected value λ_i is modeled as an exponential function of a vector of explanatory variables X_i;

$$\lambda_i = \exp(\beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_k X_{ki}) + \mathcal{E}_i$$

Where;

- $Y_i =$ is the number of SLM practices adopted,
- $X_{i1}, X_{2i}, \ldots, X_{ki}$ represent the socioeconomic explanatory variables that influence SLM adoption (e.g., education level, farm size, access to credit, etc.),
- $\beta_0, \beta_1, \ldots, \beta_k$ are the coefficients to be estimated.

Socioeconomic factors that could influence adoption intensity include, farmers with more formal education are more likely to adopt sustainable practices Oluwaseun et al.

(2024). Larger farms may have more capacity for adopting multiple SLM practices. Likewise, access to credit increases financial resources and enable farmers to invest in SLM (Issahaku & Abdulai, 2020).

Necessary Conditions for the Poisson Model are as follows;

1. Non-Negativity: The dependent variable (number of SLM practices adopted) must be non-negative.

2. Equidispersion: The Poisson model assumes that the mean and variance of the dependent variable are equal, i.e.,$E(Y_i) = Var(Y_i) = \lambda_i$ If this assumption is violated (i.e., overdispersion occurs where the variance exceeds the mean), a Negative Binomial regression might be more appropriate.

3. Independence: The counts for each observation (farmer) should be independent of each other.

4. No Excess Zeros: The Poisson model assumes that the proportion of zeros in the dependent variable is not excessively high. If there are many zero-adopters, a Zero-Inflated Poisson model might be needed.

The estimated coefficients in the Standard Poisson Regression model will provide us with more precise information into how the various socioeconomic factors such as age, education, farm size, access to extension services and access to credit influence the number of SLM practices a farmer adopts in boosting their agricultural outputs.

3.7.2 The Control Function Model for Estimating the Effect of SLM Adoption Intensity on Welfare Outcomes

The Control Function model is used to estimate the effect of SLM adoption intensity on farmers' welfare, while seeking to address any potential endogeneity issues (i.e. the correlation between the explanatory variables and the error term). In this case, the control function model introduces an additional term known as the residual which will account for the presence of endogeneity whiles at the same time, recover consistent estimates of causal effects. The adoption intensity of SLMs may directly influence a farmer’s welfare, which is typically measured by their household consumption expenditure, while simultaneously a farmer’s welfare may also impact their ability to adopt the various SLM practices. Interestingly, the control function model can be combined with instrumental variables (IV) estimation to address the endogeneity problem. The IV estimation will help identify the causal effect of SLM adoption intensity on welfare outcomes by exploiting the exogenous variation in SLM adoption intensity. This can generate a robust estimate of the effect of SLM adoption intensity on well-being outcomes relative to other econometric models because it accounts for the possibility that there can be endogeneity of SLM adoption intensity. Again, this econometric model will enable us to address the problem of selection bias. Hence, the adoption of SLM practices can make smallholder farmers different from non-adopters in observable and unobservable factors. For instance, adopting farmers may be more likely to have access to extension services, credit, or markets, which also influence their welfare outcomes. The control function model can address such differences by controlling for the induced selection bias which will then enable one to quantify SLM adoption intensity impact on welfare outcomes more precisely, as it compensates for differences in adopters and non-adopters. Finally, the control function model quantifies the impacts of intensity of SLM adoption on farmers' welfare outcomes over time. This is most appropriate in the case of smallholder farmers, where farmers welfare outcomes can vary over time based on factors such as climate change, market volatility, or policy interventions. In estimating the impact of SLM adoption intensity on farmers welfare outcomes over time, the control function model can be more informative in terms of the intricate relationship between SLM adoption intensity and smallholder farmers welfare outcomes.

1. Adoption Equation (First Stage): Models and estimates the likelihood of adopting SLM as a function of socioeconomic factors. It can be expressed mathematically as;

$A_i = \alpha_0 + \alpha_1 X_{1i} + \alpha_2 X_{2i} + \alpha_3 Ext_{3i} + \cdots + \alpha_k X_{ki} + v_i$.........................(1)

Where;

- $\mathrm{A_i}$: is a binary variable indicating whether household i has adopted SLM's (1 = adopted, 0 = not adopted),
- Ext_i: Access to extension services by household i,(Instrumental Variable)
- $X_{1i}, X_{2i}, \ldots, X_{ki}$: are vector of other exogenous covariates affecting SLM adoption of household i, (education, farm size, access to credit, etc.),
- v_i: is the error term capturing unobserved factors affecting adoption.

2. Welfare Equation (Structural Equation): Models the welfare outcome (measured by consumption expenditure) as a function of SLM adoption intensity. It can be expressed mathematically as;

$W_i = \beta_0 + \beta_1 A_i + \beta_2 Z_{1i} + \beta_3 Z_{2i} + \cdots + \beta_p Z_{pi} + v_i$.........................(2)

Where;

- W_i is the welfare outcome of household i, measured as consumption expenditure,
- A_i is the adoption intensity variable from the first equation,
- $Z_{1i}, Z_{2i}, \dots, Z_{pi}$ are vectors of the exogenous variables (household size, farm income, etc.),
- υ_i is the error term capturing the unobserved factors affecting welfare.

Addressing the Endogeneity with the Control Function Approach;

Thus, to correct the endogeneity of A_i in the Welfare Equation:

1. First Stage Regression:

We estimate the adoption equation using Ordinary Least Squares (OLS) to obtain the residuals Û:

$$\hat{U}_i = A_i - (\hat{a}_0 + \hat{a}_1 X_{1i} + \hat{a}_2 X_{2i} + \hat{a}_3 Ext_{3i} + \cdots + \hat{a}_k X_{ki})$$

2. Second Stage Regression:

Here, we include the residual $\hat{U}_i$ as an additional regressor in the welfare equation

$$W_i = \beta_0 + \beta_1 A_i + \beta_2 Z_{1i} + \lambda \hat{U}_i + \cdots + \beta_k Z_{ki} + \varepsilon_i$$

Where;

- $\hat{U}_i$ serves as the control function to account for the endogeneity of A_i
- β, λ are parameters to be estimated

The Empirical Model Specification of the Control Function Using the System of Equations;

1. For the Adoption Equation;

$Adopted\ SLM_i$ (1 = adopted, 0 = not adopted) $= \alpha_0 + \alpha_1 Age\ HH_{1i} +$

$\alpha_2\ Gender\ of\ HH_{2i} + \alpha_{3i} Ext\_Services_{3i} + \alpha_4 Number\_Workforce_{4i} +$

$\alpha_5 Land\_Size_{5i} + \alpha_6 Agric\_Subsidy_{6i} + \alpha_7 Edu\_Level\ HH_{7i} + \alpha_8 Income\ HH_{8i} +$

$\alpha_9 VSLA\_Group_{9i} + \alpha_{10} Reason\_Loan_{10i} + \alpha_{11} Dist\_Cooperative_{11i} +$

$\alpha_{12} Savings\ HH_{12i}$ ....(1)

2. For the Welfare Equation (Measured by Total Household Consumption Expenditure);

$Welfare\ Outcome_i = \alpha_0 + \alpha_1 Age\ HH_{1i} + \alpha_2\ Gender\ of\ HH_{2i} +$

$\alpha_{3i} Edu\_Level\ HH_{3i} + \alpha_4 Number\_Workforce_{4i} + \alpha_5 Land\_Size_{5i} +$

$\alpha_6 Agric\_Subsidy_{6i} + \alpha_7 Income\ HH_{7i} + \alpha_8 VSLA\_Group_{8i} + \alpha_9 Reason\_Loan_{9i} +$

$\alpha_{10} Dist\_Cooperative_{10i} + \alpha_{11} Savings\ HH_{11i} + \alpha_{12} Adopt\ Count\_Square_{12i} +$

$\alpha_{13} Residual_{13i}$...................................(2)

Where α, β, are the variables and coefficients to be estimated.

The use of the control function model allows us to test whether there is a possible endogeneity of SLM adoption intensity (as adoption may be dependent on welfare levels), and it also gives us comparable and unbiased estimates for the adoption and the welfare equation. Extension Services is used as an Instrumental Variable: In using this model, extension service is employed as an instrumental variable (IV) to take care of a potential endogeneity of SLM adoption in the welfare equation. For the instrument z_i(extension services) to be valid, it must meet two underlined conditions of its relevance and exogeneous in this context.

The Relevance Condition: Extension services must be correlated with the endogenous variable A_i (SLM adoption intensity). Thus, extension service is relevant as an instrument because extension services offered to smallholder farmers can influence agricultural practices and land use decisions. For instance, extension services, such as agricultural trainings on fertilizer, chemical and improve seed usage, information on how to combine the various SLM practices, may promote sustainable farming and environmental stewardship, leading to greater adoption intensities of SLM's (Abdoulaye and Abdulai, 2020). This makes extension services relevant as it influences adoption, but not directly the welfare outcome. I also conducted an instrumental validity test, by calculating for the F-Statistic for the first-stage regression to verify whether extension services as an instrumental variable meets the relevance condition. Interestingly, after estimating the first-stage the results showed that, the F-Statistic value was greater than the threshold value of 10 (F-statistic = 33.36, $p < 0.000$) and also the probability values were found to be significant (Prob > 0.0000), thus indicating that the instrument is strongly correlated with the endogenous variable, passing the rule-of-thumb threshold of 10 for weak instrument tests. I therefore concluded that, the instrumental variable (i.e. extension services) is highly relevant. However, for the sake of simplicity the further details of all this results output can be seen in the appendix of the thesis including the Durbin-Wu-Hausman test for a potential endogeneity presence.

The Exogeneity Condition: Extension services should not directly affect the welfare outcome W_i (consumption expenditure), except through its influence on SLM adoption. Thus, extension services must not be correlated with the error term. In other words, while extension services may influence whether a farmer adopts SLM's or not, it should not independently affect consumption expenditure. This ensures that the only way extension services influences welfare is through its effect on adoption, making it a valid instrument for the model estimation (Dawuni & Mabe, 2021). Now to check whether the exogeneity condition is met, I resorted to using the under-identification test (Anderson LM Test), where the test clearly states that, if the test rejects the null hypothesis of under-identification, it indicates that the instrumental variable is exogenous and hence valid. As it is clearly seen in my case where the test results of the under-identification test (Anderson LM test) where, the (Chi-square (1) = 31.62, $p < 0.000$) and hence we reject the null hypothesis of under identification, confirming that the instrument is valid.

Therefore, by this careful and correct evaluation of the exogeneity and relevance condition, it can be concluded that the existence of a potential endogeneity problem was curtailed which automatically give rise to a more confident and validity pronouncement on the instrumental variable estimates of its accuracy in assessing the effects of SLM adoption intensity on the welfare outcomes of smallholder farmers in the northern and savannah regions of Ghana.

3.4.3 The Kendall Coefficient of Concordance Rankings of the Various Constraints Farmers Face in Intensifying the Adoption of SLM Practices.

The Kendall coefficient of concordance (W) was used to evaluate the level of agreement among farmers regarding the ranking of the constraints they face in intensifying the adoption of sustainable land management (SLM) practices. This approach focuses on understanding the degree of consensus on the various barriers to SLM adoption intensity and their association with farmers' welfare outcomes, particularly in the northern and savannah regions of Ghana. The model is structured to examine critically the various constraints and their effect on the rates of adoption and subsequently farm household welfare outcomes in such areas. In addition, one of the foremost reasons why utilization of this model has been utilized is that it is non-parametric, thus does not involve exceptional distributional assumptions of the data. Therefore, because we have ranked or ordinal data as is common with survey data on the intensity of SLM adoption constraints. Again, use of this model is because, it provides immunity against outliers or extreme values in the data. This is crucial when working with survey data, which can have outliers or extreme values due to response errors or otherwise. The model also supports tied rankings, such that tied rankings occur when there are many constraints to be ranked by the respondents. Therefore, it provides better rankings estimates even in situations with tied rankings. Finally, the Kendall coefficient of concordance offers flexibility in its estimations of different types of data, including ordinal, interval, and ratio data. This flexibility makes it makes a useful method for estimating the rankings of the various constraints of SLM adoption intensity on the welfare outcomes of smallholder farmers in the northern and savannah regions of Ghana.

Mathematically, the model can be written as;

$$W = \frac{12\sum_{j=1}^{m} T_j^2 - 3n(m+1)^2}{n(m^2-1)}$$

Where;

- W =Kendall's coefficient concordance
- n =Number of farmers (Respondents)
- m = Number of constraints being ranked
- T_j^2 = Sum of squared ranks assigned by farmers to constraints j across n farmers

Table 3. 3 : The Constraints Rankings of SLM Adoption Intensity of Smallholder Farmers

Various SLM Constraints	Definition	Measurement
Lack of Access to Credit	SLM Constraint 1	Rank=1
Labor Requirements and Availability	SLM Constraint 2	Rank=2
Extension Services and Knowledge Dissemination	SLM Constraint 3	Rank=3
Farmer Awareness and Understanding of SLM Practices	SLM Constraint 4	Rank=4
Land Tenure Security and Customary Land Rights	SLM Constraint 5	Rank=5
Market Access and Value Chain Integration	SLM Constraint 6	Rank=6
Policy Incoherence and Implementation Gaps	SLM Constraint 7	Rank=7
The Role of Indigenous Knowledge and in SLM Adoption	SLM Constraint 8	Rank=8
Lack of Coordination Among Stakeholders and Institutions	SLM Constraint 9	Rank=9

Table Source: Author's Calculation

The above table presents the various SLM Adoption Intensity constraints hindering smallholder farmers from intensifying their level of SLM adoption in the northern and savannah regions of Ghana, ranging from Constraint 1 as the highest ranked constraint down to constraint 9 as the lowest ranked constraint in that order.

Also, the Kendall W statistic ranges from 0 to 1,

where;

$W = 0$ indicates no agreement among the farmers on the ranking of constraints

$W = 1$ indicates perfect agreement

This coefficient will help in understanding how strongly the identified constraints affect the adoption of SLM practices. A higher W value indicates greater agreement among farmers regarding the importance of a particular constraint.

This formulation allows us to assess how farmers shared views on specific constraints influence their welfare outcomes. Previous studies, such as Nkegbe & Shankar (2014) and Issahaku & Abdulai (2020), have explored similar constraints affecting agricultural practices in Ghana, highlighting the importance of credit access, extension services, and market integration in shaping farmers' decisions. Moreover, research by Dawuni et al. (2021) and Azumah et al. (2023) has explored the role of land tenure and indigenous knowledge systems in shaping agricultural practices in northern Ghana.

To conclude, the Standard Poisson Regression Model, and the Control Function Model provides a robust framework for analyzing the determinants of SLM adoption intensity and its impact on the welfare of smallholder farmers. The Standard Poisson model estimates adoption intensity. The Control Function model, using extension services as an instrumental variable, allows for a causal analysis of the impact of SLM adoption intensity on welfare (measured by consumption expenditure), while accounting for endogeneity. Additionally, the Kendall coefficient of concordance model evaluates how consistently farmers perceive barriers to SLM adoption intensity and link these perceptions to welfare outcomes. This multi-model approach not only identifies the most significant constraints but also assists policymakers in addressing the most commonly agreed-upon barriers to improving SLM adoption rates and welfare outcomes of farm households in the regions.

Together, these models form a comprehensive framework for understanding the socioeconomic factors influencing SLM adoption intensity and its welfare implications in the northern and savannah regions of Ghana.

