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CLIMATE-SMART AGRICULTURE, TRADE FLOWS AND RURAL FARM HOUSEHOLDS RESILENCE TO CLIMATE CHANGE IN GHANA

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DEDICATION

I dedicate this study to the West African Science Centre on Climate Change and Adapted Land Use (WASCAL) for sponsoring this study.

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AfCFTA	African Continental Free Trade Area
AfDB	African Development Bank
BAU	business-as-usual
CAEMU	Central African Economic and Monetary Community
CC	Climate change
CSA	Climate-smart agriculture
DCGE	Dynamic Computable General Equilibrium model
ECOWAS	Economic Community of West African States
FAO	Food and Agriculture Organization
FDI	Foreign direct investment
GCF	Green Climate Fund
GEF	Global Environment Facility
GHG	Greenhouse gas
GoG	Government of Ghana
GSS	Ghana Statistical Service
IFPRI	International Food Policy Research Institute
LDAs	Local Agriculture Directorates
MoFA	Ministry of Food and Agriculture
PFE	Planting for Food and Export
PFJ	Planting for Food and Jobs
R&D	Research and Development
SAM	Social Accounting Matrix
SSA	Sub-Sahara Africa
TAM	Technology acceptance model
TFP	Total Factor Productivity
UN	United Nations
UNCTAD	United Nations Conference on Trade and Development
WB	World Bank

RÉSUMÉ

Les externalités du changement climatique (CC) sur l'agriculture nécessitent que les agriculteurs et les gouvernements adoptent des pratiques d'agriculture intelligente face au climat (AIC). Cette étude évalue l'impact de l'AIC sur le commerce des produits agricoles et la résilience des ménages agricoles ruraux face au CC au Ghana. Nous avons adopté le modèle d'équilibre général calculable dynamique (DCGE) pour analyser l'effet des investissements dans les pratiques d'AIC sur les flux commerciaux des produits agricoles et les fluctuations des prix. Notre modèle a été calibré à partir de la matrice de comptabilité sociale (SAM) du Ghana pour l'année 2019. Par ailleurs, nous avons utilisé des modèles de comptage pour analyser l'impact du système d'approvisionnement en intrants agricoles et des contrats agricoles sur l'intensité d'adoption des pratiques d'AIC par les agriculteurs ruraux ghanéens. Afin de contrôler l'endogénéité, nous avons adopté la méthode de régression par variable instrumentale (IV) pour estimer l'impact des pratiques d'AIC sur la pauvreté en temps. Pour répondre aux deuxième et troisième objectifs, nous avons mené une enquête auprès des agriculteurs dans les régions du Centre et du Haut Ghana oriental, avec un échantillon de plus de 610 ménages agricoles. Nos résultats indiquent qu'un investissement public d'au moins 5 % dans les pratiques d'AIC permet de réduire les prix des produits agricoles à un rythme plus rapide que les scénarios de maintien du statu quo (BAU), bien que les prix augmentent dans les deux cas. De plus, nous avons constaté que le scénario d'investissement public conduit à des volumes d'exportation plus élevés que le scénario BAU. En outre, nous avons observé que l'investissement public dans l'AIC réduit davantage les importations de produits agricoles par rapport au scénario BAU. Par ailleurs, l'étude a révélé que les contrats agricoles et les systèmes d'approvisionnement favorisent l'intensification de l'adoption des pratiques d'AIC. Enfin, nous avons constaté que l'intensité des pratiques d'AIC n'a pas d'effet significatif sur le nombre réel d'heures travaillées par semaine ni sur la pauvreté en temps totale des ménages agricoles, bien que les effets estimés soient négatifs. Notre étude recommande que le gouvernement complète les investissements publics dans l'AIC par des politiques facilitant l'accès des agriculteurs aux marchés, améliorant les infrastructures de stockage et de transport, et renforçant l'accès au crédit. En outre, le ministère de l'Alimentation et de l'Agriculture (MoFA) devrait mettre en place des dispositifs de crédit intrants permettant aux agriculteurs d'accéder aux intrants agricoles sans paiement initial. Enfin, l'intégration des pratiques d'AIC dans les systèmes éducatifs formels et informels contribuerait à renforcer la base de connaissances et à instaurer une culture de durabilité.

Mots-clés : changement climatique, adoption de l'agriculture intelligente face au climat, investissement public, résilience et durabilité, pauvreté en temps

ABSTRACT

Climate change (CC) externalities on agriculture necessitate that farmers and governments adopt climate-smart agriculture (CSA) practices. Our study evaluated the impact of CSA on agricultural commodity trade and rural farm households' resilience to CC in Ghana. We adopted the DCGE model to analyze the effect of investment in CSA practices on agricultural commodities trade flows and price fluctuations. Our model was calibrated to the SAM of Ghana for the year 2019. Also, we used count data modeling to analyze the impact of the agricultural input supply system and contract on nudging the adoption intensity of CSA among rural farmers in Ghana. To control for endogeneity, we adopted the instrumental variable regression (IV) to estimate the impact of CSA practices on time poverty. For the second and third objectives, we surveyed farmers in the Central and Upper East regions of Ghana. A sample of over 610 farm households was surveyed. We found that public investment in CSA practices by 5% or more reduced prices of agricultural commodities at a higher rate than the BAU scenarios, even though prices increased in both scenarios. Furthermore, we found that the public investment scenario case had higher export volumes than BAU. Additionally, we found that public CSA investment scenarios reduce agricultural commodities imports more than the BAU scenario. Also, the study found that agricultural contracts and supply systems increased the adoption intensity of CSA practices. Finally, we found that CSA practice intensity had no effects on actual hours per week and the total time poverty of the farm households, although the effects are negative. Our study suggested that the government needs to complement public CSA investments with policies that help farmers increase market access, improve storage and transport infrastructure, and facilitate access to credit. Furthermore, the Ministry of Food and Agriculture (MoFA) should establish input credit schemes to allow farmers to access agricultural inputs without upfront payment. Integrating CSA practices in formal and informal education systems to build a knowledge base and foster a culture of sustainability.

Keywords: climate change, climate-smart agriculture adoption, public investment, resilient and sustainability, time poverty

GENERAL INTRODUCTION

Climate change (CC) externalities on agriculture require that farmers and governments adopt climate-smart agriculture (CSA) practices to be resilient, sustainably increase yields (Cao *et al*., 2023; Fei *et al*., 2023) and trade. CC negatively affects almost every aspect of our lives, including health, agriculture, manufacturing, and education, among others (Carlson *et al*., 2022; Cao *et al*., 2023). Increased temperatures, changing patterns of rainfall, greater frequency of extreme weather events, increased heat stress, and reduced water availability are expected to adversely affect humans (Carlson *et al*., 2022; Fei *et al*., 2023), crop and animal productivity, and the cost of agricultural production. The agriculture sector is the foremost and the most vulnerable to changing climatic conditions (Cheng *et al*., 2023; Fei *et al*., 2023). Agriculture affects CC through greenhouse gas (GHG) emissions (Su *et al*., 2023; Sun *et al*., 2023). GHGs are considered as causes of environmental externality and tragedy of the commons resource (Haris *et al*., 2017).

CC is one of the greatest market failures the global economy has experienced (Burke *et al*., 2015; Streimikiene *et al*., 2020; Stern *et al*., 2006). The CC impacts are a result of negative externalities (Haris *et al*., 2017) emanating from economic activities, including agriculture production and consumption, food insecurity and hunger. CC creates externalities that are larger, more complex, and more uncertain than any other environmental problems of the current and the next generations (Chenkov-Shaw, 2019). These externalities occur when the welfare of an individual economic agent depends not only on its activity but also on the activity of other agents without any transaction taking place to repair the damage or withdraw the benefits created (Arrow, 1969; Tietenberg and Lewis, 2018). Externalities distract the first theorem of welfare economics (Laffont, 1989), hence affecting the welfare of people in society. Welfare is affected by CC through utility, productivity, loss and damages, labor supply, and depreciation. The phenomenon is pernicious as it involves many daily life activities. However, the magnitude of such externalities depends on geographical location and the socioeconomic conditions of the region and the people. In particular, the rural areas would be most affected since agriculture constitutes the base of livelihoods of the rural population.

Considering the pressure on agricultural production driven by population growth, growth in the gross domestic product (GDP) and a consequent change in diets toward higher consumption of animal-source foods, and the risks posed by CC, farmers need options to sustainably increase their production (Dubey *et al*. 2016; Tripathi and Mishra 2017). The single most important source of mitigation in agriculture results from increases in the efficiency with

which agriculture uses natural resources and more efficient land use, which increases yields and helps to avoid land use changes. That also involves more efficient use of animals, water, and chemicals. These agricultural productivity gains can also contribute to increased incomes for farmers. For agricultural productivity gains to result in climate mitigation, they frequently need to be explicitly linked to protecting forests and other native landscapes since they can otherwise encourage local land expansion. Mitigation depends particularly on improvements in management in the use of ruminant livestock and land conversion (Egbendewe, 2018). To achieve climate goals, mitigation efforts must also strongly emphasize innovations, for which many promising options exist, including climate-smart agriculture (CSA) practices.

In line with this, many governments across the globe have profoundly subsidized modern agricultural inputs. Conversely, the Chicago tradition associated with Schultz (1964) begins with the presumption that farmers are rational profit maximizers, so subsidies will distort CSA practices away from the optimal levels. CSA subsidies are typically regressive as richer farmers and those who have a large land and more resources often benefit most from subsidies (Donovan, 2004). Also, loans for farmers often go to farmers who have low repayment rates and are politically connected. Moreover, moderate CSA subsidies might lead to the involvement of the government in CSA politicization, distribution, and very costly failures to supply the right kind of CSA at the right time. Heavy subsidies could induce CSA use by stochastically hyperbolic farmers, but they also could lead to overuse by farmers without time consistency problems. However, studies such as Donovan (2004) and Schultz (1964) indicate that agricultural subsidies have less effect on the adoption of agricultural technologies than the elimination of demand-size and supply-size barriers to adoption. This implies that timing offers before or after harvest for purchasing inputs and time-limited discounts on CSA practices could induce sizeable changes in CSA adoption. In particular, early discounts of the same order of magnitude as the psychic costs associated with CSA purchases can induce the same increase in CSA adoption as much larger discounts of the order of magnitude of the out-of-pocket costs of CSA later in the season. Moreover, ex-ante harvest, some farmers would choose to be eligible for the discount early on, to have the option to commit to CSA adoption.

Most times, information about new technology is usually acquired when farmers experiment on a small portion of their land or when they learn from their neighbors who have experience with the technologies (Dzanku *et al*., 2020; Abdul-Mumin and Abdulai, 2021; Yitayew *et al*., 2022). It is noteworthy that many authors argue that learning may not be the important driver of imperfect adoption decisions observed in Africa because modern inputs have been available for several decades and are supported by extension services in the region

(Suri, 2011; Yitayew *et al*., 2022). However, new varieties of experimentation tend to affect the learning process, especially when supplied in packages or quantities that will enable rural and smallholder farmers to test new technologies on a small scale (Pannell *et al*., 2006; Yitayew *et al*., 2022). Consequently, if CSA practices are not marketed in desirable packages or quantities and at affordable prices for rural farmers, it may lead to low adoption. An inefficient input delivery system is partly accountable for the low rates of adoption of CSA practices. Also, farmers who have contracts with their suppliers may want to increase output to be able to meet their contractual agreements. According to the UN Economic Commission for Africa (2010), most times, it is the public or parastatal companies that hold the largest share of the improved inputs markets in Africa with low contribution from the private sector. Thus, improved inputs are often marketed in a one-size-fits-all fashion in one or two large sizes, which makes it difficult for rural farmers to find inputs in suitable quantities they intend to use and can afford (Yitayew *et al*., 2022).

There is a need for building households' and individuals' resilience, such as public investment in CSA practices, adopting other income/livelihood diversification strategies, and reducing the cost of production to enhance farmers' resilience to CC. After the global crisis in 2008, many governments in developing countries enticed investors into agriculture (Khadjavi, Sipangule, and Thiele, 2021). In many African countries, the demand for agricultural lands has increased due to speculation of gaining high profitability from investing in agriculture and government incentives for investors investing in agriculture (Collier and Venables, 2012; Khadjavi *et al*., 2021). This has increased the demand for large tracts of land for agricultural purposes and has triggered large-scale investment in agriculture. These investments have resulted in infrastructure development and employment creation (Khadjavi *et al*., 2021). Lay *et al*. (2018) indicate that rural farmers within areas with large-scale investments in agriculture have higher yields than their counterparts not within areas with large-scale investments in agriculture. According to Deininger and Xia (2016), large-scale agriculture investments lead to input use and agricultural practices adoption among smallholder farmers. Thus, investment in agriculture and CSA practices could lead to household sustainability. To reduce the risks from the agriculture sector and maintain household livelihood, economic empowerment through livelihood diversification has become an important strategy used by farmers to improve their livelihoods, become resilient, and respond to CC or variability risks.

Teshager Abeje *et al*. (2019) emphasized that it is pivotal to explore the empirical relationship between household livelihood diversification—access to sources of nonfarm and off-farm income activities—and agricultural technology adoption among rural households.

Issahaku and Abdul-Rahaman (2019) found that the diversification of livelihoods among smallholder farmers is geared toward increasing household incomes. Yet, these livelihood diversifications cannot be achieved with time poverty. Time poverty is a developmental issue that affects individuals or households differently, even for those earning the same income since these individuals or households may be using different labor hours (Martey *et al*., 2022). This implies that individuals or households participating in CSA practices and earning the same income may face different time poverty. The poor can only rely on their labor as their main asset as they generally can engage in (paid or unpaid) work to meet their needs and hope to escape poverty. Time is an input to the production of commodities and, therefore, provides direct utility (Becker, 1965). The issue of time usage and its relationship to consumption poverty is especially important. Households have a high probability of being consumption-poor, so strategies that enable household members to gain a better livelihood—for example, by shifting their time from low-productivity to high-productivity activities—should be pursued.

Time-use issues have strong gender dimensions, as African women must often work long hours performing domestic chores and collecting water and wood, apart from their paid or unpaid work in the fields or other labor market activities (ILO, 2021; UNECA, 2021). SDG 8 encourages countries to promote sustained, inclusive, and sustainable economic growth, full and productive employment, and decent work for all by 2030 (UN Department of Economic and Social Affairs, 2018; UNFPA, 2022) to reduce poverty. Further, the agriculture sector in Ghana is faced with the major challenge of low productivity, especially for staple crops such as cocoyam, soybeans, cassava, maize, and rice (Ministry of Food and Agriculture [MoFA], 2017), implying that yields in Ghana are still far below the achievable potential. This underperformance is attributed to the low capacity to adopt and use improved technologies (MoFA, 2017). Based on this logic, there is a need to increase the adoption of CSA practices.

Additionally, Searchinger *et al*. (2020) indicate that agriculture contributes about a quarter of GHG emissions, of which more than half comes from the process of production emitting largely nitrous oxide and methane. The remaining half of GHG from agriculture is created through CO_2 released by peat soil degradation and clearing woody savanna and forest areas for agricultural purposes (Searchinger *et al*., 2020). GHG emissions result, for instance, from enteric fermentation, application of synthetic fertilizers, deforestation, and changes in land usage, while a sink removes atmospheric GHG by storing (sequestering) it in other forms through photosynthesis (De Pinto and Ulimwengu, 2017). Without mitigation, the current emissions from agriculture of about 12 billion tonnes of CO_2 equivalents annually are more likely to rise to 15 billion tonnes of CO_2 equivalents by the year 2050 (Searchinger *et al*., 2020).

In these scenarios, agriculture alone will use almost 70% of the annual allowable emission budgets for all emissions from humans, including energy, that will be necessary to hold warming to international climate goals.

At the same time, food systems are estimated to contribute more than a third of the global GHG emissions responsible for CC (IPCC, 2019), placing food production at the center of attention as both a contributor to global warming and a critical sector for mounting an adaptive response to CC. Thus, beyond its direct impacts on production, CC will create trickle-down effects on livelihoods and sustainability through interconnections among economic, environmental, social, and political spheres. Even in the absence of CC, food systems face enormous challenges and demands. Hunger and malnutrition are rising, and over 3 billion people currently cannot afford a healthy diet (FAO, 2021; World Food Programme, 2021), while 2.5 billion people worldwide depend on agriculture for their livelihood (FAO, 2016). Food systems are the world's largest "employer," but for many, particularly women, youth, and other vulnerable groups, agriculture-based livelihoods are precarious. In addition, food systems are major contributors to environmental degradation beyond GHG emissions, including the deterioration of water resources and loss of habitat and biodiversity, which compromise environmental services that support food production (IFPRI, 2022).

Furthermore, of all the world regions, sub-Sahara Africa (SSA) including Ghana, are most vulnerable to CC because of its high dependence on rain-fed agriculture, and natural resources (Egbendewe *et al*., 2017; FAO, 2016; IPCC, 2014), weak governance or lack of quality institutions (Amoah *et al*., 2020), majority of the farmers practicing subsistence farming and are resource-poor (Peprah, Oteng and Sebu, 2020), and inadequate infrastructure (IPCC, 2014; Clark *et al*., 2018; Egbendewe *et al*., 2017; Thorn *et al*., 2021). According to the World Bank (2020), the significant intensification of the pace and scale of climate impacts challenges the ability of many countries in SSA to reach their economic growth and development goals. Yet, Africa accounted for 15% of the world's agriculture-related GHG emissions in 2012, making it the third most important contributor, after Asia (45%) and the Americas (25%) (Tubiello *et al*., 2014). Between 2000 and 2018, agricultural emissions in Africa steadily increased, reaching 2.2Gt of CO_2eq by 2018. This represented 24% of global agricultural emissions, up from 18% in 2000 (FAO, 2020). Most SSA economies, including Ghana, are unable to fully self-finance climate mitigation and adaptation projects. Within the continent itself, rural populations and farmers are the most vulnerable groups to CC and variability.

Therefore, agricultural production under changing climatic conditions is a serious challenge for SSA and nations like Ghana, where agriculture contributes a significant part of

the socioeconomic well-being and livelihood of the population (Adji, Egbendewe, Lokonon, 2021). Ghana's agricultural sector accounts for export earnings of almost 40% and provides 90% of the food needs of the country (FAO, 2019). According to the Ghana Statistical Service (GSS) (2022), the agricultural sector in Ghana contributes 33% to the GDP and accounts for about 78.7% of employment in rural areas. The majority of these rural farmers in Ghana practice subsistence farming, have only small land holdings (less than 1.2 hectares) (GSS, 2021; Peprah *et al*., 2020), representing 80% of all farms (GSS, 2021), and barely have insurance capacities and access to institutional services like extension services to reverse the adverse effects and farming conditions resulting from CC (AU, 2021; Preprah *et al*., 2020). The changing climatic conditions exert additional pressure on rural farmers through a reduction in soil fertility and water resource availability and enhanced incidences of pests that negatively affect crop physiology (World Meteorological Organization [WMO], 2019), thereby reducing yields (Lokonon, Egbendewe, *et al*., 2019).

The consideration of adaptation and mitigation possibilities such as CSA practices, especially for smallholder farmers in rural areas and farmers in poor countries, would help achieve SDGs 1, 2 and 13. The CSA approach was developed in response to limitations in the international climate policy arena in the understanding of agriculture's role in food security and its potential for capturing synergies between adaptation and mitigation (FAO, 2018). CSA relies on agricultural systems that contribute to three outcomes: (1)sustainable and equitable increases in agricultural productivity and income; (2)greater resilience of food systems and farming livelihoods; and (3)reduction and removal of GHG emissions associated with agriculture, wherever possible. Agricultural production systems that follow the tenets of CSA are expected to be not only more productive and efficient but also resilient to short-, medium-, and long-term shocks and risks associated with CC and climate variability. Ultimately, CSA's utility is its effectiveness in integrating CC response into sustainable agricultural development strategies on the ground (FAO, 2018). Crop rotation, agroforestry, improved seed varieties, mulching, and other practices are largely recognized as promising adaptation strategies for averting CC effects on systems of agricultural production (Azumah *et al*., 2022; Egbendewe *et al*., 2017; FAO, 2015).

The CSA approach represents a departure from the single-objective approach that underlies most work to ensure food and nutrition security (FAO, 2018) and sustainably improve the livelihood of adopters (Azumah *et al*., 2022; Amadu, 2020; Asare-Nuamah and Amungwa, 2020). CSA's multi-objective approach facilitates important conversations, negotiations, and coordination of interventions among different organizations. Many operational aspects of CSA,

however, are still under investigation. Local contexts determine the enabling environment, the trade-offs, and the synergies of CSA practices. The conditions for their adoption are highly specific to contexts and locations, with fundamental implications for the operational aspects of CSA. Achieving agricultural sustainability requires that a wide range of approaches that meet the needs and priorities of farmers are looked at and implemented at different levels. This is because agricultural output growth is considered one of the surest ways of effectively addressing poverty in the developing world, such as Ghana (Tesfaye *et al*., 2021; WB, 2020).

Another approach being promoted to ensure the eradication of extreme poverty and promote inclusive and sustainable development is trade (Egbendewe *et al*., 2017; Sommer and Luke, 2016). Trade is recognized as a cross-cutting means of implementing the 2030 Agenda for Sustainable Development under SDG 17 (Appiah *et al*., 2023; Hagos *et al*., 2023; World Bank, 2020). Hence, the establishment of several regional economic communities to promote economic integration and trade, including the Common Market for Eastern and Southern Africa (COMESA), the Economic Community of West African States (ECOWAS), and the Southern African Development Community (SADC), African Continental Free Trade Area (AfCFTA) aimed at tapping their benefits. Economic integration is encouraged because it remains a vibrant path through which growth and development can be achieved (Hagos *et al*., 2023; Appiah *et al*., 2023; UNCTAD, 2020). Increasing the export capacity of developing countries such as Ghana to the markets of the industrialized nations has long been considered an important tool for promoting sustainable development, reducing poverty, and reaping the benefits of potential globalization for the developing world (World Bank, 2020).

From the foregoing, there is a need to understand the role of economic empowerment, including CSA practices adoption and CSA investment in trade, time poverty and its role in addressing vulnerability to CC. In the face of high CC and climate variability, an assessment of CSA adoption, trade flows and resilience of rural farmers to CC in Ghana would justify its upscale and extension.

Objectives of the Study

The main objective of this research is to evaluate the impact of CSA on agricultural commodity trade and rural farm households' resilience to CC in Ghana. Specifically, the study seeks to;

i) simulate the impacts of the government's CSA investment on agricultural commodities trade flows and price fluctuations in Ghana between now and 2050

ii) examine the impact of the agricultural input supply system and contract on nudging the adoption intensity of CSA among rural farmers in Ghana
iii) estimate the impact of CSA practices on rural farm households' time poverty in Ghana.

Research questions

Therefore, the question worth probing is: does CSA enhance agricultural commodity trade flows and rural farm households' resilience to CC in Ghana? Specifically;

i) what is the impact of the government's CSA investment on agriculture commodities trade flows and price fluctuations in Ghana between now and 2050?
ii) how can the agricultural input supply system and contracts nudge CSA adoption intensity among rural farmers in Ghana?
iii) Do CSA practices impact rural farm households' time poverty in Ghana?

Hypotheses of the study

i) H1: government CSA investment has a significant positive effect on agriculture commodity trade flows and a significant negative effect on price fluctuations in Ghana
ii) H1: agricultural input supply systems and contracts have a significant positive impact on CSA adoption in Ghana
iii) H1: CSA practices have a significant positive impact on rural farm households' time poverty in Ghana

Value added

The adverse externalities posed by CC in current and future generations and by estimation, the world population hitting 9 billion in 2050, requires a corresponding improvement in the production of food by about 70% (UN, 2021). For developing countries, it is estimated they will witness a significant population boom by 2050, doubling their current population of about 6.62 billion to more than 7.5 billion (which is 85.22% of the global population). With population surges, the possibility of a threatening food crisis remains imminent, especially among economically vulnerable and disadvantaged populations such as Ghana. Further, underinvestment in agricultural inputs such as hybrid seeds, labor, or CSA practices is thought to drive low crop productivity and yields. This is a crucial step to achieve the SDGs, particularly SDG 1.3 and SDG 2. Climate-smart trade policies and openness to trade are critical to reducing poverty. Agro-food global value chains can positively influence factors

such as productivity, production growth and quality (UNCTAD, 2009), which is influenced by investment and trade policies, such as the availability of specific investment incentives, investment restrictions, tariffs, technical requirements, quality standards, and the presence of bilateral and regional trade and investment agreements (OECD, 2014; Punthakey, 2020).

Due to these, there has been substantial literature (e.g., Kowalski *et al*., 2015; Greenville *et al*., 2017; Punthakey, 2020; Webber and Labaste, 2010) on foreign participation in the agriculture and food sectors. Yet, there has been little analysis of the impact of investment in CSA practices on participation and domestic value-added creation in agro-food global value chains. Previous studies have largely focused on the impacts of trade policies on global value chain participation, with some peripheral analysis of FDI and investment policies. Furthermore, even less is known about the influence of government investment and policies on CSA practices in the agro-food sector and the specific policy and market conditions that affect agricultural commodities trade flows and price fluctuations. Despite the effect of investment on trade, studies on the impact of investing in CSA practices on agricultural commodities trade flows and price fluctuations have been neglected in the literature, especially in Ghana. For example, studies attempted to reveal the impacts of trade preferences on receiving regions such as SSA, ECOWAS, CAEMU, etc (e.g., Baah, 2015; Didia *et al*., 2015; Haile *et al*., 2017) while studies such as Egbendewe *et al*. (2017) analyzed intra-regional trade on food security. Therefore, this study contributes to the debate on the effects of CSA on the exports of beneficiary countries to fill this gap. Further, macroeconomic development remains an important policy goal because of its ability to move people out of poverty. Macro development policies include large-scale policies in a wide range of taxes, trade, infrastructure, education, and health. This study aids in opening up more domestic opportunities for export promotion and modifications that put Ghana in a position to reap more benefits. This study would also provide basic information to policymakers on the role of economic empowerment in addressing rural inequalities and climate vulnerability.

Again, this study seeks to estimate how to model agriculture input supply systems and contracts to influence the adoption of CSA, which other empirical studies have ignored. For example, studies such as Adji *et al*. (2022); and Shahzad and Abdulai (2021) focused on credit and subsidies, studies such as Ali *et al*. (2020) and Budhathoki *et al*. (2019) focused on willingness to pay while Beaman *et al*. (2021) considered contagious learning environment and network theory on the adoption of new agricultural technology. To fill this gap, this study contributes to the literature on the impacts of agricultural input marketing strategies and contracts on the adoption of CSA practices in rural areas in Ghana. The findings from this study

could provide useful insights for policymakers and other stakeholders to develop better strategies for targeting and enhancing CSA adoption by making shelved agricultural inputs available to rural and smallholder farmers and, as such, contribute to improving agricultural productivity and food security. This would offer a roadmap to build resilient small-scale agri-food production.

Although time poverty affects resilience and livelihood diversification, which has been hyped in the literature as suitable for improving welfare, the roles of CSA in influencing it have not been explored. For example, Dhakal *et al*. (2022); Martey *et al*. (2019); Ojo and Baiyegunhi (2020; 2021); and Diallo *et al*. (2020) focused on traditional outcomes such as farm productivity, household income, consumption expenditure and food security while Dhakal *et al*. (2022); Di Falco *et al*. (2011) focused on risk exposure and others such as Etwire *et al*. (2022) focused on assets. Martey *et al*. (2022a) considered off-farm work on time poverty, while Martey *et al*. (2022b) considered parental time poverty on child work and schooling. With the given assumption that rural farmers could reduce hunger by as much as 17% (FAO, 2011), understanding time poverty differentials among adopters and nonadopters of CSA is vital. Therefore, this study would offer the mechanisms through which the potential of CSA adoption intensity is harnessed and how welfare gaps in rural and urban areas could be minimized, if not eradicated.

This study suggests useful policy information that can serve as a turning point for bridging the developmental challenges, especially resilience, time poverty, and sustainable production to CC. Specifically, this study provides recommendations to CC policymakers, especially the MoFA, Ministry of Environment, Science and Technology, and other Non-governmental Organisations on the policy directions required to address agricultural production risks associated with CC.

This study is organized into three essays. Essay One focuses on simulated impacts of the government's CSA investment on agricultural commodities trade flows and price fluctuations in Ghana between now and 2050. Essay Two examines the impact of the input supply system and contracts on nudging the adoption intensity of CSA among rural farmers in Ghana and Essay Three analyses the impact of CSA adoption on farm households' time poverty in the rural areas in Ghana. The General Conclusion is presented in the last section of the study.

ESSAY ONE

SIMULATING THE IMPACTS OF CLIMATE-SMART AGRICULTURAL INVESTMENT ON TRADE FLOWS AND PRICE FLUCTUATIONS IN GHANA

1.1 Introduction

The impact of CC requires a holistic approach, such as public investment in CSA practices and reducing the cost of production that can increase trade (Nugroho *et al*., 2023; Candau *et al*., 2022) and reduce prices of agricultural commodities. Agricultural production systems that employ CSA practices become more productive and efficient, as well as demonstrating resilience to CC and variability-related shocks over the short, medium, and long terms. Increasing returns to scale can lead to specialization and trade, even between similar countries (Krugman, 2009). The new trade theory of Krugman (2009) indicated that firms can achieve cost advantages by producing large quantities of goods, which incentivizes specialization, and that trade allows firms to access larger markets, spreading fixed costs over more units and lowering prices. Firms can benefit from lower costs of production, access to specialized inputs, or favorable institutional frameworks.

Moral hazard plays a key role in emission and climate investment. A country may not be incentivized to reduce local emissions of pollutants in the same way a private producer in search of profits may not be incentivized to also clean and protect the environment. Moral hazards in the context of carbon emissions and CC can also arise when governments implement policies that aim to reduce emissions, such as emission trading or carbon tax schemes (Mintz-Woo *et al*., 2021; Barragán-Beaud *et al*., 2018). As a result of this, economists suggest the use of command-and-control approaches to incentivize economic agents (Tietenberg and Lewis, 2018). Therefore, government intervention becomes necessary when it comes to the control of the problems of externalities. These interventions may come in the form of pollution abatement technologies, subsidies, taxes, bans, and fines (Tietenberg and Lewis, 2018), as well as investment in CSA practices (El-Dukheri, 2024). For instance, some countries internalize externalities by making laws that protect the environment. For some governments, it is now a priority to define economic policies that are appropriate to contain environmental degradation and consequently improve the quality of the environment (Liu 2011; Allison *et al*., 2011).

SSA and countries such as Ghana have a comparative advantage in cash crops such as cacao and coffee production since agriculture in Africa accounts for more than 50% of employment (Gero and Egbendewe 2020). Economic opinions suggest that it is a difficult and slow process for SSA to become a major manufacturing center like Asia (Kormawa and Jerome 2014). It is, then, better to exploit opportunities to promote the growth of productive jobs, such

as the transformation of agriculture. This is because agriculture is a dominant employer in SSA and Ghana faces a rapid demand at both country and continental levels (Diao *et al*., 2019). Generally, investment is a curative measure. Ghana must, therefore, invest in agricultural production such as CSA practices to achieve the benefits of comparative advantages in the face of CC and climate variability.

Badiane and Ulimwengu (2017) project that Africa's agricultural demand will increase by more than 100% by 2050. This is driven by rising income, population growth, rapid urbanization, changes in national consumption towards higher consumption of fresh and processed foods, and more open intra-regional trade policies. World Bank (2014) estimates that agribusiness in Africa could become a US$1 trillion market by 2030, excluding the value of additional agricultural production that would be required to support agribusiness growth. Further, WFP and FAO (2023) warn that many countries are sliding into acute food insecurity exacerbated by CC. Their report is clear on helping people to adapt to CC to prevent hunger. The hunger crisis is not only affecting an increasing number of individuals across the globe, but the severity is reaching unprecedented levels. Hence, a need for the investment accelerator model, which requires a major transition from conventional to more sustainable, productive, and market-driven agricultural practices. This is a very relevant growth opportunity for SSA but requires that SSA governments be keen on investing in agriculture.

Climate-smart development can be cost-effective in both the short and long terms (World Bank, 2020) to improve agricultural production. The Global Commission on Adaptation (2019) asserts that the overall rate of return on investments in improved resilience can be high, with benefit-cost ratios ranging from 2:1 to 10:1 and, in some cases, even higher. Increased investment in agriculture and food systems is critical to enhancing food security and nutrition, reducing poverty, and adapting to CC. To generate sustainable benefits, however, it is crucial to ensure not only that more investments are made but that more responsible investments are made (El-Dukheri, 2024; FAO, 2021; Bulman *et al*., 2021).

Beyond the essential public investment that governments make in the agricultural sector, governments also play an important role in facilitating and supporting investment by small-scale producers and other private-sector investors in agriculture and food systems (El-Dukheri, 2024; FAO, 2019). Strategic policy interventions, such as targeted investment incentives, can help to steer investors to invest more and in a responsible manner, to promote sustainable development and achieve the SDGs. However, incentives may be ineffective, and even detrimental, if certain fundamentals are not in place. These fundamentals include factors such as strong institutions, reliable infrastructure, and laws that protect human rights and the

environment. Investment in infrastructure may be used to induce economic growth by improving the country's attractiveness (El-Dukheri, 2024; Fosu and Twumasi, 2022; Mustafakulov, 2017). It is important to mention that solving CC involves collective efforts as individual efforts may prove futile (Nordhaus, 2019). Often, the general approaches to environmental policymaking consist of command-and-control regulation, market-based incentives, hybrid approaches, and voluntary initiatives (Heinzerling, 2012).

Other countries embark on investing in climate-friendly programs such as CSA practices. In line with the modern portfolio theory, which suggests that investors can minimize risk and maximize returns by diversifying their portfolios across different asset classes, Ghana must diversify its economy from the service sector to the agriculture sector by investing in CSA practices. According to modern portfolio theory, investors should aim to achieve the highest possible return for a given level of risk, taking into account the correlation between different investments (Cui and Cheng, 2022). In the face of high CC and climate variability risks, public investment in CSA practices must be prioritized by all governments across the globe and must be an integral part of their business and investment models.

Another approach being promoted to ensure the eradication of extreme poverty and promote inclusive and sustainable development, especially in the face of climate-induced changes, is trade (Sommer and Luke, 2016). Trade is recognized as a cross-cutting means of implementing the 2030 Agenda for Sustainable Development under SDG 17. Climate-smart trade policies and openness to trade will be critical for Ghana to reduce its poverty level. As indicated by Hagos *et al*. (2023) and Appiah *et al*. (2023), trade is a major catalyst for economic development. It is not surprising that agricultural commodity trade in Africa has increased steadily over the past three decades, with net exports rising from 2% to 6% of GDP between 1980 and 2014 (IMF, 2016). Despite these improvements, the region not only accounts for a small share of the global commodity trade but also has one of the lowest intraregional trades in goods (16%, versus 17% for South and Central America, 42% for North America, 62% for the EU, and 64% for Asia) (Davis, 2016). Nevertheless, several regional economic communities have been established, such as ECOWAS, CAEMU, and the recent AfCFTA, which is expected to boost trade by 52% (Appiah *et al*., 2023; Hagos *et al*., 2023; UNECA, 2017). These call for investigating the effect of public investment in CSA practices on trade flows and price fluctuations.

The main objective of this essay is to analyze the effect of investment in CSA practices on trade flows and price fluctuation in Ghana between now and 2050, characterizing efficiency in an equilibrium model of investment. Specifically, the essay seeks to;

(i) assess the effect of government investment in CSA on agriculture commodity trade flows in Ghana;
(ii) estimate the effect of government investment in CSA practices on agricultural prices in Ghana.

The choice of our study period is informed by the fact that the UN (2021) simulates that the world population will be nine billion in 2050. Also, to meet the demand for Africa's agriculture, which is projected to increase by more than 100% by 2050 (Badiane and Ulimwengu, 2017). Visualizing simulated future scenarios can engage and inform the public, policymakers, and stakeholders about long-term challenges and opportunities. This can foster a better understanding of complex systems, encourage proactive decision-making, and promote dialogue and collaboration toward desirable futures. This has become necessary since new investment reduces future prices of the old capital, providing a rationale for new investment subsidies. Also, globally, macroeconomic policies have been one of the main reasons many remain in poverty. Macroeconomic development policies target economic development that is large enough to have important economy-wide or aggregate welfare and distributional implications.

Thus, the macroeconomic question of what determines the distribution and aggregate level of income remains of utmost importance. Also, it is worth mentioning that several researchers over the years have made attempts to reveal the impacts of trade preferences on receiving regions (e.g., Didia *et al*., 2015; Haile *et al*., 2017; Yousif, 2024). Using a theoretical model, Kleemann and Thiele (2015) evaluate the welfare effect of investment in large-scale agricultural land on rural populations in SSA. Other studies, such as Egbendewe *et al*. (2017) analyze intra-regional trade on food security. Thus far, the literature on investment in the agricultural sector has focused mainly on directly observable outcomes such as employment opportunities, productivity, and income. Yet, these insightful studies have neglected the key role of investment in CSA practices on trade flows and price fluctuations in enhancing resilience. Despite the numerous research on trade, serious attempts to look critically at the impact of public investment in CSA practices are very limited. Therefore, this essay analyses the effect of government CSA investment on agricultural trade flows and price fluctuations in Ghana.

The organization of this chapter is as follows. The next section is on the background of agriculture investments and outputs, with a particular focus on Ghana. The next section focuses on theoretical and empirical reviews. The fourth section presents the methodology, the dynamic computable equilibrium model, and the data sources. The fifth section presents the

interpretations and discussions of the results of the essay. The final section focuses on the conclusion and policy implications of the chapter.

1.2.1 Background of Agriculture Investments and Outputs

As part of the 2014 Malabo Declaration, Heads of State and Governments in Africa committed to building a climate-resilient food system and ensuring the provision of social protections for rural and vulnerable groups (Kramer *et al*., 2019; MoFA, 2022). The key commitments of the declaration include increased investment finance in agriculture, reducing postharvest losses, and boosting intra-Africa trade (MoFA, 2022). The specific commitments and targets to reach 2025 are the following: a)improving the resilience capacity of at least 30% of pastoral, farmer, and fishing households by equipping them to adapt to, mitigate and recover from stresses and shocks; b)having 30% of agricultural land under sustainable land and water management or CSA practices; and c)creating investment and an enabling environment for resilience initiatives, especially for disaster preparedness plans, early warning and response systems, social safety nets and weather-based index insurance (Kramer and Ceballos, 2018). Some African countries are on track to achieve the share of agricultural land under sustainable management practices (Annosi *et al*., 2021; Benami *et al*., 2021; Casino *et al*., 2021).

Furthermore, important investments are being made at the continental and national levels, led by the African Development Bank (AfDB) (Jouanjean, 2019). AfDB, through the African Financial Alliance on CC, is mobilising US$25 billion for low-income African economies. It has also established the Africa NDC Hub to serve as a resource pool for its member countries, with a focus on fostering long-term climate action, mobilizing resources for implementation, and coordinating other NDC-support activities on the continent (AfDB, 2021). In Ghana, the Alliance of Biodiversity International, in collaboration with the International Centre for Tropical Agriculture, has implemented agricultural development projects such as Accelerating Impact of CGIAR Climate Research for Africa. CGIAR supports the development and implementation of CSA practices, with monitoring and evaluation frameworks at the regional and sub-national levels for building resilience in agrifood systems (UNDP, 2018).

The Government of Ghana (GoG) has invested and made efforts in adaptation and mitigation strategies to increase agricultural production and exports. Emmanuel *et al*. (2016) and Donkor *et al*. (2018) assert that Ghana's agriculture sector has received a glaring focus and attention from both state and non-state agricultural institutions since the 1970s, with several policies and programs geared towards enhancement in production and productivity. Currently, some of the flashy programs and policies of the GoG include 'Planting for Food and Jobs' (PFJ),

'Planting for Food and Export (PFE)', 'Eat What We Grow and Grow What We Eat' and others are to promote domestic consumption, trade and export of other non-traditional agriculture commodities, increase the productivity of food crops and emergency preparedness. According to the MoFA (2022), the ministry was allocated a total budget of GH₵0.9billion, GH₵1.2billion, GH₵1.4billion, and GH₵1.6billion in 2018, 2019, 2020, and 2021, respectively. This is expected to ensure the provision of irrigated land use efficiency, fertilizer application, agriculture extension services, greenhouse farming, improved seed varieties, access to mechanization services, and monitoring of agricultural trade statistics and producer prices. Similarly, a target of halving chicken meat importation by 2026 via a project under the Ghana CARES program was proposed in 2021 (MoFA, 2022; USDA Foreign Agricultural Services [USDAFAS] and Global Agricultural Information Network [GAIN], 2022).

In 2021, GoG spent an amount of US$70 million to fund the program. In 2022, the government spent US$98 million on the program, an increase of 40% in funding over that of 2021. The number of PFJ beneficiaries increased from 0.202 million in 2017 to more than 1.74 million in 2020. More than 1.93 million crop farmers were projected to be beneficiaries in 2021. The PFJ program had targets of increasing the 2016 production levels of corn by 30% from 1.722 million metric tonnes to 2.239 million metric tonnes; rice (paddy) by 49% from 0.69 million metric tonnes to 1.03 million metric tonnes; soybean by 25% from 0.14 million metric tonnes to 0.18 million metric tonnes; and sorghum by 28% from 0.23 million metric tonnes to 0.29 million metric tonnes, all within the program period of four years. At the end of the original program period, the 2020/2021 crop production figures for corn (3.03 million metric tonnes), paddy rice (0.99 million metric tonnes), soybean (0.21 million metric tonnes), and sorghum (0.35 million metric tonnes) indicated that all the targets were realized except for rice (USDAFAS and GAIN, 2022). The program is deemed to have improved food security, reduced poverty, and ensured the availability of selected food crops on the market, as well as provided job opportunities within the agribusiness value chain. However, it is asserted that the gains made from the PFJ program are not able to fully impact the country's rice import trade.

1.2.2 Agriculture Investment and Trade in the Ghanaian Context

Figure 1.1 displays that the number of rice imports recorded in 2017 (after the launch of the PFJ) was only 8% lower than the quantity recorded in 2016. Indeed, imports increased in the subsequent years (2018-2020), buttressing the fact that the country is still far from achieving self-sufficiency in rice supply. Maize imports decreased by approximately 30% in 2016 and further decreased to approximately 49% in 2017. However, in 2018, imports of maize

increased to more than 100% and subsequently decreased sharply by 89% in 2019. In 2020, imports of maize increased by 6%. Import for rice in the same period decreased by 9.3% in 2016 and further by 16.5% in 2017. However, in 2018, imports of rice increased by 1.3% and tremendously increased by 31% in 2019, and decreased by 34.89% in 2020. This could probably be, for instance, due to minimal rainfall in 2017, and the yields of many cereal crops were greatly affected in 2018.

As shown in Figure 1.2, maize exportations to neighboring countries such as Burkina Faso, Togo, and Cote d'Ivoire increased from 11.015 thousand metric tonnes in 2015 to 23.483 thousand metric tonnes in 2018 after which it fell sharply to 0.759 thousand metric tonnes in 2018 and rose again to 14.128 thousand metric tonnes in 2019 and 17.240 thousand metric tonnes in 2020. The exportation of rice was stable at around 3.2 thousand metric tons until 2019, when its exportation dropped significantly to 0.759 thousand metric tons and further decreased to 0.322 thousand metric tons in 2020. These are not surprising since there was an increase in the import of rice and maize in 2018. The trends of yam exports have been positive since 2015, from 2.489 thousand metric tons to 31.127 thousand metric tonnes in 2020. Similarly, exports of plantain have been increasing from 16.052 thousand metric tons in 2015 to 43.802 thousand metric tons in 2018, after which it decreased to 40.190 thousand metric tons and further decreased to 20.667 thousand metric tons in 2020. Exports of soybeans were around 2.1 thousand metric tons in 2015 and 2016 and 3.56 thousand metric tons in 2017 and 2018. It, however, decreased sharply to 0.830 thousand metric tonnes in 2019 and further decreased to 0.697 thousand metric tonnes in 2020.

The total exports of these staple food crops have shown an increase from 31.154 thousand metric tons in 2015 to 99.054 thousand metric tons in 2018. However, the total exports decreased to 84.986 thousand metric tonnes in 2019 and further to 70.052 thousand metric tonnes in 2020. Plausibly, the COVID-19 pandemic caused a global economic slowdown, which led to a reduction in demand for many products, including agricultural exports. This demand reduction resulted in lower prices for Ghana's agricultural products, which in turn led to a decline in exports. Also, CC has had an impact on Ghana's agriculture sector, with changing weather patterns affecting crop yields and productivity. Extreme weather events such as floods and droughts have led to crop failures and reduced agricultural output, which has contributed to the decline in exports.

Yet, current agricultural supports go largely to agricultural producers, mainly in forms that affect market prices and distort incentives for consumers and producers (IFPRI, 2022).

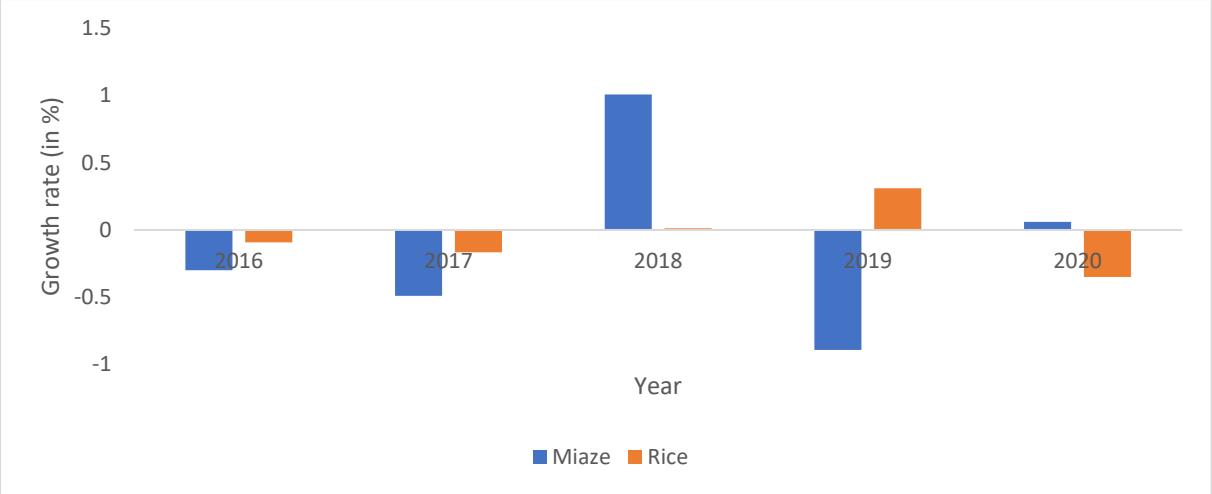


Figure 1.1: Ghana's importation of maize and rice (plot based on data sourced from MoFA (2022)

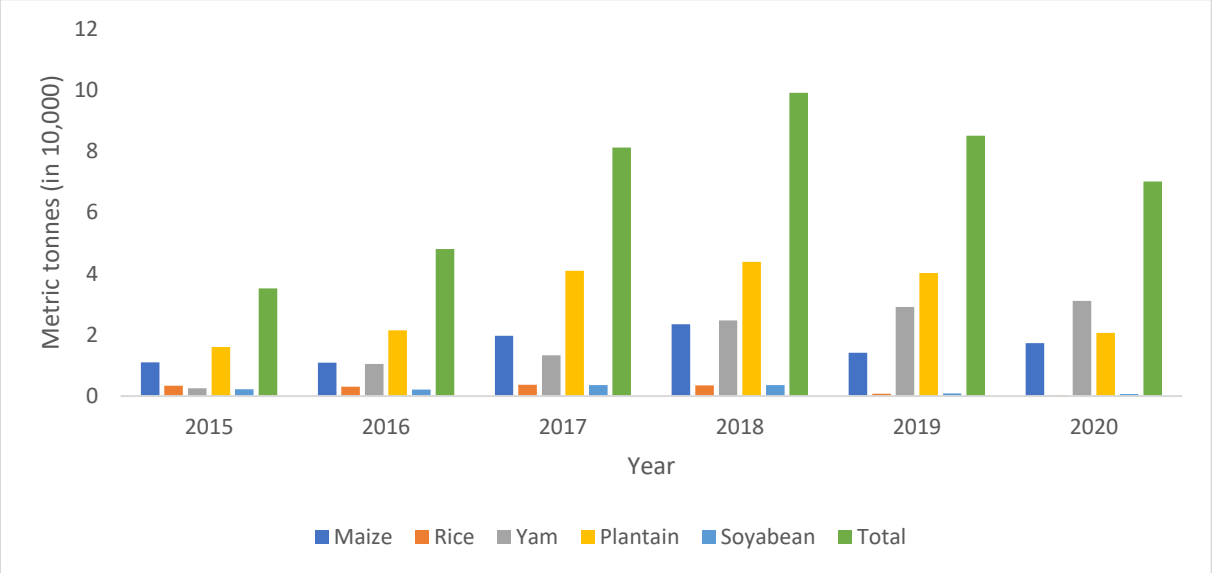


Figure 1.2: Ghana's exportation of staple food to neighbouring countries (plot based on data sourced from MoFA (2022))

According to the report, these current supports amount to US$616 billion annually, net of taxes on agriculture for the period 2018 to 2020. Out of this amount, positive direct farmer support is US$540 billion annually, but some farm activities, primarily exports, are taxed at US$104 billion annually worldwide (OECD, 2021). The positive direct farmers' support includes market price support and trade measures, which, in total, are valued at US$272 billion annually. They entail implicit transfer from consumers to producers by creating a price gap between border prices and domestic market prices for specific agricultural commodities. Agricultural

policy reform must be carefully thought through to achieve drastic reductions in GHG emissions. Only a limited portion of budgetary support is for research and development and agricultural innovation systems, infrastructure, and other services for the agricultural sector. According to the World Bank analysis, only 5% of direct public support for agriculture explicitly targets conservation and other public goods, and only 6% supports research, extension, and technical assistance (Searchinger *et al*., 2020; IFPRI, 2022).

The need for reforms is now well recognized, and the urgency of GHG emission reduction and CC adaptation has added impetus to the calls for reforms (OECD, 2021). The 2021 UN Food Systems Summit called for support repurposing as part of a just rural transition to curative sustainable food systems (Searchinger *et al*., 2020), in which CSA practices play critical roles. These calls for the adoption of CSA practices, investment in CSA practices, and other innovative solutions to increase exports and earn more foreign exchanges and revenues (FAO, 2021). Policy priorities include a) investments along value chains for efficient and safe storage and transport of food crops and products; b) efforts to reduce transport-related GHGs and open trade should be an integral part of CSA and food policies; c) increasing consumer demand for sustainably produced foods, for example through certification programs, can create incentives for changing practices along the entire value chains.

1.2.3 Conceptual Framework of Investment in Climate-smart Agriculture on Trade

The linkage between CC, agricultural production, and trade flow is quite complex, as summarised in Figure 1.3. Given the overreliance of Ghana's agriculture on the weather (GSS, 2021), and its role in the region's trade (FAO, 2019), climatic changes such as rising temperature, weather variability, and extreme weather events will have a significant impact on the availability of productive resources, productivity, food security (Fei *et al*., 2023), foreign exchange, and physical infrastructure (Müller and Robertson, 2014). Important drivers of the relationship between agriculture and trade in the region are the production landscape and the biophysical conditions (Egbendewe *et al*., 2017). Favorable climatic and weather conditions increase net exports by affecting the supply of exportable commodities such as cacao, coffee and other staple crops, whereas CC and climate variability that reduce the supply of agricultural production have the opposite effect, given the possibility of substitution between internally produced and externally procured goods.

CC affects not only yields but also the pattern of production. The pattern of production affects countries' comparative advantage in the production of certain crops. Changing

precipitation patterns and reservoir storage will also impact water availability for power production and irrigation (You *et al.*, 2011). The effects of CC will vary by agroecology and by countries' adaptive capability (Wheeler, 2011). For instance, increasing temperatures are expected to extend the growing season in mid- and high-latitude regions, while cooler temperatures could shorten it in low-latitude areas. In this context, the broad implementation of advanced agricultural technologies and management practices that lower GHG emissions, enhance carbon sequestration in agricultural soils, and prevent harmful land use changes could be instrumental in mitigating the impacts of CC.

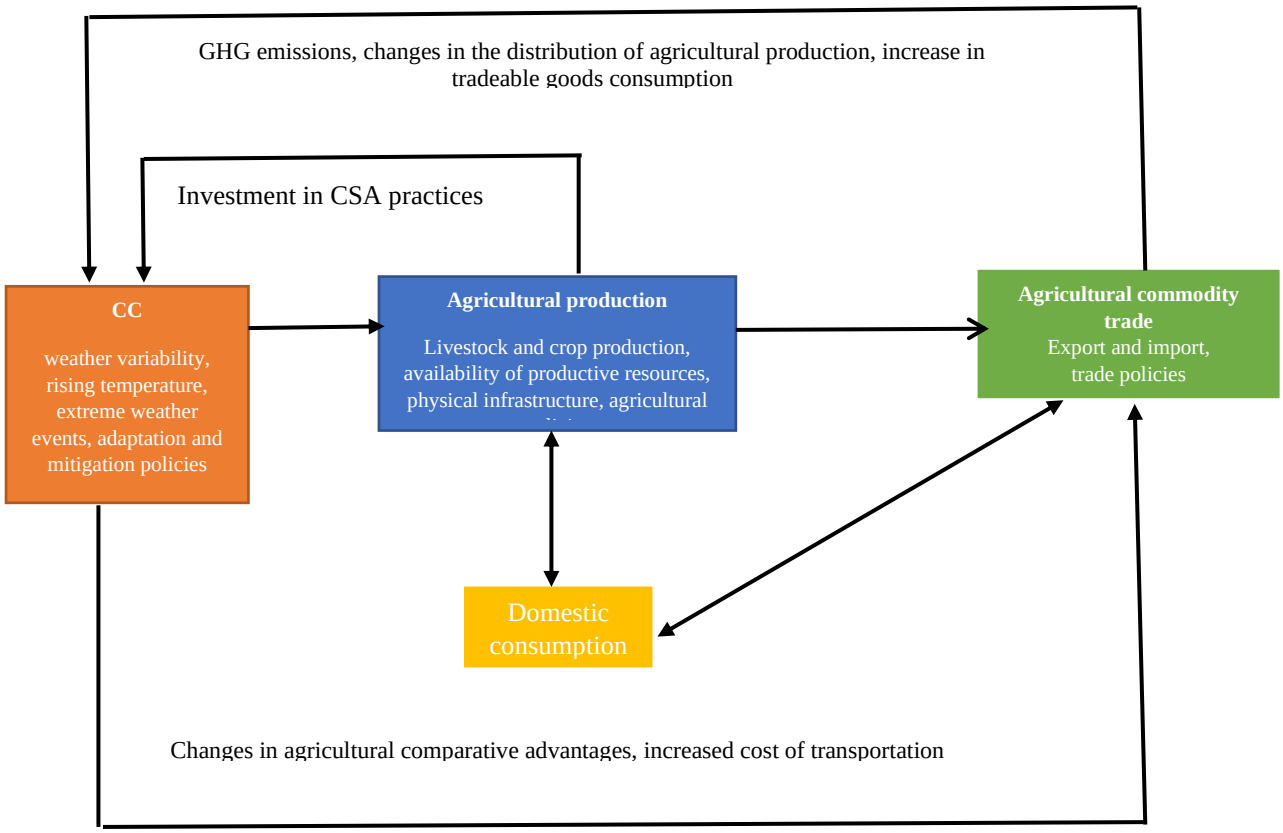


Figure 1.3: Linkages of CSA investment, agricultural production, and Trade
Sources: Adapted from Haile *et al.* (2017)

Unlike continuous tillage, which exposes soils to erosion and contributes significantly to soil carbon loss (Reicosky *et al.*, 2005), no-till practices enhance overall soil fertility by conserving water and nutrients. These practices also improve soil aeration and support soil biota, potentially boosting agricultural productivity (Hobbs *et al.*, 2008; Thierfelder *et al.*, 2013). With no-till as a key component, research on conservation agriculture suggests yield improvements; however, these outcomes vary significantly depending on location-specific factors such as soil type and climate (Pittelkow *et al.*, 2015; Lal, 2015). Similarly, integrated

soil fertility management—a set of context-specific practices that combine organic and inorganic inputs like crop residues, animal manure, and green manure—can substantially enhance productivity (Vanlauwe *et al*., 2011).

Given that agriculture is a crucial foreign exchange earner in Ghana, climatic changes that affect productivity and the distribution of production will ultimately impact Ghana's trade flow. In addition, extreme weather events such as La Niña and El Niño, which interfere with ship navigation and port operations as well as damaged physical infrastructure (Qin *et al*., 2023), could hamper the flow of trade locally, regionally, and internationally (De Pinto and Ulimwengu, 2017). At the same time, trade contributes to CC through increased GHG emissions due to the transportation of commodities and increased consumption of tradable goods. Free trade can help offset climate-induced changes in agricultural production and food supply, and trade liberalization and investments can encourage the introduction of more efficient production processes that emit fewer GHGs per unit of output produced and traded (De Pinto and Ulimwengu, 2017). Thus, trade can serve as both a mitigation and an adaptation strategy to CC.

In conclusion, trade and agricultural policies can either exacerbate or alleviate CC impacts, depending on whether they promote or restrict the production and distribution of goods with high GHG emissions (IPCC, 2007). Additionally, the widespread adoption of advanced technologies and practices may lead to agricultural surpluses if local, regional, and international markets cannot absorb the increased output, potentially discouraging optimal adoption in future planting seasons. While untangling the intricate relationships between CC, agriculture, and trade, this study explores the potential of CSA to enhance trade flows in Ghana amidst anticipated climatic changes.

1.3 Theoretical and Empirical Literature Reviews

1.3.1 Theoretical Review of Investment

The Ricardian model of comparative advantage states that a country has a comparative advantage in producing a good if the opportunity cost of producing that good in terms of other goods is lower in that country than it is in other countries (Krugman *et al.*, 2012). Investment flows to countries with a comparative advantage in specific sectors, where firms can benefit from lower costs of production, access to specialized inputs, or favorable institutional frameworks (UNCTAD, 2020). Investment in critical areas like agriculture and its related infrastructure may be used to induce economic growth by improving the country's attractiveness (Fosu and Twumasi, 2022; Mustafakulov, 2017). Badiane and Ulimwengu

(2017) project that Africa's agricultural demand will increase by more than 100% by 2050. World Bank (2014) estimates that agribusiness in Africa could become a US$1 trillion market by 2030. Exploiting these potentials requires a major transition from conventional to more sustainable, productive, and market-driven agricultural practices. These require government investment in CSA practices.

Krugman's new trade theory challenges traditional neoclassical models of international trade that are based on comparative advantage (Krugman, 1994). New trade theory suggests that economies of scale and imperfect competition play crucial roles in explaining patterns of trade. In industries where economies of scale exist, the production of a good becomes cheaper as output increases. This leads to the concentration of production in a few firms, allowing them to capture a significant market share. Krugman argued that economies of scale (the cost advantages that enterprises obtain due to size, output, or scale of operation) could explain why certain industries are concentrated in specific regions or countries. This challenges traditional trade theories that focus solely on comparative advantage. Krugman emphasized the role of increasing returns to scale in international trade, suggesting that industries with increasing returns may naturally become concentrated in a particular location. This concept challenges the classical assumption of constant returns to scale. Krugman extended his ideas to the field of economic geography, explaining the concentration of economic activity in specific regions (Krugman, 2009). He proposed that agglomeration effects, where industries cluster together, could result from historical accidents or random events. Krugman introduced the concept of the home market effect, suggesting that large markets tend to have a comparative advantage in industries that require a significant domestic market size. This can lead to a concentration of production in countries with large markets.

According to Krugman *et al.* (2012), the first reason countries engage in international trade is that countries differ from each other, so there is a high possibility of having their respective strengths in production as well as other important fields. According to their submission, just as individuals, nations go into agreements in which each has an absolute advantage, thereby benefiting from their differences. Secondly, countries engage in international trade to achieve economies of scale in production. The reason is that when a country produces only a limited range of goods, there is a higher possibility that the country in question will produce more efficiently and at a larger scale than if it made efforts to produce everything. Patterns of international trade in the real world reflect the interaction of these motives. Countries where governments invest in CSA practices in the face of CC will enjoy economies of scale and will be able to export to other countries. CSA practices involve the

adoption of local farming practices and management that improve agricultural production in the face of CC.

Investment in CSA practices by the GoG will require the use of the nation's abundant resources since agriculture in Ghana accounts for about 33% of the GDP (GSS, 2022). Ghana will be able to increase the export of agricultural commodities and have stable prices in the CC era if it invests more in CSA practices. For instance, CSA practices, such as improved soil management, water efficiency, and climate-resilient crops, enhance yields and reduce climate-related production losses. This results in higher supply, which can lower prices if demand remains unchanged. By stabilizing production in the face of climate variability, CSA reduces supply-side disruptions, ensuring consistent trade flows and moderating extreme price fluctuations. Increased production can exert downward pressure on prices, while improved market stability reduces price volatility, benefiting both producers and consumers. Eco-conscious consumer preferences for sustainably produced goods may create premium markets, potentially increasing the price of CSA-certified commodities. If markets cannot absorb increased output, surpluses may lead to temporary price drops, discouraging future investments. This is because Ghana will have a comparative advantage in agricultural production over countries that do not invest in CSA practices.

1.3.2 Empirical Review of Agriculture Investment and Trade Flows

Many studies have been conducted to analyze the effect of investment and other natural occurrences on agriculture and food trade flows and prices. For example, employing a global CGE model, Heimann and Delzeit (2024) found an adverse effect on the agricultural market for fishmeal substitution with plant-based feed. Haile *et al*. (2017) employed the Decision Support System for Agrotechnology Transfer (DSSAT) and combined crop modeling and econometric analyses to simulate the effect of CSA on cereal exports in SSA with a particular focus on COMESA, SADC, and ECOWAS. Expected simulated effects for 2018-2050 indicated that CSA significantly increases trade flows of cereal commodities, which suggests the role of CSA in improving resilience and spreading risks.

From a different perspective, Zhou *et al*. (2023) conducted a study to comprehensively analyze the impact of COVID-19 and the locust plague on crop yield and trade restrictions in South Asia, specifically focusing on major grain crops such as paddy rice and wheat. The researchers used the GTAP model to simulate and quantify the changes in production and trade patterns. The findings indicate that grain production decreased by 15%, resulting in a significant reduction in global trade. Total imports and exports decreased by 5.79% and 1.41%

respectively. Consequently, the imports of processed rice from Sri Lanka, Nepal, Bhutan, the Maldives, and Bangladesh declined by 81%, 77%, 80%, and 89%, respectively. Additionally, the global grain trade patterns were severely disrupted, weakening the trade links between South Asian countries and China, Europe, Africa, and Latin America. Yousif (2024) also found a positive difference in trade performance after Saudi Arabia joined the WTO, although there was a decline in total export growth.

In their study, Cheng *et al*. (2023) examined the impact of temperature anomalies on the agriculture sector. Employing the Distributed Lag Non-Linear Model (DLNM), they found that it affects various aspects of the food supply and demand channels, resulting in increased volatility in food markets. Similarly, Vishwakarma *et al*. (2022) analyzed the influence of extreme weather stress on global wheat trade by utilizing statistical exponential random graph models, random forest models, and machine learning models. They recommended enhancing the current international trade network by considering the patterns of extreme weather stress to achieve synchronization in yields among countries. Also, using a diverse shock to the agriculture sector, Feng *et al*. (2023) investigated the consequences of the Russia-Ukraine crisis on food security and trade patterns using a structural general equilibrium trade model. Their research delved into the effects on both food security and the trade flow of agricultural products. The researchers discovered that the conflict would result in a significant decline in trade volume and a severe state of food insecurity, particularly for nations heavily reliant on grain imports from Ukraine and Russia. Again, the study found that limitations on energy and fertilizer supplies, which are crucial for agricultural production, would exacerbate the adverse consequences of food insecurity.