3.6 Definition of Variables, Measurement and A priori Expectations

From table 3.1, the study hypothesizes that various factors influence the adoption intensity of Sustainable Land Management (SLM) practices and the welfare outcomes of smallholder farmers in northern Ghana. The dependent variable is total household consumption expenditure, and household specific, socio-economic, institutional, and environmental variables are hypothesized to influence both SLM intensity of adoption and welfare outcomes. These variables are investigated with the hope that they pose opportunities for promoting farmers to adopt more intensive SLM practices, which will improve crop yields, farm incomes, and living standards.

First and foremost, the age of the head of household may have a dual effect on SLM intensity and income levels. Experienced older farmers may be reluctant to change practices, which will negatively affect SLM intensity. The experience, however, may increase productivity and therefore income, so a positive effect with income levels. Younger farmers, while more open to innovation, may lack the necessary resources to fully exploit SLM benefits. Again, male-headed households will be more resourceful and informed, and thus potentially higher SLM practice adoption rates and income. Female-headed households would, however, be more responsive to more sustainable practices, particularly those that mitigate labor intensity or improve food security, to higher levels of more sustainable practices and possibly improved welfare. Religion can also have an influence on the adoption of SLM through neighborhood networks and social norms. Conformity with a dominant religion may improve information sharing and coordination, which will have beneficial consequences for SLM adoption as well as income outcomes. However, the direction of impact might vary with respect to the specific religious context. Moreover, increased labor supply allows for the employment of labor-based SLM practices and the management of various farming activities. This factor is bound to have a positive impact on both SLM adoption intensity and income through increasing productivity and enabling increased involvement in farm work. Increased education is also bound to enhance both SLM adoption intensity and income. Trained farmers are likely to be more aware of the advantages of SLM practices and have better available information and knowledge for conducting advanced agricultural practices effectively. Socio-economically, and as a surrogate for information and technological availability, mobile phone ownership is expected to be positively effective on SLM adoption intensity where it will provide farmers with access to weather information, market prices, and agricultural advice. The effect on income could be mixed, depending on how effectively this technology is leveraged in agricultural practices. Additionally, larger farms typically have more resources to invest in SLM practices and the potential for economies of scale. This factor is expected to positively affect both SLM adoption intensity and income by allowing farmers to implement more intensive, resource-efficient practices and achieve higher productivity. Again, with total household income, wealthier households can afford the initial costs of adopting SLM practices, such as investment in technology or infrastructure. While this relationship is expected to be positive, the effect on future income may exhibit diminishing returns as wealthier households might reach a saturation point in terms of the benefits, they can derive from additional adoption intensity. Institutional factors such as extension service access will be likely to boost SLM intensity and income levels of adoption through equipping farmers with the expertise and information needed for sustainable agriculture adaptation. Useful guidance on adaptation of practices into local contexts may also be given by extension agents. More critically, Village Savings and Loan Associations (VSLAs) may offer farmers access to credit, savings, and knowledge sharing. These services can finance both adoption and income levels by providing farmers with the financial resources to invest in SLM measures and enhance farm productivity. Subsidies will also tend to support the level of adoption of SLM measures by lowering implementation costs. Short-run impacts on income can be positive since farmers can utilize money to invest in enhancing, but long-run impacts can be mixed depending on the sustainability of subsidy schemes. It is worth mentioning that longer distances to cooperative centers will have a tendency to discourage access to resources, markets, and mutual benefits. This variable will have a negative impact on both the adoption level of SLM and income benefit because of the additional costs and amount of time it takes to obtain cooperative resources. Finally, environmental variables such as flood frequency might encourage farmers to raise the adoption level of SLM measures that reduce flood risks, for example, advanced water management systems. Still, the occurrence of floods also impairs income by destroying crops and infrastructure and hence inhibiting income generation. Further, droughts can encourage farmers to implement water-saving SLM measures, e.g., water conservation strategies for soil or crops that are drought-resistant. Nonetheless, similar to floods, droughts will impair income, as they lower crop yields and boost supplemental irrigation requirements. Also covered is the topic of non-linear effects, and the squared adoption intensity term for SLM is introduced to capture any potential non-linear effects. Adoption intensity and income would both be predicted to have positive associations but which weaken after a certain level of adoption, that is, the payoffs of higher levels of SLM practices stop after a certain level is exceeded. Lastly, aggregate household spending, as a proxy for investment capability, may have counter-intuitive implications for income. While increased spending may be an indicator of investment in productive assets and resulting increased incomes, excessive spending can diminish the available capital to undertake future upgrade investments, potentially to set an upper bound on income growth. These a priori assumptions constitute a general framework of analysis for testing the dynamic determinants of SLM adoption intensity and income levels across northern Ghanaian smallholder farm households. Empirical observation will take the central role in confirming these relations and establishing any spurious interactions or local heterogeneity. Empirical knowledge of such determinants is important for policymakers to enable them to design appropriately targeted interventions to enhance the intensity of SLM adoption, enhanced well-being of farm households, and elimination of the intended barriers that trap the smallholder farmers in this situation.

Table 3. 4: Definition of Variables, Measurements and A priori Expectations

Variables	**Measurement**	**Apriori Expectations**	
Household Specific Factors		**SLM Adoption Intensity**	**Consumption Expenditure**
Age(years)	Years	+/-	+/-
Household Head Gender	Dummy (1=Male, 0=Female)	+/-	+/-
Household Head Religion	Category (1=Christianity, 2=Islam, 3= Traditional, 4=Others)	+	+
Household Head workforce	Count	+	+
Household Head Level of Education	Category (1= Primary, 2= JHS, 3= SHS, 4=Tertiary, 5= Others)	+	+
Socioeconomic Factors			
Total Farm Size	Numeric (Acres)	+	+
Phone Ownership	Dummy (1= Yes, 0= No)	+/-	+/-
Total Household Income	GH₵	+	+
Institutional Factors			
VSLA_Group	Dummy (1= Yes, 0=No)	+	+
Extension Services	Count	+	+
Subsidy Received	Dummy (1= Yes, 0=No)	+	+
Distance to Cooperative Center	Kilometers (Km)	+/-	+/-
Environmental Factors			
Flood Frequency	Count	+	+/-
Drought Frequency	Count	+	+/-

Table Source: Author's Calculation

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents the empirical findings of the study. Descriptive statistics of household-demographics characteristics, socio-economic factors, and institutional factors, which are identified to determine adoption intensity of Sustainable Land Management practices and their impact on smallholder farmers' welfare outcomes are elaborated in section 4.2. Section 4.3 elaborates the Poisson estimates of different determinants that determine adoption intensity of Sustainable Land Management (SLM) practices. Whiles section 4.4 will examine how the intensity level of adoption of Sustainable Land Management practices affects savannah and northern farm household welfare outcomes employing the Control Function Approach Method and taking extension services as a legitimate instrumental variable for the welfare as well as adoption equations. Section 4.5 will seek to unravel the various constraints that hinders smallholder farmers in the two regions from adopting SLM practices. This will be analyzed using the quantitative approach, i.e. econometric analysis, followed by concluding on the findings of the results estimation.

4.2 Summary Statistics of the Various Factors Influencing the Adoption Intensity of SLM practices in the Northern and Savannah Regions of Ghana.

The socioeconomic factors presented in table 4.1 shows a clear description of those factors that are influencing the Intensity of adoption of Sustainable Land Management Practices (SLMs) in Ghana.

To begin with, the mean age of household respondents is 41.9 years (SD = 14.1), which shows a mostly middle-aged farming population, as is the case with wider trends in Ghana's agricultural sector. According to Ummah (2019) reports, the farming population is aging, with younger generations leaving the rural areas to urban areas in greater proportions. This age profile could have mixed impacts on the extent of SLM adoption but more experienced and better-off older farmers could be in a position to invest in new technologies and at the same time are more traditional and recalcitrant, which implies that there should be focused education and extension inputs. Once more, the mean farm size is 12.7 acres (SD = 12.2), much larger than the Ministry of Food and Agriculture (MoFA) reported national average of 3.2 acres in 2017. This therefore implies that the sample in the study might be representative of commercial or established farmers. Larger farm sizes have the capacity to accommodate SLM adoption intensity since these farmers have space to test new methods. This is also supported by research conducted by Etwire et al. (2022) which revealed that farmers with more extensive farm sizes were more inclined to adopt SLMs. The high land size standard deviation reflects high land size heterogeneity and implies diversity in land ownership, which affects the adoption of SLMs for varying sizes of farms. Additionally, the mean number of people per household is 4.1 (SD = 3.6) and aligns with the mean household size of Ghana. This is a critical variable for the intensity of SLM adoption, particularly for labor-intensive practices. Further research findings from Nketia et al. (2018) established that labor-abundant households were likely to adopt soil and water conservation measures. A high standard deviation, thus, indicates that family sizes were highly unlike one another, which would have a possible effect on the capacity of different families to adopt SLM practices with labor. The income data are completely unstable with a mean income of 5,479 GHS and much too wide a standard deviation of 49,560 GHS. This provides the broader inequality of incomes in Ghana, which is seen by the Gini coefficient for Ghana being 43.5 (Diaz-bonilla & Lakner, 2024). Wealthier farmers can afford to intensify their adoption of SLM's, while poorer farmers can be limited by lack of funds. Richer farmers have been quoted by a study conducted by (Antwi-Agyei & Nyantakyi-Frimpong, 2021) as more likely to adopt climate-smart agriculture since they would be capable of weathering shocks and paying for new technology. The income disparity points towards the possibility of having the need for incentive or support policies to promote intensity of SLM adoption by poor farmers. Moreover, distance to cooperative centers is a mean of 10.8 km (SD = 13.6) and influences farmers' access to farm inputs as well as to agricultural information. Distance has also been reported to affect the uptake of new agriculture methods, where farmers residing in the vicinity of regions of population tend to uptake (Abass et al., 2018). Irregular dispersion of distances results in uneven access to valuable resources, a variable that would likely influence the intensity of SLM uptake based on regions. For example, while older age farmers will possess greater land and resources, they will also be further away from cooperative centers or will have fewer members of their household on whom they can rely to share labor for labor-intensive practices. Younger farmers, however, may be more susceptible to the uptake of innovations but are limited by small farm sizes and low incomes. On the basis of financial involvement, 23.06% of the respondents are members of Village Savings and Loan Associations (VSLAs), and 33.98% involve themselves with other financial associations, whereas 42.96% are not members of any such association. This is a sign of evidence and increased relevance of rural community-based financial institutions in Ghana since VSLAs are now at the center of scaling up financial outreach and investment in rural agricultural settings. The finding is backed by Antwi-agyei et al. (2018) who asserted that, joining VSLAs raises savings capacity and investment in sustainable agriculture. Evidence of the vast coverage of membership under VSLAs and other savings unions demonstrates the scope for spreading as well as increasing SLM adoptions through such unions, though nearly 43% of the respondents interviewed are members of no financial groups, thus offering space for growth in such unions. Moreover, gender output in table 4.1 shows that 77.67% of the household heads are male and 22.33% are female. This disparity represents cultural norms within Ghanaian farm society as female-headed households are at a disadvantage when it comes to adopting new farming practices because they are excluded from access to the resource assets such as land, credit, and extension (Dzanku et al., 2024). This disparity has the potential to impact SLM adoption rates. For example, male-headed households enjoying a comparative advantage over improved access of these resources compare to their female counter-parts. Specific gender gap policies have an important role to ensure everyone has equal access to sustainable agricultural methods. Notably, the rate of mobile phone ownership has exceeded expectation, with 91.02% of the respondents indicating they possessed a mobile phone. The access to mobile technology is high and therefore offers a potential opportunity for agricultural growth as it is possible to use mobile phones to exchange information on sustainable farming, receive weather forecasts, and gain access to agricultural inputs and markets (Ankrah et al., 2020). However, even as phone ownership is common, it does not necessarily mean that the phones are being used optimally for agricultural purposes, which is why training and associated mobile-based services are necessary. Also, access to extension services is nearly evenly divided, with 50.49% of farmers having access and 49.51% without access and thus conceals the possible variations in the quality and quantity of services offered. Further studies have shown that consistent contact with extension services has been proven to increase the adoption of sustainable practices (Antwi-Agyei et al., 2015). The fact that nearly half of the respondents lack access suggests a significant barrier to SLM adoption intensity. Improving the reach and quality of extension services, perhaps through mobile or farmer-to-farmer models, could help boost the uptake of sustainable practices. Again, flood frequency data reveals that 63.11% of respondents experienced at least one flood event in the past five years, with 12.14% experiencing floods every year which further highlights the vulnerability of Ghanaian agriculture to climate change. Again, empirical studies from Asante et al. (2024) found that frequent floods drive farmers to adopt more resilient farming practices, suggesting that farmers in flood-prone areas may be more open to intensify the adoption of flood-resistant SLM practices. Surprisingly, only 14.32% of respondents received subsidies for agricultural inputs, indicating limited government support for SLMP adoption. This low subsidy rate could be a barrier, particularly for practices requiring initial investments. Furthermore, Etwire et al. (2022) found that input subsidies in Ghana significantly influenced the adoption intensity of sustainable practices, suggesting that expanding or redesigning subsidy programs could help encourage SLM adoption intensity. Moreover, drought experience is widespread, with 78.64% of respondents reporting droughts during the year, underlining the pervasive risk of drought in the study area. This experience would increase the awareness of drought-resilient agriculture, and hence farmers will be more likely to intensify their adoption of SLM practices (Antwi-Agyei & Nyantakyi-Frimpong, 2021). On the other hand, the level of education among the household heads is woefully low, with 67.72% of them never having been to school. Such a low level of education may be a limitation to the adoption of more technology-based SLM's, particularly those that rely on knowledge-intensive practices. Other findings from Yahaya et al. (2024) noted that greater levels of education were associated with greater intensity of adoption of SLM practices, indicating that simplifying information and field training would promote overcoming this hindrance. Finally, religious faith of the heads of households reveals that Islam is the prevalent religion at 61.41%, followed by Christianity at 23.06%, traditional beliefs at 15.29%, and others at 0.24%. These religious affiliations may determine the adoption level of SLM practices because religious and cultural beliefs tend to dictate farmers' attitude and practices towards land management practices. Islamic influence (61.41%) as the dominant religion, is expected to have the greatest impact on the extent to which farmers intensify their adoption levels of sustainable land management (SLM) practices. The Islamic faith places serious emphasis on environmental stewardship and the careful management of the natural resources bestowed on us by God. Empirical research conducted by Ankrah et al. (2020) confirmed that Muslim farmers in the northern region had greater chance to adopt as well as intensify SLM practices based on their religious teachings and primary duty to preserve the land and what it embodies. The Islamic tenet of "Khalifah" system (stewardship) also impels Muslims to make substantial efforts in preserving the earth and its adornments, and this has a direct positive impact on adoption levels of SLM practices (Oluwaseun et al., 2024). Also, Christian influence recorded a (23.06%): Christians who comprise close to a quarter of the population also has a great influence in the adoption of SLM practices in the two regions. In another study conducted by Ummah (2019), sub-Saharan African Christian farmers such as Ghana, implement climate-smart agriculture practices since this notion is embedded in biblical teachings of environmental stewardship and land management practices. The 'creation care' concept in Christian doctrines aligns with modern SLM principles. Once more, Dittoh et al. (2012)conducted another extensive study and highlighted with a firm conviction that Christian farmer organizations in northern Ghana would be in a pioneer position to spread useful information on SLM adoption practices which in turn increases the rate of SLM adoption among members. Furthermore, traditional beliefs being (15.29%): despite the lower number of people who holds traditional beliefs, it remains a very key actor in pushing farmers to intensify their adoption of SLM practices. Also, Antwi-Agyei et al. (2014) discovered that farmers in Ghana's savannah region who follow traditional beliefs have a strong connection to the land and use indigenous knowledge systems that align with SLM. These farmers may be more inclined to embrace SLM practices that incorporate traditional ecological knowledge. With others (0.24%): Though this group represents a small portion of the population, their diverse belief systems may bring fresh perspectives to SLM adoption. Further research from Issahaku & Abdulai (2020) suggested that individuals from minority or non-religious backgrounds in northern Ghana might be more open to new agricultural practices, including SLM, since they may be less influenced by the religious norms of the majority. Again, religious organizations are some of the cross-cutting interveners who serve as information centers. To a greater extent, Issahaku and Abdulai (2020) affirmed that places of worship, no matter the religion, are platforms for the dissemination of farming information, for example, SLM methods. To a greater extent, religious beliefs regulate social networks, which support the diffusion and adoption of these farming approaches (Okolie et al., 2023).