Focusing on cost-benefit analysis, Rosegrant *et al*. (2023) conducted a cost-benefit analysis of expanding agricultural research and development (R&D) in the Global South. They employed the IFPRI's IMPACT model to determine the investments needed to decrease global hunger prevalence below 5%. They found that increased funding over 35 years would result in a 10% boost in agricultural output and a 35% reduction in hunger prevalence. These estimates are in comparison to a hypothetical scenario where funding continues to follow historical trends. Using FDI, Punthakey (2020) explored the landscape of FDI in the agriculture and food sectors. The author used the OLS estimation technique and found that FDI plays an important role in driving participation in agro-food GVCs, underscoring the close interdependencies between FDI, trade, and the various other channels that multinational enterprises use to engage with global value chains. The results from a survey of agro-food multinational enterprises suggest that FDI decisions are underpinned by a diverse range of strategic motivations that go

beyond commercial considerations and market-related factors. In particular, open, transparent, and predictable trade and investment policies can have a strong positive influence on agro-food FDI.

Similarly, De Lima *et al*. (2022) analyzed the potential consequences of public agricultural R&D expenditures in Brazil and, hence, on productivity growth rates, agricultural output and yields over the 2017–2050 horizon. Employing a Simplified International Model of Prices, Land Use and the Environment (SIMPLE-BR) model, national and global food and environmental security benefits through a combination of greater agricultural output and yields and diminished cropland expansion. In contrast, when diminishing global agricultural R&D expenditures are considered in their baseline scenario, the world will face its worst-case scenario. Cropland would have to increase globally by more than 100 million hectares by 2050 to sustain a crop output that is only 59% of the level projected in the historically high total factor productivity growth scenario. The impact at the national level is projected to be even worse, and it will be aggravated in the scenarios in which Brazil's response to the COVID-19 pandemic further reduces agricultural R&D expenditures over the next decade.

Employing a module of trade cost minimization built within a bio-economic crop allocation optimization model, Egbendewe *et al*. (2017) evaluated how CC can impact agricultural trade and food security for both intra and inter-trade in the ECOWAS and found unspecific patterns. However, the study forecasted some countries to export food for a period but would become importers later, and this depends on socioeconomic conditions prevailing during that period. In different studies, Didia *et al.* (2015) utilized the gravity model to analyze the effect of receiving AGOA status on trade flows. The study threw some light on the issue of trade preferences by investigating the flow and composition of trade that exist between the US and the AGOA beneficiary countries. Their study revealed that having AGOA status has a strong positive impact on trade with the US. Nonetheless, it is interesting to know that the analysis also revealed a disproportionate impact of crude oil imports from the oil-intense exporting countries (Gabon, Angola, and Nigeria), which is not the intent of the act. Furthermore, Zenebe (2013) analyzed the impacts of the AGOA trade preference on agricultural exports in Africa. The statistical results specified that the AGOA preference does not have a statistically significant impact on agricultural exports of SSA countries, though some of the model results showed a potential positive effect of AGOA on agricultural exports of SSA countries to the US.

In a similar study, Beghin *et al*. (2017) evaluated the impact of a potential Transatlantic Trade and Investment Partnership bilateral free trade agreement on the EU and US bio-

economies (feedstock, biofuels, by-products, and related competing crops) and major trade partners in these markets. The analysis developed a multi-market model that incorporates bilateral trade flows (US to EU, EU to US, and similarly with third countries) and was calibrated to the OECD-FAO baseline for 2013–2022 to account for recent policy decisions. EU sugar and isoglucose production expanded along with US ethanol, biodiesel and oilseed crushing. EU sugar would flow to the US, and US biofuels and vegetable oil to the EU. The study further quantified non-tariff measures affecting these trade flows between the EU and the US. EU oilseed production contracted, and EU crushing expanded with improving crushing margins following reduced non-tariff measure frictions.

Differing in perspective, Lakatos and Fukui (2014) used the computable general equilibrium (CGE) framework to quantify the economic impact of the removal of investment restrictions on the retail sector in India. Yuan and Tsigas (2018) used FDI data to quantify the economic impact of US offshoring activities in China and Mexico, employing the CGE model. However, the methodology used by these studies to construct missing data and balance the dataset using gravity models makes the data inappropriate for use in econometric estimations. Payet-Burin *et al*. (2019) applied the methodology in the Zambezi River basin in which multiple investment opportunities exist, including new hydropower plants, new or resized reservoirs, development of irrigation agriculture, and investments into the power grid. The authors indicated that it is crucial to consider the links between the different systems when evaluating the impacts of CC and socioeconomic development, which will ultimately influence investment decisions. Also, the study showed that the value of the irrigation development plan is sensitive to the evolution of crop yields, world market crop prices, and CC.

Seok and Moon (2021) analyzed the effect of agricultural export on agricultural growth (agricultural value-added) between 1997 and 2016 for developed countries using OLS. Applying the Common Correlated Effects Mean Group (CCEMG) technique, the study found ambiguous effects of agricultural exports on agricultural growth. The findings revealed that while agricultural exports are positively correlated with agricultural growth in all regressions, they significantly enhance agricultural growth only in the case of the EU subsample. Similarly, Murugesan (2019) examined the effect of agricultural exports on economic growth in India by using the Error Correction Model. The findings indicated that agricultural exports and non-agricultural exports significantly increase the real GDP.

Despite these thoughtful studies, studies have not considered critically the effect of CSA on trade flows except Haile *et al*. (2017). Also, a serious attempt to look critically at the effect of CSA investment on agricultural commodities trade is non-existent. Hence, this implies

that there is still a gap in the literature. To fill this gap in the literature, this study analyzes the effect of CSA investments on agricultural commodities trade flows in Ghana. The study seeks to contribute to the debates on the effects of CSA by looking at CSA investment on agricultural commodities export potentials and trade flows in Ghana.

1.3.3 Empirical Review of CSA and Price Fluctuations

Employing a global CGE model, Heimann and Delzeit (2024) found that acquation production has a direct effect on food prices and prices for captured fish through the demand for fishmeal. The authors also found that sustainable fish stock reduces food prices. Zhou *et al*. (2023) conducted a study to comprehensively analyze the impact of diseases and pests on crop yield and trade restrictions in South Asia using the GTAP model. The findings indicate that these infestations led to significant fluctuations in international food prices, which particularly affected the affordability and accessibility of food, especially in developing countries that heavily rely on imports. Among the affected regions, Nepal, Sri Lanka, and Bangladesh experienced the highest increases in grain import prices. Focusing on conflicts, Feng *et al*. (2023) investigated the consequences of the Russia-Ukraine crisis on food prices using a structural general equilibrium trade model. They found that the conflict would result in a significant increase in agricultural prices, particularly for nations heavily reliant on grain imports from Ukraine and Russia.

De Lima *et al*. (2022) deviated from the previous studies by evaluating the consequences of public agricultural R&D expenditures in Brazil and its impact on food prices at both the national and global levels for the 2017–2050 period horizon. The authors employed the SIMPLE-BR model. They found that public R&D lowers agricultural crop prices for consumers. Also, a decrease in global agricultural R&D expenditures makes the situation worse in the baseline scenario.

Focusing on cost-benefit analysis, Rosegrant *et al*. (2023) conducted a cost-benefit analysis of expanding agricultural R&D in the Global South. Building on a recent modeling effort that utilized IFPRI's IMPACT model to determine the investments needed to decrease global hunger prevalence below 5%, the study projected that increased funding over 35 years would result in a 16% decline in food prices and a 4% rise in per capita incomes.

Boulanger *et al*. (2015) presented some macro and food security impacts of deeper economic integration between the EU and three North African countries. It conducted a quantitative impact assessment of the increase in trade and investment flows using the Modular Applied General Equilibrium Tool (MAGNET). The study found that trade liberalization

enhances food security by counteracting the rise in food prices, fostered by the growing demand for agricultural products in North Africa. The study results suggested that economic growth is stimulated mostly by widespread productivity gains (not restricted to the agri-food sector) and boosted by trade integration through the removal of non-tariff measures.

Focusing on oil prices, Dutta *et al*. (2022) employed the Markov regime-switching regression to evaluate the implications of green investment on oil price shocks. They found that there is no statistically significant effect of crude oil on green investment. In a similar study, Cao *et al*. (2020) analyzed the effect of oil price uncertainty on renewable energy investment. Employing the system GMM, they found that oil price uncertainty significantly reduces investment in renewables and that large-sized firms are less sensitive to oil price volatility impacts. Sun *et al*. (2021) employed the Granger causality test to evaluate how agriculture commodity prices are affected by trade policy uncertainty. They found that trade policy uncertainty significantly affects agricultural commodities prices.

Despite these insightful studies, they have not considered critically the effect of investing in CSA practices on price fluctuations. Also, a serious attempt to look critically at the effect of CSA investment on agricultural commodities prices is non-existent. Hence, we fill this gap in the literature by analyzing the effect of CSA investments on agricultural commodities prices in Ghana. The study seeks to contribute to the debates on the effects of CSA by looking at CSA investment on agricultural commodities' price stability in Ghana.

1.4 Research Methods

Empirical analyses of the relationship between investment in CSA practices and trade flows and price fluctuation is a complex issue. The reasons range from measurement issues to the fact that simultaneous impacts coming from various other policy measures and exogenous shocks cannot be isolated. Also, the fact that there are many channels through which investment in CSA practices shocks are transmitted, both directly and indirectly, to households, is an issue. The commonly identified channels are through factor payments, government transfers, and product prices in the short to medium term, while adjustment to human capital accumulation and productivity would yield long-term consequences. Studying such a complex situation requires estimation techniques that can capture all these linkages.

The general equilibrium framework provides an ideal experimental setting to investigate this relationship. The general equilibrium framework not only allows analysts to capture the direct as well as the indirect interactions among different agents and markets but

also provides a convenient framework to carry out controlled policy experiments where the impact of investment in CSA practices reforms could be isolated from other shocks by fixing their impacts. CGE models, the numerical counterparts of the Walrasian general equilibrium analysis, are the most widely used general equilibrium analytical tools. For instance, Srinivasan and Whalley (1986) noted that the numerical general equilibrium approach can combine both policy and theory to improve the analytical foundations of policy evaluation work and to bring the theoretical work that already exists in the literature more fully into the policy debate.

The capability of CGE models to generate highly disaggregated micro-level results while maintaining a consistent macro framework makes them dominate the whole of counterfactual analytical approaches (Seung and Kraybill, 2001). A major criticism of CGE modeling, however, is that it is too theoretical, which often incorporates abstraction from the real workings of an economy. Other criticisms have been directed at the functional form of the model, the database used to describe the initial equilibrium and the behavioral parameters—elasticities—used in the functional form (Bianchi, 2004). On balance, the advantages exceed the disadvantages. In addition, the Dynamic Computable General Equilibrium (DCGE) model adapted for this essay, to a very large extent, reflects the specific characteristics of the Ghanaian economy.

1.4.1 Dynamic Computable General Equilibrium (DCGE) Model

Following the studies of Diao and Thurlow (2012); Seung and Kraybill (2001); and the DCGE model of IFPRI by Breisinger *et al*. (2011), our study adopts the DCGE model to analyze the impact of investment in CSA practices on agricultural commodities trade flows and price fluctuations. The model is recursive dynamic, and so it is solved one period at a time through updating parameters such as investment spending on CSA practices and population growth rate to reflect changes that have taken place in the current period. The model is adopted to investigate the trade and price implications of CSA practices investment in Ghana from 2022 to 2050. The dynamics of the model involve updating the subsequent period's parameters to reflect either changes that have taken place in the current period, such as investment spending on CSA practices, or exogenous changes in the economic environment, such as population growth. Our model represents a small open economy that has no influence on international markets and it is calibrated to the Social Accounting Matrix (SAM) of Ghana for the year 2019. Production is characterized by a two-level nesting structure and involves the combining of factors and intermediate inputs. Aggregate intermediate quantity and price are determined by

a Leontief or fixed share aggregation of individual intermediate commodities. The Models of this essay are presented in Appendix A.

Our study allows the economywide capital stock to be flexible and introduces CSA practices investment inflow into the model. It is, therefore, prudent to expound on the key equations introducing the exogenous capital inflows into the model. Permitting public investment in CSA practices means the introduction of an exogenous variable into the BOP and allows the economywide capital stock to be flexible. For details on default macroeconomics balance and assumption and the set of equations, refer to the DCGE model developed by Breisinger *et al*. (2008).

The DCGE model's demand side is primarily characterized by a set of consumer demand functions. In our model, these consumer demand functions are determined by optimizing a Stone-Geary utility function. We analyze how public investment in CSA practices affects trade and prices of agricultural commodities, focusing on the annual growth rate of the fixed sector-specific crop. GoG has a program of 'Planting for Food and Jobs' (PFJ), and 'Planting for Food and Export (PFE) and has distributed improved seed varieties, improved breeds, and irrigation activities. In this study, we introduce productivity shocks in the CGE model to simulate the benefits of CSA adoption. The pattern of international capital flows includes reverse spillover effects, where outward direct investment contributes to improving labor productivity in the investor's home country (Qi, 2024). Herzer and Klasen (2008) indicate that outward direct investment in developing countries positively influences long-term macro TFP growth. This occurs through mechanisms such as horizontal or market-oriented outward direct investment, which enhances related service exports like R&D, design, and marketing strategies. Similarly, Potterie and Lichtenberg (2001) show that technology-seeking outward direct investment from developing countries boosts macro TFP growth by enabling spillovers from the host country’s R&D stock and lower production costs, increasing intermediate goods exports. This leverages natural resources to enhance TFP dynamics (Dunning, 1993).

Following the work of Qi (2024), we increase Total Factor Productivity (TFP) parameters in relevant agricultural sectors such as maize, rice, other cereals, vegetables, and pulses. We use the annual growth rate of TFP in addition to the baseline (changes begin in the simulation start year). This is because CSA often aims to improve productivity and reduce resource intensity, which can be captured by efficiency shocks. We use TFP shocks to simulate productivity gains and how this affects trade and price. We simulate a 5%, 10%, 15%, and 20% improvement in TFP for the agricultural sectors. This approach allows flexibility and captures varying adoption scales without needing a detailed CSA representation. We gradually phase in

productivity improvements and model a gradual 30-year adoption path of CSA practices with incremental productivity gains. This is flexible and easy to implement in our CGE models.

1.4.2 Data Sources

The main source of data for this empirical essay is the 2019 SAM for Ghana. The SAM reflects a snapshot of all the goods and services that have been produced and the flow of incomes and expenditures in Ghana for the year 2019. It also captures the inflow of resources from the rest of the world to Ghana, as well as payments from Ghana to the rest of the world. The SAM also contains detailed information on the demand and production structure of 90 sectors, made up of 34 agricultural sub-sectors. There is also information on three factors of production (land, labor and capital) and the incomes and expenditures of 15 household categories with 13 factors. Finally, the SAM contains information on the sources of government revenue and expenditure.

The SAM was constructed from a wide range of data sources. In building the SAM, data was made of the national accounts rebased using 2013 base year and was provided by the Ghana Statistical Service, Crop and livestock and producer prices data from Ministry of Food and Agriculture and the FAO 2021 database, mining, manufacturing, and energy sector data from Ghana's Industry, Business and Enterprise Survey 2014 Industrial Census, household income and consumption data from 2016/17 Ghana Living Standards Survey (GLSS-R7), total value of export and import data from the national accounts and goods exports from the UN Commodity Trade Statistics 2021 database. The SAM was built by the GSS in collaboration with the Institute of Statistical, Social and Economic Research (ISSER) of Ghana and IFPRI. It was released in October 2023.

Table 1.1 presents the descriptive statistics across different agricultural commodities in terms of the value of share, employment shares, and share of production maize, which accounts for 1.288 times the share of value relative to the average across all crops, indicating that maize contributes significantly to the overall value of agricultural production in Ghana. The production share of maize is 0.818, meaning it represents a smaller share of total agricultural production compared to its value share. This suggests that maize is relatively more valuable per unit of production. Maize employs 1.342 times the average share of labor compared to other crops, indicating it is labor-intensive and a key source of employment in the agricultural sector. Rice has a lower value share (0.638), indicating that it contributes less to total agricultural value relative to other crops. The production share of rice is also lower (0.418), meaning it constitutes a smaller portion of the total agricultural output. Rice's employment share is nearly equal to

the average (0.996), suggesting that rice farming employs labor proportionally to other crops, but the relatively low value and production shares indicate that it may not be as economically important as maize or root crops. The value share of other cereals (millet, sorghum, etc.) is quite low (0.306), indicating these crops contribute relatively little to the total agricultural value. The production share is even smaller at 0.179, indicating that these crops are produced in low quantities compared to others. The employment share is higher than its production share (0.510), suggesting that even though these cereals contribute less to total production, they are labor-intensive, perhaps due to traditional farming practices.

Table 1.1: Structure of the agricultural commodities in the Ghanaian economy in 2019

Crop	Share of value	Production share	Employment share
Maize	1.288	0.818	1.342
Rice	0.638	0.418	0.996
Other cereals	0.306	0.179	0.510
Pulse	0.152	0.097	0.307
Root crops	5.960	3.453	6.149
Vegetables	0.429	0.262	0.229

Pulses have a very low-value share (0.152), meaning they contribute minimally to the overall agricultural economy. The production share is also low (0.097), reinforcing the idea that pulses are not produced in large quantities. The employment share is higher than its production and value shares (0.307), suggesting that pulse farming is relatively labor-intensive, but the economic returns are not significant. Root crops (like cassava, yam, and sweet potatoes) have a very high-value share (5.960), indicating they are a critical contributor to Ghana's agricultural value. Root crops are one of the most important commodities in the agricultural economy. The production share is also high (3.453), meaning root crops dominate agricultural production in terms of volume. The employment share is the highest of all the crops at 6.149, showing that root crop farming employs a large portion of the agricultural workforce. This reinforces the fact that root crops are central to both economic value and rural livelihoods in Ghana. Vegetables have a relatively low-value share (0.429), which suggests they contribute moderately to the agricultural economy. The production share is also low (0.262), meaning vegetables are not produced in large quantities relative to other crops. The employment share is relatively low (0.229), indicating that vegetable production is less labor-intensive compared to other crops, possibly due to more mechanized or small-scale production practices.

Maize and root crops dominate in terms of employment, with root crops having the highest impact on both value and employment. This aligns with the fact that root crops are a staple in Ghana and contribute heavily to both food security and the agricultural economy. Pulses and other cereals have relatively low contributions across all metrics, which could imply that they are grown in smaller quantities, possibly for niche markets or subsistence rather than commercial export. Vegetables have a moderate impact but lower employment intensity, suggesting potential room for expansion, especially with climate-smart practices that could enhance both productivity and export potential.

1.5 Results and Discussions

1.5.1 Simulation of Public Agricultural Investment on Price Fluctuations

We analyze the impacts of public CSA investment scenarios on the prices of agricultural commodities. Figures 1.4a to 1.4e display the impact of public investment on the price of maize, rice, other cereals, pulses, tubers, and vegetables. We observe that for both the BAU and the simulated CSA investment scenario cases, the futures of all the commodities will increase except for vegetables. However, the simulated scenario cases will have a lower price increase than the BAU case. For maize and tuber crops, the differences become pronounced after 2028. For vegetables, an increase in public investment in agriculture increases prices more than the BAU scenario case.

CSA practices improve the resilience and yield of crops. Higher productivity increases the supply of agricultural commodities, leading to a reduction in prices. When local farmers can grow more food per unit of land, it creates a surplus, reducing market prices. CSA promotes resource efficiency. As farmers adopt more sustainable practices, their input costs decrease. This cost savings is often passed on to consumers in the form of lower prices. For example, efficient irrigation systems reduce water costs, while organic fertilizers can lower the need for expensive chemical inputs. CSA creates more stable production cycles. A steady and reliable supply of agricultural commodities helps prevent the large price fluctuations often caused by climate-related disruptions, such as crop failures or shortages. Investments in CSA also include improvements in storage, transportation, and post-harvest handling. In many countries, significant portions of crops are lost after harvest due to poor infrastructure, pests, or spoilage. By minimizing these losses, the overall supply of food increases, which can help lower prices in the market.

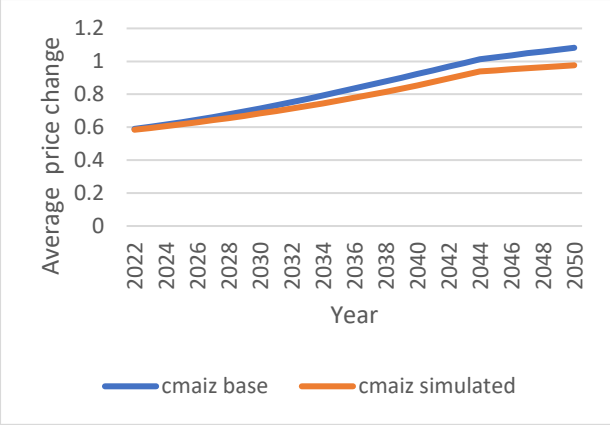


Figure 1.4a: the simulated price of maize

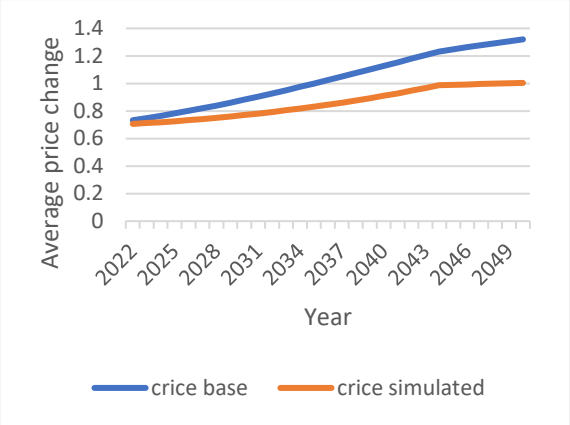


Figure 1.4b: the simulated price of rice

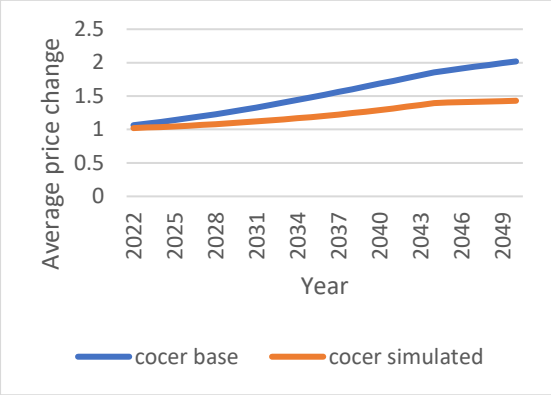


Figure 1.4c: the simulated price of other cereals

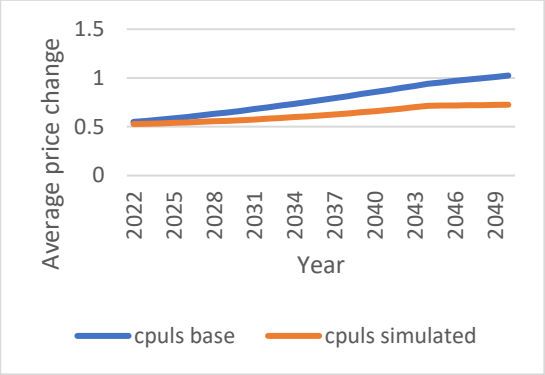


Figure 1.4d: the simulated price of pulse

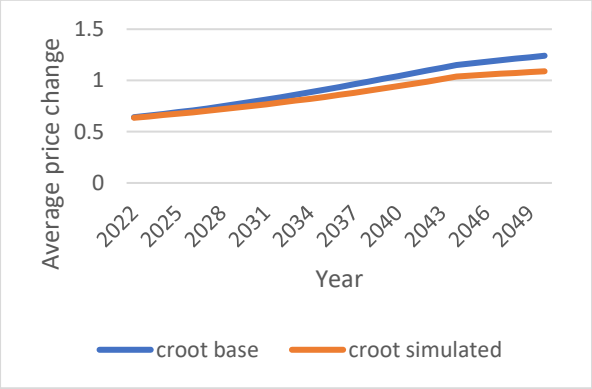


Figure 1.4e: the simulated price of tuber crops

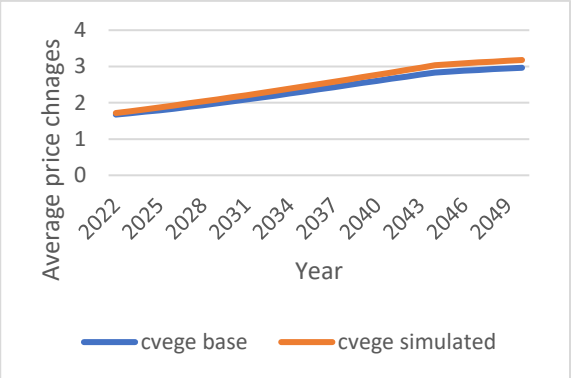


Fig 1.4f: the simulated price of vegetables

In the case of pulse and other cereals, the rate of price reduction in the public CSA investment scenario case is higher than in the BAU scenario. Without significant investment in CSA, traditional farming methods and climate change reduce the productivity of pulses and other cereals, leading to lower supply. The reduced supply keeps prices relatively high or stable over time due to scarcity. Public CSA investments result in improved crop varieties, better soil management, and enhanced water use efficiency, leading to higher yields. The increased productivity boosts the supply of pulses and cereals, putting downward pressure on prices due

to greater availability. In the CSA scenario, the enhanced supply of pulses and other cereals through climate-smart practices increases the market supply faster than the rate of demand growth. Even though demand might be growing (due to population growth or increasing exports), the significant boost in production under the CSA scenario leads to a greater reduction in prices. With no major improvements in productivity, the supply of pulses and other cereals may stagnate or grow slowly. This limited supply growth keeps prices from falling significantly, as demand may still be relatively strong. The rapid increase in supply from higher yields under CSA exceeds the growth in demand, leading to a higher rate of price reduction as the market is more abundantly supplied. This is a classic supply-demand effect, where surplus supply drives prices lower.

CSA practices focus on making farming more efficient and resilient to CC, which could stabilize domestic supply. This reduces vulnerability to external market shocks such as import price fluctuations, even if Ghana continues importing significant amounts of maize or other crops. Ghana may establish better market mechanisms to stabilize domestic prices, reducing the impact of imports even if their volume increases. This might include strategic grain reserves, improved storage infrastructure, or forward contracts that protect against global price volatility.

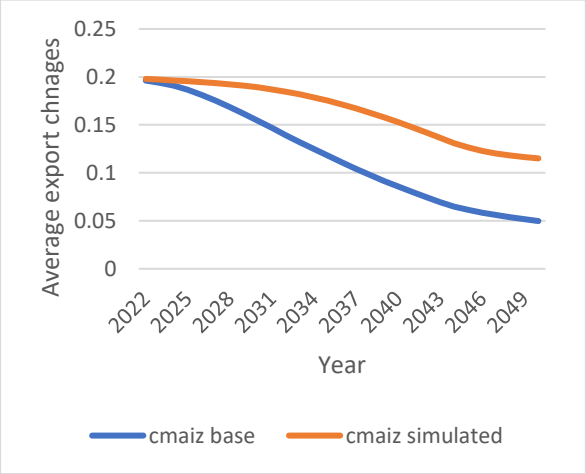
Our findings correspond to Heimann and Delzeit (2024), who found that acquation production has a direct effect on food prices and prices for captured fish. They found that sustainable fish stock could reduce food prices. Furthermore, our findings support those of De Lima *et al*. (2022), who found that public R&D lowers agricultural crop prices for consumers. Also, a decrease in global agricultural R&D expenditures makes the situation worse in the baseline scenario. Similarly, Rosegrant *et al*. (2023) conducted a cost-benefit analysis of expanding agricultural R&D in the Global South and found that investments needed in agriculture would result in a 16% decline in food prices.

1.5.2 Simulated impact of Public Investment on Exports of Agricultural commodities

Figure 1.5a displays the simulated impact of CSA investment on maize exports. It is observed that Ghana's maize exports will continue to decline for both the BAU and the simulated scenario cases. The simulated scenario case has higher export volumes than BAU. Plausibly, while Ghana is moving toward more climate-resilient agricultural practices, the transition is slow. CSA investments may take time to yield tangible benefits in terms of increased production, meaning maize export volumes could continue declining in the short and medium terms. Additionally, Ghana has prioritized ensuring food security over maize exports,

especially during times of food shortages or high domestic demand. Ghana faces competition from other maize-producing countries in Africa, such as South Africa and Zambia, which can produce maize more cheaply. This limits Ghana's ability to capture international markets, especially when domestic maize prices fluctuate due to supply chain inefficiencies or weather shocks. Post-harvest losses, due to inadequate storage facilities, pests, and poor infrastructure, significantly reduce the quantity of maize available for export. Up to 20-30% of maize production is lost after harvest, according to some estimates, reducing the surplus for trade.

We evaluate the impact of public investment in CSA practices on other cereals crops such as rice and wheat export volumes. We present the results in Figure 1.5b. We observe a decline in the volume of exports of other cereals. However, up till the next eight years (2032), the BAU case has higher export volumes than the simulated scenario case. After 2032, export volumes of the simulated scenario would be higher than BAU even though export volumes would continue to decline. While the total production may still face challenges from environmental factors, the rate of decline in production would be slower under CSA. Therefore, the simulated scenario would result in higher maize production than under BAU, where farmers continue traditional methods with lower resilience to climate stresses. Without significant investment in CSA, cereal production is expected to fall more sharply due to worsening climatic conditions and inefficient farming techniques. CSA would mitigate some of these challenges, resulting in higher production, even if the absolute levels of cereals exports continue to decline compared to historical peaks.



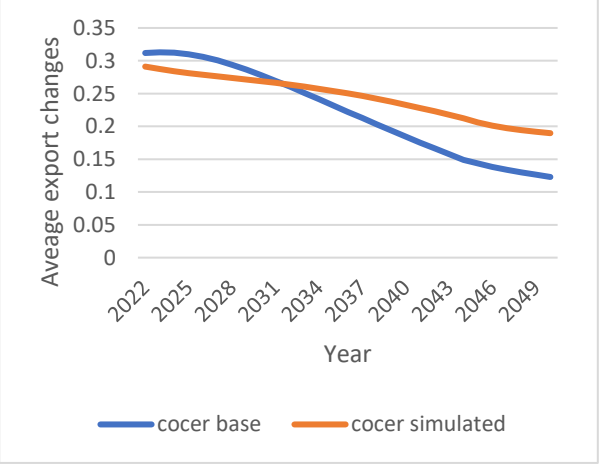


Figure 1.5a: the simulated impacts on maize export exports of other cereals

Figure 1.5b: the simulated impacts on

CSA can contribute to more stable maize prices by increasing production resilience to climate variability, thereby making Ghana's cereals more competitive internationally. In the

BAU scenario, frequent climate shocks could create supply shortages, causing price spikes that make Ghana's cereals less competitive in the global market. This can discourage export growth. Higher price volatility and reduced maize quality due to climate variability could reduce international demand for Ghanaian maize in the BAU. In the simulated CSA scenario, more consistent production and stable prices under CSA practices would help maintain a more stable export market, even if total volumes continue to decline.

Figure 1.5c shows the export of pulse crops. There is clearly a contrasting impact on pulse export volumes between the BAU and the simulated scenarios. The BAU case has a decreasing impact on exports of pulse, while the simulated scenario has an increasing impact on export volumes. Pulses, like other crops, are sensitive to climate variability, including changes in temperature, rainfall, and soil moisture. Under the BAU scenario, without targeted interventions or investment in climate-resilient agriculture, pulses are likely to experience yield declines due to the worsening effects of CC. In the BAU scenario, farm households continue using traditional practices, which may not be optimized for dealing with increasing droughts, erratic rainfall, or degraded soils. As a result, pulse yields may fall, reducing the exportable surplus and causing a decline in export volumes over time. In the simulated CSA scenario, CSA practices introduce more resilient farming techniques, such as drought-tolerant pulse varieties. These practices help stabilize or even increase yields, resulting in an increased supply of pulses for both domestic consumption and export.

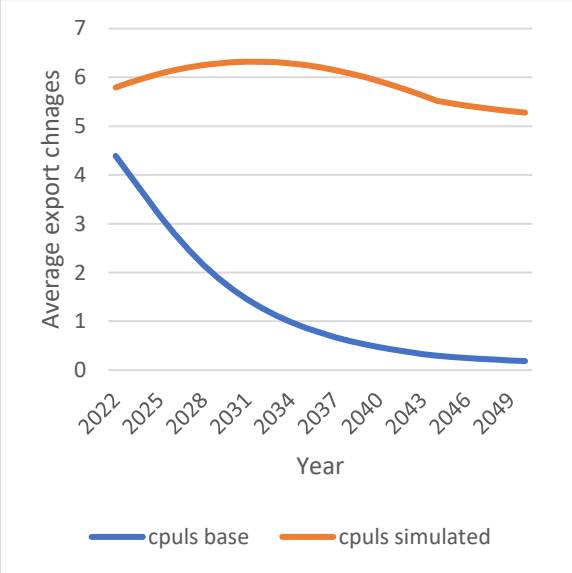


Figure 1.5c: the simulated impacts on pulse exports

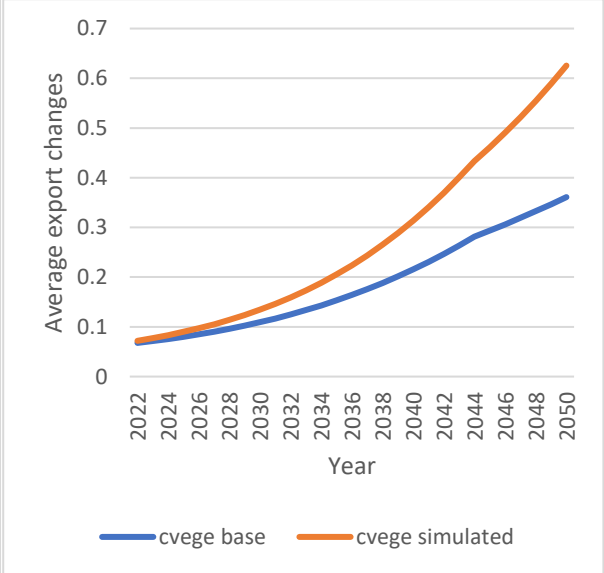


Figure 1.5d: the simulated impacts on exports of vegetables

In the simulated scenario, policies and strategies associated with CSA might encourage a greater focus on export-oriented production. This has been the focus of PFJ and 'planting for

export' programs of the Ghanaian government since 2017. The government seeks to increase the export of nontraditional agricultural commodities. This includes developing high-value pulse varieties that are in demand internationally or providing incentives for farmers to increase pulse production for export markets. In the BAU scenario, without targeted support, pulse production may focus more on meeting domestic needs, especially as climate challenges make export production less viable. This shift away from export-oriented production could reduce the volumes available for export. However, in the simulated CSA scenario, the simulated scenario involves specific policies and programs that promote the production of export-quality pulses, thereby increasing the volume of pulses that are available for international markets. Without significant technological or financial support, pulse farmers may struggle to invest in inputs or adopt new practices that could enhance yields. This leads to stagnant or declining production and, consequently, lower exports. Farmers in the simulated CSA scenario may receive better access to finance and technology, allowing them to invest in higher productivity. This results in greater output and a surplus available for export, thereby increasing export volumes.

Furthermore, we analyse the impact of public investment on the export of vegetables. Figure 1.5d shows the BAU and simulated CSA scenarios. Both scenarios increase the export volume of vegetables. We observe that after 2026, simulated CSA scenarios have higher export volumes of vegetables than the BAU scenario. This could be because vegetables generally require more intensive care, including water management, pest control, and nutrient application, compared to other crops. Under the CSA scenario, the adoption of improved farming techniques significantly boosts vegetable yields by addressing these challenges. In the BAU scenario, in the absence of CSA interventions, vegetable farmers continue using traditional farming practices, which may be less effective in optimizing water use, managing pests, or enhancing soil fertility. As a result, vegetable yields are lower, and the surplus available for export decreases. CSA practices, such as drip irrigation, integrated pest management, and improved soil health techniques, increase yields. Higher productivity leads to more vegetables being available for export, boosting export volumes.

As indicated in the previous sections, the CSA scenario promotes diversification into high-value vegetable varieties that are in demand in international markets. CSA practices can enable farmers to grow vegetables more efficiently and target export markets with premium-quality produce. Without the incentives or support for diversification, farmers may focus on lower-value or subsistence vegetable varieties that are less suited for export. This limits their ability to capture high-value export markets. By adopting climate-smart techniques, farmers

may shift toward producing high-quality vegetables with better market value, such as organic or speciality varieties. This shift enables Ghana to tap into lucrative export markets, thereby increasing the overall volume and value of vegetable exports. The Government of Ghana's CSA scenario includes interventions that strengthen market access for vegetable producers, improving their ability to reach export markets. This could involve better coordination with buyers, improved logistics, or government support for trade facilitation.

1.5.3 Simulated Impacts of Public Investment on Imports of Agricultural Commodities

Figures 1.6 show the impact of public investment on imports of agricultural commodities. Figure 1.6a displays that the impacts on maize imported to Ghana will decrease after 2034, about 10 years from now, even though at a higher import rate. This is very similar to rice, other cereals, pulse and vegetables. CSA practices enhance the resilience and productivity of local farms. As local production becomes more efficient and reliable, Ghana can rely less on imports to meet domestic demand. CSA encourages crop diversification, which reduces the dependence on single crops that may be more vulnerable to climate change. With a more diversified agricultural system, Ghana can produce a wider range of food products locally, reducing the need to import agricultural commodities such as cereals, pulses, and vegetables. Furthermore, CSA practices often focus on resource efficiency. This can lower production costs for farmers, making locally produced crops more competitive with imports, which tend to be more expensive due to transportation and global market factors. Public investment in CSA in Ghana has gone hand-in-hand with improvements in infrastructure, such as better storage facilities, transportation networks, and access to markets. These improvements reduce post-harvest losses and make it easier for farmers to sell their produce, further reducing the need to rely on imports to fill supply gaps.

Ghana's economy has been growing steadily, with forecasts predicting continued expansion. This growth enables increased investment in the agricultural sector, leading to improved production efficiency and higher domestic yields. As local production of crops like maize becomes more robust, the reliance on imports diminishes. CSA investments and innovations could lead to improved yields and greater resilience of maize and other staple crops, reducing the country's reliance on imports. By 2034, these investments may result in increased local production, even as the country continues to import at a higher rate. This would reduce the impact of imports on overall food security and prices. CSA practices focus on

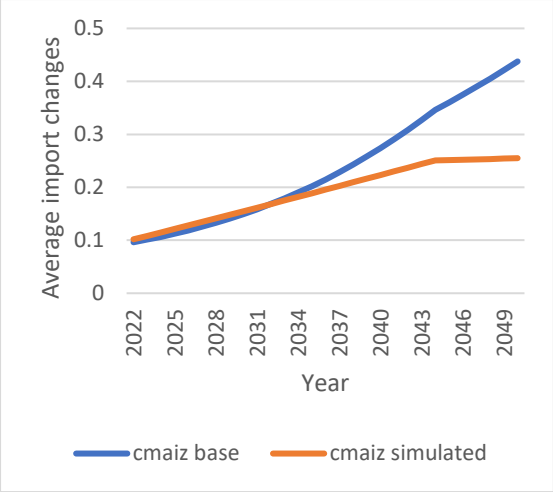


Figure 1.6a: simulated imports of maize

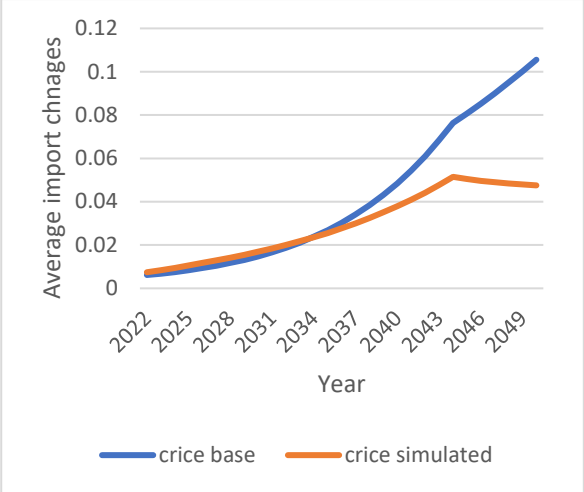


Figure 1.6b: simulated imports of rice

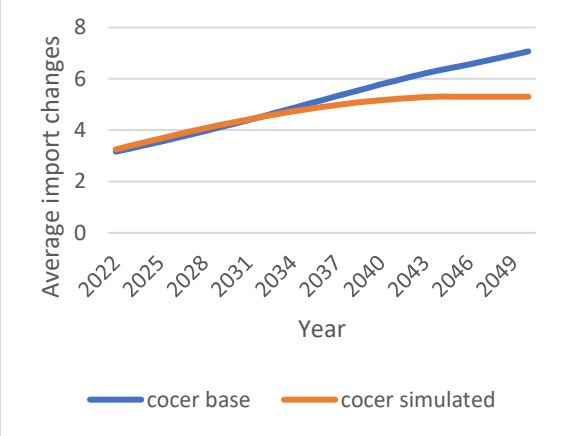


Figure 1.6c: simulated imports of other cereals

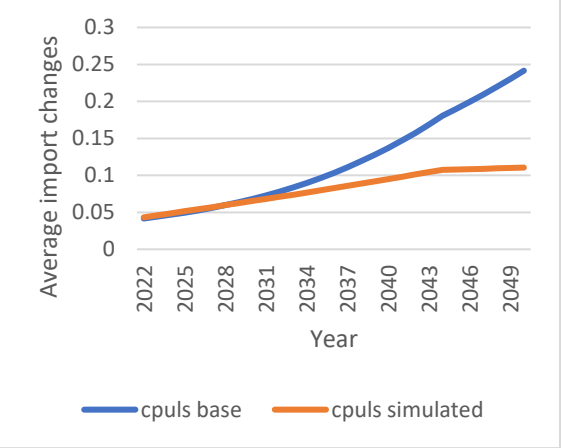


Figure 1.6d: simulated imports of pulse

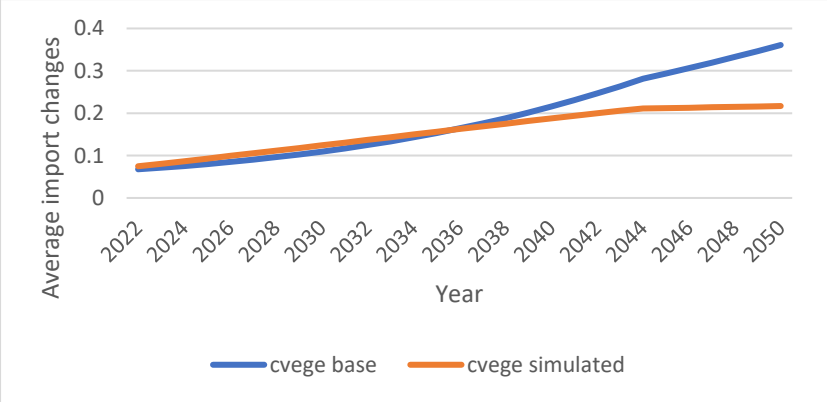


Figure 1.6e: simulated imports of vegetables

making farming more efficient and resilient to climate change, which could stabilize domestic supply. This reduces vulnerability to external market shocks, even if Ghana continues importing significant amounts of maize or other crops. As Ghana develops economically and

urbanizes, consumption patterns might shift toward other food sources, which could lower the relative demand for imported maize and similar crops.

Our trade results confirm the findings of Haile *et al*. (2017) that CSA significantly increases trade flows of cereal commodities, which suggests the role of CSA in improving resilience and spreading risks. Our findings also support Rosegrant *et al*. (2023) who found that increased funding over 35 years would result in a 10% boost in agricultural output and Punthakey (2020) who found that FDI plays an important role in driving participation in agro-food GVCs, underscoring the close interdependencies between FDI, trade, and the various other channels that multinational enterprises use to engage with global value chains. Again, De Lima *et al*. (2022) found that public agricultural R&D expenditures promote national and global food and environmental security benefits through a combination of greater agricultural output and yields and diminished cropland expansion. They noted that a reduction in global agricultural R&D expenditures in the BAU scenario would lead to a worst-case scenario, and the impact at the national level is projected to be even worse, and it will be aggravated in the BAU scenarios. Similarly, our findings corroborate that of Payet-Burin *et al*. (2019) that the development of agricultural irrigation is sensitive to the evolution of crop yields and world market crop prices. Conversely, our findings do not support that of Egbendewe *et al*. (2017), who evaluated how CC can impact agricultural trade and food security for both intra and inter-trade in the ECOWAS and found unspecific patterns. Their study forecasted some countries to export food for a period but would become importers later.

1.6 Conclusions and Policy Implications

The adverse externalities posed by CC in current and future generations and by estimation, the world population hitting 9 billion in 2050, requires a corresponding improvement in the production of food by about 70% (UN, 2021). With population surges, the possibility of a threatening food crisis remains imminent, especially among economically vulnerable and disadvantaged populations such as Ghana. Further, underinvestment in agricultural inputs such as hybrid seeds, labor, or CSA practices is thought to drive low crop productivity and yields. This is a crucial step to achieve the SDGs, particularly SDG 1.3 and SDG 2. Climate-smart trade policies and openness to trade are critical to reducing poverty. Agro-food global value chains can positively influence factors such as productivity, production growth and quality, which are influenced by investment and trade policies, such as the availability of specific investment incentives, investment restrictions, technical requirements, quality standards, and the presence of bilateral and regional trade and investment agreements.

From the analyzes conducted, public investment in CSA practices by 5% or more reduced prices of agricultural commodities at a higher rate than the BAU scenarios even though prices increased in both scenarios since prices are sticky downwards. We conclude that public investment in CSA practices will reduce the price of agricultural commodities. Lower food prices make agricultural commodities more affordable for consumers, especially low-income households. Public investment in CSA leading to price reductions can help mitigate the effects of global food price volatility, making food supplies more stable and reliable in Ghana. Consumers benefit from reduced food prices, leaving them with more disposable income for other needs. This could enhance household welfare and stimulate demand for other goods and services, potentially boosting the local economy. Lower prices for staples (like maize, rice, and vegetables) can improve the standard of living, as consumers spend a smaller proportion of their income on food, particularly in rural and low-income urban areas.

Furthermore, we found that Ghana's agricultural commodities exports declined for both the BAU and the CSA investment scenario cases. The public investment scenario case had higher export volumes than BAU. We conclude that the CSA public investment scenario case by more than 5% reduces the decline in agricultural commodities exports. The ability to slow or reverse the decline in exports by more than 5% signifies that higher productivity and climate resilience achieved through CSA practices allow Ghanaian farmers to produce surplus quantities for export, meeting both domestic and foreign demand. This improvement in export performance can enhance Ghana's foreign exchange earnings, bolstering the country's trade balance and contributing to macroeconomic stability. As CSA practices improve agricultural productivity and reduce the decline in exports, Ghana may have the opportunity to diversify its export markets. By maintaining or increasing export volumes of commodities like maize, rice, vegetables, pulses, and cereals, Ghana can explore new trading partners or strengthen its position in existing markets. Agricultural exports contribute significantly to Ghana's trade balance, and a smaller decline in exports means a reduction in the trade deficit or an improvement in the country's current account balance.

Additionally, we found that public CSA investment scenarios reduce agricultural commodities imports more than the BAU scenario. However, the import volume of agricultural commodities still increases in both cases. While CSA investments help boost domestic production, the increase in demand outpaces these gains, forcing Ghana to still rely on imports to meet total consumption needs. The growing demand could reflect a shift in consumer preferences toward certain commodities (such as rice or wheat), which Ghana may not produce at scale domestically despite improvements in other areas of agriculture. The continued rise in

import volumes suggests that Ghana has not fully achieved self-sufficiency in some key agricultural commodities, particularly those that are difficult to grow domestically due to climatic, soil, or infrastructural limitations. Ghana's domestic production capacity in processed food products, rice, and wheat is still limited.

Our study suggests that policies promoting import substitution and better integration into regional trade agreements like the AfCFTA. Trade agreements that facilitate the import of critical inputs (such as seeds, fertilizers, and machinery) at lower costs can support local production, while export promotion policies may help offset the impact of rising imports. To ensure the effectiveness of CSA investments, it is essential to develop strong monitoring and evaluation frameworks. These frameworks should track the progress of CSA programs in terms of increased production, reduced import dependency, and environmental sustainability. Governments and NGOs should run awareness campaigns to highlight the importance of CSA for food security, economic stability, and climate resilience. By educating consumers, farmers, and investors about the benefits of CSA, more people will support and participate in CSA-related initiatives. Again, developing better storage facilities and cold chains can reduce post-harvest losses, which is critical for maintaining export quality and increasing food availability domestically, reducing the need for imports. Moreover, Ghana can tap into international climate finance mechanisms, such as the Green Climate Fund (GCF), the Global Environment Facility (GEF), and the Adaptation Fund, to secure funding for CSA projects. These funds could help scale up successful CSA programs and introduce new technologies and practices at a larger scale.

ESSAY TWO

AGRICULTURAL INPUT SUPPLY SYSTEM AND CONTRACT ON NUDGING THE ADOPTION INTENSITY OF CLIMATE-SMART AGRICULTURE IN GHANA

2.1 Introduction

The uncertainty associated with the negative externalities of CC requires integrated and adapted efforts to deal with these challenges (Cheng *et al*., 2023). Agricultural experts see the utilization of modern inputs and CSA practices as the keys to increased agricultural productivity growth (Diao *et al*., 2019). Pointing to the strong correlation between irrigation, improved seed varieties, changing time of planting, agroforestry, and others and productivity, it is argued that these practices generate high returns and dramatic growth in agricultural yields globally (Ajayi *et al*., 2022; Amadu *et al*., 2020). Acquainted with its relevance, governments and donors give considerable focus and attention to the agricultural research agenda. Nevertheless, the rate of adoption among rural and smallholder farmers is a bit low (Forum for Agricultural Research in Africa, 2015; Yitayew *et al*., 2022). These low adoption rates of improved agricultural technologies have contributed to low agricultural productivity. It is even argued that higher growth in agricultural productivity in Asia and the stagnation of yields in SSA could be attributed to increased modern agricultural practices in Asia and continuous low utilization in SSA (Yitayew *et al*., 2022; Walker and Alwang, 2015; Yitayew *et al*., 2021). This could ultimately lead to food insecurity (Issahaku and Abdulai, 2020).

A key assumption in the Chicago traditional case against CSA subsidies is that farmers would adopt the privately optimal quantity of CSA without subsidies. According to the Coase theorem (1969), individuals may negotiate their way through the resolution of an environmental problem. That is, in a situation where the number of decision-makers involved is small, a voluntary bargaining process and compensatory payments by the affected due to the externality may provide an optimal result. This means that the agent affected by the externality may compensate the one behind the externality to desist from or cease production activities or at least reduce the damage to an optimal level. In the Nash equilibrium, individual utility maximization and profit maximization take the flow of environmental services as given. That is, rational rural farm households take CSA packages as given and make decisions on agricultural contracts that maximize their utility. Essentially, this means that the Nash equilibrium is a feasible state such that each consumption plan is derived from utility maximization, and each production plan is derived from profit maximization. It is similar to the Lindahl equilibrium, which is defined as a feasible state in which each household and producer buys environmental services. Each has to pay an individual price such that their

demand is equal to the supply of the services. The total supply of these services is determined in such a way that the total income accruing to the environment from the purchases of the environmental services and the payments for the excess supply is maximized.

Moreover, since improved seed varieties are divisible, standard economic theory would not predict that credit constraints would lead to low adoption traps in this context. That is, profits are concave rather than convex in improved seed varieties used per unit of land area. Since farmers always have the option of applying improved seed varieties intensely on some land while leaving other pieces of land on unimproved seed varieties, returns must be non-increasing. Low CSA adoption rates in the face of such high returns are particularly puzzling. There could, of course, be fixed costs in buying or learning to use improved seed varieties (for example, making a trip to the store). Indeed, small fixed costs of this type play an important role in economic modeling (Duflo *et al*., 2011).

Achieving agricultural sustainability requires that a wide range of approaches that meet the needs and priorities of rural farmers are looked at and implemented at different levels. Agricultural output growth is considered one of the surest ways of effectively addressing poverty in the developing world (AU, 2021; World Bank, 2020). CSA practices such as new crop varieties, agroforestry, and other practices account for 50 to 90% of the increase in global crop yield (Yitayew *et al*., 2022). However, the agriculture sector in Ghana is faced with the major challenge of low productivity, especially for staple crops such as soybeans, maize, and rice (MoFA, 2017). With this, the yields in Ghana are still far below the achievable potential. Despite the investment made by the GoG, domestic cereal consumption is still below domestic production levels, with more than 50% of domestic consumption demand augmented by imports (MoFA, 2018). According to the International Trade Administration (2022), Ghana imported food and agricultural-related products worth US$1.90 billion in 2021. Also, the agriculture sector's contribution to Ghana's economy has been dwindling from as high as 39% in the 1990s to 33% in 2022 (GSS, 2022). It is asserted that Ghana currently imports cassava from China to augment local supplies to feed starch factories. This underperformance is attributed to the lower capacity to adopt and use improved technologies (MoFA, 2017; Kangogo *et al*., 2021). Based on this logic, there is a need to increase the adoption of CSA practices.

The GoG spent US$98 million to fund the PFJ program in 2022 but at a reduced input subsidy rate of less than 30% of 2021 (USDA Foreign Agricultural Services and GAIN, 2022). Conversely, the Chicago tradition associated with Schultz (1964) begins with the presumption that farmers are rational profit maximizers, so subsidies will distort CSA practices away from

the optimal levels. Subsidies on CSA practices might create large costs far beyond the Harberger triangles. They are typically regressive as richer farmers and those who have a large land and more land often benefit most from subsidies (Donovan, 2004), and loans met for farmers often go to farmers who have low repayment rates and are politically connected. Moreover, while moderate CSA subsidies might lead to the involvement of the government in CSA politicisation, distribution and very costly failures to supply the right kind of CSA at the right time are a challenge. This makes subsidies a palliative rather than a curative to low adoption of CSA practices.

Our study suggests that government decision-making biases are not the only factors limiting investment in CSA practices in Ghana. Farmers may also be affected by behavioural biases, as indicated by the technology acceptance model, that prevent them from investing profitably in CSA practices. It is assumed that some farmers are stochastically present-biased and at least partially naïve, systematically underestimating the odds that they will be impatient in the future, at least in the case when they are patient today. For example, purchasing improved seed varieties involves a utility cost, and farmers who discount future utility may choose to delay this investment until the last possible moment. Even if this cost is small, so long as farmers discount future utility, farmers who plan to use improved seed varieties will choose to defer incurring the cost until the last moment possible if they expect to still be willing to purchase the improved seed varieties later. However, if they become impatient in the last period when buying is possible, they may miss the opportunity to invest in CSA altogether. To address this issue, it is important to better understand the underlying challenges.

Most times, information about new technology is usually acquired when farmers experiment on a small portion of their land or when they learn from their neighbors who have experience with the technologies (Dzanku *et al*., 2020; Abdul-Mumin and Abdulai, 2021; Yitayew *et al*., 2022). It is worth noting that many authors argue that learning may not be the important driver of imperfect adoption decisions observed in Africa because modern inputs have been available for several decades and are supported by extension services in the region (Suri, 2011; Yitayew *et al*., 2022). However, new varieties of experimentation tend to affect the learning process, especially when supplied in packages that will enable rural and smallholder farmers to test new technologies on a small scale (Pannell *et al*., 2006; Yitayew *et al*., 2022). Consequently, if CSA practices are not marketed in desirable quantities and at affordable prices for rural farmers, it may lead to low adoption. An inefficient input delivery system is partly accountable for the low rates of adoption of CSA practices. According to the Economic Commission for Africa (2010), most times, it is the public or parastatal companies

that hold the largest share of the improved inputs markets in Africa with low contribution from the private sector. Thus, improved inputs are marketed in a one-size-fits-all fashion, often in one or, at most, in two large sizes, which makes it difficult for rural farmers to find inputs in suitable quantities they intend to use and can afford (Yitayew *et al*., 2022).

Furthermore, many studies show that the relaxation of liquidity constraints through the accessibility and availability of credit for rural and smallholder farmers increases new technologies (Adji *et al.*, 2022; Shahzad and Abdulai, 2021; Karlan *et al*., 2014). In the same vein, relaxation of liquidity constraints through delivering inputs in small quantities might encourage small farmers to adopt CSA practices because they can afford to spend less on the inputs when supplied in small and cheap bags. Therefore, small input package availability might contribute to the increased utilization of CSA practices. For instance, rural farmers may prefer immediate cost payments by buying small packages to later payments for bigger ones, as asserted by the present-based preference theory. O'Donoghue and Rabin (1999) assert that when there is consideration of a two-time horizon, bias in favor of the present provides a relatively stronger weight to the option of obtaining the opportunity or dealing with uncertainty at the earlier time horizon.

The main objective of this essay is to analyze factors in nudging the adoption intensity of CSA among rural farmers in Ghana. Specifically, the essay seeks to;

i) analyze the impact of the agricultural input supply system on CSA adoption among rural farmers in Ghana and

ii) analyze the impact of agriculture contracts on CSA adoption among rural farmers in Ghana.

Some studies have focused on CSA adoption in Ghana (e.g., Azumah *et al*., 2022; Asare-Nuamah and Amungwa, 2020). The main focus of these studies has been on education and gender. Other studies on different countries focus on credit and subsidies (Adji *et al*., 2022; Shahzad and Abdulai, 2021; Beamamn *et al*., 2021; Karlan *et al*., 2014), willingness to pay (Ali *et al*., 2020; Budhathoki *et al*., 2019) while Di Falco *et al*. (2020) focused on peer effects. Also, previous adoption studies have focused on the impact of input subsidies on technology adoption (e.g. Carter *et al*., 2014) and relaxing credit constraints on decisions of smallholder farmers (e.g. Karlan *et al*., 2014) while others consider network and learning (e.g., Blasch *et al*., 2022; Beaman *et al*., 2021). Meanwhile, these thoughtful studies have completely ignored the significant impact of the agricultural input supply system and contract on the adoption of CSA practices among rural farmers in Ghana. Understanding the determinants of CSA adoption rates has clear implications for the design of agri-environmental policies. A regulator must

possess an accurate understanding of the decision problem of the producer to design cost-effective incentives for resource conservation and environmental quality. If the decision problem is incorrectly specified, then the derived decision rule will be incorrect, and the incentive may be both inefficient and ineffective. Hence, this study seeks to analyze the impact of the agricultural input supply system and contract on the adoption of CSA practices among rural farm households in Ghana. This study hypothesizes that supplying inputs with divisible packages could enhance farmers' adoption of CSA in Ghana in a quasi-experiment. The target-input model of new technology by Bardhan and Udry (1999) motivates this hypothesis. The availability of agricultural inputs in smaller packages will encourage farmers to adopt CSA practices at a smaller scale, thereby learning by doing and ultimately fully replacing their old farming practices. Again, we hypothesize that payment of inputs after crop harvest could enhance the adoption of CSA more than before harvest.

The organization of this essay is as follows. The next section is on the backgrounds and trends of CSA adoption, with a particular focus on Ghana. After this section, the essay focuses on theoretical and empirical reviews. The fourth section presents the methodology, a count data Poisson regression model, and the data sources. The fifth section presents the interpretations and discussions of the results of the essay. The final section focuses on the conclusion and policy implications of the essay.

2.2 Background and Trends of Climate-smart Agriculture Adoption

Despite its promise, CSA adoption in Africa is low (Forum for Agricultural Research in Africa, 2015). Continent-wide, CSA is used on less than one million hectares, accounting for less than 1% of the total global area under CSA management. There are several important issues and constraints associated with the practice of CSA in SSA. Barriers to CSA adoption can be traced to the farm level, the landscape level, and the level of the entire food system (FAO, 2015). The identification of farm-level limiting factors or some farmer typologies that could be addressed by interventions such as land tenure reform, improvements in marketing, or information infrastructure may be more significant. In addition, community-level barriers have to be identified before certain CSA practices and technologies are recommended amongst some communities. Further, there is a need to examine human behavior as indicated by the technology acceptance model and cultural and institutional barriers to the adoption of CSA. CSA requires concerted training efforts and participatory engagement to overcome knowledge constraints and entrenched customs. CSA may also require different farming inputs and

implements than conventional agriculture, such as seeds for new cover crops and new hand tools or mechanical attachments (Forum for Agricultural Research in Africa, 2015).

The Mitigation of Climate Change in Agriculture of the FAO has helped build the knowledge base on what CSA practices are about (FAO, 2010). Farmers participated in several consultations in the field to identify existing agricultural practices and their possible impacts. This allowed farmers to compose a menu of potentially suitable climate-smart practices that can be readily integrated into their current farming systems. This was followed by a set of training sessions to facilitate the adoption and scaling-up. In Ghana, the Alliance of Biodiversity International, in collaboration with the International Centre for Tropical Agriculture 2022, implemented an agricultural development project to help more than 100 crop farmers in the Central Region. The project, known as the Accelerating Impacts of CGIAR Climate Research for Africa (AICCRA), seeks to make climate information services and CSA more accessible to small-scale farmers across Africa for optimal outcomes. A GH₵6 million three-year project covers 22 communities, 12 districts, and 31 demonstration sites in the Northern, Greater Accra, Bono East, Upper East, Central, and Upper West regions. To promote the adoption of CSA practices at a wide scale in Ghana, the Rainforest Alliance has continued organising national and local workshops on climate-smart cocoa farming for farmers, licensed buying companies, and technical officers from the Ghana Cocoa Board, the Ministry of Foreign Affairs and Regional Integration, and the Forestry Commission (FAO, 2021).

Several institutions, including the Savannah Agriculture Research Institute (SARI) and the International Institute of Tropical Agriculture (IITA), have been involved in research on improved crop production technologies in Ghana for close to a decade. Since 2015, MoFA and some non-governmental organisations, such as the International Fertilizer Development Centre, have led in the implementation of improved crop production technologies, certified seeds, and pest and disease control measures. using various extension approaches aimed at stimulating the adoption of improved production technologies. Certified seeds are sourced from known and reliable institutions such as research organisations, private seed producers/traders, and agro-input dealers after passing inspection and testing. Certified seeds are high-quality seeds that are not broken, diseased, wrinkled, or shrunken (Bogdanovic *et al*., 2015).

According to the MoFA (2022), the number of agricultural extension officers has increased from 1,586 in 2016 to 2,700 in 2020, with the ratio of extension officers to farmers decreasing from 1:1,900 to 1:709 persons. About 50 warehouses have been handed over to MoFA. Also, 23.188m seedlings have been distributed over three years now, as well as the construction of dams for irrigation purposes. Furthermore, a total of 8,980 units of various

machinery and equipment were imported and distributed in 2019 and 2020. The ministry also indicates that 8,148ha of land was developed for 76 commercial and smallholder rice, maize, and soybean farmers under the Savannah Zone Agricultural Productivity Improvement Project (SAPIP) funded by AfDB. Again, 1,290 improved breeding stock of West African Dwarf goats sourced from Burkina Faso have been distributed, and a total of 7,500 improved breeding stock Djalonke sheep sourced from Burkina Faso were distributed. This has benefited 13,000 smallholder farmers and farmers in Ghana. These, according to the ministry, are due to massive government investment in CSA practices.

The successful practice of CSA requires an enabling environment characterized by functional institutions, policies, markets, rules and regulations, and governance structures that favor the generation, dissemination, and use of CSA-relevant technologies, innovations, information, knowledge, and skills. In a community where institutions, policies, and markets fail to function; information, technologies, and innovations are not generated and disseminated; farmers lack the requisite skills; and cultural practices are not pro-CSA, adoption of CSA becomes a problem. Inconsistent and unstable agricultural policies have increased the vulnerability of food production and security in SSA. Thus, political and institutional inefficiencies have resulted in resource inequities in SSA (Magadza, 2000), thereby compromising the resilience of poor and vulnerable smallholder farmers. Ngigi (2009) observes that established institutions in developed countries not only facilitate the management of current climate-related risks but also provide an institutional capacity to help deal with the risks associated with CC. This implies that input delivery and contract might be essential in increasing CSA adoption intensity.

2.3 Theoretical and Empirical Literature Review

This section presents the theoretical framework, empirical literature reviews, and syntheses related to this essay. The theoretical reviews present the concept of the technology acceptance model by Davis (1993), which considers human behavior and cultural barriers to CSA practices adoption. The empirical reviews focus on the agriculture input supply system and contract on the adoption of CSA practices.