The results in table 4.1 emphasize the necessity of some strategies for promoting and expanding SLM adoption in Ghana. The policymakers and agricultural extension staff need to consider different needs of different farmer groups, offering differential economic incentives to poor farmers, mobile extension services to remote-area farmers, and education programs accounting for different issues and possibilities of different age groups. Longitudinal research would be of enormous value to determine the effects with temporal changes to such socioeconomic drivers have on adoption and sustained use of SLM's in Ghanaian farming. The data also indicates areas of challenge such as low literacy and lack of subsidies and areas of opportunity such as mobile phone penetration and greater climate risks to which climate-resilient agriculture has to adapt. To address these issues effectively, a combined approach is needed that includes education, long-term extension services, climate-resilient agricultural support, and the application of technology and community-based financial groups to encourage and facilitate SLM adoption intensity.

Tables 4. 1: Descriptive Statistics of Factors Influencing the SLM Adoption intensity Used in the Analysis

Variables	Mean	Standard Deviation
Age of Household Head	41.944	14.087
Land Size of Household Head	12.692	12.161
Number of Household Workforce	4.112	3.638
Household Head Total Income	5479.269	49559.517
Distance to Cooperative Center	10.765	13.623
Total Consumption Expenditure	18080.05	14306.29
Variables	**Frequency**	**Percentage (%)**
VSLA_Group		
0= No	177	42.96
1= Yes	95	23.06
2=Others		33.98
Household Head Gender		
0= Female	92	22.33
1= Male	320	77.67
Phone Ownership		
0=No	37	8.98
1= Yes	375	91.02
Access to Extension Services		
0= No	204	49.51
1=Yes	208	50.49
Flood Frequency in the Last Five Years		
0=Never	152	36.89
1= Once	73	17.72
2= Twice	81	19.66
3= Thrice	40	9.71
4= Four times	16	3.88
5= Five times	50	12.14
Subsidy		
0= No	353	85.68
1=Yes	59	14.32

Drought Experience During the Year		
0=No	88	21.36
1=Yes	324	78.64
Education Level of Household Head		
0=Never in School	279	67.72
1=Drop out of Primary School	28	6.80
2=Graduate from Primary School	6	1.46
3=Drop out of Junior Secondary School	22	5.34
4=Graduate from Junior Secondary school	24	5.83
5=Drop out of Senior Secondary School	5	1.21
6=Graduate from Senior Secondary School	33	8.01
7= Graduate from University	12	2.91
8= College	2	0.49
9= Non-Formal Education	1	0.24
Drought Frequency in the Last Five Years		
0=Never	40	9.71
1=Once	51	12.38
2=Twice	149	36.17
3=Thrice	90	21.84
4= Four times	26	6.31
5= Five times	56	13.59
Household Head Religion		
1=Christianity	95	23.06
2= Islaam	253	61.41
3=Traditional	63	15.29
4=Others	1	0.24
Total	**412**	**100.00**

Table Source: Author's Calculation

4.3 Summary Statistics of SLM Practices Adopted by Smallholder Farmers in Northern Ghana

The figures in Table 4.2 show a standing difference in depth of adoption of Sustainable Land Management (SLM) practices by Smallholder farmers in the savannah and northern regions of Ghana. Crop residue retention (93.21 %), application of inorganic fertilizer (96.12 %), cover cropping (86.65 %), bonding crops (89.08 %), organic fertilizer (85.44 %), green manure (85.92 %), row planting (91.50 %), and improved seeds (83.74 %) had very high adoption rates. These adoption levels indicate that an extremely high percentage of farmers have adopted practices enhancing the fertility of the soil, saving water, and potentially enhancing yield outcomes seemingly in response to both the availability of inputs and the perceived agronomic benefits of the interventions.

Also, moderate adoption is observed for other types of conservation agriculture, including intercropping (61.17 %), relay cropping (63.59 %), crop rotation (66.02 %), and crop levelling (63.59 %). These are likely to be associated with more advanced planning or organization, and their adoption at the intermediate stage indicates some experience but likely limitations through labor needs, knowledge, or reallocation of resources. On the other hand, comparatively lower adoption occurs in case of integrated pest management (52.67 %), rhizobium inoculation (39.32 %), and zero/minimum tillage (34.71 %). These may either be associated with technical complexity, initial investments in training or system re-design (e.g., system re-designing tillage), or risk-reward imbalances perceived.

These trends are generally coinciding with evidence in the region. For example, studies by Issahaku and Abdulai (2020a) show that farmers adopting climate smart practices encompassing crop diversification together with conservation of soil water have greater crop revenues in addition to lower yield volatility. Drivers of adoption are extension services, education, and climate information (Issahaku & Abdulai, 2020a). Therefore, the high rates of adoption for practices like residue retention and quality seeds among this group presumably are not solely related to the material reward but also to the facilitating extension-supported context.

Consequently, technology adoption studies in Ghana emphasizes the role of social capital and institutional participation. For example, System of Rice Intensification (SRI) adoption in Ghana was considerably linked with farmers' cooperative membership, which suggests that social networks matter in the adoption of technology (Yahaya et al. 2019). Although SRI is crop-specific, it concurs that social structures contribute to diffusion of SLM practice.

However, adoption of zero/minimum tillage remains low, echoing broader findings that the practice, while agro-ecologically well-founded, is slowed by economic and pedagogic limitations in Ghanaian agro-ecosystems (Amponsah, 2017). This only serves to emphasize the difficulty process of paradigm changes in contexts where traditional practice is exceedingly embedded.

Lastly, a policy analysis of seed commercialization in Ghana (Amanor, 2024) concludes the existence of contradictions in efforts to improve high-yielding certified seed and seed sovereignty and preservation of biodiversity among farmers. The extremely high adoption rate (83.74 %) reported in Table 4.2 for improved seed is a reflection of the desire of farmers to adopt improved varieties where benefit is obvious but also of the necessity to keep alive access for adaptable, locally well-adapted material to diversity against ecologic risk and to assist in underpinning long-term resilience.

Secondly, the descriptive statistics provide evidence that smallholder farmers in the northern and savannah agro-ecological zones are involved in a battle against adversity to adopt a range of sustainable land management practices for which the prevalence rates are very high among farmers experiencing short-term yield and soil fertility benefits. Adoption declines step-wise with increasing technical knowledge, structural change, or perceived risk. Base trends are a synthesis of the literature to focus on extension services, social networks, technical advice, and adaptation to modernization and farmer independence and biodiversity conservation. Finally, this adoption practices puts the focus on an interactive dynamism, whereas farmers are open to rising enhancements that support productivity and resilience, they are in fact working at the margins of access to knowledge, provision of infrastructures, and socio-cultural models, which clearly is in need of a plan of future policy and research inquiry to uncover enhancing on making rigorous systems into becoming realizable, expanding farmer networks, and building context-sensitive approaches that balance technical efficacy with locally embedded praxis.

Tables 4. 2: Descriptive Statistics of SLM Practices Adopted by Smallholder Farmer

List of SLM Practices	Freq. (No. of Farmers who Adopted)	Percentage (%)
Crop Residue		
0=No	28	6.79
1=Yes	384	93.21
Crop Rotation		
0=No	140	33.98
1=Yes	272	66.02
Inter-cropping		
0=No	160	38.83
1=Yes	252	61.17
Relay Cropping		
0=No	150	36.41
1=Yes	262	63.59
Inorganic Fertilizer		
0=No	16	3.88
1=Yes	396	96.12
Cover cropping		
0=No	55	13.35
1=Yes	357	86.65
Crop bonding		
0=No	45	10.92
1=Yes	367	89.08
Organic Fertilizer		
0=No	60	14.56
1=Yes	352	85.44
Green Manuring		
0=No	58	14.08
1=Yes	354	85.92
Rhizobium Use		
0=No	250	60.68
1=Yes	162	39.32
Row Planting		
0=No	35	8.50
1=Yes	377	91.50
Crop Levelling		
0=No	150	36.41
1=Yes	262	63.59
Integrated Pest Management		
0=No	195	47.33
1=Yes	217	52.67
Improved Seeds		
0=No	67	16.26
1=Yes	345	83.74
Zero/Minimum Tillage		
0=No	269	65.29
1=Yes	143	34.71
Total=SLM (15)	**412**	**100**

Table Source: Author's calculation

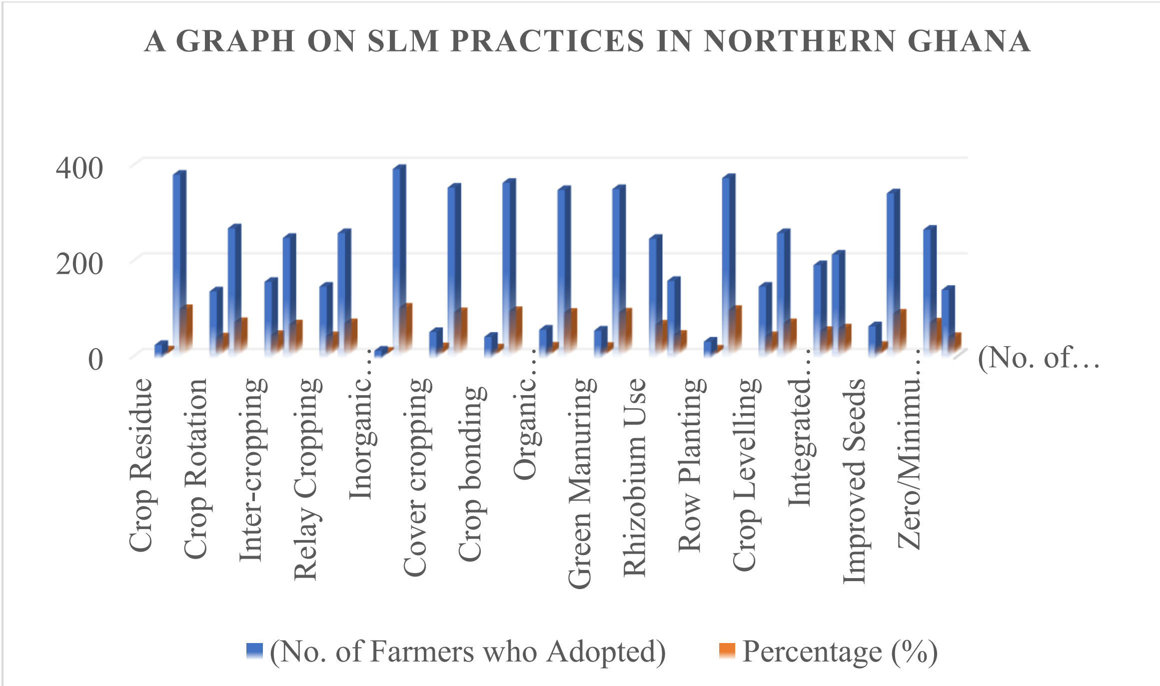


Figure 4: A Bar Graph Representation of the Various SLMs Adoption Among Smallholder Farmers in the Northern and Savannah Regions of Ghana

4. 4 Descriptive Statistics of SLM Adoption Intensity of Smallholder Farmers in Northern Ghana

The evidence of Table 4.3 shows significant evidence of the intensity of Smallholder farmers' adoption of Sustainable Land Management (SLM) practices in Ghana's northern and savannah regions. The distribution shows a definite central tendency with three and four practices each having been adopted by 19.17 % of farmers the modal categories. Remarkably, a mere 14.56 % of farmers use one practice, while adoption declines for more than four practices: five practices (8.50 %), six (8.25 %), seven (4.85 %), eight (3.88 %), nine (3.40 %), and all ten (1.21 %). Here it is evident that most farmers use an intermediate bundle of SLM interventions, not minimal or maximum bundles.

This observed trend aligns with the results reported by (Issahaku et al., 2019), who found that the implementation of climate-smart practices, particularly when adopted in bundled forms, markedly improves agricultural performance and mitigates production risks; however, the advantages tend to stabilize past a certain threshold of technique combinations (Issahaku & Abdulai, 2020a). This observation implies that a moderate degree of adoption may signify a state of equilibrium where the cumulative advantages are maximized in relation to limitations such as labor availability, access to inputs, and levels of technical expertise. In support of this notion, Mahama and associates conducted a model examining the intensity of sustainable production technology adoption among soybean farmers in northern Ghana, which indicated that the average farmer employs 50% of the recognized innovations, consistent with our findings regarding central tendency (Mahama et al., 2020). Additionally, they identified education, frequency of extension visits, and risk perception as significant positive factors influencing greater adoption intensity. What is more, a later study in 2024 on several climate-smart farm technologies used by maize farmers such as in zero tillage, row planting, and drought-tolerant seed observed that adopting varied combinations had promoted maximum gains in maize productivity as well as net farm returns (Boansi et al. 2024). This further highlights the argument that purposeful combinations of practices such as those represented by settings of three or four can produce substantial gains in productivity as well as welfare outcomes of farmers.

Finally, an extensive study of SLM adoption in Ghana identified technical and environmental efficiency gains among adopters as a result of access to extension, credit, and land tenure security (Issahaku and Abdulai, 2020b). Although, it did not directly measure the extent of adoption but considers its facilitating conditions which largely affect farmers' exposure to different sustainable alternative practices. In general terms, the descriptive statistics confirm the salient trend of intermediate adoption intensity in the sense that the majority of smallholder farmers in the northern and savannah regions of Ghana adopt between three to four SLM practices. The medium-level of SLM adoption is likely to be achieving a balance between those desirable ends of sustainable productivity, soil fertility, and climate resilience and those feasible constraints in the availability of labor, input cost, and knowledge. Substantial evidence thus indicates that, such moderate SLM bundles is needed to develop and yield significant welfare outcomes and enhance productivity especially when accompanied with the requisite education and training, extension support, and enabling institutions. It is therefore necessary for policymakers as well as agricultural practitioners to concentrate on developing those support systems and pushing for realistically synergistic sets of practices with maximum gains while staying within smallholder farmers capacities.