2.3.1 Theoretical framework

The theory of the Technology Acceptance Model (TAM) has been widely used to predict the acceptance of a new technology. It theorizes that perceived usefulness and perceived ease of use have great importance to technology acceptance and usage behaviors. For farmers to adopt CSA practices, it must be useful and easy to use. CSA practices are essentially

transformational agriculture and innovation through which adopted farmers increase production and yields. Studies show that the acceptance of an innovative agricultural practice varies with the context of the adopters. Farmers apply local ecological knowledge to identify key local CSA practices, including agroforestry, cover cropping, crop rotation, mulching, and mixed cropping (Mensah *et al*., 2021). Local contexts determine the enabling environment, the trade-offs, and the synergies of CSA practices. The conditions for their adoption are highly specific to contexts and locations, with fundamental implications for the operational aspects of CSA (Tesfaye *et al*., 2021; WB, 2020).

Moreover, CSA practices are adopted for adaptation to and mitigation of CC and increase yield. Our research focuses on the effect of agricultural contracts and input supply systems on CSA practices adoption and applies the TAM. This theory explains how farmers come to accept and adopt CSA practices, as explained by Davis (1993). TAM suggests that when users are presented with new technologies, some factors influence users' decisions about how and when to adopt them. These factors are perceived usefulness and perceived ease of use, displayed in Figure 2.1.

Perceived ease of use is the degree to which farm households believe that adopting CSA practices would be free from stress and effort (Davis, 1993). Liu and Li (2010) further explain that to use a particular form of technology, little effort should be needed by the user. This effort can be physical and mental (Davis, 1993). CSA requires concerted training efforts and participatory engagement to overcome knowledge constraints and entrenched customs. CSA may also require different farming inputs and implements than conventional agriculture, such as seeds for new cover crops and new hand tools or mechanical attachments (Forum for Agricultural Research in Africa, 2015). In CSA practices adoption, perceived ease of use includes how easy it is to acquire improved seed varieties, easy access to markets, easy access to government support (Abay *et al*., 2022), supply system (Yitayew *et al*., 2022), easy access to credit (Adji *et al.*, 2022; Shahzad and Abdulai, 2021) among other factors.

The perceived usefulness deals with how farm households believe that using new agricultural innovative and transformational technologies increases their productivity. Thus, a farmer could use a social welfare function to pick the most equitable and efficient outcome, and then use lump sum transfers followed by competitive trade to bring it about. Individuals have many needs associated with constraints such as the limitation of available resources. Facing the limitation of resources, they must make choices among alternatives to reach a higher utility. Their objective is to maximize their utility or welfare when they make a choice.

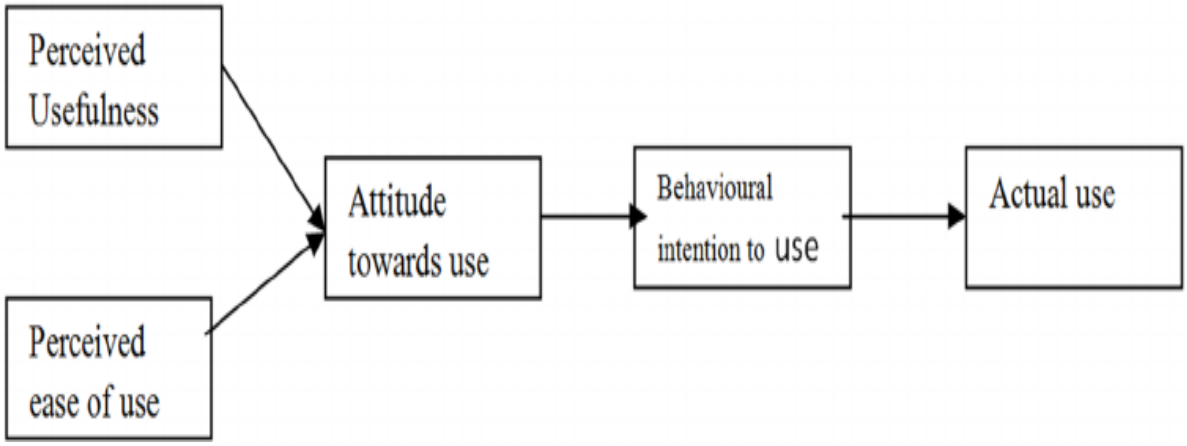


Figure 2.1 The technology acceptance model
Source: Davis (1993)

Rational choice theory assumes that preferences are defined over outcomes, that those outcomes are known and fixed, and that decision-makers maximize their net utilities by choosing an alternative that yields the highest level of benefits (discounted by costs). Thus, for rural farm households to choose CSA practices, these practices should maximize farmers' net benefits. That is, rural farm households maximize the expected utility from adopting CSA practices. Choices among competing goals are handled by indifference curves (twice differentiable) that specify substitutability among goals.

Because decision-makers lack the ability and resources to arrive at the optimal solution, they instead apply their rationality only after having greatly simplified the choices available. Rural farm households make decisions on whether to accept pre-harvest contracts or patronise smaller packages of CSA since they sometimes do not know the best options. Like rational choice, bounded rationality assumes that actors are goal-oriented, but it also takes into account the cognitive limitations of decision-makers in attempting to achieve those goals. In this case, agriculture contracts and input delivery systems could influence rural farmers to adapt to CC by adopting CSA practices.

2.3.2 Empirical Review of Adoption of Climate-Smart Agriculture

A growing body of literature has revealed that farmers have adapted to CC through multiple on- and off-farm adaptation strategies such as CSA practices to enhance their livelihood and food security, which depend largely on the environment. For instance, Awuni *et al*. (2018) used zero-inflated Poisson to measure the intensity of adoption of rice production technologies and found that farmers, experience, demonstration fields, sex of the farmer and training enhance improved agricultural technologies adoption. Azumah *et al*. (2017) and

Mensah-Bonsu *et al*. (2017) used Poisson to explain the adoption intensity of CC coping strategies and land and water management practices. Azumah *et al*. found that contract farming, extension services, and land ownership influence CC adaptation strategies adoption. However, Mensah-Bonsu *et al*. found that credit, extension contact, and experiences of farmers are the driving factors. Mahama *et al*. (2020) employed count data modeling to estimate the determinants of the adoption intensity of sustainable soybean production technologies. The authors found that education, age, mass media, extension services, and perception influence the adoption of sustainable soybean technologies. Using multivariate and random effect ordered probit, Teklewold *et al*. (2019) studied multiple climate-smart practices in the Nile Basin of Ethiopia. The study found that tenure security, social capital, and climate shocks determine adaptation strategies.

Ngaiwi *et al*. (2023) aimed to enhance our understanding of conversation agriculture practices by examining the factors that determine its adoption and intensity among small-scale farmers in Cameroon. Employing multivariate probit analysis, the findings revealed that several factors significantly influenced the adoption of conservation agriculture practices, including gender, age, family size, extension services, use of modern farm technology, distance from the house to the farm, ownership of livestock, and soil fertility. Moreover, the results indicated that gender, distance from the house to the farm, and the number of livestock owned were key drivers of the intensity of the adoption of conservation agriculture practices. Anuga *et al*. (2019) employed a binary logistic regression and found that environmental, economic, institutional, and sociocultural factors influence CSA adoption. Conversely, Mensah *et al*. (2021) analyzed local ecological knowledge to adopt CSA and found that farmers used local ecological knowledge to identify key local CSA practices, including agroforestry, cover cropping, crop rotation, mulching, and mixed cropping. However, some of their farming practices are not consistent with sustainable agricultural practices. According to the authors, limited access to agricultural inputs, high labour-intensive activities for CSA practices, limited access to agricultural information on CSA options, inadequate agricultural training for farmers on CSA practices, and land tenure issues prevent farmers from adopting CSA and adversely affect access to arable land for farming need.

Adji *et al*. (2022) evaluated the impact of sustainable agriculture policies on income and land use using mathematical programming and found that credit and subsidy policies enhance the adoption of sustainable agricultural practices. Ali *et al*. (2020) and Budhathoki *et al*. (2019) evaluated the willingness of farmers to pay for weather-index-based insurance. Using choice modeling, Ali *et al*. found that weather formation, media operating in local

languages, and education positively influence participation in weather index-based insurance, while Budhathoki *et al* found better communication, subsidies, and price to influence participation in weather index-based insurance. Blasch *et al*. (2022) employed mixed and latent class logit models to evaluate farmers' willingness to adopt precision farming technologies and explore the role of social influence. The study showed that the social network of farmers influences precision farming technologies. In a different study, Barnes *et al*. (2019a) employed count data modeling to estimate that age and belief in the knowledge of the field influence the adoption of precision agricultural technologies.

Beaman *et al*. (2021) investigated whether utilizing network theory-based targeting can enhance technology adoption rates. The authors focused on the adoption of agricultural technologies among smallholder farmers in Uganda. They acknowledged that despite the potential benefits of adopting modern farming techniques, many farmers in developing countries are hesitant to adopt them due to various barriers such as limited information, financial constraints, and social norms. The study involved a randomized controlled trial where different targeting strategies were tested. The study found that network theory-based targeting significantly improves technology adoption rates compared to traditional targeting approaches. Also, they found that both the high-degree and structural targeting strategies lead to a higher adoption rate, with the structural targeting approach having a slightly stronger impact. Again, they found that the provision of financial incentives further boosted the adoption rates.

Furthermore, Makate *et al*. (2019) employed multinomial logistic regression in analyzing the drivers of the adoption of multiple and individual conservation agriculture on income and farm productivity. The authors found that information, education, farm size, credit, and income influence the adoption of multiple agriculture innovations. Barnes *et al*. (2019b) empirically examined the uptake of machine guidance and variable rate nitrogen technologies and observed that farm size, attitudes in the sense of expectations about the returns of the technology, and information-seeking behavior matter using multilevel random intercept regression.

Engel and Muller (2016) analyzed the effect of payments for environmental services on the promotion of CSA and found that payments for environmental services promote CSA practices in the context of small-scale farming that has low ecological and socioeconomic conditions and addresses leakage risks. The authors showed that payments for environmental services are more effective where synergies with food security, climate adaptation, agricultural development, or other environmental services exist. Contrarily, Connolly-Boutin and Smit

(2016) and the IPCC (2014) argued that poor natural resource management, low adaptive capacity, and poverty make adaptation strategies ineffective in Africa.

Blasch *et al*. (2022) investigated the factors influencing the adoption of precision farming technologies among farmers in Italy in a choice experiment. The study aimed to gain insights into farmers' preferences and decision-making processes regarding the adoption of precision farming techniques. In gathering data, the authors conducted surveys and interviews with farmers in Italy, aiming to understand their attitudes, perceptions, and considerations related to precision farming technologies. The study explored various factors that either facilitate or hinder the adoption of these technologies by farmers. Using multinomial, mixed, and latent logit estimations, they found that the adoption of precision farming technologies is influenced by a combination of economic, technical, and social factors. Furthermore, the study identified distinct segments among farmers based on their attitudes toward precision farming technologies. These segments included early adopters, cautious adopters, skeptical adopters, and non-adopters. Each segment exhibited specific preferences, concerns, and barriers to adoption, emphasizing the need for tailored strategies and interventions to encourage adoption across different farmer groups.

Mujeyi *et al*. (2022) evaluated adoption patterns and determinants of CSA technologies using a multivariate analysis approach and found that patterns of CSA varied across household typologies. Resource-endowed, experienced farmers have a high use of crop rotation and minimum tillage that require more resources, while resource-constrained clusters shunned those. Double hurdle model results showed that the adoption of CSA is significantly affected by distance to the tarred road, access to weather information, livestock income share, and ownership of transport assets. Adoption intensity is significantly affected by the sex of the household head, labor size, frequency of extension contacts, credit access, access to weather forecasts, off-farm income, distance to input and output markets, number of traders, and asset ownership.

On a dissimilar focus, Zakaria *et al*. (2020) fitted an Endogenous-Switching Poisson regression model to determine the drivers of farmers' participation in the adoption intensity of CSA practices. The study found that participation in capacity-building training, family labor, and agricultural insurance significantly influences the adoption intensity of CSA practices among farmers. Azumah *et al*. (2022) employed a multinomial treatment effect regression model and examined the drivers of single and joint adoption of selected CSA. The authors found that experience, education, and extension services positively influence joint adoption of improved seed and irrigation, while social capital, farm size, and livestock ownership

negatively influence joint adoption. Similarly, studies have demonstrated that adaptation is dependent on multiple socioeconomic factors, such as age, gender, years of farming experience, assets, level of education, household size, and technology (Koudjom, 2022; Adu *et al*., 2018; Lopez-Ridaura *et al*., 2018). Etwire *et al*. (2022) applied an endogenous switching regression to account for endogeneity and selection bias. The study found access to information to have a positive effect on the decision to adapt. Di Falco *et al*. (2020) employed two instrumental variables to the issue of endogeneity. The study found that peer choices positively affect the uptake of different adaptation strategies.

Mume *et al*. (2023) carried out a study to analyze the factors driving the decisions of farmers to implement small-scale irrigation practices as a CC adaptation strategy. The information was gathered from a sample of adopter and non-adopter families. Primary and secondary sources were used to collect both qualitative and quantitative data. The drivers of irrigation plan acceptance were identified using a binary logistic regression model. The findings show that the age of the household head, dependency ratio, distance from a water source, household size, frequency of extension contact, access to credit, livestock holding, off/nonfarm activities, membership in an agricultural cooperative, access to climate information, and perception of CC all had a significant positive effect on the adoption of small-scale irrigation schemes.

From the foregoing studies, it can be noted that all these insightful studies have neglected the impact of input delivery systems and pre-harvest contracts, implying that there is still a gap in the literature to be filled. The study closer to this current study is Yitayew *et al*. (2022), who analyzed divisible seed package availability on trying a new variety of wheat under a random control trial setting. Using OLS, the study found that farmers tend to experiment with newly introduced varieties on their farmlands and are unlikely to adopt new varieties as a coping mechanism for risk exposure at the experimentation stage, while the treatment heterogeneity showed that supplying seed in smaller bags has differential causal effects on farmers. To fill the gap in the literature, this study aims to estimate the impact of the input delivery system and pre-harvest contract on effective CSA adoption intensity among rural farmers in Ghana. This study contributes to the literature on the impacts of input marketing strategies on the adoption of CSA practices in rural areas in Ghana.

2.4 Research Methods

The essay adopts the quasi-experimental design with the use of control and experimental or treatment groups. Data was collected from two groups: those who adopt CSA

practices and those who do not, and those who prefer smaller packages and those who do not. Also, data were collected on those who preferred the before-harvest contract and those who did not. One of the ways of measuring the impacts of agricultural divisible packages and contracts on the adoption intensity of CSA practices is to assume two groups: smaller packages and larger packages or payment before harvest and payment after harvest with common characteristics. The analyses of this study utilize the quantitative approach, which conforms with the positivist philosophy. The choice for this research design, therefore, becomes necessary not only due to the quantitative nature of the study but also because it is found to be suitable for analyzing a phenomenon, situation, or issue by considering a cross-section of the population at one point in time (Litvin *et al*., 2008). A cross-sectional rural farm households survey in Ghana was conducted for the data analyses.

2.4.1 Modelling the Impact of Agricultural Input Supply System and Contract on CSA Adoption

It is assumed that farm households adapt to minimize the damaging impacts of CC on their farm production. Another assumption made is that farm households adapt to CC through the adoption of any specific recommended CSA practices only when the perceived utility from this strategy is high. That is, its utility must be significantly greater than the utility gained from non-adaptive farming practices. The study also acknowledges that in addition to perceived CC, an individual's profit-seeking mentality may drive adaptation strategies. Notwithstanding this implicit link, our study assumes that the choices and actions farmers make are driven by their perceived appraisal of the threat of climatic factors and perceived adaptive and socio-economic factors such as agricultural input supply systems and contracts. This understanding was highlighted during the questionnaire administration.

Choice experiments remain a preferential method to analyze human behavior (Narayanan and Antoniou, 2023). In deriving the random utility theory, a decision maker n is confronted with a choice among j alternatives (Filiz-Ozbay and Masatlioglu, 2023). The decision maker obtains a defined utility or profit from each level of the alternatives; thus, the utility that the decision maker obtains from the levels of alternative $j = 1 \ldots \ldots \mathrm{J}$. Here, the farmers obtain the highest utility (by adopting more CSA practices) from the alternative they choose. With these in mind, the behavioral model, therefore, is to choose i if and only if $U_{ni} > U_{nj} \ \forall j \neq i$. Considering the unobservable utility of the farmer $x_{nj} \, \forall \, j$, and some inherent attributes s_{n}, the observable characteristics are utilised to arrive at the utility of the decision maker. The utility is then denoted by $V_{nj} = V(x_{nj}, s_{\mathrm{n}}) \forall j$. This form of the utility function is

the representative utility. Normally, V is dependent on unobservable parameters and is statistically estimated. McFadden (1978) proposed modeling expected utility η_{ij} in terms of the characteristics of the alternatives rather than the characteristics of the individuals.

Based on the works of Mahama *et al*. (2020) and Awuni *et al*. (2018), our study uses count data modeling. This study considers a simple static model of the value-to-input supply system and contract on CSA intensity. Most real-life data are often characterized by over-dispersion, under-dispersion, and excess zeros, therefore, the equality of the conditional mean and variance of the distribution could be rejected in most count data modeling (Mahama *et al*., 2020; Greene, 2018). Most variables that consist of count data are often analyzed or modeled with basic count models such as the Poisson regression model (Harris *et al*., 2012; Mahama *et al*., 2020). The underlying assumption of the Poisson regression model is that the variance is equal to the mean (qui-dispersion). This assumption of the equip-dispersion is usually not reflective of most count data (Mahama *et al*., 2020). The most likely occurrence in count data is over-dispersion; that is, where the variance is less than the mean, the data is said to be under-dispersed.

2.4.2 The Generalized Poisson Regression

The Poisson regression model, which is appropriate for count-dependent variables (Greene, 2018; Cameron and Trivedi, 2005), is employed to estimate the agricultural input supply and contract on CSA practices' intensity participation of farmers in Ghana. The probability of adopting CSA k practices (the K^{th} degree of CSA practices) given n independent behaviors of farmers is represented by the binomial distribution:

$$P(C = K) = \binom{n}{k} p^k (1-p)^{n-k} \tag{5}$$

where $\binom{n}{k} = \frac{n!}{k!(n-k)!}$ and p is the probability of adopting CSA k practices. The density function for Poisson regression is given as:

$$f(c_i|X_i) = \frac{e^{-\lambda_i} {\lambda_i}^{-c_i}}{c_i!} \tag{6}$$

where λ_i is assumed to be log-linearly related to regressors X_i: $ln\ \lambda_i = X_i'\beta$. The log-likelihood function for a Poisson regression model is given as:

$$\ln L = [-\lambda_i + c_i X_i'\beta - lnc_i!] \tag{7}$$

The mean and variance of this distribution can be shown to be:

$$E(c_i|X_i) = var(c_i|X_i) = \lambda_i = e^{X_i'\beta} => \frac{\partial E(X_i'\beta)}{\partial X_i} = \lambda_i\beta \tag{8}$$

The Poisson model has been criticized because it assumes equip-dispersion, which restricts the conditional variance to equal the conditional mean (Greene, 2018). The equip-dispersion condition in the Poisson distribution is often not realistic because count data variance usually exceeds the mean (Cameron and Trivedi, 2005). The data is called overdispersion if the variance exceeds the mean and under-dispersion if the variance is less than the mean.

According to Harris *et al*. (2012); Mahama *et al*. (2020); and Israel *et al*. (2020), dealing with under-dispersed data will require that the best models are utilized to avoid cases where the standard errors are overestimated and inferences are misleading. Few models have been developed to deal with the incidence of under-dispersed data. Normally, for under-dispersed data, a model that is based on the generalized Poisson distribution may be appropriate (Mahama *et al*., 2020). Suppose C_i is a count response variable (intensity of CSA practices), and follows a generalized Poisson distribution, the probability mass function (PMF) of $C_i, i = 1, 2, \dots, n$. According to Famoye *et al*. (2004), Mahama *et al*. (2020), is specified as:

$$f(C_i) = \Pr(C_i = c_i) = \left(\frac{\lambda_i}{1+\alpha\lambda_i}\right)^{c_i} \frac{(1+\alpha c_i)^{c_i-1}}{c_i!} exp\left[\frac{-\lambda_i(1+\alpha c_i)}{1+\alpha\lambda_i}\right], c_i = 0, 1, 2, \dots \quad (9)$$

The mean and variance of C_i are mathematically specified as:

$$E(Y_i|x_i) = \lambda_i, Var(C_i|x_i) = \lambda_i(1 + \alpha\lambda_i)^2 \quad (10)$$

The generalized Poisson model is by far an extension or generalization of the Poisson regression model. Where $\alpha = 0$, the probability of mass function reduces to the standard Poisson regression model. In practice, this assumption is often not reflective of real-life data because the conditional variance could either be greater or lesser than the conditional mean. However, if there is an inequality of the variance and mean, the estimates in the Poisson regression model are still consistent but are inefficient, leading to overestimation or invalidation of the standard errors and wrong inferences (Mahama *et al*., 2020; Famoye *et al*., 2004). When $\alpha > 0$, it is assumed the variance is greater than the mean, in which case the Generalised Poisson Regression (GPR) model represents the count data with over-dispersion. Further, when $\alpha < 0$, the variance is assumed to be less than the mean, and therefore, the generalized Poisson regression model represents count data with under-dispersion. The dispersion parameter (α) is called the dispersion parameter and can be estimated along with the regression parameters in the generalized Poisson regression model. The maximum likelihood method is used to calculate the estimates of α and β in the GPR model.

Several non-parametric tests can be used to measure the goodness-of-fit of the GPR model based on the Pearson test statistics or deviance (Famoye *et al*., 1993; Mahama *et al*., 2020). The test based on the Pearson statistics or deviance is approximated by the distributional

effect of the chi-square when $\mu_i's$ are large. Usually, computing Pearson test statistics or deviance can be complex. Therefore, the log-likelihood value is often used to measure the goodness-of-fit of the GPR model. In comparing the Standard Poisson and the GPR models, the model with a large log-likelihood value is considered the best (Mahama *et al*., 2020; Rashwan and Kamel, 2011; Israel *et al*., 2020).

The log-likelihood (L) for the GPR model is specified as:

$$lnL(\beta,\alpha) = \sum_{i=1}^{n}\left[c_i \ln\left(\frac{\lambda_i}{1+\alpha\lambda_i}\right) + (c_i-1)\ln(1+ac_i) - lnc_i! - \frac{\lambda_i(1+ac_i)}{1+a\lambda_i}\right] \quad (11)$$

A test of the hypothesis of the adequacy of the GPR model over the Standard Poisson model is given by $H_0: a = 0$ against $H_1: a \neq 0$. The test of H_0 is an indication of the significance of the dispersion parameter. Therefore, when H_0 is rejected, the appropriate model to use is the generalized Poisson Regression model. The test could be conducted by using the asymptotically normal Wald $'t'$, which is defined as the ratio of the estimate of a to its standard error. Alternatively, the likelihood ratio test statistic could be used to test for the null hypothesis. This is approximately chi-square distributed and has one degree of freedom when the null hypothesis is true. According to Mahama *et al*. (2020), one other way of choosing the best count data model is by considering the value of the Akaike Information Criterion (AIC). Mathematically, the AIC is presented as follows:

$$AIC = -2lnL(\widetilde{\theta}) + 2k \quad (12)$$

where the $L(\theta)$ is defined as the log-likelihood value, and k denotes the number of the parameters considered for estimation. Usually, the model with a smaller AIC value is considered the best model (Fabozzi *et al*., 2014; Mahama *et al*., 2020).

The adoption of CSA practices is conceptualized within the framework of the standard theory of technology adoption. In our model, we depict a representative farm household, characterized by risk aversion, deciding to adopt CSA practices to maximize the expected utility derived from an increased production period. This decision is made in consideration of the impact of CC and various constraints related to land and other resources. It is important to note that we presume farmers to be price-takers, participating in a market structure characterized by perfect competition. In such a setting, the decisions made by farmers regarding production and input allocation do not impact either output or input prices. Under the assumption that the utility function is independent of the state, solving this problem would yield an optimal adaptation strategy pursued by the representative farm household, as expressed in the empirical model in Equations 14-16:

$$CSA_i = f(input_i, sex_i, marital\ status_i, age_i, education_i, region_i) \quad (13)$$

$$CSA_i = c_1 input_i + c_2 sex_i + c_3 marital_i + c_4 age_i + c_5 educ_i + c_6 region_i + \varepsilon_i \quad (14)$$

To model the impact of agricultural contract types on CSA adoption intensity, CSA adoption is the dependent variable. Equation 16 states the empirical model.

$$CSA_i = f(contract_i, sex_i, marital\ status_i, age_i, education_i, region_i) \quad (15)$$

$$CSA_i = c_1 contract_i + c_2 sex_i + c_3 marital_i + c_4 age_i + c_5 educ_i + c_6 region_i + \varepsilon_i \quad (16)$$

2.4.3 Sources of Data

2.4.3.1 Study Areas

The focus of the study was on rural farmers in two key regions of Ghana—Central and Upper East regions. They mostly produce twice a year—major and minor seasons. We surveyed farmers in the Assin South, Awutu Senya West, Nadowli, and Sissala West Districts in Ghana. These districts are known for their production of crops such as cocoa, yam, maize, rice, and other staple crops. Also, they are known for their production of crops such as sorghum, millet, maize, yam, and shea nuts. The major source of income and livelihood in these districts is agriculture. These areas have a tropical savanna climate with two distinct seasons: a wet season and a dry season. The wet season lasts from April to October and is characterized by high temperatures and heavy rainfall. The heaviest rainfall occurs in July and August, with an average of about 200mm of rainfall per month. During this season, temperatures range from 22°C to 32°C, with high humidity. The dry season lasts from November to March and is characterized by lower temperatures and little to no rainfall. During this season, temperatures range from 20°C to 30°C, and humidity is generally lower than during the wet season. The harmattan season also affects these areas between December and January. During this season, dry and dusty winds blow from the Sahara Desert, causing hazy skies and reduced visibility. These places have low infrastructure in many respects and mostly engage in agricultural activities. These places are the Savanna belt of Ghana, where there is not much rainfall and have already started experiencing the impact of CC.

Nadowli has 47,845 (70.1%) of the people in the district living in rural areas. The proportion of agricultural activities by households in the rural areas of the district constitutes 79.56%. More than 53% (65,396) of people in the Awutu Senya District live in rural areas. The proportion of agricultural activities by households in the rural areas of the district constitutes 61.62%. Assin South has 57,698 (41.4%) people in the district living in rural areas. The proportion of agricultural activities by households in the rural areas of the district is more than 67.84%. Sissala has 30,133 (80%) of the people in the district living in rural areas. The

proportion of agricultural activities by households in the rural areas of the district is more than 94.65% (GSS, 2022).

2.4.3.2 Sampling Procedure

Employing a multistage sampling technique, the administrative regions of Ghana were stratified into two main zones (North Zone and South Zone). One region was selected from each zone. Afterward, two districts were selected from each region. In these locations, we randomly selected farmers based on lists provided by cooperative leaders. A sample of over 590 farm households was interviewed from an overall population of about 289,286. The sample size is chosen based on the formula proposed by Bartlett (2001). The sample size is chosen based on the formula:

$\frac{N}{1+(N*e^2)} = \frac{N}{1+(N*0.05^2)}$ (Bartlett, et al., 2001), where N is the population and e is the margin of error. This formula is repeated for all communities involved in the study.

We selected respondents of different ages and diverse educational levels. The selected respondents were based on simple random sampling due to the availability and accessibility of the farmers. The quantitative questionnaire for face-to-face interviews was developed based on the GSS approach in collaboration with WASCAL and the thesis supervisor (details available upon request). Extension officers and executives of various farmers' associations were contacted to help get the farmers. This was done through visits, telephone calls, and other media. Field assistants and supervisors were recruited based on their levels of education, proficiency in English and the local languages, availability for the entire training and fieldwork period, familiarity with study areas, and experience in data collection. The field staff were taken through a three-day intensive training before the start of the survey. All protocol and ethical standards were duly observed. However, there was a non-response rate of 7.5% due to incomplete responses.

2.4.3.3 Variables

Table 2.1 presents the summary description of the variables used for analyses in this study. The measurements and the nature of the variables with their expected signs are also presented. The summary statistics of the study are presented in Table 2.2. On average, farmers in Ghana have adopted approximately 3.235 out of the eight identified CSA practices, where some farmers may have adopted more than the average, while others have adopted fewer practices. The minimum value of zero suggests that there are farmers in Ghana who have not yet adopted any of the identified CSA practices. This implies that some farmers may still rely

on conventional agricultural methods without incorporating climate-smart techniques into their farming systems.

Table 2.1: Summary of Variable Definition and Measurement

	Type	Measurement	Expected sign
CSA	Continuous	The number of CSA practices/ the portion of the farm size the farmer uses climate-smart agriculture practices	
Input	Dummy	Whether respondents prefer buying larger sizes to smaller sizes	-
Contract	Dummy	Whether the farmer has a sale/harvest based on a contract	+
Age	Continuous	The age of the farmer at the time of the interview in years and captures the years of experience in farming	+/-
Sex	Dummy	Taking the value of 1 if the farmer is a male, 0 otherwise	+
Farm size	Continuous	Total agricultural farm size in hectares	+
Formal lender	Dummy	Taking the value of 1 if the farmer has access to a formal lender, 0 otherwise	+
Information	Dummy	Taking the value of 1 if the farmer has access to agricultural information, 0 if otherwise	+
Education	Categorical	The education level of the farmer	+
Marital	Categorical	Marital status of the farmer	+/-
MM	Dummy	Whether the farmer has adopted mobile money	+
Association	Dummy	Whether the farmer belongs to an agricultural association	+
Farm distance	Continuous	Distance to farm by foot in minutes	+/-
Market distance	Continuous	Distance to market in minutes	+/-
Extension	Dummy	Whether the farmer has access to extension services	+

Table 2.2: Summary Statistics of the Variables

Variable	Obs	Mean	Std. Dev.	Min	Max
CSA Adoption Intensity	520	3.235	1.446	0	8
Buyer contract	343	0.006	0.076	0	1
Pre-planting Commitment	520	0.157	0.364	0	1
Small	520	0.363	0.481	0	1
After harvest	520	0.951	0.215	0	1
Receive agric info	520	0.095	0 .293	0	1
Hired labour	520	1.404	0.491	0	1
Age	520	49.783	14.800	15	98
Farm size	520	3.507	4.373	0.12	10
Market distance	520	25.090	25.411	15	120
Farm distance	520	35.579	37.139	0	60
Farm-based group	520	0.076	.265	0	1
Female	520	0.215	0.411	0	1
MM	520	.2421637	.4284523	0	1
Formallender	520	.423919	.4942454	0	1

Informallender	520	.5184082	.4997287	0	1
Upper West	520	1.496055	.5000502	1	2
Categorical variables		Percent			
Education					
Never		2.81			
Basic		93.06			
SHS and above		4.13			
Marital					
Never married		1.33			
Married		81.70			
Widowed		12.13			
Separated		4.85			

The maximum value of eight indicates that some farmers in Ghana have adopted all eight identified CSA practices. These farmers are likely implementing a comprehensive approach to CSA, considering various practices to address CC and promote sustainable agricultural production. The adoption of CSA practices among farmers in Ghana varies by approximately 1.4, that is, adopting either fewer or more practices than 3.2. The low mean value of buyer contracts of 0.006 suggests that only 0.6% of the farmers involve buyer contracts. This might indicate that buyer contracts are not commonly utilized or may not be prevalent within the specific context. The presence of buyer contracts can be influenced by economic factors such as market dynamics, buyer preferences, and the nature of the products being traded. If there are alternative market mechanisms or pricing structures, the utilization of buyer contracts might be limited. Also, the availability and enforcement of legal frameworks and institutions related to contract law and dispute resolution can affect the prevalence of buyer contracts. Strong and effective institutions ensuring contract compliance and enforcing agreements could impact the use of buyer contracts.