Tables 4. 3 Descriptive Statistics of SLM Adoption Intensity of Smallholder Farmers in Northern Ghana

Count of SLMs Adopted	Frequency	Percentage (%)
1	60	14.56
2	70	16.99
3	79	19.17
4	79	19.17
5	35	8.50
6	34	8.25
7	20	4.85
8	16	3.88
9	14	3.40
10	5	1.21
Total	**412**	**100.00**

Table Source: Author's Calculation

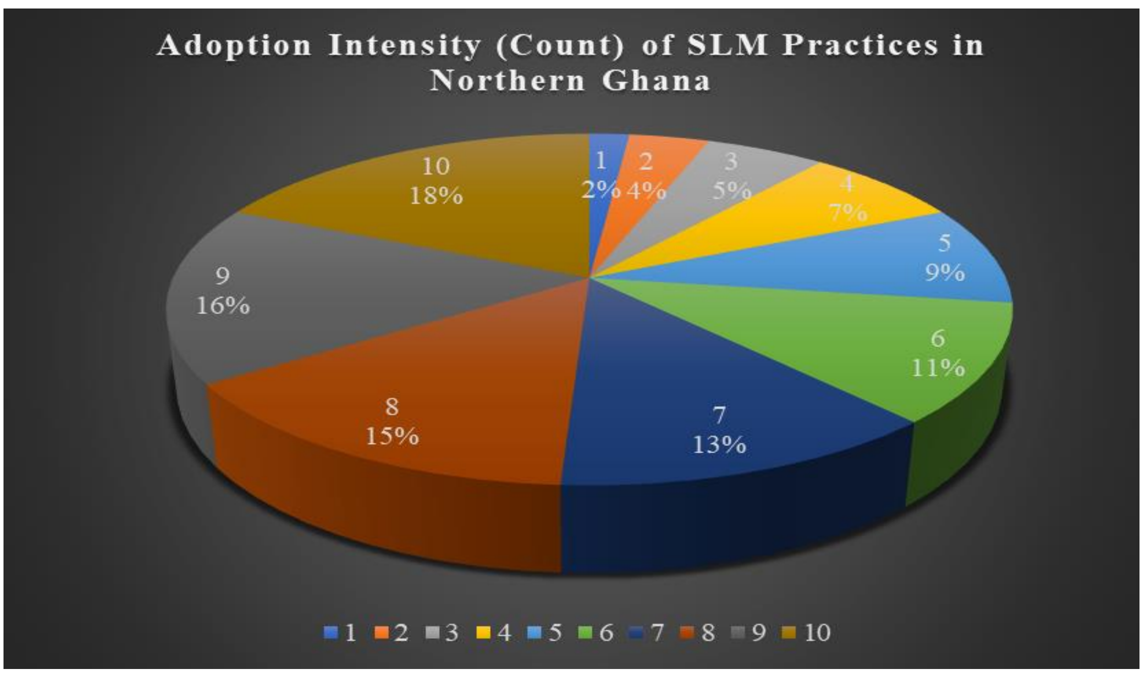


Figure 5 : A Pie Chart Distribution of the Intensity of SLM Adoption Among Smallholder Farmers in the Northern and Savannah Regions of Ghana

4.3. The Standard Poisson Model in Estimating the Determinants of SLM Adoption Intensity of Smallholder Farmers

The results from table 4.2 provides an estimate of the Standard Poisson and Negative Binomial regression models to estimate several factors that determine the intensity of adoption of Sustainable Land Management (SLM) practices in northern Ghana. A model diagnostic test between the Akaike and Bayesian Information Criterion, where the AIC and BIC values of the Standard Poisson Model are lower compared to the Negative Binomial Model, and thus implies that, the Standard Poisson Model is more adequately and marginally better fit to the data while been simpler (with 12 degrees of freedom compared to the 13 for the Negative Binomial Model). Also, the similarity in coefficients of the two models and the non-significant likelihood ratio test (p-value = 0.000), (LR Chi2(11) =153.79) as well as the (LR test of alpha=0) satisfy the requirement of the Equidispersion principle and thus indicate that the Standard Poisson model is adequate for this analysis. The statistically significant factors, are subsidy received, extension services annually, VSLA group participation, and cooperative centers distance.

From table 4.2, farm subsidies have a strongly positive impact on the extent of adoption of SLM practice ($\beta = 0.277$, $p < 0.01$). This result confirms the result of Etwire et al. (2022) which established that input subsidies are critical in motivating farmers to intensify the adoption of SLM practices in Ghana. The positive correlation indicates that subsidies reduce economic obstacles, and it becomes simpler for farmers to spend money on new sustainable agricultural practices and technologies. Interestingly, only 14.32% of farmers received subsidies from the results output, signaling a vast potential for government to expand its subsidy schemes as well as connecting them with the adoption of multiple of sustainable land management practices. Also, availability of extension services for agriculture has the strongest positive effect ($\beta = 0.476$, $p < 0.01$) on SLM intensity of adoption, which indicates the critical role extension services plays in promoting the intensity of adoption of sustainable agricultural practices. This finding is consistent with Antwi-agyei et al. (2018) who observed and highlighted how critical extension services are to the enhancement of climate-smart agriculture in Ghana. The significant effect means that long-term exposure to these services greatly promotes the adoption intensity of SLM practices since it provides farmers with essential knowledge, skills, and extension support. Increased and quality extension services with regular visits, improve content, and the use of digital media would be one of the best means of promoting intensive and extensive adoption of SLM. Moreover, VSLA membership has a very strong and positive contribution ($\beta = 0.255$, $p < 0.01$) towards the adoption of SLM intensity. This finding corroborates that of Antwi-agyei et al. (2018) who established that, the promotional effect of VSLA membership on farm investment in Ghana. The fact that the coefficient is positive shows that VSLAs provide smallholder farmers with a source of credit for technology access, and meeting places for exchanging information on sustainable agriculture, whiles belonging to a positive social network that promotes agricultural innovation. The large effect captures the potential for the application of community-based institutions such as VSLAs in order to foster adoption intensity of SLM practices. Interestingly, nearness to cooperative centers emerges as statistically significant modest positive effect ($\beta = 0.013$, $p < 0.05$) on the intensity of SLM adoption. It shows that farmers who are far from cooperative centers adopt as well as intensifies SLM practices more, in contrast to other studies, such as Abass et al. (2018) who claimed that farmers' distance from agricultural services was likely to increase the level of adoption of improved SLM practices in northern Ghana. One is that more distance farming farmers are more autonomous, engaging in more types of sustainable practice as forms of adaptation to risk. The alternative explanation could be that cooperative centers are not the main channel of information or support for further adoption of SLM practices in this context. In summary, the highly positive impacts of subsidies, extension, and VSLA membership suggest that a multi-component strategy that includes financial support systems, training, and group activities could be central to initiating subsequent adoption of sustainable agricultural practices. The unexpected outcome involving distance to cooperative centers also underscores the necessity for context-adaptive strategies taking into account the environmental factors. Subsequent research can examine these links more intensively, providing useful insights to guide more successful policies to advance sustainable agriculture in Ghana and beyond.

Tables 4. 4: The Standard Poisson Estimates of the Factors Influencing the Intensity of SLM Adoption of Smallholder Farmers

Variables	Standard Poisson Model	Negative Binomial
Age of Household Respondent	-0.001	-0.001
	(0.002)	(0.002)
Gender of Household Head	0.090	0.090
	(0.078)	(0.078)
Education Level of Household Head	(0.006)	(0.006)
1=Primary School		
	0.78	0.78
2=Junior High School	(0.412)	(0.412)
	1.542	1.542
3=Senior High School	(0.432)	(0.432)
	1.204	1.204
4=Bachelor's Degree	(0.201)	(0.201)
	1.260	1.260
5=Master's Degree	(1.034)	(1.034)
	0.59	0.59
Land Size of Household Head	(1.595)	(0.685)
	0.000	0.000
Subsidy Received	(0.000)	(0.000)
	0.277***	0.277***
Extension Services	(0.084)	(0.084)
	0.476***	0.476***
Household Head Total Income	(0.072)	(0.072)
	0.000	0.000
	(0.000)	(0.000)
Household Head Off-farm Income	0.006	0.006
	(0.077)	(0.077)
VSLA Group	0.255***	0.255***
	(0.038)	(0.038)
Reason for Loan	-0.014	-0.014
	(0.015)	(0.015)
Distance to cooperative center	0.013**	0.013**
	(0.006)	(0.006)
Household head savings Amount	-.0.050	-0.050
	(0.184)	(0.184)
Constant	0.367***	0.367***
	(0.126)	(0.126)
		LR $Chi^2(11) = 153.79$
		Prob>Chi^2=0.000

Standard errors in parenthesis
***p<0.001, **p<0.05, *p<0.1

Table Source: Author's Calculation

4.5 The Control Function Model Estimates of the Effect of SLM Adoption Intensity on Welfare Outcomes of Farmers

The results in table 4.3 below shows the effects of intensity of SLM adoption on the welfare of farm households (Total Household Consumption Expenditure) using extension services of household head as instrumental variable. The discussion will be focused on the statistically significant variables such as Household Head Education Level, Number of Household Workforce, Subsidy Received, Extension Services, Household Head Off-farm Income, Household Head Total Income, Household Head Savings Amount, Farm Size of Household Head, VSLA Group, and Distance to Cooperative Centers.

First and foremost, education level of the household head is the strongest predictor in this study because the results exhibit a statistically significant and positive relationship between welfare outcomes and education. Thus, household heads who attained a junior high school (2.431, $p<0.01$) and senior high school (1.514, $p<0.10$) levels of education showed a much significant improvement in their welfare outcomes. This result aligns with empirical studies by Kermah et al. (2018) who emphasizes the importance of human capital accumulation for farm sustainability and household resiliency. Remarkably, master's degree also had a significant welfare effect (2.283, $p<0.01$), under which more advanced education can potentially enable farmers to have better agricultural management skills and resilience. An empirical study from Dawuni and Mabe (2021) further explained that education is capable of enabling farmers to simply understand and adopt the huge array of sophisticated sustainable land management practices available devoid of challenges and hence improve their household welfare outcomes at large. Also, two important variables were selected in order to be able to forecast the welfare outcomes (Total Household Consumption Expenditure): received subsidy (0.444, $p<0.01$) and extension services (0.000, $p<0.01$). These findings are in line with Sanou et al. (2019) who showed the effectiveness of agricultural support systems in changing farmers livelihoods. Government and institutional intervention in the areas of subsidy and extension services is a very pertinent policy intervention in championing the course of sustainable land management practice and farmers' welfare outcomes. Again, off-farm income and total household income were again statistically significant and positively correlated to both welfare outcomes and SLM adoption intensity. It can be observed from the findings that farm households with multiple sources of income (0.268, $p<0.01$ for off-farm income) have better prospects of investing more in sustainable land management. This empirical result agrees with Estruch (2021) who holds a substantial view that, income diversification wise and relevant resilience strategy for smallholder farmers to cope with varied agricultural environments. More importantly, number of household workforce composition also reveals a significant result in the manner, it recorded a significant and positive correlation with welfare outcomes (0.033, $p<0.01$) which indicates that larger or labor-available households can effectively and efficiently implement and benefit more from the sustainable land management practices. This finding is further supported by Odhong et al. (2024) in their recent publication, which underscores the importance of household labor capacity in adopting to agricultural practices and implementation.

The distance to cooperative centers (0.427, $p<0.05$) emerges as a significant variable, indicating that institutional proximity plays an important role in agricultural development. This empirical finding resonates with Mensah et al. (2015), whose research studies categorically emphasizes on the relevance of institutional supporting systems in facilitating knowledge transfer and resource availability for smallholder farmers. This finding also aligns with Boansi et al. (2024), who examined on how institutional proximity and accessibility impacts agricultural productivity and household economic upliftment. Again, the frequency of extension services shows a strong positive impact on the likelihood of intensifying the adoption of SLM practices (1.029, $p<0.01$) with small impact on welfare outcomes (0.000, $p<0.01$). While more frequent extension services help promote SLM adoption intensity according to Essegbey and Maccarthy (2020), the small effect on welfare might suggest that the benefits of adoption have not yet been fully realized in terms of increased consumption, possibly due to the initial costs involved in implementing SLM. Furthermore, farm size indicates a small but statistically significant positive relationship with welfare outcomes (0.000, $p<0.05$). This mixed relationship suggests that while land area contributes to economic potential of farm households, the quality of sustainable land management practices potentially outweighs mere land quantity. Also, participating in Village Savings and Loan Associations (VSLAs) positively influences the adoption intensity of SLM (0.618, $p<0.01$) but has a slightly negative impact on the welfare outcomes of smallholder farmers in these regions (-0.012, $p<0.1$). This empirical finding shows that while VSLAs enhances the likelihood of a farmer accessing credit and information whiles at the same time impacting a farmer's willingness to intensify the adoption of SLM practices Dawuni et al. (2021), Although the short-term financial recruitments that entail joining these associations can restrict consumption expenditure in the short term.

Finally, these empirical evidences gave a clear and conclusive evidence that adoption intensity of sustainable land management practices is not only an environmental intervention to counteract land degradation and restore soil fertility but also a crucial catalyst to improving farmers overall welfares and economic development. Through a focus on the intricate relationship between land management practices, income diversification, institutional support, and education, the study presents important recommendations to development experts, agricultural scientists, and policymakers in devising policy packages that will help in effective implementation of SLM practices, in a bid to intensify adoption levels and, and subsequently enhance the welfare outcomes of the smallholder farmers in the northern and savannah regions of Ghana.

Tables 4. 5: The Control Function Estimates of the Effects of SLM Adoption Intensity on Farmers Welfare Outcomes

Variables	Adoption Equation	Welfare Equation
Age Household Head	0.286	0.056
	(0.184)	(0.082)
Gender of Household Head	-0.002	-0.002
	(0.006)	(0.00)
Education Level of Household Head		
1=Primary School	0.87*	0.582*
	(0.513)	(0.232)
2=Junior High School	2.431***	1.212***
	(0.911)	(0.437)
3=Senior High School	1.514*	0.811**
	(0.911)	(0.412)
4=Bachelor’s Degree	1.174	0.032
	(1.604)	(0.697)
5=Master’s Degree	0.69	2.283***
	(1.595)	(0.685)
Number of Household Workforce	-0.007	0.033***
	(0.021)	(0.009)
Subsidy Received	0.855***	0.444***
	(0.229)	(0.129)
Extension Services	1.029***	0.000***
	(0.163)	(0.000)
Household Head Total Income	0.000***	0.000***
	(0.000)	(0.000)
Household Head Off Farm Income	0.045	0.268***
	(0.190)	(0.060)
VSLA_Group	0.618***	-0.012*
	(0.090)	(0.014)
Farm Size of Household Head	0.000	0.000**
	(0.000)	(0.000)
Reason for Loan	-0.019	0.014
	(0.032)	(0.009)
Distance to Cooperative Center	0.049**	0.427**
	(0.020)	(0.186)
Household Head Savings Amount	-0.223	-0.113
	(0.431)	(0.068)
Residuals		0.193***
		(0.071)
Constant	0.213	8.781***
	(0.595)	(0.255)
Observations	412	412
R-squared	0.3105	0.2400

Standard errors in parentheses
*** p<0.01, ** p<0.05, p<0.1

Table Source: Author’s Calculation

4.6 The Kendall's Coefficient of Concordance Estimates of the Various Constraints of SLM Adoption Among Smallholder Farmers

The Kendall Coefficient (W) value of 0.71 from table 4.4 shows a high and statistically significant agreement among the respondents ($p < 0.001$) in terms of the ranking of the various constraints smallholder farmers encounter in adopting SLM practices in Northern Ghana. From the table we observe that;

First and foremost, the results from table 4.4 indicates that farmer awareness and understanding of Sustainable Land Management (SLM) practices (Mean = 5.54, Rank = 1st) is a major challenge in Ghana's northern and savannah regions. Recent research identifies that farmers have insufficient information regarding new sustainable agriculture practices and their long-term gains. For example, Issahaku & Abdul-Rahaman, (2019) document that only 34% of northern Ghanaian smallholder farmers comprehend fully how to apply SLM practices. Lack of proper knowledge in this case greatly retards the intensity of adoption and correct application of sustainable agricultural practices. Also, security of tenure and traditional rights to land (Mean = 5.54, Rank = 1st) are still imposing impediments to adoption intensity of SLM, representing the complexities and dynamism of land tenure regimes in the region. Apprehension of insecure tenure rights, identified by (Alare et al., 2018), discourages farmers from committing an investment in green agriculture on the long-term agenda. Specifically, customary practices tend to restrict land ownership, particularly by female farmers, who, although they are very important in farm operations, have limited ownership of the land. Lack of extension services (Mean = 5.52, Rank = 2nd) is the other major constraint that hinders farmers ability to intensify the adoption of SLM practices in northern Ghana. An empirical research findings from Moore et al. (2015) indicate that, the extension officers to farmers ratio in northern Ghana is staggering at 1:1500 against the required 1:500, and thus accounting for the sharply reducing of farmers' access to much-needed technical support and new agriculture information. Besides, lack of coordination among agricultural stakeholders and institutions (Mean = 5.36, Rank = 3rd) enhances bottlenecks in implementation. Further research findings from Piñeiro et al. (2020) also note that uncoordinated activities by government, NGOs, and research institutions create replicated programs and inefficient utilization of resources, hindering farmers' efforts to effectively scale up SLM practice adoption. Labour needs (Mean = 5.18, Rank = 4th) are also an issue, as most SLM practices are labor intensive. More importantly, Khatiwada et al. (2017) point out that at times of intense agriculture, shortages of labor tend to incline farmers to attend to pressing tasks rather than pursuing sustainable agriculture. Secondly, the contribution of indigenous knowledge in advancing the adoption of SLM (Mean = 5.15, Rank = 5th) is also a core motivator. Though indigenous knowledge is extremely critical to sustainable agriculture, integrating it with contemporary SLM practice continues to be problematic. According Yeboah et al. (2021), the lack of documentation and validation of traditional farming methods makes it difficult to combine them with contemporary approaches. Again, market access and value chain integration (Mean = 4.94, Rank = 6th) negatively hinders SLM adoption intensity in the sense that, farmers has better accessibility to markets are more likely to invest in sustainable farming practices as demonstrated by Acheampong et al. (2021) who found that farmers with improved market access are 40% more likely to adopt ,sustainable practices. Policy incoherence and implementation gaps (Mean = 4.46, Rank = 7th) add to the challenges. Another research revelation from Acheampong et al. (2021) highlights that inconsistencies between national agricultural policies and local implementation strategies create confusion, undermining farmers' confidence in adopting new practices. Finally, while access to credit (Mean = 3.31, Rank = 8th) remains a barrier, it ranks the lowest in the identified challenges. Furthermore, Awafo et al. (2024) note that only 25% of smallholder farmers in northern Ghana have access to formal credit facilities, limiting their ability to invest in sustainable farming.

In Summary, while various factors can support the adoption intensity of SLM practices, their direct impact on welfare is not always clear, suggesting the need for comprehensive approaches to agricultural development. The findings from the Kendall estimates reveal that SLM awareness, land tenure security, and extension services are the most critical challenges in impacting the intensity of SLM adoption practices among smallholder farmers in the northern and savannah regions of Ghana.

Tables 4. 6: The Kendall's Rankings of the Various Constraints of SLM Adoption Intensity of SLM Practices in Northern Ghana

Variables	Concordance Value	Mean Rank
Farmer Awareness and Understanding of SLM Practices	5.54	1st
Land Tenure Security and Customary Land Rights	5.54	1st
Extension Services and Knowledge Dissemination	5.52	2nd
Lack of Coordination Among Stakeholders and Institutions	5.36	3rd
Labour Requirements and Availability	5.18	4th
The Role of Indigenous Knowledge in SLM Adoption	5.15	5th
Market Access and Value Chain Integration	4.94	6th
Policy Incoherence and Implementation Gaps	4.46	7th
Lack of Access to Credit	3.31	8th
SS(N)= 412 Df=8	Kendall's W= 0.71	Asymp.Sig. 0.000

Table Source: Author's Calculation

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

The final chapter of the study contains the summary of the research's key findings, conclusion and policy recommendations. Section 5.2 contains the research key findings. Section 5.3 contains the research-based conclusions, while section 5.4 contains the policy recommendations.

5.2 Key Findings of the Study

The study has revealed various key findings that will be used in guiding policies and practices that will propel the intensity of adoption of SLM practices by smallholder farmers from the savannah belt and northern regions of Ghana.

One of the most striking findings is the existence of a robust positive relationship between access to agricultural extension services and SLM intensity of adoption. Smallholder farmers who received more regular extension services during the year were more likely to intensify the adoption of more SLM practices. This is consistent with other existing literatures on the basis that, regular extension services play a crucial role in bringing about sustainable agriculture in Ghana. Also, extension services offer farmers the necessary knowledge, skills, and continuous guidance to farmers, which are needed in the successful adoption of new farm practices.

Another major determinant of high adoption rates of SLM practice is being a member of Village Savings and Loan Associations (VSLAs). VSLA members who were engaged in SLM practices themselves recorded higher adoption rates for other sustainable practices. This finding is backed by several research studies which acknowledged that the support from local financial institutions in promoting sustainable agriculture was an important determinant. Thus, farmers who obtained credit and savings through membership in VSLAs, are able to alleviate financial shortages that accompany the adoption rates of SLM practices.

The research also confirmed that there was a strong positive correlation between subsidy access in agriculture and the level of SLM adoption intensity. This finding confirms the well- known argument that, input subsidies play a crucial role in promoting the adoption of climate-resilient agricultural practices. As a matter of fact, subsidies lower the economic burden of adopting SLM practices, thereby enhancing accessibility among poor farmers. Interestingly, it was evident that proximity to farming services centers also had the same high positive effect on SLM adoption intensity. This further suggests that higher proximity to agricultural services tends to be good for the adoption of sustainable agricultural practices. Here, the result can imply that farmers who reside near cooperative centers employ SLM as a measure in reaction to limited access to other agricultural centers or facilities and services. Again, education level of the smallholder farmers is the major in defining welfare trajectories of smallholder framers in these two regions under study.

The analysis revealed a statistically significant contrasts in welfare observable improvements between various levels of education, for which welfare improvement is accounted by higher educational attainment. Comparatively, both Junior high school ($p<0.01$) and senior high school level ($p<0.05$) educated farmers are identified with significant positive welfare impacts as against farmers who never attained any level of the educational ladder available. Specifically, most notable welfare improvement was experienced by the master's degree holders ($p<0.01$), with the implication that, higher educational levels have greater agricultural management capacity and innovational capabilities along with adaptation mechanisms to ensure that SLM adoption intensity are appropriately implemented and intensified.

It was observed positively that the greater the number of members in a household who could work, the more SLM adoption was practiced intensively. This implies that an increase in labor within a household has more potential for undertaking intensive sustainable farming practices. Similar research findings point to the fact that, larger labor availability has always been one of the determinants of successful sustainable agricultural adoption practices. Moreover, the research depicted that household income directly correlates with the intensity of adopting SLM practices at the same time that the level of their welfare greatly increased. Households whose incomes are on the rise were more likely to intensify the practice of SLM because they are able to invest in sustainable agriculture activities and, consequently, increase their welfare levels. This result further cements the argument with other research findings which showed that richer households in northern Ghana would adopt various sustainable agriculture activities. Similarly, Off-farm income was statistically significant in being positively correlated with welfare outcomes ($p<0.01$) and against the background of smallholder farmers' desperation to seek alternative strategies of diversifying income earnings into a number of investments in an attempt to reduce dependence on alternative sources of income. These observations highlight the importance of adopting an approach to rural development that transcends the conventional farm-based agriculture interventions and initiatives

5.3 Conclusions from the Study

The research delivers reflective outcomes on the determinants of SLM adoption level and their effects on smallholder farmers' well-being in Ghana's savannah and northern regions. The outcomes establish the interactive processes between the institutional, socioeconomic, and environmental determinants and their effects on farmers' decisions and outcomes.

A number of key drivers were identified to have a significant impact on SLM adoption intensity. For instance, access to subsidies is among the most significant drivers, which clearly indicates that, economic incentives thus play a major role in promoting sustainable agriculture. Also, the positive correlation between extension services and SLM adoption intensity vividly highlights the significance of sharing information and technical assistance play in moving towards the various sustainable agricultural methods. This aligns with other studies which vividly showcases the contribution of agricultural extension towards educating farmers on conservation agriculture. Furthermore, VSLA membership was also a major catalyst towards the intensity of SLM adoption. This indicates that farmers are more likely to have the opportunity to invest in sustainable agricultural practices through social networks as well as informal financial institutions, complemented by observing impact of social networks on technology adoption. Most critical, though, is that the study discovered that relatively closer farmers to cooperative centers enjoyed greater prospects of SLM practice adoption.

Further analysis showed that factors such as household head's education level, household workforce size and total income were positively correlated with the extent of SLM practice adoption. Additionally, off-farm income has been confirmed to be highly correlated with level of SLM adoption and again with farmers welfare measures, showing that as the farmers diversify into the other agriculture practices intensity levels increase that in the long run increases productivity as well as their welfare measures. Again, with the implications for welfare, the study further established that the magnitude of SLM adoption is inversely proportional to the adopt count square variable, indicating that the levels of the first-round adoption can be expensive in type and therefore can induce diminishing farmer's welfare, thus automatically curbing their welfare levels. But this association is indirect implying that the advantage of SLM adoption intensity would be higher in the long term at an increasing rate, particularly with farmers increasing their intensities of SLM adoption. The research also revealed some major constraints hindering the extensive adoption of SLM practice.

The Kendall's coefficient of concordance (W) test confirmed that there existed a high degree of consistency between respondents' understanding of these obstacles despite the differing experiences of the farmers across the region. The greatest constraints were found to be low knowledge and awareness of SLM practices, followed by land tenure security and customary land rights, and then inadequate extension services were the most pressing constraints farmers faced in increasing their adoption rates. Surprisingly, access to credit was the least constraining factor farmers faced in terms of intensifying their adoption rates. It would then necessitate overcoming these challenges through targeted interventions such as the institutionalization of agricultural extension systems, land tenure security, and enhanced farmer education and training. These recommendations would greatly enhance the intensity of SLM adoption and the general well-being of smallholder farmers in the regions under study.

Future research should combine quantitative approaches with in-depth qualitative studies to better understand the unique challenges faced by farmers in different areas and contexts. This holistic approach will help design more effective policies and programs that support smallholder farmers in overcoming the barriers to SLM adoption intensity and improving their overall welfare.

5.4 Policy Recommendations

Base on this empirical research findings and conclusions, certain policy prescriptions can be formulated with the objective of enhancing the intensity of adoption of sustainable land management (SLM) practices and smallholder farmers' incomes in the northern and savannah agro-ecological zones of Ghana.

To begin with, the predominantly beneficial role of subsidies to the intensity of SLM adoption translates to policymakers supporting and being more selective in their subsidy programs for sustainable farming. Subsidies may be applied in funding front-end investment of SLM practices, which in most cases acts as an inhibitive pre-situation condition among the poor smallholder farmers. However, the programs should be well designed in such a way that they remain affordable to them and do not induce long-term dependency. A phased of eliminating the subsidies over a period along with capacity development would be the most suitable intervention for inducing long-term intensity of adoption of the practices.

Extension services are also required to increase the intensity of adoption of SLM practices. There ought to be greater emphasis on setting up and expanding agricultural extension services with close reference to SLM practices. This may entail employing additional extension agents, enhancing their training in sustainable land management, and leveraging information and communication technology in widening coverage to more individuals. Integrating existing extension methods and new approaches such as farmer field schools and mobile extension services, which would enhance the efficiency of the services since some of the farmers have undergone some formal education. The research further established that there existed a positive correlation between membership in VSLAs and the intensity of SLM adoption. This once again demonstrates how important the utilization of community financial institutions is in promoting sustainable agriculture. Policy-driven consolidation and marketing of VSLAs among farmers in remote rural areas would enable farmers to gain access to financial services as well as social services for upscaling SLM technology adoption. Linking these informal financial institutions to the formal banking sector, as suggested would also drive their ability to contribute to agricultural finance and innovation even faster.

The study also revealed an intriguing fact regarding the connection between far-away cooperative centers and the intensity of adoption of SLM practices. While increased access to cooperative centers would be welcomed, policymakers are forced to dive into interventions that promote the autonomy of remote agricultural communities. This involves promoting decentralized green agricultural technology, which has minimal reliance on off-farm input and service needs. To offset the probable short-run welfare impact of intensity of SLM adoption, policymakers can give new social protection programs that would act as shock absorbers for farmers during the adaptation period. Cash transfers to the less privilege or food security programs, for example, would be a lifeline support during the adaptation period of farmers. This agrees with those who argue in mainstreaming social protection into farm-related interventions. A non-linear relationship was also discovered between the adoption intention of SLM and welfare impacts, where policies have to induce the simultaneous adoption of multiple complementary SLM practices rather than focusing on individual implementation. Designing bundled packages of SLM practices tailored to local agroecology and marketing them on the principle of integrated farm management strategy is an available option. Besides, because SLM adoption intensity relates inversely to off-farm income, policies must be utilized to increase synergies between agricultural development and rural non-agricultural development. Other agro-allied industries and agro-processing can induce farmers to enjoy maximum utilization of SLM practice while diversifying the sources of their income generation.

Finally, Kendall's coefficient of concordance (W) values indicated by the results showed that there existed a high level of concordance among the farmers for the various constraints affecting their ability to expand SLM adoption rates in the study area, but were highly variable in their experience. It indicates that a more context-sensitive and specific approach needs to be implemented in addressing the problems. Future studies should employ mixed approaches, including quantitative analysis such as the Kendall's W with qualitative analysis to explore further and create a more diverse and accurate explanation of the underlying differences and causes at regional level in farmers' experience. This would include comprehensive case studies of individual communities to examine the individual adoption barriers to SLM intensity base on geographical, socioeconomic status, and belief systems, extensive studies in the future would also trace the long-term effects of SLM adoption intensity on farmers' health, i.e., income, food security, and climate and economic shock resilience. Lastly, co-research among the local actors, e.g., policy-makers, extension officers, and farmers, would render the solutions that are more context-specific and sustainable. Through a more participatory and integrated research style, policymakers and researchers can produce more policy-relevant evidence that can bridge more directed policy design and implementation towards assisting smallholder farmers in overcoming the SLM adoption intensity constraints and promoting their SLM adoption levels and ultimately their overall welfare outcomes. Policy-makers also need to ensure interventions are framed with the assistance of local stakeholders and communities so that policies are made context-relevant as well as responsive to local needs. Again, ongoing monitoring and evaluation of these interventions will be critical for adapting strategies and ensuring long-term success in increasing the adoption rates as well as promoting sustainable land management (SLM) and improving the welfare of farmers in the northern and savannah regions of Ghana.

REFERENCES

Abass, R., Mensah, A., & Fosu-mensah, B. (2018). The Role of Formal and Informal Institutions in Smallholder Agricultural Adaptation : The Case of Lawra and Nandom Districts , Ghana. 26, 56–72.

Abdulai, A., & Huffman, W. (2014). The adoption and impact of soil and water conservation technology: An endogenous switching regression application. Land Economics, 90(1), 26–43. https://doi.org/10.3368/le.90.1.26

Acheampong, E. O., Sayer, J., Macgregor, C. J., & Sloan, S. (2021). Factors Influencing the Adoption of Agricultural Practices in Ghana's Forest-Fringe Communities. 1–21.