Approximately 15.7% of the observations involve pre-planting contract commitments. This could imply that there are social norms or practices in place where farmers and other stakeholders engage in pre-planting contractual arrangements. Pre-planting contracts can provide farmers with greater security and assurance in terms of market access, pricing, and inputs. Economic factors such as crop characteristics, market volatility, and the availability of credit could influence the prevalence of these contracts. About 36.3% of the respondents prefer a small input supply to a large input supply. This could indicate the importance of small-scale agriculture within the context, potentially driven by factors such as household-based farming practices or local economic dynamics. A vast majority (95.1%) of the respondents prefer after-harvest payment methods. This could indicate the significance of post-harvest income availability.

On average, 59.6% of farmers hire farm laborers. This suggests that the utilization of hired labor is prevalent within the context, possibly driven by factors such as labor availability or division of labor. Also, the use of hired labor can be influenced by economic factors such as labor costs, productivity gains, and economies of scale. The specific characteristics of the agricultural sector and the cost-benefit analysis of hiring labor can impact its prevalence. The average age of farmers is approximately 50 years. Some farmers are as young as 15 years old. This suggests the presence of young individuals involved in farming activities, possibly due to intergenerational farming practices or early engagement in agricultural activities. Also, some farmers are as old as 98 years. This implies that there are individuals who have been engaged in farming for a significant portion of their lives, demonstrating the presence of long-standing farmers in the country. There is a 15-year range of ages among farmers within the farming communities. Factors such as generational dynamics, the influence of agricultural policies, the impact of age on farming practices, decision-making, and knowledge transfer within the farming community could influence this.

On average, farmers in Ghana possess a farm size of approximately 3.507 acres. The minimum value of 0.12 acres suggests that there are farmers with relatively small landholdings. This indicates the presence of farmers who cultivate very limited areas of land, possibly due to factors such as land scarcity or resource constraints. However, some farmers hold as large as 10 acres. This implies the existence of farmers who possess substantial agricultural land, allowing them to cultivate larger areas and potentially engage in more extensive farming operations. With a dispersion of 4.373 acres, it suggests that there is a considerable variation in farm sizes among farmers in Ghana. Moreover, factors such as land tenure systems, agricultural policies, and market dynamics can influence farm sizes and their distribution. Also, about 21.5% of the farmers were females. The minimum and the maximum values of 0 and 1 suggest that there are observations where no females are present as heads of household and where females are heads of household, respectively. This conforms to the situation in Ghana, where heads of household are dominated by men. Furthermore, about 9.5% of the farm households receive agricultural information, while 90.5% do not receive agricultural-related information. Possible factors influencing the observations could include the availability and accessibility of agricultural information, the effectiveness of communication channels, the influence of agricultural extension services, or the impact of agricultural policies or initiatives promoting information dissemination. It is observed that a few farm households (7.6%) belong to agriculture-based organizations.

Again, from Table 2.2, on average, farmers have a distance of approximately 25.090 minutes to reach the market, suggesting that there is variability in the proximity of farmers to the market. The minimum distance to the market is 15 minutes, which suggests that there are farmers who have relatively shorter distances to reach the market. This implies that some farmers are located closer to markets, enabling them to access markets more conveniently and potentially reducing transportation costs and time. However, some farmers travel as long as 120 minutes to reach the market. This implies that some farmers are located farther away from markets, which can pose challenges in terms of transportation logistics, costs, and potential delays in accessing markets. There is considerable variation in the distances to markets among farmers in Ghana. Some farmers may have distances to the market that are close to the mean, while others may have significantly longer or shorter distances, indicating a wide range of market access conditions within the farming community. Additionally, factors such as road conditions, availability of transportation options, and market accessibility initiatives can influence the distances to markets and their distribution among farmers.

Moreover, on average, farmers have to walk approximately 35.579 minutes to reach their farms. The minimum value of 0 minutes on foot suggests that there are farmers in Ghana who have their residences located on their farms or very close to their farms. This implies that some farmers have the convenience of having their farms nearby, enabling them to easily access and work on their agricultural land. The maximum value of 60 minutes indicates that there are farmers in Ghana who have farms located at considerable distances from their residences. This suggests that some farmers face significant travel times and potentially use other means of transportation, such as vehicles or bicycles, to reach their farms. There is considerable variation of 37.139 minutes in the distances to farms among farmers in Ghana. Some farmers may have distances to their farms that are close to the mean, while others may have significantly longer or shorter distances, indicating a wide range of farming location conditions within the farming community. Factors such as land availability influence the distances to farms and their distribution among farmers.

About 49.6% of the respondents were from the Upper East, while about 50.3% were from the Central Region. For lending opportunities, 42.39% had formal lenders, and 51.84% had informal lenders. More than 93% of the respondents had at least a basic education, while just 4.13% had SHS and above qualifications. Only 2.81% never had any form of education qualification. From our study, married farmers constituted 81.70% of the respondents. Those who were never married were 1.33%, while the widowed were 12.13%, and those separated were 4.85%.

Figure 2.2 shows the distribution of farm households that have a contract with buyers and those that do not have a buyer contract across education, gender, marital status, farm-based organization, received agricultural information, and access to formal lenders. It is indicated that 100% of farmers with basic education have a contract with buyers, while 2.6% of farmers who have no level of education and 6.16% of farmers who have higher education than basic school education have no buyer contracts. This is quite surprising since the educated are supposed to have a partnership for their agricultural activities. From the gender perspective, 15.48% of females have no buyer contract at all, while 100% of the male farmers have buyer contracts. No female farmer has a buyer contract. This shows the underrepresentation of female-headed households in Ghana. Many females in Ghana do not have decision-making powers concerning their production. The production decisions are being made by their husbands. All the farmers who do not receive agricultural information have buyer contracts, while 0% of farmers who receive agricultural information have buyer contracts.

More than 90.7% of farmers who receive agriculture information have no buyer contracts, but 9.23% of farmers who receive agriculture information have no buyer contracts. This indicates that the majority of the farmers in Ghana do not have buyer contracts. This is not surprising since the farmers who receive agricultural information might think that they manage their agricultural activities better than those who do not receive it. It is also indicated that 100% of the farmers who have access to formal lenders have buyer contracts. This is possible because their formal lenders might be those signing the contract. Furthermore, except for married farm households, all the other farmers do not have buyer contracts. This is because the married farmers have extended relationships with other families who might help their in-laws secure contracts. Also, the married farm households might be pulling their resources to secure contracts. As it is always stated, two heads are better than one.

The distribution of the level of education across gender, marital status, farm-based organizations, receiving agricultural information, and having access to formal lenders is shown in Figure 2.3. It is observed that the majority of the male farmers have acquired at least a secondary level of education as compared with their female counterparts. That is, 66.67% of males have an education above secondary education while 33.33% of female farmers have acquired SHS and above education, representing an increase in education among females after basic school. However, that of males drops by more than 12%. Almost 21% of females have basic education, while 79% of males have basic education. This is plausibly due to the free SHS education, which has increased enrolment levels continuously over the years for both sexes. Surprisingly, those who receive agriculture information constitute about 18% of farmers

with at least basic education. This is generally the case in Ghana, where the farming subsector is dominated by farmers with no or low levels of education. However, 50% of farmers who have SHS and higher have access to formal lenders. It is observed that 60% of farmers who do not have any education level do not have access to formal lenders. This represents the situation in Ghana, where most of the farmers are not able to access formal financial institutions.

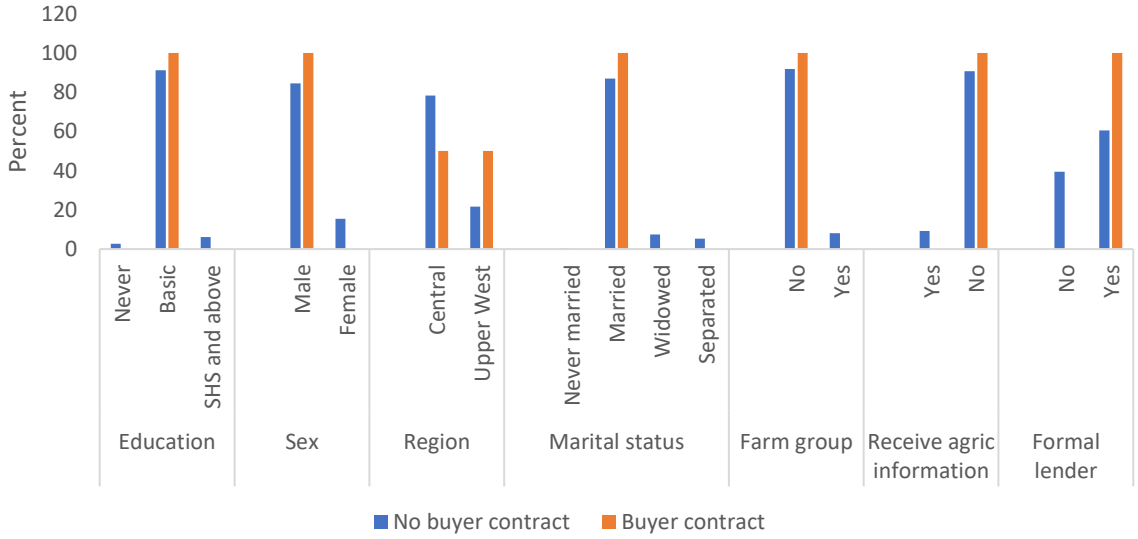


Figure 2.2: Distribution of whether the Farmer had a Contract with a Buyer

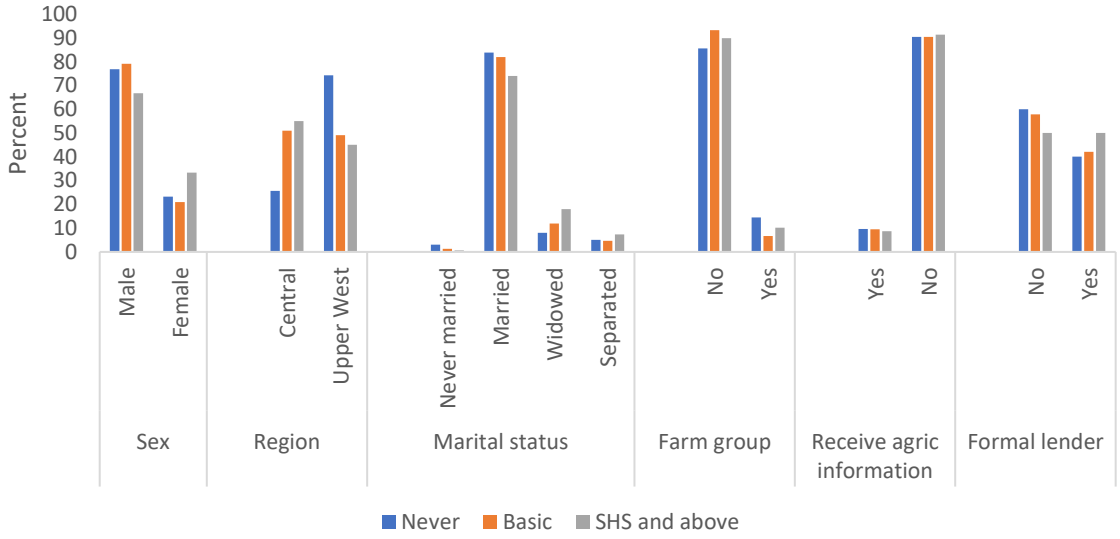


Figure 2.3: Distribution of Education across Key Variables

2.5 Results and Dissemination

2.5.1 Impact of Agricultural Contracts on CSA Adoption Intensity

Table 2.3 presents the impact of agricultural contracts on the adoption intensity of CSA practices. The results show that farm households that had a pre-planting contract commitment

adopted CSA intensity more than farm households that did not have a pre-planting contract commitment. For the Generalized Poisson and Negative Binomial, farmers who had pre-planting contracts are 9.2% more likely to adopt more CSA practices than their counterparts who did not have pre-planting contract commitments, and it is significant at 5% (p-value=0.035). For the Standard Poisson, farmers who had pre-planting contracts are 12.8% more likely to adopt more CSA practices than their counterparts who did not have pre-planting contract commitments, and it is significant at 1% (p-value=0.005). Furthermore, farm households that had buyer contracts were 25.1% more likely to adopt CSA practices intensity than those that did not and it is significant at 10% (p-value=0.076).

Agricultural contracts provide farm households with a guaranteed market for their produce, ensuring a stable and predictable income. This stability incentivises farmers to invest in more CSA practices. With assured income, farm households may have more financial resources to invest in CSA infrastructure and techniques, such as improved irrigation systems, organic fertilizers, or protective structures. It is noteworthy that agricultural contracts often involve long-term relationships and mutual trust between farmers and buyers. Such relationships foster collaboration and knowledge sharing, making it easier to implement CSA

Table 2.3: Agricultural Contract on CSA Adoption Intensity

	Pre-planting Contract Commitment			Buyer Contract		
CSA Adoption Intensity	Generalized Poisson	Standard Poisson	Negative Binomial	Generalized Poisson	Standard Poisson	Negative Binomial
Pre-planting Contract Commitment						
Commit	0.092**	0.128***	0.092**			
	(0.044)	(0.045)	(0.044)			
	0.035	0.005	0.035			
Buyer contract				0.251*	0.251*	0.251*
				(0.141)	(0.141)	(0.141)
				0.075	0.075	0.075
Age	0.018*	0.012	0.018*	0.040***	0.040***	0.040***
	(0.009)	(0.010)	(0.009)	(0.015)	(0.015)	(0.015)
	0.056	0.201	0.056	0.008	0.008	0.008
age2	-0.016*	-0.012	-0.016*	-0.036**	-0.036**	-0.036**
	(0.009)	(0.009)	(0.009)	(0.015)	(0.015)	(0.015)
	0.066	0.195	0.066	0.017	0.017	0.017
Female	-0.053	-0.043	-0.053	-0.086	-0.086	-0.086
	(0.085)	(0.087)	(0.085)	(0.123)	(0.123)	(0.123)
	0.534	0.619	0.534	0.483	0.483	0.483
Farm size	0.013***	0.014***	0.013***	0.014	0.014	0.014
	(0.005)	(0.005)	(0.005)	(0.014)	(0.014)	(0.014)
	0.008	0.006	0.008	0.328	0.328	0.328
Farm group	0.169**	0.148*	0.169**	-0.118	-0.118	-0.118

	(0.081)	(0.081)	(0.081)	(0.147)	(0.147)	(0.147)
	0.036	0.067	0.036	0.420	0.420	0.420
Marital status (never married)						
Married	-0.324**	-0.184	-0.324**	0.264***	0.264**	0.264**
	(0.134)	(0.150)	(0.134)	(0.134)	(0.134)	(0.134)
	0.016	0.218	0.016	0.048	0.048	0.048
Widowed	-0.226*	-0.113	-0.226*	0.226	0.226	0.226
	(0.132)	(0.152)	(0.132)	(0.206)	(0.206)	(0.206)
	0.087	0.457	0.087	0.271	0.271	0.271
Separated	-0.436***	-0.315*	-0.436***	-0.117	-0.117	-0.117
	(0.167)	(0.181)	(0.167)	(0.336)	(0.336)	(0.336)
	0.009	0.082	0.009	0.727	0.727	0.727
Market distance	-0.002	-0.002	-0.002	0.009	0.009	0.009
	(0.023)	(0.023)	(0.023)	(0.039)	(0.039)	(0.039)
	0.919	0.915	0.919	0.827	0.827	0.827
Farm distance	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
	0.954	0.780	0.954	0.920	0.920	0.920
Formal lender	0.077*	0.095*	0.077*	0.077	0.077	0.077
	(0.046)	(0.050)	(0.046)	(0.098)	(0.098)	(0.098)
	0.096	0.058	0.096	0.436	0.436	0.436
Education (no education)						
Basic	-0.109	-0.134	-0.109	0.165	0.165	0.165
	(0.115)	(0.115)	(0.115)	(0.120)	(0.120)	(0.120)
	0.341	0.245	0.341	0.170	0.170	0.170
SHS and above	-0.275*	-0.302**	-0.275*	-0.166	-0.166	-0.166
	(0.158)	(0.151)	(0.158)	(0.249)	(0.249)	(0.249)
	0.083	0.046	0.083	0.504	0.504	0.504
Receive agric information	0.081*	0.131***	0.081*	0.109	0.109	0.109
	(0.046)	(0.051)	(0.046)	(0.112)	(0.112)	(0.112)
	0.074	0.010	0.074	0.331	0.331	0.331
Hired labour	0.100**	0.098**	0.100**	0.167*	0.167*	0.167*
	(0.042)	(0.044)	(0.042)	(0.091)	(0.091)	(0.091)
	0.016	0.027	0.016	0.066	0.066	0.066
Mm	-0.064	-0.063	-0.064	-0.074	-0.074	-0.074
	(0.049)	(0.052)	(0.049)	(0.090)	(0.090)	(0.090)
	0.194	0.230	0.194	0.415	0.415	0.415
Informal lender	-0.040	-0.048	-0.040	0.027	0.027	0.027
	(0.043)	(0.047)	(0.043)	(0.096)	(0.096)	(0.096)
	0.358	0.306	0.358	0.779	0.779	0.779
Upper West	3.011**	0.007	3.011**	0.103	0.119	0.103
	(1.260)	(0.197)	(1.260)	(0.168)	(0.166)	(0.168)

Table 2.3: Agricultural Contract on CSA Adoption Intensity con't

	0.017	0.973	0.017	0.542	0.471	0.542
_cons	1.010***	0.959***	1.010***	-0.427	-0.427	-0.427
	(0.290)	(0.307)	(0.290)	(0.374)	(0.374)	(0.374)
	0.000	0.002	0.000	0.254	0.254	0.254
/lnalpha			-32.600			-34.200
			0.000			0.000
Statistics						
N	503	503	503	230	230	230
r2_pseudo						
chi2	49.900	53.900	49.900	.	.	.
Ll	-922.800	-938.200	-922.800	-195.800	-195.800	-195.800
Aic	1883.600	1914.400	1883.600	425.600	425.600	425.600
Bic	1963.700	1994.600	1963.700	471.400	471.400	471.400

Standard errors in brackets *** p <1%, ** p < 5% * p < 10%

practices, which often require close cooperation and coordination. If farmers within a community observe their peers benefiting from agricultural contracts and adopting CSA, they may be more inclined to follow suit, driven by social norms and aspirations for improved livelihoods. Agricultural contracts typically connect farmers to established markets or distribution networks. This enhanced market access allows farmers to sell their CSA products more easily, encouraging them to adopt CSA practices. Government policies promoting sustainable agriculture, local food production, or CC adaptation may provide incentives or subsidies for CSA adoption. If the agricultural contracts align with such policies, farmers with commitments are more likely to engage in CSA to meet these requirements and access support. Ghanaian culture often emphasizes community solidarity and collective decision-making. CSA, with its emphasis on community involvement and shared risks and benefits, aligns well with these cultural values, making it more attractive to farmers with pre-planting contracts. These findings corroborate those of Azumah *et al*. (2017) and Wu and Li (2023) that contract farming influences innovative technology and innovative seed adoption.

Moreover, it observed that age, farm size, farm-based organizations, region-specific characteristics, formal lender, and marital statuses somehow significantly influence CSA adoption intensity among rural farmers in Ghana. Some of these variables decrease the adoption intensity of CCSA practices, such as marital status, while others, such as the hiring of agricultural labor, farm size, and farm-based organization, among others, increase the adoption intensity of CSA practices. These findings confirm that of Blasch, *et al*. (2022); Di Falco *et al*. (2020); Koudjom; (2022); Mume, *et al*. (2023); Ngaiwi, *et al*. (2023) that several factors significantly influenced the adoption of conservation agriculture practices, including

age, family size, extension services, use of modern farm technology, distance from the house to the farm, ownership of livestock, and soil fertility. Conversely, gender is not a key driver of the intensity of CSA practice adoption.

2.5.2 Impact of Land Tenure System on Climate-Smart Agriculture Adoption Intensity

Table 2.4 presents the impact of a land tenure system on the adoption intensity of CSA practices. Compared with farmers who engage in sharecropping, farmers who have access to land at zero cost adopt more CSA practices, and it is significant at one percent for all the techniques employed. For instance, farmers who have access to land at zero cost are 12.7% more likely to adopt more CSA practices than those who share crops under the generalized Poisson, and it is significant at 1% (p-value=0.006). This is similar to the standard Poisson (14%) and the negative binomial (12.7%). This means that land tenure arrangement is important in the adoption of CSA practices. Farmers who acquire land at zero cost are farmers who mostly own their farmlands. These farmers are willing to adopt sustainable farming practices to protect their lands. They might want to protect their farms from the impact of CC to ensure long-term productivity. This instills a sense of stewardship and responsibility for the benefit of the current and future generations. Conversely, shared cropping farmers might face

Table 2.4: Land tenure system and CSA adoption intensity

	Land Tenure System		
CSA Adoption	Generalized Poisson	Standard Poisson	Negative Binomial
Tenure (Shared cropped)			
Rented	0.088	0.131	0.088
	(0.073)	(0.076)	(0.073)
Landowner	0.127***	0.140***	0.127***
	(0.047)	(0.052)	(0.047)
Age	0.021**	0.016*	0.021**
	(0.009)	(0.009)	(0.009)
age2	-0.019**	-0.016*	-0.019**
	(0.008)	(0.009)	(0.008)
Female	-0.077	-0.074	-0.077
	(0.080)	(0.080)	(0.080)
Farm size	0.012**	0.013**	0.012**
	(0.005)	(0.005)	(0.005)
Farmgroup	-0.139*	-0.111	-0.139*
	(0.078)	(0.079)	(0.078)
Marital (never married)			
Married	-0.298**	-0.165	-0.298**
	(0.131)	(0.143)	(0.131)
Widowed	-0.185	-0.0673	-0.185
	(0.131)	(0.146)	(0.131)

Table 2.4: Land tenure system and CSA adoption intensity continued

Separated	-0.403**	-0.284	-0.403**
	(0.164)	(0.175)	(0.164)
Market distance	-0.008	-0.008	-0.008
	(0.022)	(0.022)	(0.022)
Farm distance	-5.80E-05	3.10E-05	-5.80E-05
	(5.30E-04)	(5.50E-04)	(5.30E-04)
formal lender	0.101**	0.119**	0.101**
	(0.046)	(0.050)	(0.046)
Education (no education)			
Basic	-0.112	-0.136	-0.112
	(0.118)	(0.118)	(0.118)
SHS and above	-0.253	-0.281*	-0.253
	(0.157)	(0.151)	(0.157)
Received Agric info	0.101**	0.153***	0.101**
	(0.044)	(0.049)	(0.044)
Hired labour	0.105***	0.103**	0.105***
	(0.040)	(0.043)	(0.040)
MM	-0.0749	-0.0737	-0.0749
	(0.048)	(0.051)	(0.048)
Informal lend	-0.053	-0.063	-0.053
	(0.043)	(0.046)	(0.043)
Upper West	3.011**	0.007	3.011**
	(1.260)	(0.197)	(1.260)
_cons	0.828***	0.76**	0.828***
	(0.292)	(0.307)	(0.292)
/lnalpha			-32.7
Statistics			
N	529	529	529
r2_pseudo			
chi2	51.1	51	51.1
Ll	-967.4	-983.2	-967.4
Aic	1974.7	2006.5	1974.7
Bic	2060.1	2091.9	2060.1

Standard errors in brackets *** p <1%, ** p < 5% * p < 10

restrictions from owners and might prioritize short-term gains over long-term sustainability. Also, because they do not pay for the land, they can use the money that would have been used to buy the land to buy improved seed varieties, practice irrigation, and other CSA practices. Sharecropping farmers, on the other hand, might hesitate to invest in sustainable practices as they might not reap the full benefits due to their uncertain land tenure.

It is also observed that farmers who rent land for farming activities are likely to adopt more than farmers who engage in sharecropping, even though it is not significant. This means that many farmers who rent land for agricultural activities are willing to adopt CSA practices but are not large enough. This is because such farmers might leave the land at any moment and

might adopt temporary practices. They do not have a strong incentive to adopt more CSA practices. Such farmers might adopt just improved seed varieties that could give short-term higher yields.

Unsurprisingly, other control variables such as access to formal lenders, receiving agricultural information, and hiring of farm laborers influence the adoption intensity of CSA practices. Farmers who are in these categories can adopt more CSA practices than their counterparts who are not. For instance, farmers who receive agricultural and climatic information might be aware of the impact of CSA practices and might want to adopt more practices. Also, farmers who have access to formal lenders can afford to purchase improved seed varieties and practice irrigation and other sustainable practices. Furthermore, farmers might hire labor to help in planting, land preparation, and harvesting. These farmers might be financially capable of adopting sustainable practices that require a high initial investment.

2.5.3 Impact of Input Supply System on CSA Adoption Intensity

Table 2.5 presents the impact of input supply systems on CSA adoption intensity. It is observed that farm households that were able to pay agricultural credit after harvest were more likely to adopt more CSA practices than their counterpart who had to pay for agriculture credit before harvest. That is, from the Generalised Poisson regression, farmers who paid for input supplied after harvest were 97.8% more likely to adopt more CSA practices than farmers who paid before harvest, and it is significant at 10% (p-value=0.077). However, for the Standard and Negative Binomial regressions, farm households who paid input supplied after harvest were 18.1% more likely to adopt CSA practices, and it is significant at 1% (p-value=0.005). These are likely to happen because farm households that can pay agricultural credit after harvest have improved cash flow. They can use the income from their harvest to repay their credit, which reduces the financial burden and increases their ability to invest in CSA practices. By paying credit after the harvest, farmers have a better understanding of their actual income and profitability. This allows them to assess the financial feasibility of adopting CSA practices and allocate their resources accordingly. Paying agricultural credit after the harvest demonstrates a level of trust between farmers and lenders. This trust can lead to stronger relationships, where lenders are more willing to provide additional support, such as training, technical assistance, or access to CSA networks, to the farmers.

It is also observed from Table 2.5 that when agricultural inputs are supplied in smaller quantities, it increases the likelihood of adopting more CSA practices than when supplied in larger quantities. For the Negative Binomial, it is observed that supplying quantities in smaller

quantities increases CSA practices adoption intensity by more than 180% than supplying in larger quantities, and it is significant at 1% (p-value=0.000). However, for the Generalised and Standard regressions, supplying quantities in smaller quantities increases CSA practices adoption intensity by 17.6%, and it is significant at a 1% level (p-value=0.028).

Smaller quantities of agricultural inputs are often associated with lower costs and lower financial burdens for farmers. CSA practices sometimes involve low-cost or no-cost strategies, such as agroecological approaches, natural pest control, or rainwater harvesting. When inputs are scarce, farmers are motivated to explore these cost-effective practices, leading to increased adoption. CSA practices emphasize resource efficiency and conservation. When agricultural inputs are supplied in smaller quantities, farmers are compelled to use them more judiciously and efficiently. Limited resources encourage farmers to explore innovative techniques like precision agriculture, drip irrigation, or integrated pest management, which optimize input use while minimizing environmental impacts. Also, CSA practices require tailoring to local environmental conditions and farming systems. When agricultural inputs are supplied in smaller quantities, farmers are encouraged to adopt practices according to their specific context. This localization allows for the integration of traditional knowledge, local crops, and

Table 2.5: Impact of Input Supply on CSA Adoption Intensity

	Credit Payment Preference			Input Supply Preference		
CSA Adoption	Generalized Poisson	Standard Poisson	Negative Binomial	Generalized Poisson	Standard Poisson	Negative Binomial
Payment Preference						
After harvest	0.978*	0.181***	0.181***			
	(0.554)	(0.064)	(0.064)			
	0.077	0.005	0.005			
Input Supply						
Small				0.721***	0.176**	1.800***
				0.207	0.080	0.480
				0.001	0.028	0.000
Age	0.030	0.009	0.009	0.044	0.017	0.425***
	(0.107)	(0.041)	(0.041)	(0.344)	(0.082)	(0.001)
age2	0.040	-0.016*	-0.016*	-0.043	-0.032*	-1.580***
	(0.028)	(0.009)	(0.009)	(0.044)	(0.017)	(0.430)
	0.154	0.058	0.058	0.325	0.052	0.000
Female	0.226	-0.032	-0.032	0.052	-0.033	-4.490**
	(0.369)	(0.083)	(0.083)	(0.425)	(0.160)	(2.030)
	0.540	0.699	0.699	0.903	0.838	0.027
farm size	0.071***	0.011**	0.011**	0.105***	0.041***	-0.015
	(0.017)	(0.005)	(0.005)	(0.023)	(0.011)	(0.113)
	0.000	0.025	0.025	0.000	0.000	0.891
Farm group	0.432	-0.163**	-0.163**	0.406	0.042	21.70***
	(0.428)	(0.080)	(0.080)	(0.440)	(0.142)	(2.280)

Table 2.5: Impact of Input Supply on CSA Adoption Intensity continued

	0.312	0.042	0.042	0.356	0.770	0.000
Marital (never married)						
Married	-0.799*	-0.304**	-0.304**	-1.170**	-0.264	67.80***
	(0.469)	(0.132)	(0.132)	(0.502)	(0.197)	(5.080)
	0.088	0.021	0.021	0.020	0.180	0.000
Widowed	-0.265	-0.221*	-0.221*	-0.703	-0.226	6.130
	(0.533)	(0.133)	(0.133)	(0.483)	(0.212)	(4.620)
	0.620	0.096	0.096	0.146	0.287	0.185
Separated	-1.710***	-0.409**	-0.409**	-1.950***	-0.384*	16.50***
	(0.665)	(0.167)	(0.167)	(0.634)	(0.228)	(6.140)
	0.010	0.015	0.015	0.002	0.091	0.007
Market distance	0.261**	-0.004	-0.004	0.094	0.009	-0.670
	(0.106)	(0.023)	(0.023)	(0.108)	(0.043)	(0.895)
	0.014	0.854	0.854	0.382	0.841	0.454
Farm distance	-0.006*	0.000	0.000	-0.009**	-0.001	-0.187***
	(0.003)	(0.001)	(0.001)	(0.004)	(0.001)	(0.014)
	0.055	0.920	0.920	0.012	0.305	0.000
Informal lender	0.628***	-0.054	-0.054	1.250***	0.161*	3.690***
	(0.244)	(0.042)	(0.042)	(0.296)	(0.088)	(1.360)
	0.010	0.193	0.193	0.000	0.068	0.007
formal lender	-0.522**	0.110**	0.110**	-0.334	-0.143	-16.60***
	(0.262)	(0.048)	(0.048)	(0.232)	(0.087)	(3.490)
	0.046	0.023	0.023	0.151	0.101	0.000
Mm	0.598*	-0.070	-0.070	-0.242	-0.076	4.550*
	(0.323)	(0.049)	(0.049)	(0.305)	(0.085)	(2.410)
	0.064	0.152	0.152	0.428	0.374	0.059
Education (no education)						
Basic	-1.090**	-0.036	-0.036	-0.814*	-0.111	12.80***
	(0.517)	(0.089)	(0.089)	(0.474)	(0.182)	(4.850)
	0.035	0.685	0.685	0.086	0.543	0.008
SHS and above	-1.540**	-0.153	-0.153	-2.020***	-0.453*	-12.200
	(0.661)	(0.137)	(0.137)	(0.656)	(0.239)	(8.300)
	0.020	0.263	0.263	0.002	0.058	0.140
Receive agric info	5.980***	0.091**	0.091**	5.880***	-0.315***	-24.40***
	(0.270)	(0.045)	(0.045)	(0.330)	(0.097)	(3.070)
	0.000	0.040	0.040	0.000	0.001	0.000
Hired labour	0.129	0.049	0.346	0.129	0.049	0.346
	(0.216)	(0.069)	(1.730)	(0.216)	(0.069)	(1.730)
	0.552	0.476	0.841	0.552	0.476	0.841
Upper West	0.007	0.036	0.036**	3.011	0.007**	3.011
	(0.197)	(0.049)	(1.260)	(0.197)	(1.260)	(0.197)
	0.973	0.468	0.017	0.973	0.017	0.973

_cons	-151.00**	1.120***	1.120***	-152.00***	-3.740***	-94.90***
	(1.200)	(0.279)	(0.279)	(1.460)	(0.506)	(3.620)
	0.000	0.000	0.000	0.000	0.000	0.000
/lnalpha			4.590			4.590
			0.027			0.027
			0.000			0.000
Statistics						
N	519	519	519	397	397	397
r2_pseudo						
chi2	1902.300	47.000	47.000	1713.700	46.800	17858.10
Ll	-56522.500	-969.700	-969.700	-43937.400	-1087.400	-2593.60
Aic	113081.000	1977.400	1977.400	87912.800	2212.900	5227.300
Bic	113157.900	2058.600	2058.600	87988.500	2288.600	5306.900

Standard errors in brackets *** p <1%, ** p < 5% * p < 10%

agroecological principles, resulting in more effective CSA solutions. Smaller quantities of agricultural inputs may necessitate farmers to seek additional knowledge and skills to optimize their resource use. This drives them to engage in capacity-building initiatives, training programs, or knowledge-sharing networks focused on CSA. As a result, farmers become more aware of sustainable practices and are more likely to adopt them. These findings corroborate the findings of Yitayew *et al*. (2022) that farmers adopt CSA practices when they can experiment in smaller quantities.