Acheampong, P. P., Obeng, E. A., Opoku, M., Brobbey, L., & Sakyiamah, B. (2022). Does food security exist among farm households? Evidence from Ghana. Agriculture and Food Security, 11(1), 1–14. https://doi.org/10.1186/s40066-022-00362-9

Adams, F., Ohene-yankyera, K., Aidoo, R., & Wongnaa, C. A. (2021). Economic benefits of livestock management in Ghana. 0–17.

Adolwa, I. S., Schwarze, S., Waswa, B., & Buerkert, A. (2019). Understanding system innovation adoption: A comparative analysis of integrated soil fertility management uptake in Tamale (Ghana) and Kakamega (Kenya). Renewable Agriculture and Food Systems, 34(4), 313–325. https://doi.org/10.1017/S1742170517000485

Alare, R. S., Owusu, E. H., & Owusu, K. (2018). Climate Smart Agriculture Practices in Semi-arid Northern Ghana: Implications for Sustainable Livelihoods. Journal of

Sustainable Development, 11(5), 57. https://doi.org/10.5539/jsd.v11n5p57

Amanor, K. S. (2024). Contradictions between commercializing seeds , empowering smallholders farmers , and promoting biodiversity in Ghana : Seed policy within a historical framework. 1–15.

Amponsah, K. (2017). Sustained no_till adoption in the agro_ecosystems of Ghana: A framework for financial and risk management options. 125.

Aniah, P., Millar, K. K., & Abindaw, B. (2016). International Journal of Sciences : Basic and Applied Research The Effects of Climate Change on Livelihoods of Smallholder Farmers in the Upper East Region of Ghana. July.

Ankrah, D. A., Freeman, C. Y., & Afful, A. (2020a). Gendered access to productive resources -evidence from small holder farmers in Awutu Senya West District of Ghana Gendered access to productive resources – evidence from small holder farmers in Awutu Senya West District of Ghana. Scientific African, 10(November), e00604. https://doi.org/10.1016/j.sciaf.2020.e00604

Ankrah, D. A., Freeman, C. Y., & Afful, A. (2020b). Gendered access to productive resources – evidence from small holder farmers in Awutu Senya West District of Ghana. Scientific African, 10(November), e00604. https://doi.org/10.1016/j.sciaf.2020.e00604

Antwi-agyei, P., Dougill, A. J., Agyekum, T. P., Lindsay, C., Antwi-agyei, P., & Dougill, A. J. (2018). Alignment between nationally determined contributions and the sustainable development goals for West Africa sustainable development goals for West Africa. Climate Policy, 0(0), 1–17. https://doi.org/10.1080/14693062.2018.1431199

Antwi-Agyei, P., Dougill, A. J., Agyekum, T. P., & Stringer, L. C. (2018). Alignment between nationally determined contributions and the sustainable development goals for West Africa. Climate Policy, 18(10), 1296–1312. https://doi.org/10.1080/14693062.2018.1431199

Antwi-Agyei, P., Dougill, A. J., & Stringer, L. C. (2015a). Barriers to climate change adaptation: evidence from northeast Ghana in the context of a systematic literature review. Climate and Development, 7(4), 297–309. https://doi.org/10.1080/17565529.2014.951013

Antwi-Agyei, P., Dougill, A. J., & Stringer, L. C. (2015b). Impacts of land tenure arrangements on the adaptive capacity of marginalized groups: The case of Ghana's Ejura Sekyedumase and Bongo districts. Land Use Policy, 49(March), 203–212. https://doi.org/10.1016/j.landusepol.2015.08.007

Antwi-Agyei, P., & Nyantakyi-Frimpong, H. (2021). Evidence of climate change coping and adaptation practices by smallholder farmers in northern ghana. Sustainability (Switzerland), 13(3), 1–18. https://doi.org/10.3390/su13031308

Antwi-Agyei, P., Stringer, L. C., & Dougill, A. J. (2014). Livelihood adaptations to climate variability: Insights from farming households in Ghana. Regional Environmental Change, 14(4), 1615–1626. https://doi.org/10.1007/s10113-014-0597-9

Asante, B. O., Ma, W., Prah, S., & Temoso, O. (2024). Farmers' adoption of multiple climate-smart agricultural technologies in Ghana: determinants and impacts on maize yields and net farm income. Mitigation and Adaptation Strategies for Global Change, 29(2), 1–23. https://doi.org/10.1007/s11027-024-10114-8

Awafo, E. A., Amrago, E. C., Amankwah, E., & Akolgo, G. A. (2024). Planting for food and jobs participation and its impact on maize productivity in Ghana: implications for research and policy. Cogent Social Sciences, 10(1). https://doi.org/10.1080/23311886.2024.2328883

Azumah, F. D., Onzaberigu, N. J., & Adongo, A. A. (2023). Gender, agriculture and sustainable livelihood among rural farmers in northern Ghana. Economic Change and Restructuring, 56(5), 3257–3279. https://doi.org/10.1007/s10644-022-09399-z

Baffour-Ata, F., Antwi-Agyei, P., Nkiaka, E., Dougill, A. J., Anning, A. K., & Kwakye, S. O. (2022). Climate Information Services Available to Farming Households in Northern Region, Ghana. Weather, Climate, and Society, 14(2), 467–480. https://doi.org/10.1175/WCAS-D-21-0075.1

Balana, B. B., Bizimana, J. C., Richardson, J. W., Lefore, N., Adimassu, Z., & Herbst, B. K. (2020). Economic and food security effects of small-scale irrigation technologies in northern Ghana. Water Resources and Economics, 29, 0–29. https://doi.org/10.1016/j.wre.2019.03.001

Bardy, R., Akolgo-azupogo, H., & Rubens, A. (2022). Advances in Environmental and Engineering Research The Role of Tribal Leaders / Traditional Leaders in Regulating Land Use and Biodiversity Among the Gurune-Speaking People of the Upper East Region in Ghana. https://doi.org/10.21926/aeer.2203036

Bayala, J., Kalinganire, A., Tchoundjeu, Z., Sinclair, F., & Garrity, D. (2011). Conservation agriculture with trees in the West African Sahel – a review. In World Agroforestry Centre (Vol. 14, Issue July 2014). www.worldagroforestry.org

Bayala, J., Sanou, J., Bazié, H. R., Coe, R., Kalinganire, A., & Sinclair, F. L. (2020). Regenerated trees in farmers' fields increase soil carbon across the Sahel. Agroforestry Systems, 94(2), 401–415. https://doi.org/10.1007/s10457-019-00403-6

Boansi, D., Owusu, V., & Donkor, E. (2024). Impact of integrated soil fertility management on maize yield, yield gap and income in northern Ghana. Sustainable Futures, 7(March), 100185. https://doi.org/10.1016/j.sftr.2024.100185

Boudalia, S., Dawit Teweldebirhan, M., Ariom, T. O., Diouf, N. S., Nambeye, E., Mwatitha Gondwe, T., Mbo'o-Tchouawou, M., Okoth, S. A., & Huyer, S. (2024). Gendered Gaps in the Adoption of Climate-Smart Agriculture in Africa and How to Overcome Them. Sustainability (Switzerland) , 16(13). https://doi.org/10.3390/su16135539

Danso-abbeam, G., & Baiyegunhi, L. J. S. (2017). Adoption of agrochemical management practices among smallholder cocoa farmers in Ghana. October. https://doi.org/10.1080/20421338.2017.1380358

Dawuni, P., & Mabe, F. N. (2021). Effects of village savings and loan association on agricultural value productivity in Northern Region of Ghana. February 2022. https://doi.org/10.1108/AFR-02-2020-0024

Dawuni, P., Mabe, F. N., & Tahidu, O. D. (2021). Effects of village savings and loan association on agricultural value productivity in Northern Region of Ghana. Agricultural Finance Review, 81(5), 657–674. https://doi.org/10.1108/AFR-02-2020-0024

Diaz-bonilla, C., & Lakner, C. (2024). The World Bank ' s New Inequality Indicator

The Number of Countries with High Inequality. June.

Dittoh, S., Akudugu, M. A., & Edward, S. M. (2012). The Implications of Climate Change on Food Security and Rural Livelihoods : The Implications of Climate Change on Food Security and Rural Livelihoods : Experiences from Northern Ghana. September 2014.

Doering, O., & Sorensen, A. (2018). The land that shapes and sustains us. How to Feed the World, 46–58. https://doi.org/10.5822/978-1-61091-885-5

Dzanku, F. (2024). Feed the future all-in project in brief reducing poverty among women by strengthening the shea value chain in northern. 000.

Essegbey, G. O., & Maccarthy, D. S. (2020). Situational analysis study for the agriculture sector in Ghana Situational analysis study for the agriculture sector in Ghana. July.

Estruch, E. (2022). Promoting economic diversification and decent rural employment towards greater resilience to food price volatility.

Etwire, P. M., Koomson, I., & Martey, E. (2022). Impact of Climate Change Adaptation on Farm Productivity and Household Welfare. SSRN Electronic Journal, January. https://doi.org/10.2139/ssrn.4054084

Fané, S., Agbotui, D. K., Graefe, S., Sanou, L., Sanogo, S., & Buerkert, A. (2024). Adoption of agroforestry systems by smallholders' farmers in the Sudano-Sahelian zones of Mali and Burkina Faso, West Africa. Agroforestry Systems, 2(Un 2023). https://doi.org/10.1007/s10457-024-01020-8

Gyampoh, B. A., Idinoba, M., & Amisah, S. (2008). Water scarcity under a changing climate in ghana: Options for livelihoods adaptation. Development, 51(3), 415–

417. https://doi.org/10.1057/dev.2008.46

Hundie, B., Oyinbo, O., Hoeschle-zeledon, I., Rahman, A., Kizito, F., & Boyubie, B. (2022). Smallholder farmers ' preferences for sustainable intensification attributes in maize production : Evidence from Ghana. World Development, 152, 105789. https://doi.org/10.1016/j.worlddev.2021.105789

Issahaku, Gazali, Abdulai, A. (2019). Sustainable Land Management Practices and Technical and Environmental Efficiency among Smallholder Farmers in Ghana. Journal of Agricultural and Applied Economics, 1–21. https://doi.org/10.1017/aae.2019.34

Issahaku, G. (2019). Adoption of climate - smart practices and its impact on farm performance and Adoption of climate-smart practices and its impact on farm performance and risk exposure among smallholder farmers in Ghana. December. https://doi.org/10.1111/1467-8489.12357

Issahaku, G., & Abdul-Rahaman, A. (2019). Sustainable land management practices, off-farm work participation and vulnerability among farmers in Ghana: Is there a nexus? International Soil and Water Conservation Research, 7(1), 18–26. https://doi.org/10.1016/j.iswcr.2018.10.002

Issahaku, G., & Abdulai, A. (2020a). Adoption of climate-smart practices and its impact on farm performance and risk exposure among smallholder farmers in Ghana. Australian Journal of Agricultural and Resource Economics, 64(2), 396–420. https://doi.org/10.1111/1467-8489.12357

Issahaku, G., & Abdulai, A. (2020b). Sustainable Land Management Practices and Technical and Environmental Efficiency among Smallholder Farmers in Ghana.

Journal of Agricultural and Applied Economics, 52(1), 96–116. https://doi.org/10.1017/aae.2019.34

Issaka, R. N., Buri, M. M., Sekyi-Annan, E., Musah, M., & Dugan, E. (2021). Enhancing Soil Productivity in Ghana through the Use of Leguminous Cover Crops and Tillage Practices. West African Journal of Applied Ecology, 29(2), 24–32.

Jinbaani, A. N. (2016). Sustainable Land Management in the Upper West Region of Ghana : a Forgotten Solution To Land Degradation , Communication Failure or a Non- Priority Option ? October.

Kansanga, M., Andersen, P., Kpienbaareh, D., Mason-Renton, S., Atuoye, K., Sano, Y., Antabe, R., & Luginaah, I. (2019). Traditional agriculture in transition: examining the impacts of agricultural modernization on smallholder farming in Ghana under the new Green Revolution. International Journal of Sustainable Development and World Ecology, 26(1), 11–24. https://doi.org/10.1080/13504509.2018.1491429

Kermah, M., Franke, A. C., Adjei-nsiah, S., Ahiabor, B. D. K., Abaidoo, R. C., & Giller, K. E. (2018). Agriculture , Ecosystems and Environment N2-fixation and N contribution by grain legumes under di ff erent soil fertility status and cropping systems in the Guinea savanna of northern Ghana. Agriculture, Ecosystems and Environment,261(August2017),201–210. https://doi.org/10.1016/j.agee.2017.08.028

Kermah, M., Franke, A. C., Adjei-Nsiah, S., Ahiabor, B. D. K., Abaidoo, R. C., & Giller, K. E. (2018). N2-fixation and N contribution by grain legumes under different soil fertility status and cropping systems in the Guinea savanna of northern Ghana. Agriculture, Ecosystems and Environment, 261(December 2016), 201–210. https://doi.org/10.1016/j.agee.2017.08.028

Khanal, K., Ojha, G., Chataut, S., & Ghimire, U. K. (2024). IoT-Based Real-Time Soil Health Monitoring System for Precision Agriculture. International Research Journal of Engineering and Technology, July. www.irjet.net

Khatiwada, S. P., Deng, W., Paudel, B., Khatiwada, J. R., Zhang, J., & Su, Y. (2017). Household livelihood strategies and implication for poverty reduction in rural areas of central Nepal. Sustainability (Switzerland), 9(4), 1–20. https://doi.org/10.3390/su9040612

Kpotor, P., Akromah, R., Ewool, M. B., Kena, A. W., Owusu-Adjei, E., & Tuffour, H. O. (2014). Assessment of the Relative Yielding Abilities and Stability of Maize (Zea mays L) Genotypes under Different Levels of Nitrogen Fertilization across Two Agro-Ecological Zones in Ghana. International Journal of Scientific Research in Agricultural Sciences, 2(7), 128–141. https://doi.org/10.12983/ijsras-2014-p0128-0141

Mahama, A., Awuni, J. A., Mabe, F. N., & Baanni, S. (2020). Heliyon modelling adoption intensity of improved soybean production technologies in Ghana - a Generalized Poisson approach. Heliyon, 6(March), e03543. https://doi.org/10.1016/j.heliyon.2020.e03543

Mensah, F., Adanu, S. K., & Adanu, D. K. (2015). Remote sensing and GIS based assessment of land degradation and implications for Ghana's ecological zones. Environmental Practice, 17(1), 3–15. https://doi.org/10.1017/S1466046614000465

Moomen, A. W., Yevugah, L. L., Boakye, L., Osei, J. D., & Muthoni, F. (2024). Review of Applications of Remote Sensing towards Sustainable Agriculture in the Northern Savannah Regions of Ghana. Agriculture (Switzerland), 14(4), 1–22. https://doi.org/10.3390/agriculture14040546

Moore, B. A., Ferguson, O., & Lolig, V. (2015). Assessment of Extension and Advisory Services in Ghana ' s Feed the Future Zone of Influence. July.

Nasare, L. I., Rahman, L. A., & Darko, F. D. (2023). Indigenous knowledge systems for land condition assessment and sustainable land management in the Talensi District, Ghana. Journal of Degraded and Mining Lands Management, 10(2), 4209. https://doi.org/10.15243/jdmlm.2023.102.4209

Nkegbe, P. K., & Shankar, B. (2014). Adoption intensity of soil and water conservation practices by smallholders: Evidence from northern Ghana. Bio-Based and Applied Economics, 3(2), 159–174. https://doi.org/10.13128/bae-13246

Nkegbe, P., & Shankar, B. (2014). Adoption intensity of soil and water conservation practices by smallholders : evidence from Northern Ghana Adoption intensity of soil and water conservation practices by smallholders : evidence from Northern Ghana. August. https://doi.org/10.13128/bae-13246

Nketia, K. A., Adjadeh, T. A., & Adiku, S. G. K. (2018). Evaluation of suitability of some soils in the forest-Savanna transition and the Guinea Savanna Zones of Ghana for Maize production. West African Journal of Applied Ecology, 26(1), 61–73.

Nyagango, A. I., Sife, A. S., & Kazungu, I. (2023). Factors influencing the use of mobile phone for accessing agricultural marketing information by grape smallholder farmers in Tanzania. Cogent Business and Management, 10(3).

https://doi.org/10.1080/23311975.2023.2257865

Nyamekye, A. P., Tian, Z., & Cheng, F. (2021). Analysis on the Contribution of Agricultural Sector on the Economic Development of Ghana. 1297–1311. https://doi.org/10.4236/ojbm.2021.93070

Odhong, J., & Manners, G. R. (2024). Strides in sustainable agricultural intensification: contributions of the Africa Rising program (2011-2023). June. www.greenink.co.uk

Okolie, C. C., Danso-Abbeam, G., Groupson-Paul, O., & Ogundeji, A. A. (2023). Climate-Smart Agriculture Amidst Climate Change to Enhance Agricultural Production: A Bibliometric Analysis. Land, 12(1). https://doi.org/10.3390/land12010050

Oluwaseun, T., Ojo, O., Adesiyan, O. F., Ige, A. O., Emenike, C. U., Kassem, H. S., Elhindi, K. M., Kitole, F. A., & Sesabo, J. K. (2024). The role of sustainable land management practices in alleviating household food insecurity in Nigeria. November, 1–19. https://doi.org/10.3389/fsufs.2024.1414243

Owiredu, P., Wongnaa, C. A., Acheampong, P. P., Addison, M., Agyei Adu, K., & Awunyo-Vitor, D. (2024). Farmer Business School participation and its impact on cocoa productivity and food security in Ghana. Journal of Agribusiness in Developing and Emerging Economies, 14(3), 637–654. https://doi.org/10.1108/JADEE-05-2022-0102

Owusu, V., Donkor, E., & Owusu-Sekyere, E. (2018). Accounting for the Gender Technology Gap Amongst Smallholder Rice Farmers in Northern Ghana. Journal of Agricultural Economics, 69(2), 439–457. https://doi.org/10.1111/1477-

9552.12236

Partey, S. T., Zougmoré, R. B., Ouédraogo, M., & Campbell, B. M. (2018). Developing climate-smart agriculture to face climate variability in West Africa: Challenges and lessons learnt. Journal of Cleaner Production, 187(March), 285–295. https://doi.org/10.1016/j.jclepro.2018.03.199

Pealore, Z. (2022). Women Smallholder Farmers Access to Agricultural Extension Services; Challenges And Prospects. A Case Study of the Builsa South District of the Upper East Region of Ghana. October.

Piñeiro, V., Arias, J., Dürr, J., Elverdin, P., Ibáñez, A. M., Kinengyere, A., Opazo, C. M., Owoo, N., Page, J. R., Prager, S. D., & Torero, M. (2020). A scoping review on incentives for adoption of sustainable agricultural practices and their outcomes. Nature Sustainability, 3(October). https://doi.org/10.1038/s41893-020-00617-y

Rosenstock, T. S., & Nowak, A. (2019). The Climate-Smart Agriculture Papers: Investing the Business of a Productive,Resilient and Low Emission Future.

Sanou, L., Savadogo, P., Ezebilo, E. E., & Thiombiano, A. (2019). Drivers of farmers' decisions to adopt agroforestry: Evidence from the Sudanian savanna zone, Burkina Faso. Renewable Agriculture and Food Systems, 34(2), 116–133. https://doi.org/10.1017/S1742170517000369

Shiferaw, B. A., Okello, J., & Reddy, R. V. (2009). Adoption and adaptation of natural resource management innovations in smallholder agriculture : reflections on key lessons and best practices. 601–619. https://doi.org/10.1007/s10668-007-9132-1

Siakwa, K. N. A. (2023). Water Resource Management-Ghana Vízgazdálkodás-Ghána. Journal of Central European Green Innovation, 11(2), 34–48.

The, W., & Bank, W. (2005). Sustainable Land Management Activities (OP 15). Op 15.

Timothy J. Coelli, D.S.Prasada Rao, Christopher J. O'Donnell, G. E. B. (2005). An Introduction to Efficiency and Productivity Analysis.

Ummah, M. S. (2019). Ghana Annual Household Income and Expenditure Survey, 2022 (Ghana Statistical Service Report). Sustainability (Switzerland), 11(1), 1–14. http://scioteca.caf.com/bitstream/handle/123456789/1091/RED2017-Eng-8ene.pdf?sequence=12&isAllowed=y%0Ahttp://dx.doi.org/10.1016/j.regsciurbeco.2008.06.005%0Ahttps://www.researchgate.net/publication/305320484

Westerberg, V., Doku, A., Damnyag, L., Kranjac-berisavljevic, G., Owusu, S., Jasaw, G., Falco, S. Di, & Provost, J. (2019). The economics oF The Case for Farmer Managed Natural Regeneration (FMNR) in the Upper West Region of Ghana An Economics of Land Degradation study carried out in the framework of the " Reversing Land Degradation in Africa by Scaling-up Evergreen Agricul.

Wood, T. N. (2013). DigitalCommons @ University of Nebraska - Lincoln Agricultural Development in the Northern Savannah of Ghana.

World Bank. (2008). Sustainableb Land Management Sourcebook.

Yahaya, I., Zereyesus, Y. A., Nakelse, T., & Haruna, B. (2019). Complementarity of technology adoption and social capital participation : The case of systems of rice intensification in Ghana. https://doi.org/10.1002/jid.3420

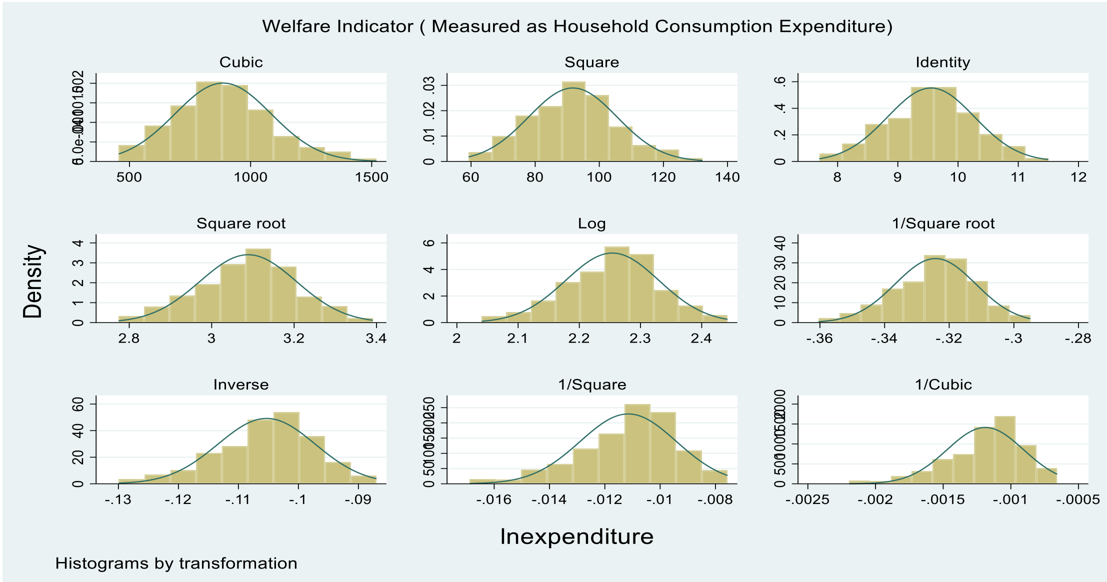
Yahaya, M., Mensah, C., Addaney, M., Damoah-Afari, P., & Kumi, N. (2024). Climate change and adaptation strategies in rural Ghana: a study on smallholder farmers in the Mamprugu-Moaduri district. International Journal of Climate Change

Strategies and Management, 16(1), 112–139. https://doi.org/10.1108/IJCCSM-08-2022-0110

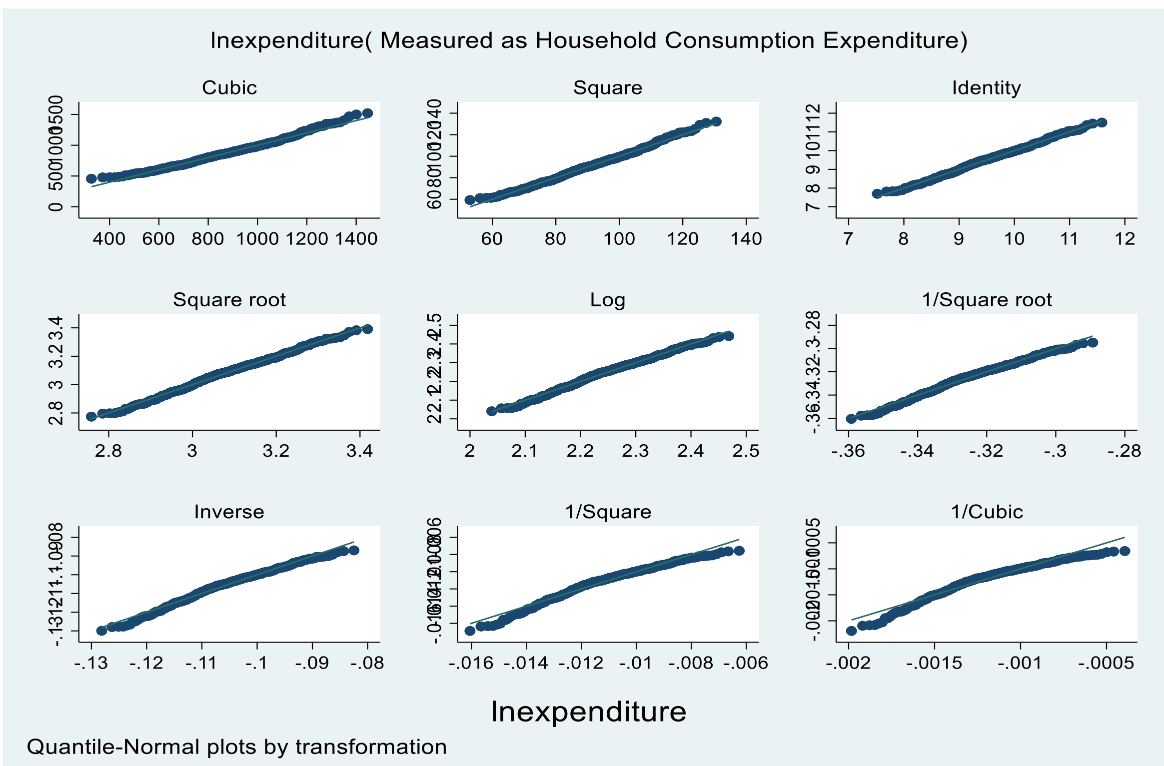
Yeboah, E., Opoku, A., & Fosu, M. (2023). Integrated Soil Fertility Management in Ghana : challenges and opportunities Gestion Intégrée de la Fertilité des Sols au Ghana : Défis et Opportunités. 16(December 2023), 1712–1739.

Zougmoré, R. B., Partey, S. T., Ouédraogo, M., Torquebiau, E., & Campbell, B. M. (2018). Facing climate variability in sub-saharan africa: Analysis of climate-smart agriculture opportunities to manage climate-related risks. Cahiers Agricultures, 27(3). https://doi.org/10.1051/cagri/2018019

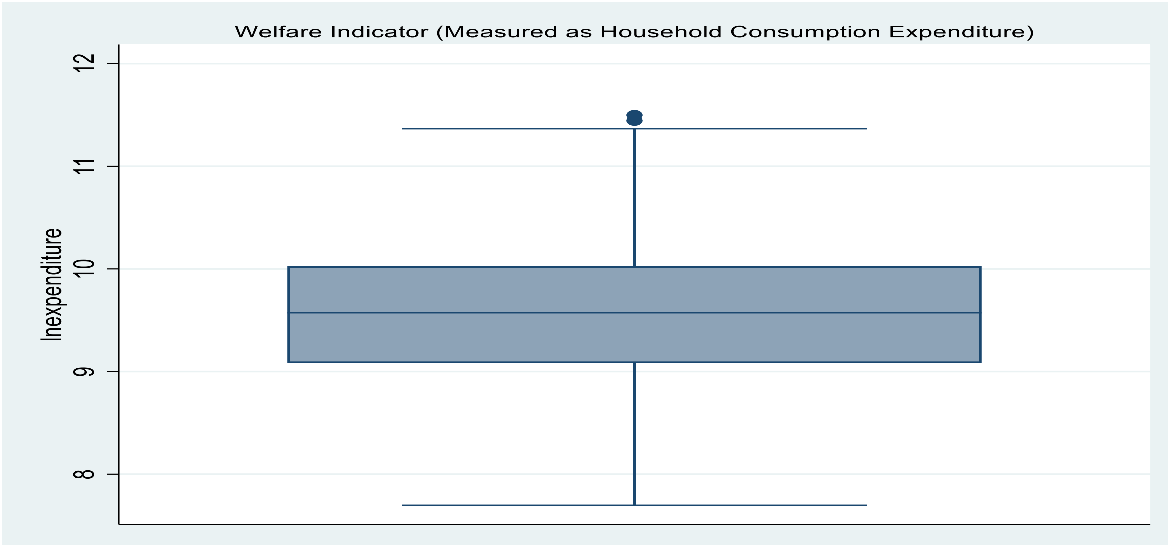
APPENDIX



Appendix 1. Ladder of Powers for Cumulative Distribution Index (CDI)



Appendix 2. Ladder of Powers for Cumulative Distribution Index (CDI)



Appendix 3. Box Plot for Cumulative Distribution Index (CDI)

Appendix 4: A First-Stage Summary Statistics of the Control Function

Regression Estimations

```
. estat firststage

  First-stage regression summary statistics
```

Variable	R-sq.	Adjusted R-sq.	Partial R-sq.	F(1,262)	Prob > F
adopt_count2	0.4513	0.4157	0.1129	33.3568	0.0000

```
  Minimum eigenvalue statistic = 33.3568

  Critical Values                      # of endogenous regressors:    1
  H0: Instruments are weak             # of excluded instruments:     1
```

	5%	10%	20%	30%
2SLS relative bias	(not available)			
	10%	15%	20%	25%
2SLS size of nominal 5% Wald test	16.38	8.96	6.66	5.53
LIML size of nominal 5% Wald test	16.38	8.96	6.66	5.53

Appendix 5. A Test for Endogeneity for the Instrumental Variable (Extension Services and the Error Term (Residual)

H_0: Variables are Exogenous	
Durbin (Score) Chi2(1)	= 9.07677 (P= 0.0026)
Wu-Hausman F (1261)	= 8.74431 (P= 0.0034)