2.6 Conclusions and Policy Implications

The CC uncertainty associated with the negative externalities requires mitigation and adaptation strategies that boost agricultural productivity growth as well. One such strategy is the utilization of modern inputs and CSA practices. However, the adoption rate of CSA is low in SSA countries such as Ghana. The main research question of the study was: how can agricultural input supply systems and contracts nudge CSA adoption intensity among rural farmers in Ghana? This study evaluated the impact of agricultural input supply and agricultural contracts to drive the adoption intensity of CSA practices among rural farmers in Ghana.

The study found that farm households who were committed to pre-planting contracts had a higher adoption intensity of CSA practices than farm households who did not commit to pre-planting contracts. Also, farm households that had a buyer contract adopted more CSA practices than those who did not have a buyer contract. Furthermore, the study found that farmers who paid for CSA input supplied after the harvest had higher adoption intensity than farm households who paid for CSA input supplied before harvest. Finally, farm households that preferred small CSA inputs supply to large CSA inputs supply adopted more CSA practices than their counterparts. Therefore, the study concludes that agricultural input supply and

agricultural contracts significantly increase the adoption intensity of CSA practices among rural farm households in Ghana. It is important to combine supportive policies and interventions to create an enabling environment for agricultural input supply in smaller quantities, create access to pre-planting contracts and buyer contracts, and enable payments after harvest.

The study recommends that the Local Agriculture Directorates (LDAs) should facilitate contract farming arrangements between farmers and buyers. The contracts should specify the terms of payment, especially payment after harvest, by ensuring that farmers have ready markets for their climate-smart produce and receive payment once their products are sold. Furthermore, MoFA should develop the value chains and market linkages between farmers and buyers. This can be done by building systems that enable farmers to connect with buyers who are willing to pay for climate-smart products. The GoG should also establish input credit schemes that allow farmers to access agricultural inputs without upfront payment. Under this scheme, inputs will be provided to farmers with a deferred payment arrangement until farmers have generated adequate revenue from the sales of CSA produce. Again, the LADs should foster partnerships between agricultural input suppliers and farmers to develop favourable payment arrangements that align with the various harvest cycles. This should involve negotiating agreements where input suppliers receive payment from farmers after the sale of their CSA products. This approach could ensure that farmers have access to inputs while delaying payment until they have generated income from their produce. Finally, LADs should encourage collaborations between public and private entities interested in CSA by developing innovative financing models for input delivery. Such collaborations could involve agricultural financial institutions, input suppliers, and government agencies working together to design payment schemes that are tailored to the needs of farmers and promote CSA adoption.

One major limitation of our study is the lack of longitudinal data. Our data does not permit longitudinal analyses. We are not able to account for changes that might happen over time and are not able to explore dynamic processes over time. Cross-sectional biases are not accounted for in point-in-time surveys. We are not able to capture trends in variables that are key for understanding comprehensively. This limitation, however, has less impact on the outcome and robustness of the study since several studies. Future studies can use nationally representative survey data over time to account for cross-sectional biases.

ESSAY THREE

CLIMATE-SMART AGRICULTURE ADOPTION AND RURAL FARM HOUSEHOLDS' TIME POVERTY IN GHANA

3.1 Introduction

Recognizing the importance of the externalities associated with CSA is essential to correctly estimating the welfare benefits, such as time poverty of its adoption and investments (Karanja Ng'ang'a *et al*., 2021). Knowing the value of the externalities is essential for two main reasons. The first benefit is that it assists farmers in determining whether intervention is justified by comparing the social benefit to a specific threshold. The second advantage is that if the threshold is surpassed, understanding how externalities are generated helps farmers in selecting and prioritizing policies with the greatest social benefits from a range of options available to them. Externalities are prevalent, particularly in the agricultural sector. Numerous CSA practices and agricultural technologies provide positive externalities, which can lead to adoption rates lower than socially optimal when individuals fail to recognize the overall social benefit of adopting these technologies. This could be one of the reasons behind the continued low adoption rates of CSA practices observed in many lower-income countries, as indicated by various studies (Pigou, 1920; Ajayi *et al*., 2022; Yitayew *et al*., 2022). In low-income countries, farmers' suboptimal adoption of CSA practices is partly due to farmers' limited realization of the positive externalities that come with the adoption.

Choices are influenced not only by budgetary limits and preferences but also by informational constraints (Bhattacharya *et al*., 2021). Whether the individual knows they will be affected by CC and whether the people with whom they encounter are themselves aware. The rational choice theory assumes that preferences are defined over outcomes, that those outcomes are known and fixed, and that decision-makers maximize their utilities by choosing the alternative that yields the highest level of benefits discounted by costs (Brush, 2019; Houser and Stuart, 2020). In the context of economics, rational choice theory is often used to explain how individuals make decisions about time consumption, investment, and savings. For example, an individual may choose to invest in a particular CSA practice if they believe that the potential returns outweigh the risks and transaction costs associated with the investment. Similarly, a consumer may choose to purchase a particular product if they believe that the utility, convenience, etc, outweigh the cost. This means that for rural farm households to choose CSA practices, these practices should maximize farmers' net benefits (in this study, time poverty).

Labor surplus theories, such as structural unemployment theory, suggest that changes in the economy, such as technological advances or shifts in consumer demand, can lead to job losses and a surplus of labor supply. These changes can also have broader social and economic impacts, such as increasing time poverty for those who have lost their jobs or who are unable to find work (Kim *et al*., 2024). The increase in time poverty in the era of technological advancement presents puzzles in standard economic models. For example, technological advances that automate certain types of work may lead to job losses and increased competition for remaining jobs. This can lead to a situation where workers are forced to accept low-paying jobs with long hours to make ends meet, resulting in time poverty. Similarly, shifts in consumer demand toward industries that require longer hours, such as the service sector, may also contribute to time poverty (Williams *et al*., 2016). The Lewis (1954) model is a surplus labor model, which assumes the coexistence of the backward agricultural sector and the advanced industrial sector. The rural agricultural sector is assumed heavily overpopulated, implying land shortage that leads to the existence of surplus labor, reducing the marginal productivity of labor to zero.

According to Singh *et al.* (1986), rural household model assumes a rural farm household to be making both production and consumption decisions simultaneously and is active in the labor market as well. The same situation applies in the study area where some households are simultaneously engaged in both agricultural production and off-farm employment (Nyamwanza, 2014), increasing their time poverty. According to Singh *et al*. (1986) farm household model, the rural farm household maximizes the household's utility function over agricultural staple food, a market-purchased good, and leisure. The household utility function is maximized subject to production, time, budget, and non-negativity constraints. The model considers the fact that farm profit may not be the only source of income for the farmer; labor markets do exist so that hiring in and out of labor is possible. The solution for the household utility maximization problem shows that the household will only participate in off-farm employment if there is enough time to do so. Unlike Singh *et al.* (1986)'s rural household model, the drudgery aversion theory by Chayanov (1966) assumes that the labor market does not exist in rural areas for farm households such that they entirely rely on family labor. This leads to the time spent working on the field to enter the households' utility function as an argument separate from that of income. The utility maximization here involves a trade-off between higher income from the farm work and more time spent on activities other than farm work (off-farm and leisure hours).

Broader planning against the agricultural calendar is a crucial step in farm households' decision to seek off-farm employment or hire workers for family members. Agricultural activities are seasonal, and demand for and supply of farm labor for production and harvest ebb and flow depending on the time of the year and the skills of the workers. In many contexts, there is a reduction in demand for farm labor after planting, often called a lean season, where farm households have less disposable income. Therefore, there is a need to generate economic opportunities or activities for farm households outside of agriculture in their local market or nearby urban centers. Several adaptation strategies are available, promoted, and adopted by farmers to build resilience, including livelihood diversification and the eradication of time poverty. The recent objective of livelihood diversification and time poverty has been to respond to CC and variability. It is estimated that Ghana's agriculture is predominantly rural-based (76.6%) (GSS, 2020), and poverty and inequality continue to be higher among the rural areas that host these farmers. For instance, the contribution to national income by the rural areas is 23.4% (GSS, 2019). The implication is that any variation or change in the agricultural environment would worsen rural livelihoods, economic status, and developmental paths of the rural areas and the country as a whole. It is suggested that off-farm employment activities improve rural households' incomes and food security (Mishra and Rahman, 2018) in the context of CC. Therefore, rural farmers in Ghana might need to increase their involvement in livelihood diversification and off-farm activities, including full-time and part-time wage employment, which can affect their time poverty.

Ghana witnessed a reduction in consumption poverty from 2012 to 2017, while time poverty increased in the same period (GSS, 2018). The data further shows that in rural settings, women tend to be more time-poor than men, which influences the extent to which they participate in the labor market and home production. Women's time allocation is directly linked to the entire household's well-being, such as child welfare, domestic care, fetching of water, collection of firewood, and cooking (UNECA, 2021). An increase in time poverty presents conundrums for standard economic models. Risk-averse farmers must benefit from the adoption of CSA practices, even as a pure adaptation strategy against CC risks. Beyond adaptation strategies, evidence indicates that CSA practices mitigate CC and increase yields. However, the directional impact of CSA on time poverty among rural farmers remains unresolved and must be of much interest to economists and policymakers. The factors influencing the choice to participate are not altogether known.

Many agricultural practices are being labeled as 'climate-smart' without due diligence being given to the importance of location-specific scientific evidence (FAO, 2017). This can

create confusion, as many of these practices are likely to be climate-smart in certain places, but none of them are likely to be climate-smart elsewhere. An additional challenge comes from the timescale to achieve SDG Indicator 5.4.1 on the proportion of time used by sex, location, and work. Under the dynamic effects of CC, practices that may be climate-smart today might not be by 2040. The scale at which interventions are implemented also matters. Policies need to take these dimensions into account before promoting interventions for rural farm households' resilience. Given that CSA is an approach to policy making rather than a fixed set of practices, analyses on different dimensions, such as time poverty among rural farmers, will shed light on areas of uncertainty and confusion to support sound policies that can create resilient food systems in Ghana. This study adds to the literature on the impacts of CSA practices by providing evidence from rural Ghana. This study, therefore, goes beyond affirming the CSA's role and interrogates the CSA's potential for enhancing adaptation to both non-agricultural and agricultural activities and building the resilience of rural farmers in Ghana.

The main objective of this essay is to estimate the impact of CSA practices on rural farm households' time poverty in Ghana. Earlier micro-impact assessments of adaptation strategies mainly focus on traditional outcomes such as farm productivity, household income, consumption expenditure, and food security (Adego *et al*., 2019; Dhakal *et al*., 2022; Etwire *et al*., 2022; Martey *et al*., 2022c; Martey *et al*., 2019; Sedebo *et al*., 2022), risk exposure (Dhakal *et al*. 2022; Di Falco *et al*., 2011; Huang *et al*., 2015), while others focus on assets (Etwire *et al*., 2022). Martey *et al*. (2022a) consider off-farm work on time poverty, while Martey *et al*. (2022b) consider parental time poverty on child work and schooling. Kim *et al*. (2024) analyzed time poverty and travel behavior. Yet, micro-evidence on the impacts of CSA practices on time poverty and rural farm household resilience and livelihood diversification is barely addressed and discussed. There is relatively limited information and inadequate documentation of the effects of how climatic variables and CSA practices impact time poverty and rural farm-household resilience. Also, there is an issue of generalization of their findings since CSA practices change and each geographic area has unique climate characteristics as it relates to variables such as temperature and rainfall. The lack of empirical studies on the relationship between time poverty and CSA practices limits the formulation of effective policies to address time poverty. With the changing climate, the need for sustainable and all-inclusive development is most appropriate and cannot be overemphasized.

The organization of this essay is as follows. The next section is on the background and implications of CSA practices. After this section, the essay focuses on theoretical and empirical reviews. The fourth section presents the methodology, endogenous switching regression

model, and data sources. The fifth section presents the interpretations and discussions of the results of the essay. The final section focuses on the conclusion and policy implications of the essay.

3.2 Background and Implications of Climate-Smart Agriculture Practices

Martey *et al*. (2022) showed that, apart from the Upper West Region, time poverty increased between 2013 and 2017 for all households in Ghana and had a directional relationship with consumption poverty. While time poverty in the Upper East increased from 0.25 to 0.31, that of the Upper West decreased from 0.34 to 0.28. Northern Region had time poverty increased from 0.29 to 0.34, Brong Ahafo Region had time poverty increased from 0.33 to 0.39, and Ashanti Region had time poverty increased from 0.32 to 0.47. In the same perspective, the Central Region had a time poverty increase from 0.22 to 0.28, Greater Accra had a time poverty increase from 0.41 to 0.47, the Western Region from 0.22 to 0.25, the Volta Region from 0.25 to 0.38, and the Eastern Region from 0.25 to 0.29. From their estimates, the mean time poverty in 2016/2017 (0.347) was higher than the mean time poverty in 2012/2013 (0.302) for committed times greater than 1.25 times the median. Similarly, the mean time poverty in 2016/2017 (0.221) was higher than the mean time poverty in 2012/2013 (0.167) for committed times greater than 1.5 times the median. However, time poverty based on committed time greater than 10.5 hours in 2016/2017 (0.030hrs) was lower than in 2012/2013 (0.572hrs).

The contributions of CSA interventions to increased productivity and incomes can be measured using various indicators (e.g., crop yields, agricultural income, total income, food consumption, and food deficit). Most of these indicators can document the different dimensions of food security: availability, access, stability, and utilization (FAO, 2008). Most of these are at the household or production unit level (e.g., food consumption expenditure per capita, crop production per hectare, milk production per cow). Most indicators are also project-based (e.g., project participants have achieved a 50% increase in maize production per hectare) and are used in project monitoring and evaluation (FAO, 2017). However, to assess the potential impact of these practices on agricultural productivity and incomes at the national level, they should ideally be combined with larger-scale socioeconomic analyses, which can incorporate current and potential management conditions. High-resolution data on climate variables are increasingly integrated into socio-economic studies to assess a large set of field- and farm-level practices controlling for critical weather variables and agro-climatic shocks (Di Falco *et al*., 2011; FAO, 2016, Asfaw *et al*., 2016). It is important to ensure that there is enough cross-

sectional diversity in the data used in these studies to cover areas with different exposure and vulnerability to risks and adaptive capacities (FAO, 2017).

Some analyzes conducted by the Rice Research and Development Institute indicate that farmers cut back total irrigation requirements for rice cultivation per season by 10-20% by adopting new water management practices. This allows water storage for the next cropping season. Farmers initiate land preparation early (at the start of the rainy season), instead of waiting for water reservoirs to fill and irrigation water to be released from the reservoir. Farmers can expand land under irrigation by 15% during the dry season. This expansion was made possible by the training received by farmers in the alternate wetting and drying techniques, which allows them to save water during the main growing season. The community experienced the highest water capacity ever recorded at the end of the dry season. The combination of practices such as early planting, the use of rainwater (instead of irrigation water), and the alternate wetting and drying technique permit this change. By using soil testing kits and leaf color charts and by applying fertilizer to parachute trays, farmers can apply fertilizer more precisely, thus reducing the amount of fertilizer used by 27% (FAO 2020). Thus, CSA practices reduce the time allocated to fertilizer use by 27%.

Ng (2023) asserted that in a society where higher qualifications and skill development are emphasized for career advancement, working non-standard and uncontrollable hours poses challenges for low-wage young individuals to attend training courses that are typically designed for standard working hours. Consequently, the study found that lower-wage respondents were less likely to participate in training programs. Regarding parenting responsibilities, working shifts and weekends limits the time that individuals can spend with their children, especially when the children are not in school during the individual's working hours. The inability to control work hours also complicates childcare arrangements, such as drop-off and pick-up timings at care centers.

3.3 Theoretical and Empirical Literature Reviews

This section presents the theoretical framework, empirical literature reviews, and syntheses related to this essay. The theoretical framework focuses on the agricultural household model, which regards the household that is jointly engaged in production, consumption, and labor supply; random utility theory, which assumes that a decision-maker faces a choice among n alternatives and that he/she would obtain a certain level of utility (or profit) from each alternative. The empirical review focuses on CSA adoption and time poverty. Most empirical

studies on off-farm employment used labor surplus theories as the basis of their studies. These theories are labor migration theories, which explain the individuals' decisions to move from the agricultural sector to the industrial (off-farm) sector but not participate in both sectors. Models that consider the rural farm households' decision to allocate labor between farm and off-farm labor would be more appropriate for the studies that deal with off-farm labor allocation decisions.

3.3.1 Theoretical Reviews

The Agricultural Household Model (AHM) regards the household that is jointly engaged in production, consumption, and labor supply (Singh *et al*. 1986). A farm household is assumed to maximize the household's utility over consumption goods and leisure subject to time, budget, production function, and non-negativity constraints. The main feature of agricultural households is the integration of a single institution's decisions regarding production, consumption, and reproduction over time, and even without market failures, a part of their production is kept for home consumption, and a part of labor resources is used directly for home production (Sadoulet and de Janvry 1995). AHM supposed that the agricultural household's objective is to maximize a discounted future stream of expected utility from a list of consumer goods, including home-produced goods, purchased goods, and leisure, subject to what may be a large set of constraints (Yilma 2005). The constraints could include cash income, family time, and endowments of fixed productive assets, production technologies, and prices of inputs, outputs, and non-produced consumption goods. In the case of household, tradable products with perfect markets, the price-related constraints fix prices exogenously, but with household, non-tradable products with missing markets, these constraints specify an internal "shadow price" determination condition, which means that the household's demand for a good equals its output (de Janvry *et al*., 1991). AHM can be static or dynamic. Moreover, it can be assumed that agricultural households are risk-neutral or can take into account risk aversion.

AHM is different from the standard consumer model. In the standard consumer model, the budget is fixed, whereas in the AHM, it is endogenous and linked to production (production contributes to income through farm profits). Moreover, a profit effect is added to the standard Slutsky effects of the standard consumer model. For a normal good x, the standard result of consumer theory predicts a negative effect (an effect that results from an increase in the price of a good x). The profit effect is positive; therefore, as income rises, the household will increase the demand for the good x. Thus, the demand for the good x is subject to two opposite forces: one tends to reduce demand as a result of the traditional substitution and income effects of

standard consumer theory, and the second tends to increase demand (profit effect). The profit effect may outweigh the negative effect. Therefore, the Slutsky effect in the case of AHM may be positive, implying the opposite of the standard consumer theory.

There is an issue in AHM relative to the separability of production and consumption/work decisions. When all main markets work, the model can be solved recursively, meaning the production decision is separable from the consumption one. First, the production decision is taken (the production problem is solved). Then, the consumption problem is solved, given the level of profit achieved in production. However, in the presence of market failures, the model cannot be solved recursively. Thus, the production and consumption decisions are interrelated and made simultaneously. Another issue worth noting is the unitary versus collective decision-making issue. A household is considered a single entity that has the same objective and equal access to household resources in the unitary AHM (Yilma 2005). In the unitary AHM, the head of the household is considered a benevolent decision-maker who makes decisions to maximize each member's utility. However, this is contrary to the other assertion that individuals in a household need to be treated by their preferences. Concerning the second aspect (collective decision-making), each member of the household is considered an independent economic unit, and the model is collective, which can be cooperative or non-cooperative.

In conventional general equilibrium analysis, it is assumed that the individual has preferences over different net demand vectors and that these must belong to a consumption set, describing the physiological and other physical constraints there are on the individual's consumption possibilities. In environmental economics, it is advantageous to take a slightly different point of view, namely, to use the idea of a household production function. It suffices to base the analysis of rural farm household behavior on household production functions. We want to model livelihood diversification and time poverty within the household, and that can most easily be done by using a household production function. By assuming some simple intuitive structures of the household production functions, it may be possible to estimate the demand for CSA practice services from observed behavior in markets for private goods. In this study, we model household participation in off-farm activities and time poverty using income generated from livelihood diversification and time devoted to such activities, respectively.

3.3.2 Empirical Review of Climate-smart Agriculture Adoption and Time Poverty

Ng (2023) conducted a study on in-work poverty among young individuals and introduced a concept called "work-based time poverty." This measure takes into account factors such as long and late work hours, non-standard hours (shifts and weekends), and uncontrollable hours (lack of breaks and short notice of work schedules). The study revealed that low-wage young workers were more likely to work non-standard and uncontrollable hours, which resulted in increased conflict between work and personal life. This conflict, in turn, led to higher levels of anxiety and a diminished sense of self-efficacy among these workers. Interestingly, there was no significant difference between low-wage and higher-wage workers when it came to working long and late hours.

Musyoki *et al*. (2022) employed the multivariate probit and ordered probit models and descriptive statistics in data analysis and indicated that farm households' livelihood diversification had a significant negative influence on the adoption of stress-tolerant livestock but did not have a significant effect on the intensity of the adoption of given CSA technologies.

In a different study, Teshager Abeje *et al*. (2019) used the Herfindahl–Simpson diversity index to explore the extent of livelihood diversification. A stochastic dominance ordering was also employed to identify remunerative livelihood activities. A multivariate probit model was employed to estimate the probability of choosing simultaneous livelihood strategies. In addition to mixed cropping and livestock production, the production of emerging cash crops dominated the overall income generation of the majority of farmers. Stress/shock experience, the extent of agricultural intensification, and agroecology significantly affected the probability of choosing certain livelihood strategies. Livelihood diversification at the household level was significantly associated with the dependency ratio, market distance, credit access, extension services, membership in community organizations, level of income, and livestock ownership. Similarly, Anang and Yeboah (2019) used a double-hurdle model to estimate the factors influencing participation in off-farm work as well as the predictors of actual amounts earned from working outside the farm. The results revealed that gender, farming experience, years of education, and access to credit are the factors determining participation in off-farm work, while farming experience, years of education, and geographical location are the determinants of income from off-farm work.

Employing a bivariate tobit model and endogenous switching regression model, Issahaku and Abdul-Rahaman (2019) found that participation in off-farm is positively and significantly associated with the adoption intensity of sustainable land management practices such as organic manure and bunds while Gebru *et al*. (2018) employed the multinomial logistic

model to find that input use influence farm household choice and the adoption of livelihood diversification strategies and employing the propensity score matching, Adzawla *et al*. (2022) found that large scale farming influences livelihood diversification among maize farmers. Mohammed *et al*. (2021) findings from logistic regression analysis revealed that smallholder farming households that practiced only farm diversification and a combination of both farm and nonfarm diversification had significantly higher odds of reporting stronger resilience to CC compared to those who did not employ any diversification strategy.

Differing in perspective, Martey *et al*. (2022) employed a multinomial endogenous switching regression model and found that joint adoption of improved maize varieties and mineral fertilizer increased maize yields, food consumption scores, and consumption per adult equivalent unit. The authors asserted that the positive impact of maize yield is high among adopters of multiple CSA technologies. Using the same estimation approach, Etwire *et al*. (2022) found that farmers who adapt to CC are more productive and have more household assets than their counterfactual. Farmers who do not adapt obtain less yield and have fewer household assets than their counterfactual. Also, Adego *et al*. (2019) employed the endogenous switching regression and found that farmers who adopted adaptation strategies would have gained lower yields if they had not adopted them, and those who did not adopt a strategy would have gained higher yields than if they had. The authors asserted that contact with development agents, improved seed, compost, urea, and rainfall is significantly associated with the likelihood of increasing yield.

Sedebo *et al*. (2022) performed an impact evaluation analysis by combining endogenous switching regression with propensity score-matching models to address the issue of unobserved biases. Both models of the study revealed that smallholder farmers' adaptation practices significantly enhanced wheat yield. Martey *et al*. (2019) employed endogenous switching regression and propensity score matching methods and found that mineral fertilizer use significantly increases land productivity and agricultural income among farmers.

Focusing on risk and revenue, Dhakal *et al*. (2022) employed the control function approach in an endogenous switching regression framework to account for selection bias. The study found that adaptation to CC using improved practices positively affects crop revenue and revenue risk reduction. The counterfactual analyses indicated considerable heterogeneities in the outcomes among adapters and non-adapters. In particular, adapting farm households realize substantial and distinguishable gains in revenues and declines in risk levels relative to their non-adapting peer households. Di Falco *et al*. (2011) estimated a simultaneous equations model with endogenous switching and found that adaptation to CC lowers downside risk exposure

and that there are significant differences in downside risk exposure between farm households that did and those that did not adapt to CC.

While this may be the case, there are farmers for whom agricultural-based livelihoods are so precarious that even adaptation strategies to their agricultural systems represent a higher risk to food security and prosperity than non-agricultural livelihood options. Hence, CSA may mean the need for actions that focus on supporting people in building non-agricultural-based livelihoods (Agarwal *et al*., 2018). Changes in the climate can further be influenced by CSA if the adverse impacts of cropping are not controlled (Islam *et al*., 2022). Therefore, it is a paradox whether a climate-resilient strategy could approve an approach that simultaneously improves yield and enhances rural farm households' ability to be resilient to other shocks and diversify their sources of income. More importantly, a resilient ecosystem requires an evaluation of both services and disservices generated in that system (Toledo-Gallegos *et al*., 2022).

Harvey and Mukhopadhyay (2007) estimated time-adjusted poverty thresholds and rates for single and dual-parent Canadian families. As expected, the study found a high incidence of time deficit among employed single parents with children. In a different study, Kalenkoski and Hamrick (2013) estimated a simultaneous model to jointly analyze the relationships between time poverty and the probability of a fast-food purchase, the number of eating and drinking occurrences, minutes spent engaging in sports and exercise, and the probability of engaging in active travel (walking or cycling). Time-poor individuals were found to have different eating and physical activity patterns than non-time-poor individuals; those who were time-poor were less likely to purchase fast food and also less likely to engage in active travel.

Martey *et al*. (2022) examined the relationship between parental time poverty, child work, and school attendance in Ghana. Employing inverse probability weighting and propensity score matching, the results of the analysis indicated an increasing decline in child enrolment in public schools among time-poor household heads. In addition, parental time poverty increases children's walking hours to and from school and private school enrolment. The study observed heterogeneity of parental time poverty on child work concerning the location of households and gender disaggregation. Child work and school attendance-reducing effect of parental time poverty is mainly prevalent among male children but mixed for location.

Seymour *et al*. (2019) investigated whether time poverty, income poverty, or being "doubly" poor (i.e., poor in both income and time) is associated with household and child nutrition outcomes and, further, whether women's empowerment moderates these factors. Their analysis provided weak evidence of a relationship between time poverty and household

dietary diversity. But Martey *et al*. (2022) examined the effect of off-farm work on time poverty. After controlling for endogeneity in off-farm work by using an instrumental variable approach, the study found that an increase in off-farm work is positively associated with time poverty. Orkoh *et al*. (2020) examined the relationship between time poverty and income or consumption poverty.

Existing studies on time poverty have focused on nutrition, cooking energy choices, eating, physical activity, and parenting. To the best of my knowledge, no studies have analyzed the impact of CSA practice on time poverty. A significant gap in the literature is the implication of CSA practices adoption on time poverty among rural farmers. Hence, this study seeks to fill this gap by analyzing the impact of CSA practices on time poverty among rural farmers in Ghana. We argue here that CSA practices are required and that livelihood diversification is a viable, adaptable, and climate-resilient strategy. Rural farm households might be already aware of CC adaptation measures, including CSA and even the impact of cropping in a CC scenario, however, it is not explained how the adoption of CSA, resilience of farmers, and livelihood diversification are connected. The empirical link between CSA intensity and rural household livelihood diversification is less explored. To fill this gap in the literature, this study seeks to estimate the impact of the intensity of CSA practices on rural farmers' livelihood diversification in the context of CC among rural farmers in Ghana. This study analyses such interlinkages empirically. We argue that farmers decide their CSA intensity optimally perceiving the impact of these measures on both cultivation practices and the local environment.

3.4 Research Methods

This section presents the methodology of the essay. The essay adopts the quasi-experimental design with the use of control and experimental or treatment groups. One of the ways of measuring the impacts of the adoption of CSA practices on time poverty is to assume two groups: those who adopt and those who do not with common characteristics. The analyses of this study utilize the quantitative approach, which conforms with the positivist philosophy. The endogenous switching regression models are used for the analyses. Data were collected from two groups: those who adopt particular CSA practices and those who do not.

3.4.1 Theoretical Methodology

In the agricultural household model (Benjamin, 1992), farmers face utility optimization problems (Singh *et al*., 1986). A farm household is assumed to maximize the household's utility

over consumption goods and leisure subject to time, budget, production function, and non-negativity constraints. Following Singh *et al*. (1986) and Owusu *et al*. (2011), the following model is presented:

$$max\ U = U(c, l; H) \quad (1)$$

Where U = utility, c = household consumption of goods, l = leisure, and H = household characteristics that parameterize the utility function. The utility optimization problem in Equation 1 is subject to three main constraints: income, technology, and time constraints of the farm household.

$$T = L_1 + L_2 + H \quad (2)$$

$$Q = Q(L_1, A) \quad (3)$$

$$PX = P_1 Q_1 - w_1 L_1 + w_2 L_2 + \bar{R} \quad (4)$$

$$L_1, L_2, H \geq 0$$

Where Equation (2) is the total time endowment (T) exhaustively attributable to farm production (L_1), off-farm production (L_2) and to leisure (H). Equation (3) is the farm production function (Q), which is assumed to be a concave function of labor (L_1) and land (A). Equation (4) is the budget constraint where; P is the market price for purchased consumption goods, w_1 and w_2 are wage rates for farm labor (reservation wage) and for off-farm labor (market wage rate), respectively. More so, in the budget constraint, P_1 and Q_1 is the price for farm output and annual quantities of farm output produced and sold respectively and $\bar{R}$ is the exogenous income.

To solve the households' utility maximization problem, the first-order conditions for optimal time allocation across farm work, off-farm work, and leisure are:

$$\frac{\partial U}{\partial L_i} = w_i \frac{\partial U}{\partial Q} - \frac{\partial U}{\partial L} = 0 \quad (5)$$

$$w_i = \frac{\partial U/\partial L}{\partial U/\partial Q} \quad (6)$$

When the rural farm households have allocated their time to farm, off-farm, and leisure activities, their derived farm and off-farm labor supply functions are:

$$L_1 = L_1(w_1, w_2, P_1, P; H) \quad (7)$$

$$L_2 = L_2(w_1, w_2, P_1, P, R; H) \quad (8)$$

Where H summarizes all the demographic, infrastructural, and farm-level characteristics that influence the rural farm households' reservation (w_1) and off-farm wages (w_2). The rural farm

household will participate in off-farm activities if the market wage rate (w_2) is greater than the reservation wage (w_1). Thus, $L_i = 1$ if $w_2 > w_1$ and $L_i = 0$ if $w_2 \leq w_1$. Where: $L_i = 1$ if the household has participated, and $L_i = 0$, if otherwise. However, these marginal products of labour are not observable. The only observable is whether the household has participated in off-farm activities or not. Hence, the decision to participate can be modeled using the index functions and the binary response models (Cameron and Trivedi, 2007).

3.4.2 Empirical Strategy

A straightforward approach to estimating the impact of CSA practices on time poverty is to estimate a classical Least Square Regression where CSA practices are included as covariates. However, such an approach is likely to result in biased estimates of the impacts of CSA practices as it ignores potential endogeneity in the decision of smallholder farmers to choose to adapt and mitigate CC by assuming that the adoption of CSA practices is exogenous without any selection bias. This assumption is easily violated given that farm-level adaptation is private, voluntary, and has some expected benefits. Thus, farmers may choose CSA practices or not. Additionally, rural and smallholder farmers who choose CSA practices intensity may be systematically different from those who do not. Furthermore, there could be some unobserved characteristics or innate abilities that affect both the decision to choose CSA practices and to be time-poor. Reverse causality between the decision and the outcome variables could also be an issue of concern. To deal with potential selection and endogeneity biases, studies (e.g., Dhakal *et al*., 2022; Martey *et al*., 2022; Etwire *et al*., 2022) adopt instrumental approaches.