Appendix 6: An Empirical Results Comparism Between the Control Function Approach and the Combine Two-Stage Least Squares Method of Estimations

```
. ivregress 2sls lnexpenditure (adopt_count2= extension_yn2) age_resp2 HHGender i.HHEducation_level numadults_wor
> kforce subsidy THH_Income off_farmincome VSLA_group land_size2 Rez_loan dist_cooperative Savings_amount

Instrumental variables 2SLS regression          Number of obs   =        280
                                                Wald chi2(17)   =      68.42
                                                Prob > chi2     =     0.0000
                                                R-squared       =     0.0163
                                                Root MSE        =     .74056
```

lnexpenditure	Coefficient	Std. err.	z	P>|z|	[95% conf.	interval]
adopt_count2	-.2705632	.1014002	-2.67	0.008	-.4693039	-.0718225
age_resp2	-.0000381	.0000312	-1.22	0.222	-.0000993	.000023
HHGender	.1817417	.1145423	1.59	0.113	-.0427571	.4062404
HHEducation_level						
2	.6629433	.3021706	2.19	0.028	.0706998	1.255187
3	1.801435	.6818499	2.64	0.008	.4650342	3.137837
5	.4477987	.5213003	0.86	0.390	-.5739311	1.469528
7	.5420018	.8343216	0.65	0.516	-1.093239	2.177242
8	2.112571	.7992942	2.64	0.008	.5459834	3.679159
numadults_workforce	.0306848	.0112575	2.73	0.006	.0086206	.052749
subsidy	.8808426	.2152803	4.09	0.000	.458901	1.302784
THH_Income	2.59e-06	7.88e-07	3.28	0.001	1.04e-06	4.13e-06
off_farmincome	.2525402	.1194745	2.11	0.035	.0183745	.4867059
VSLA_group	.3380935	.0858289	3.94	0.000	.1698719	.5063151
land_size2	.0000377	.0000245	1.54	0.125	-.0000104	.0000857
Rez_loan	.0540673	.0232363	2.33	0.020	.008525	.0996097
dist_cooperative	.01206	.0174714	0.69	0.490	-.0221833	.0463033
Savings_amount	.7531633	.3400379	2.21	0.027	.0867013	1.419625
_cons	8.498874	.3188344	26.66	0.000	7.87397	9.123778

The Combine Two-Stage Least Square Estimations of the Effect of the Intensity of Adoption on the welfare Outcomes of Smallholder Farmers.

```
. regress adopt_count2 age_resp2 HHGender i.HHEducation_level numadults_workforce subsidy extension_yn THH_Income
>  off_farmincome VSLA_group land_size Rez_loan dist_cooperative Savings_amount
```

Source	SS	df	MS
Model	348.198567	17	20.4822686
Residual	417.946823	264	1.58313191
Total	766.14539	281	2.72649605

Number of obs	=	282
F(17, 264)	=	12.94
Prob > F	=	0.0000
R-squared	=	0.4545
Adj R-squared	=	0.4194
Root MSE	=	1.2582

adopt_count2	Coefficient	Std. err.	t	P>|t|	[95% conf.	interval]
age_resp2	-.0000505	.0000531	-0.95	0.342	-.000155	.000054
HHGender	.2988289	.1812943	1.65	0.100	-.0581379	.6557957
HHEducation_level						
2	.5535771	.4935425	1.12	0.263	-.4182034	1.525358
3	2.744622	1.019602	2.69	0.008	.7370357	4.752207
5	.3698829	.8783859	0.42	0.674	-1.359651	2.099416
7	1.248224	1.376775	0.91	0.365	-1.462634	3.959081
8	.2115952	1.357238	0.16	0.876	-2.460793	2.883983
numadults_workforce	.0020248	.0190694	0.11	0.916	-.0355227	.0395724
subsidy	1.327748	.2171848	6.11	0.000	.9001134	1.755383
extension_yn	.9921995	.1700321	5.84	0.000	.6574079	1.326991
THH_Income	1.62e-06	1.29e-06	1.25	0.211	-9.24e-07	4.16e-06
off_farmincome	.3093735	.1901254	1.63	0.105	-.0649815	.6837286
VSLA_group	.615823	.088223	6.98	0.000	.4421127	.7895333
land_size	.0050028	.0058609	0.85	0.394	-.0065373	.016543
Rez_loan	.1259486	.0336505	3.74	0.000	.0596911	.1922061
dist_cooperative	.0470529	.0299808	1.57	0.118	-.0119791	.1060848
Savings_amount	-.1731051	.5760559	-0.30	0.764	-1.307354	.9611435
_cons	-.3671161	.5349512	-0.69	0.493	-1.42043	.6861978

.

Appendix 7: The Control Function Approach (First-Stage) Estimations of the Effects of the Intensity of Adoption on Welfare Outcomes of Smallholder Farmers (Estimates for the Adoption Equation)

```
. regress lnexpenditure adopt_count2 age_resp2 HHGender i.HHEducation_level numadults_workforce subsidy THH_Incom
> e o Res off_farmincome VSLA_group land_size Rez_loan dist_cooperative Savings_amount
note: off_farmincome omitted because of collinearity.
```

Source	SS	df	MS			
				Number of obs	=	280
				F(18, 261)	=	4.66
Model	37.9679659	18	2.10933144	Prob > F	=	0.0000
Residual	118.13134	261	.452610499	R-squared	=	0.2432
				Adj R-squared	=	0.1910
Total	156.099306	279	.559495721	Root MSE	=	.67276

lnexpenditure	Coefficient	Std. err.	t	P>|t|	[95% conf.	interval]
adopt_count2	.0158904	.0329132	0.48	0.630	-.0489188	.0806995
age_resp2	-.0000427	.0000285	-1.50	0.135	-.0000987	.0000134
HHGender	.1595397	.103872	1.54	0.126	-.0449941	.3640735
HHEducation_level						
2	.6333997	.2740238	2.31	0.022	.0938209	1.172978
3	1.761951	.6171938	2.85	0.005	.5466375	2.977264
5	.4272434	.4734115	0.90	0.368	-.5049488	1.359436
7	.4304224	.75747	0.57	0.570	-1.061108	1.921953
8	2.113001	.7261441	2.91	0.004	.6831544	3.542847
numadults_workforce	.0308762	.0102181	3.02	0.003	.0107558	.0509966
subsidy	.9047337	.1965241	4.60	0.000	.5177592	1.291708
THH_Income	2.68e-06	7.18e-07	3.73	0.000	1.26e-06	4.09e-06
off_farmincome	.2408124	.1083835	2.22	0.027	.0273951	.4542298
Res	-.2938478	.0975189	-3.01	0.003	-.4858718	-.1018238
off_farmincome	0	(omitted)				
VSLA_group	.3392406	.0778241	4.36	0.000	.1859976	.4924836
land_size	.0073275	.0031727	2.31	0.022	.0010801	.0135749
Rez_loan	.0552276	.0209267	2.64	0.009	.0140209	.0964342
dist_cooperative	.0127374	.0158814	0.80	0.423	-.0185346	.0440094
Savings_amount	.7344401	.3090537	2.38	0.018	.1258841	1.342996
_cons	8.482242	.2892953	29.32	0.000	7.912593	9.051892

Appendix 8: The Control Function Approach (Second-Stage) Estimations of the Effects of the Intensity of Adoption on Welfare Outcomes of Smallholder Farmers (Estimates for the Welfare Equation).

Instrument Validity Tests for Both the Relevance and Exogeneity Conditions

First-stage regression of adopt_count2:

Statistics consistent for homoskedasticity only
Number of obs = 280

adopt_count2	Coefficient	Std. err.	t	P>|t|	[95% conf.	interval]
extension_yn2	.9901106	.1714317	5.78	0.000	.6525512	1.32767
age_resp2	-.000046	.0000534	-0.86	0.390	-.0001511	.0000591
HHGender	.3244152	.180742	1.79	0.074	-.0314765	.6803069
HHEducation_level						
2	.5895502	.4949297	1.19	0.235	-.3849959	1.564096
3	2.798988	1.023148	2.74	0.007	.7843477	4.813627
5	.3913161	.8825141	0.44	0.658	-1.346407	2.129039
7	1.367085	1.378765	0.99	0.322	-1.347785	4.081955
8	.2020091	1.364237	0.15	0.882	-2.484255	2.888274
numadults_workforce	.0023031	.0191871	0.12	0.905	-.0354775	.0400838
subsidy	1.314917	.2178099	6.04	0.000	.8860363	1.743798
THH_Income	1.57e-06	1.30e-06	1.21	0.228	-9.86e-07	4.12e-06
off_farmincome	.3193264	.190682	1.67	0.095	-.0561378	.6947907
VSLA_group	.6163439	.088724	6.95	0.000	.4416409	.7910468
land_size2	6.62e-07	.0000419	0.02	0.987	-.0000818	.0000832
Rez_loan	.1281294	.0341117	3.76	0.000	.0609614	.1952974
dist_cooperative	.0463718	.0301338	1.54	0.125	-.0129634	.105707
Savings_amount	-.1637792	.5788301	-0.28	0.777	-1.30353	.9759718
_cons	-.3732583	.5383071	-0.69	0.489	-1.433217	.6867005

F test of excluded instruments:
F(1, 262) = 33.36
Prob > F = 0.0000
Sanderson-Windmeijer multivariate F test of excluded instruments:
F(1, 262) = 33.36
Prob > F = 0.0000

Appendix 10: F-Test of Excluded Instruments

F-statistic = 33.36, p < 0.000: This indicates that the instrument is strongly correlated with the endogenous variable, passing the rule-of-thumb threshold of 10 for weak instrument tests.

```
Summary results for first-stage regressions
-------------------------------------------

                                           (Underid)            (Weak id)
Variable     | F(  1,   262)  P-val | SW Chi-sq(  1) P-val | SW F(  1,   262)
adopt_count2 |      33.36    0.0000 |       35.65   0.0000 |       33.36

Stock-Yogo weak ID F test critical values for single endogenous regressor:
                                   10% maximal IV size             16.38
                                   15% maximal IV size              8.96
                                   20% maximal IV size              6.66
                                   25% maximal IV size              5.53
Source: Stock-Yogo (2005).  Reproduced by permission.
NB: Critical values are for Sanderson-Windmeijer F statistic.

Underidentification test
Ho: matrix of reduced form coefficients has rank=K1-1 (underidentified)
Ha: matrix has rank=K1 (identified)
Anderson canon. corr. LM statistic       Chi-sq(1)=31.62    P-val=0.0000

Weak identification test
Ho: equation is weakly identified
Cragg-Donald Wald F statistic                                      33.36

Stock-Yogo weak ID test critical values for K1=1 and L1=1:
                                   10% maximal IV size             16.38
                                   15% maximal IV size              8.96
                                   20% maximal IV size              6.66
                                   25% maximal IV size              5.53
Source: Stock-Yogo (2005).  Reproduced by permission.

Weak-instrument-robust inference
Tests of joint significance of endogenous regressors B1 in main equation
Ho: B1=0 and orthogonality conditions are valid
Anderson-Rubin Wald test           F(1,262)=       8.63     P-val=0.0036
Anderson-Rubin Wald test           Chi-sq(1)=      9.22     P-val=0.0024
Stock-Wright LM S statistic        Chi-sq(1)=      8.93     P-val=0.0028

Number of observations               N  =        280
Number of regressors                 K  =         18
Number of endogenous regressors      K1 =          1
Number of instruments                L  =         18
Number of excluded instruments       L1 =          1
```

1. **Stock-Yogo Weak ID Test**

   The critical value for 10% maximal IV bias is 16.38, and the Cragg-Donald F-statistic = 33.36, indicating that the instrument is strong.

2. **Under identification Test** (Anderson LM Test) for the Relevance Condition

Chi-square (1) = 31.62, p < 0.000: Rejects the null hypothesis of under identification, confirming that the instrument is valid.

3. **Weak-Instrument Robust Inference**

Anderson-Rubin Wald Test (p = 0.0036): Rejects the null hypothesis that the instrument

```
Estimates efficient for homoskedasticity only
Statistics consistent for homoskedasticity only

                                                   Number of obs =       280
                                                   F( 17,    262) =      3.77
                                                   Prob > F      =    0.0000
Total (centered) SS     =  156.0993061             Centered R2   =    0.0163
Total (uncentered) SS   =  25378.30344             Uncentered R2 =    0.9939
Residual SS             =  153.5582062             Root MSE      =     .7406
```

lnexpenditure	Coefficient	Std. err.	z	P>|z|	[95% conf.	interval]
adopt_count2	-.2705632	.1014002	-2.67	0.008	-.4693039	-.0718225
age_resp2	-.0000381	.0000312	-1.22	0.222	-.0000993	.000023
HHGender	.1817417	.1145423	1.59	0.113	-.0427571	.4062404
HHEducation_level						
2	.6629433	.3021706	2.19	0.028	.0706998	1.255187
3	1.801435	.6818499	2.64	0.008	.4650342	3.137837
5	.4477987	.5213003	0.86	0.390	-.5739311	1.469528
7	.5420018	.8343216	0.65	0.516	-1.093239	2.177242
8	2.112571	.7992942	2.64	0.008	.5459834	3.679159
numadults_workforce	.0306848	.0112575	2.73	0.006	.0086206	.052749
subsidy	.8808426	.2152803	4.09	0.000	.458901	1.302784
THH_Income	2.59e-06	7.88e-07	3.28	0.001	1.04e-06	4.13e-06
off_farmincome	.2525402	.1194745	2.11	0.035	.0183745	.4867059
VSLA_group	.3380935	.0858289	3.94	0.000	.1698719	.5063151
land_size2	.0000377	.0000245	1.54	0.125	-.0000104	.0000857
Rez_loan	.0540673	.0232363	2.33	0.020	.008525	.0996097
dist_cooperative	.01206	.0174714	0.69	0.490	-.0221833	.0463033
Savings_amount	.7531633	.3400379	2.21	0.027	.0867013	1.419625
_cons	8.498874	.3188344	26.66	0.000	7.87397	9.123778

```
Underidentification test (Anderson canon. corr. LM statistic):          31.622
                                                 Chi-sq(1) P-val =      0.0000
------------------------------------------------------------------------------
Weak identification test (Cragg-Donald Wald F statistic):               33.357
Stock-Yogo weak ID test critical values: 10% maximal IV size             16.38
                                         15% maximal IV size              8.96
                                         20% maximal IV size              6.66
                                         25% maximal IV size              5.53
Source: Stock-Yogo (2005).  Reproduced by permission.
------------------------------------------------------------------------------
Sargan statistic (overidentification test of all instruments):           0.000
                                                 (equation exactly identified)
------------------------------------------------------------------------------
Instrumented:          adopt_count2
Included instruments:  age_resp2 HHGender 2.HHEducation_level
                       3.HHEducation_level 5.HHEducation_level
                       7.HHEducation_level 8.HHEducation_level
                       numadults_workforce subsidy THH_Income off_farmincome
                       VSLA_group land_size2 Rez_loan dist_cooperative
                       Savings_amount
Excluded instruments:  extension_yn2
```

Appendix 11: Marginal Values Calculated for the Standard Poisson Model

Variables	Marginals for the Count Variable
Age of Household Respondents	-0.003
	(0.006)
Number of Household Workforce	-0.004
	(0.023)
Land Size of Household Head	0.000
	(0.000)
Subsidy Received	0.667***
	(0.204)
Extension Services	1.147***
	(0.177)
Household Head Total Income	0.000
	(0.000)
Household Head Off-Farm Income	0.015
	(0.187)
VSLA Group	0.615***
	(0.093)
Reason Loan	-0.033
	(0.035)
Distance to Cooperative Centers	0.030**
	(0.013)
Household Head Savings Amount	-0.122
	(0.444)
Observations	412

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Appendix 12: Standard Poisson Model of Fit

Goodness-of-fit chi2 = 396.9661
Prob > chi2(400) = 0.5335