To control for both observed and unobserved heterogeneity, the instrumental variable regression (IV) (Greene, 2012) is adopted. Various forms of instruments, such as agricultural training participation, access to CC information, and access to extension services, among others called *z* can influence CSA practices adoption. After regressing x on z and y on z where z is the instrumental variable, we estimate the changes dx/dz and dy/dz and calculate the causal estimator. Equation 9 represents the reduced-form equation:

$$CSA_i = c_2 Z_i + U_i \qquad (9)$$

where CSA is CSA practices adoption intensity, Z is agricultural training participation, access to CC information, access to extension services, and other controls such as distance to farm, distance to market, farm size, age, gender, education, region, access to finance, and marital status of the farmer i and U_i is the error term.

In line with the approach taken in prior research (Di Falco *et al*., 2014; Martey, 2022), we examined various factors as potential instruments, including access to extension services, access to information on agriculture, and participation in agricultural training. However, we used only participation in agricultural training as the relevant instrument for CSA practice adoption. This instrument is anticipated to exert a positive influence on CSA practices. It is considered a suitable instrument because training in agricultural practices can directly impact a farmer's likelihood of adopting CSA practices. The strength of the instrument is assessed using the F-statistic test proposed by Stock and Yogo (2005). The Cragg-Donald Wald F statistics were greater than the Stock-Yogo critical values.

This study computes the outcomes of time poverty in levels. Based on the works of Etwire *et al*. (2022) and Martey *et al*. (2019), the empirical model of this essay is stated in Equation 10 as follows:

$$timepoor_i = f(CSA_i, sex_i, marital\ status_i, age_i, education_i, region_i)$$

$$timepoor_i = \emptyset_0 + \emptyset_1 CSA_i + \emptyset_2 sex_i + \emptyset_3 marital\ status_i + \emptyset_4 age_i + \emptyset_5 farmsize_i + \emptyset_6 consume_i + \emptyset_7 edu\_yrs_i + \emptyset_8 district_i + e_i \quad (10)$$

where *timepoor* captures person-days used by the farm households for planting, fertilizing, land preparation (harrowing and ridging), spraying, weeding, and harvesting. The aggregation of these gives the total time poverty level of the farm household. It also captures the expected and actual working hours in a week.

3.4.3 Time poverty measurement

Time poverty happens when one works more than the desirable hours (Kim *et al*., 2024; Martey *et al*., 2021; Parra and Wodon, 2010). Time poverty is a situation in which individuals or households lack sufficient time to meet their basic needs, pursue meaningful activities, or engage in leisurely pursuits due to a lack of available time. It is a condition where people feel overwhelmed and have limited time for essential tasks, such as household chores, childcare, and personal activities. Time poverty can arise from various factors, including long work hours, multiple job responsibilities, commuting time, caregiving responsibilities, and a fast-paced lifestyle (Garrido-Cumbrera *et al*., 2023). It is often associated with modern societies that prioritize productivity, economic growth, and efficiency, leading to a scarcity of free time for individuals. The consequences of time poverty can be significant. It can lead to increased stress levels, reduced quality of life, decreased well-being (Garrido-Cumbrera *et al*., 2023), and a lack of work-life balance (UN Women, 2022). People experiencing time poverty may have difficulty fulfilling personal goals, spending quality time with family and friends, participating

in community activities, or taking care of their health and well-being. According to Burchardt (2008), time poverty hinders individuals' ability to expand their capabilities through education and skills development, which would enhance their economic output in the labor market.

Our measurement is based on a 168-hour recall of farmer time allocation in a week. The study estimates an indicator of time poverty based on the total hours the farmer committed to economic activities in a week combined time spent on the following paid and unpaid work activities (i.e., 'committed time to economic activities') (Bardasi and Wodon, 2010): work as employed for wage salary, domestic work, farm enterprise, non-farm enterprise, farm household non-farm enterprise, non-productive agriculture, apprentice, and voluntary activities. The second measurement is based on the total hours the farmer spent on farming activities in a week (i.e., 'committed time to farming activities'). The construction of time poverty followed the conventional methods recommended in the literature (GSS, 2022; Martey *et al*., 2021; Martey *et al*., 2022; Seymour *et al*., 2019). Person days are calculated as the number of workers times the number of days they worked.

3.4.4 Data Sources

The data is from a cross-sectional survey of rural farmers in Ghana. The focus of the study was on rural farmers in selected districts in the Central and Upper East regions. We surveyed farmers in the Assin South, Awutu Senya West, Nadowli, and Sissala West Districts in Ghana. These districts are known for their production of cash crops, other perennial crops, cereals, tubers, and other staple food crops. Also, they are known for animal rearing and production. A sample of over 590 households is used for the analysis in this essay from a total of 600 sampled households. We selected respondents of different ages, different educational levels, and multiple economic activities. The quantitative questionnaire for face-to-face interviews was developed. Details are provided under sources of data in Essay 2.

3.4.5 Summary of Variable, Definition and Measurement

Table 3.1 presents the summary description of the variables used for analyses in this essay. The measurements and the nature of the variables with their expected signs are also presented. The number of person-days used for preparation has, on average, 5 person-days with a minimum value of 0 and a maximum value of 140 and 9.3 person-days. For the person days devoted to planting has a minimum of 0 and a maximum of 60 person days. Fertilizing days have a mean of 3.97 person-days with a minimum of 0 and a maximum of 75 person-days. The number of person-days devoted to weeding has a mean of 11.83, with a minimum of 0 and a maximum of 210 days. Again, from Table 3.1, on average, farmers use 1.75 person-days for

spraying. The minimum person-days for spraying is 0, which suggests that some farmers have 0 person-days because they do not hire other laborers on the farm. The maximum number of person-days for spraying is 45. Harvesting days have a mean of 23 person-days with a minimum of 0 person-days and a maximum of 378 person-days. The expected hours in the week farmers work has a minimum of 53.3 hours with a minimum of 0 hours and a maximum of 167 hours. This shows the variation in the working poverty of the farmers studied. The actual weekly working hours have a mean of 32.86 hours with a minimum of 0 and a maximum of 77 hours. This implies that the actual working poverty of the farmers is lower than the expected time poverty. However, working for 77 hours a week is very high. The total working time, proxied as the time poverty, has a mean of 55.06 person days. The minimum working time is 0 person days with a maximum of 577 person days. All other variables are discussed in Essay 2 of this thesis.

Table 3.1: Summary statistics of variables

Variable	Definition and measurement	Obs	Mean	Std. dev.
Preparation days	Number of person-days devoted to agricultural farm preparation	591	5.005	10.564
Planting days	Number of person-days devoted to crop planting	591	9.502	9.283
Fertilizing days	Number of person-days devoted to the application of fertilizers on the agricultural farm	591	3.970	7.326
Weeding days	Number of person-days devoted to weeding the farmlands	591	11.833	17.236
Spraying days	Number of person-days farmers use to spray the farm	591	1.736	2.905
Harvesting days	Number of person-days farmers harvest their crops	591	23.006	31.825
Expected Weekly working hrs	The number of hours farmers are expected to work on their farms	447	53.306	33.812
Actual weekly working hrs	The number of hours farmers actually worked on their farms	447	32.861	18.038
Total working time	The total number of days farmers devote to their farming activities	591	55.051	53.986

3.5 Results and Discussions

3.5.1 Effect of Climate-Smart Agriculture and Time devoted to some Farming Activities

To analyze the effect of CSA adoption intensity on time poverty among rural farmers in Ghana, we use diverse forms of farming activities, including planting, fertilizing, land preparation (harrowing and ridging), spraying, weeding, and harvesting. The aggregation of

these gives the time poverty level of the farm household. Table 3.2 presents some of the activities.

Table 3.2 indicates that CSA practices intensity reduces land preparation and planting person-days but has a positive effect on fertilizing person-days. For instance, one more CSA adoption intensity reduces land preparation time poverty by 1.082 person-days, and it is significant at 10% (p-value=0.095). This implies that with the implementation of CSA practices intensity, farmers can optimize their land use while reducing the labor and time traditionally associated with intensive land preparation. This approach aligns with sustainability goals, promoting resilience against CC impacts and enhancing agricultural productivity in the long run. This is because CSA promotes conservation agriculture techniques like minimal tillage or no-till farming. These practices reduce the need for extensive land preparation, such as ploughing and harrowing, which conventionally require a substantial amount of time and effort. Also, the planting of improved varieties can withstand harsh weather conditions, and the integration of cover crops and leaving crop residues on the soil surface helps to improve soil structure and fertility, which by extension reduces the need for frequent planting and intensive land preparation before planting each season. The adoption of integrated pest management practices reduces the need for excessive planting and land preparation to control pests and diseases. CSA emphasizes soil health improvement through organic matter additions, composting, and proper nutrient management. Healthy soils require less intensive land preparation and multiple planting at the same time, as they maintain good structure and fertility.

The results indicate that those farmers who are married can reduce time land preparation, planting, and fertilizing person-days more as compared to those who are single. This is not surprising as these farmers are supported by their spouses. This is because, in married households, there is typically a division of labor between husband and wife. Each spouse can specialize in certain farming tasks, including planting, allowing them to optimize their efficiency and reduce the overall time required for planting activities. Also, emotional and practical support from a spouse can motivate farmers to work more efficiently and productively. This support can translate into reduced time spent on planting tasks and increased overall productivity. Among the other marital statuses, even though those who are separated and divorced can reduce their person-days as compared to those who are single, the results are not significant.

Table 3.2: Land preparation, planting, and fertilizing person-days

	Preparation days	Planting days	Fertilizing days
	Coef.	Coef.	Coef.
CSA intensity	-1.082*	-0.543	0.005
	(0.647)	(0.578)	(0.361)
Marital (single)			
Separated	-3.351	-5.034	-3.609
	(6.553)	(5.847)	(3.650)
Married	-3.597*	-1.361	-1.290
	(1.969)	(1.756)	(1.096)
Widowed	-0.251	-3.935	-1.232
	(3.914)	(3.492)	(2.180)
Age	0.450**	0.430**	0.145
	(0.215)	(0.192)	(0.120)
age2	-0.477**	-0.462**	-0.169
	(0.242)	(0.216)	(0.135)
Female	2.527**	-0.818	0.406
	(1.149)	(1.025)	(0.640)
Farmsize	0.613**	0.273	0.268*
	(0.275)	(0.246)	(0.153)
edu_years	0.052	-0.148	0.007
	(0.123)	(0.110)	(0.068)
District (Assin South)			
Awutu Senya	9.755***	4.935**	-0.454
	(2.558)	(2.283)	(1.425)
Sissala West	6.404	18.221***	3.088
	(5.007)	(4.467)	(2.788)
Nadowli	9.021***	6.212**	3.277*
	(3.057)	(2.727)	(1.702)
Consume	-0.068	-0.010	0.124*
	(0119)	(0.107)	(0.067)
_cons	-5.391	3.699	-0.593
	(5.063)	(4.518)	(2.820)
N	580.000	580.000	580.000
Wald chi2(18)	47.050	46.690	47.190
Prob > chi2	0.000	0.000	0.000

Standard errors in brackets *** p <1%, ** p < 5% * p < 10%

Using age as a proxy for experience, one additional year increase in the age of the farmer increases land preparation and planting person-days by more than 10 hours, and it is significant at 5%. However, after 47 years, one additional year of age reduces land preparation and planting person-days by more than 11 hours. The effect on fertilizing person-days is

insignificant. This implies that experiences in farming impact the time devoted to farming activities. Younger farmers may lack experience and knowledge about efficient farming practices, which can contribute to a longer time spent on land preparation and planting. Farmers with more experience (including those above 47 years) tend to have honed their skills and acquired knowledge about efficient farming techniques. Younger individuals may still be in the learning phase, adapting to farming practices and gaining efficiency over time. Older individuals, especially those above 47 years who have spent a significant portion of their lives in farming, may have reached a point where they've plateaued in terms of optimizing their efficiency, resulting in a consistent level of time required for land preparation and planting. This experience can help them optimize their approach, reducing the time needed for land preparation and planting despite potential physical limitations. Again, younger individuals often have higher physical stamina, strength, and endurance, enabling them to perform physically demanding tasks like land preparation and planting more quickly and efficiently. They can endure longer hours of labor-intensive activities. As individuals age, their physical capabilities may decline, affecting their ability to engage in strenuous activities for extended periods. This decline may result in longer time requirements for tasks like land preparation and planting.

It is observed that females devote approximately three person-days more than males to land preparation, and it is significant at 5% (p-value=0.028). However, gender has no significant effect on planting and fertilizing person-days. This implies that women work more on land preparation than men. This is because, by their biological makeup, women are physically not as strong as men to work and engage in labor-intensive activities. Their physical abilities are limited and might require longer days to achieve the same output as men.

As shown in Table 3.2, as expected, an increase in farm size increases preparation, planting, and fertilizing person-days. Large farm sizes require more working days to clear the land and harrow, which will increase the days the farm household devotes to it. Planting seeds and fertilizing the larger lands are difficult, especially for rural farmers who may lack ploughing machines. It is also observed that farm households in the Awutu Senya, Nadowli and Sissala West Districts commit more person-days to land preparation, planting, and fertilizing than farm households in the Assin South District. This could be due to the nature of the land in these districts.

Table 3.3 presents the effect of CSA practices adoption intensity on weeding, spraying and harvesting person-days. It is observed that although CSA practices adoption intensity reduces weeding, spraying and harvesting person-days, there is no significant association

between them. Farming practices still require weed controls without leading to biodiversity loss.

Table 3.3: Weeding, spraying, and harvesting person-days

	Weeding days	Spraying days	Harvesting days
	Coef.	Coef.	Coef.
CSA intensity	-0.407	-0.152	-0.511
	(0.994)	(0.213)	(1.874)
Marital (single)			
Separated	-2.621	-0.949	-7.316
	(10.063)	(2.153)	(18.972)
Married	-0.862	-0.762	-12.420**
	(3.023)	(0.647)	(5.699)
Widowed	-3.950	-2.052	-23.861**
	(6.010)	(1.286)	(11.329)
Age	-0.261	0.054	1.049*
	(0.330)	(0.071)	(0.622)
age2	0.261	-0.041	-0.902
	(0.372)	(0.080)	(0.700)
Female	-2.037	0.292	6.356*
	(1.764)	(0.377)	(3.325)
Farmsize	0.487	0.063	1.093
	(0.423)	(0.090)	(0.797)
edu_years	-0.219	-0.018	0.162
	(0.189)	(0.040)	(0.356)
District (Assin South)			
Awutu Senya	1.153	2.159***	11.156
	(3.929)	(0.841)	(7.407)
Sissala West	14.663*	2.555	51.725***
	(7.688)	(1.645)	(14.494)
Nadowli	-3.220	2.625***	11.986
	(4.694)	(1.004)	(8.849)
Consume	-0.039	0.069*	0.206
	(0.183)	(0.039)	(0.346)
_cons	24.490***	0.510	-7.569
	(7.775)	(1.664)	(14.658)
N	580	580	580
Wald chi2(18)	18.610	47.48	32.990
Prob > chi2	0.417	0.000	0.017

Standard errors in brackets *** p <1%, ** p < 5% * p < 10%

This means that conventional weeding is not completely out amidst CSA adoption practices. CSA practices may not eliminate the need for weeding, especially if weeds have developed resistance to the practices adopted. Likewise, spraying and harvesting require human labor. The adoption of CSA cannot eliminate the person-day committed to these farming activities.

Pests and diseases can adapt and evolve, making it difficult to abolish the need for spraying person-days. CC may alter pest dynamics and necessitate adjustments in pest management strategies, including increased or altered spraying requirements. Improved mechanized harvesting equipment might not be widely accessible or affordable for many smallholder farmers in Ghana. This limitation can hinder the reduction of harvesting person-days.

3.5.2 Effect of Climate-Smart Agriculture and Weekly Hours and Total Time Poverty

Table 3.4 presents the effect of CSA adoption intensity on expected and actual hours per week households engage in farming activities and the total time poverty of the household. It is observed that CSA adoption intensity has no significant effects on expected and actual hours per week and the total time poverty of the farm households, although the effects of CSA adoption intensity on expected weekly working hours and total time poverty are negative. These imply that at this stage, the adoption of CSA practices intensity cannot eliminate time poverty, however, there is hope that continuous adoption will eventually lead to time poverty reduction. Plausibly, these selected regions in Ghana are more vulnerable to extreme weather events such as floods or droughts. Unpredictable and extreme weather patterns can disrupt agricultural activities, potentially nullifying the benefits of CSA practices and hindering the efforts to reduce or eliminate time poverty. Also, the ability of farmers to benefit economically from CSA can be stalled by limited market access or low demand for climate-smart products. If the market does not incentivize the adoption of CSA practices, the economic impact may not be significant enough to reduce time poverty. Long-standing traditional farming practices, deeply ingrained in the culture and society of Ghana, may be difficult to change. Convincing farmers to adopt new CSA practices and techniques requires targeted education and incentives to shift away from established farming methods.

The notion that CSA increases yields could be the reason Ng (2023) revealed that low-wage workers were more likely to work non-standard and uncontrollable hours, which resulted in increased conflict between work and personal life. This conflict, in turn, leads to higher levels of anxiety and a diminished sense of self-efficacy among these workers. Our study corroborates the studies of Issahaku and Abdul-Rahaman (2019), who found a positive relationship between the adoption intensity of sustainable land management practices and off-farm activities. Also, Dhakal *et al*. (2022) and Di Falco *et al*. (2011) found that improved farming practices reduce risk and, by extension, reduce time poverty.

It is also observed that a cedi increase in consumption increases actual weekly working hours by approximately 24 minutes, and it is significant at 5% (p-value=0.023). An increase in

consumption expenditure increases the need for long hours and multiple jobs, preventing them from allocating more hours to other essential activities and increasing time poverty.

Table 3.4: CSA and Total Time Poverty

	Expected weekly working hours	Actual weekly working hours	Total time poverty
	Coef.	Coef.	Coef.
CSA intensity	-0.386	0.189	-2.689
	(1.793)	(0.948)	(3.247)
Marital (single)			
Separated	-12.909	-7.802	-22.880
	(16.215)	(8.574)	(32.866)
Married	1.278	0.324	-20.293**
	(5.317)	(2.812)	(9.873)
Widowed	0.707	3.141	-35.280*
	(13.726)	(7.258)	(19.627)
Age	2.029***	1.018***	1.866*
	(0.620)	(0.328)	(1.078)
age2	-2.320***	-1.035***	-1.789
	(0.707)	(0.374)	(1.213)
Female	-10.572***	-3.518**	6.725
	(3.359)	(1.776)	(5.760)
Farmsize	-0.536	-1.041**	2.796**
	(0.775)	(0.410)	(1.381)
edu_years	0.067	-0.053	-0.164
	(0.333)	(0.176)	(0.616)
District (Assin South)			
Awutu Senya	38.290***	-6.964*	13.979
	(7.396)	(3.911)	(13.482)
Sissala West	15.708**	13.753***	28.704**
	(7.214)	(3.815)	(12.831)
Nadowli	21.318**	-0.198	29.900**
	(8.758)	(4.631)	(15.330)
Consume	-0.251	0.401**	0.283
	(0.333)	(0.176)	(0.599)
_cons	21.844	19.751***	15.148
	(14.208)	(7.513)	(25.394)
N	444	444	580
Wald chi2(18)	87.870	86.450	39.630
Prob > chi2	0.000	0.000	0.002

Standard errors in brackets *** p <1%, ** p < 5% * p < 10%

An increase in consumption expenditure sometimes leads to rising expectations and a desire for a higher living standard. Individual may feel compelled to maintain or elevate their lifestyle, leading to more spending and, consequently, longer working hours to support those lifestyles.

This could increase their actual weekly working hours as farm households devote more time to work to sustain their levels of consumption since they want to continue to 'Join the Jones'.

One additional year increase in the age of the farmer significantly increases expected and actual weekly working hours and time poverty person-days by more than two hours, more than one hour and approximately two person-days, respectively. However, after 22, 49, and 52 years, respectively, one additional year of age reduces expected and actual weekly working hours and time poverty person-days. This indicates the effect of experiences in farming on time poverty among farmers in Ghana. Young farmers might lack experience and knowledge about efficient farming practices, which can contribute to a longer time spent on agricultural activities. Farmers with more experience normally have enhanced their skills and acquired knowledge about efficient farming techniques. Younger farmers may still be in the learning phase, adapting to farming practices and gaining efficiency over time. Farmers, especially those above 22 years who have spent more than eight years in farming, may have reached a point where they have gained experience to optimise their efficiency, resulting in a consistent level of time required for agricultural activities. This experience can help them optimise their approach, reducing the time needed for farming despite potential physical limitations. Again, younger farmers often have higher physical stamina, strength, and endurance, enabling them to perform physically demanding tasks in agricultural activities. They can endure longer hours of labour-intensive activities. As farmers age, their physical capabilities may decline, affecting their ability to engage in laborious activities for extended working hours or person-days. This decline may result in longer time requirements for agricultural activities.

The size of the farm has a negative effect on actual weekly working hours but a positive effect on total time poverty. Thus, the size of the farm reduces actual weekly working hours. This is because the farmers assume that large farm will increase their crop yield and might not commit to long hours in farming activities. Small farms often require more intensive labour as farmers might lack access to modern machinery and equipment to achieve the same yields as larger farms. This increased labour intensity can result in longer working hours per week, especially during peak seasons such as planting and harvesting. Larger farms may have better access to mechanization, which can significantly reduce the time and effort required for various agricultural tasks. In contrast, smaller farms with limited resources may rely on manual labour, increasing the time needed to complete tasks. Larger farms often benefit from economies of scale, allowing them to optimise operations and allocate resources more efficiently. This efficiency can translate to shorter working hours per unit of output compared to smaller farms that may struggle with resource allocation.

The size of the farm has a positive effect on total time poverty. Thus, a one-acre increase in the size of the farm would lead to approximately three person-days, and it is significant at 5% (p-value=0.043). This means that farmers who have larger farm sizes are more time-poor than farmers who have smaller farm sizes. Larger farms might depend heavily on family labour, with family members working long hours to support the farming activities. This reliance could lead to time poverty person-days, as family members dedicate a significant portion of their time to farm-related activities. Also, managing a larger farm could entail higher operating costs, such as purchasing inputs, hiring labor, and investing in infrastructure. To meet financial obligations and generate revenue, farmers might feel compelled to work longer hours, potentially increasing person-days in farming activities. Larger farms typically require more hands to manage and maintain the farm effectively. This higher demand for labour could result in longer working hours for farmers and their families, potentially leading to time poverty as they spend a significant portion of their person-days on the farm.

3.6 Conclusion and Policy Implications

CSA adoption can generate externalities whose time value is difficult to measure since they are not sold in the market, hence lacking a time tag. Numerous CSA practices and agricultural technologies provide positive externalities, which can lead to adoption rates lower than socially optimal when individuals fail to recognize the overall social benefit of adopting these technologies. It is relevant to recognise externalities associated with CSA in terms of time poverty reduction among smallholder farmers. We therefore pose: Do CSA practices impact rural farm households' time poverty in Ghana? Our study analysed the impact of CSA practices' adoption intensity on time poverty among farmers in Ghana adopting the farm household model.

We focused on person-days devoted to spraying, harvesting, weeding, planting, fertilising, and land preparation. We also focused on expected and actual weekly working hours and the total person-days as the measurement for time poverty. We found that CSA practices intensity reduces land preparation and planting person-days but has a positive effect on fertilizing person-days. This means that with the implementation of CSA practices intensity, farmers can optimise their land use while reducing the labour and time traditionally associated with intensive land preparation. This is because CSA promotes conservation agriculture techniques. Furthermore, the planting of improved varieties can resist harsh weather conditions, and the integration of cover crops and leaving crop residues on the soil surface helps to improve soil structure and fertility, which by extension reduces the need for frequent

planting and intensive land preparation before planting each season. Additionally, we found that although CSA practices' adoption intensity reduces weeding, spraying, and harvesting person-days, there is no significant association between them. This is not surprising since farming practices still require weed controls without leading to biodiversity loss. Similarly, spraying and harvesting require human labour. The adoption of CSA cannot eliminate the person-day committed to these farming activities. Again, we found that CSA adoption intensity has no significant effects on expected and actual hours per week and the total time poverty of the farm households, although the effects are negative. This means that conventional farming practices such as weed control, harvesting, and land preparation, among others, form part of farming practices even amid CSA practices adoption intensity. CSA practices do not entirely eradicate the need for traditional farming practices, especially if the weeds and the land have developed resistance to the practices adopted. Unpredictable and extreme weather patterns can disrupt agricultural activities, potentially nullifying the benefits of CSA practices and hindering the efforts to reduce or eliminate time poverty. Also, the ability of farmers to benefit economically from CSA can be stalled by limited market access or low demand for climate-smart products. If the market does not incentivise the adoption of CSA practices, the economic impact may not be significant enough to reduce time poverty.

From the foregoing, our study concludes that CSA practices' adoption intensity reduces land preparation and planting time devoted to them in the long run. Again, we conclude that CSA practices' adoption intensity reduces time committed to weeding, spraying and harvesting in the long run. Additionally, we conclude that CSA adoption intensity reduces time devoted to expected and actual hours per week and the total time poverty of the farm households in the long run. These imply that at this stage, the adoption of CSA practices intensity cannot eliminate time poverty, however, there is hope that continuous adoption will eventually lead to time poverty reduction. Plausible because the selected districts are in the coastal or savanna areas in Ghana, which are susceptible to extreme floods or harsh droughts. These CC events can eliminate the efforts of farm households to increase crop yields.

The study recommends knowledge and awareness of the benefits of CSA practices and adoption intensity. Farmers need to be educated and aware of climate-smart practices that can help reduce weeding, spraying, and harvesting person-days. A lack of knowledge or awareness can hinder the adoption of these practices. Public education campaigns and farmer training programmes are essential to raise awareness and educate farmers about the advantages of CSA in reducing time poverty. This can be achieved by integrating CSA practices in formal and informal education systems to build a knowledge base and foster a culture of sustainability.

Again, we recommend that the MoFA promotes the use of technology, including weather forecasting, remote sensing, and mobile applications, to help farmers make informed decisions and optimize their CSA practices. Also, the GoG, through the MoFA and District Agriculture Directorate, must allocate resources to research institutions and organizations to develop and disseminate CSA technologies and practices that are tailored to local conditions and needs. This includes the provision of accurate and timely weather information to farmers in order not for farmers to spend so much time on farming activities to avoid time poverty.

One major limitation of our study is the lack of longitudinal data. Our data does not permit longitudinal analyses. We are not able to account for changes that might happen over time and are not able to explore dynamic processes over time. Cross-sectional biases are not accounted for in point-in-time surveys. We are not able to capture trends in variables that are key for understanding comprehensively. This limitation, however, has less impact on the outcome and robustness of the study since several studies. Future studies can use nationally representative survey data over time to account for cross-sectional biases.

GENERAL CONCLUSION

4.1 Brief Introduction

CC creates externalities that are larger, more complex, and more uncertain than any other environmental problem. These externalities distract the first theorem of welfare economics, causing many governments across the globe to profoundly subsidize modern agricultural inputs. Conversely, the Chicago tradition associated with it begins with the presumption that farmers are rational profit maximizers, so subsidies will distort CSA practices away from the optimal levels. Therefore, this study sought to evaluate the impact of CSA on agricultural commodity trade and rural farm households' resilience to CC in Ghana. We adopted the DCGE model to analyze the impact of investment in CSA practices on agricultural commodities trade flows and price fluctuations. Our model was calibrated to the SAM of Ghana for the year 2019. We also adopted count data modeling to analyze the impact of the agricultural input supply system and contract on nudging the adoption intensity of CSA among rural farmers in Ghana. Furthermore, to control for heterogeneity, the instrumental variable regression (IV) was adopted to estimate the impact of CSA practices on time poverty. We surveyed farmers in the Assin South, Awutu Senya West, Nadowli, and Sissala West Districts in Ghana. The quantitative questionnaire for face-to-face interviews was developed.

From the analyzes conducted, public investment in CSA practices by 5% or more reduced prices of agricultural commodities at a higher rate than the BAU scenarios, even though prices increased in both scenarios since prices are sticky downwards. We concluded that public investment in CSA practices reduces the price of agricultural commodities. Furthermore, we found that Ghana's agricultural commodities exports declined for both the BAU and the CSA investment scenario cases. The public investment scenario case had higher export volumes than BAU. We concluded that the CSA public investment scenario case by more than 5% reduces the decline in agricultural commodities exports. Additionally, we found that public CSA investment scenarios reduce agricultural commodities imports more than the BAU scenario. However, the import volume of agricultural commodities increases in both cases.

For the second objective, the study found that farm households that were committed to pre-planting contracts had a higher adoption intensity of CSA practices than farm households that did not commit to pre-planting contracts. Also, farm households that had a buyer contract adopted more CSA practices than those who did not have a buyer contract. Furthermore, the study found that farmers who paid for CSA input supplied after the harvest had higher adoption intensity than farm households who paid for CSA input supplied before harvest. Finally, farm

households that preferred small CSA inputs supply to large CSA inputs supply adopted more CSA practices than their counterparts. Therefore, the study concludes that agricultural input supply and agricultural contracts significantly increase the adoption intensity of CSA practices among rural farm households in Ghana.

On the third objective, we found that CSA practices intensity reduces land preparation and planting person-days but has a positive effect on fertilizing person-days. Additionally, we found that although CSA practices' adoption intensity reduces weeding, spraying, and harvesting person-days, there is no significant association between them. Again, we found that CSA adoption intensity has no significant effects on expected and actual hours per week and the total time poverty of the farm households, although the effects are negative.

Our study suggested that the GoG needs to complement public CSA investments with policies that help farmers increase market access, improve storage and transport infrastructure, and facilitate access to credit to ensure that price reductions do not harm farmer livelihoods. The increase in import volumes, even under CSA investments, highlights the need for policy support to further reduce Ghana's reliance on agricultural imports. This may include policies promoting import substitution and better integration into regional trade agreements like the AfCFTA. Moreover, Ghana can tap into international climate finance mechanisms, such as the GCF, the GEF, and the Adaptation Fund, to secure funding for CSA projects. These funds could help scale up CSA programs and introduce new practices at a larger scale.

The study suggested that the LDAs should facilitate contract farming arrangements between farmers and buyers specifying the terms of payment. Furthermore, MoFA should establish input credit schemes in the districts that allow farmers to access agricultural inputs without upfront payment. Inputs should be provided to farmers with a deferred payment arrangement until after harvest when farmers have generated revenue from the sales of produce. Again, the LADs should negotiate for farmers between agricultural input suppliers and farmers in alignment with the various harvest cycles of different crops. Again, we suggested that the MoFA promote the use of technology, including weather forecasting, remote sensing, and mobile applications, to help farmers make informed decisions and optimize their CSA practices.

One major limitation of our study is that we could not control the treatment and control groups since we did not administer the contract to the farmers. Some of these farmers had already agreed to some contracts before our survey. Additionally, our study lacked longitudinal data. Our data did not permit longitudinal analyses. We were unable to account for changes that might happen over time and were not able to explore dynamic processes over time.

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APPENDICES

Appendix A: Mathematical Models of Essay One

Symbols	Explanations
$a \epsilon A$	Activities
$a \epsilon AEES (\subset A)$	Activities with a CES functions at the top of the technology nest
$a \epsilon ALEO (\subset A)$	Activities with a Leontief functions at the top of the technology nest
$c \epsilon C$	Commodities
$c \epsilon CD (\subset C)$	Commodities with domestic sales of domestic output
$c \epsilon CDN (\subset\subset C)$	Commodities not in CD
$c \epsilon CE (\subset C)$	Exported commodities
$c \epsilon CM (\subset C)$	Aggregate imported commodities
$c \epsilon CEN (\subset C)$	Commodities not in CE
$c \epsilon CX (\subset C)$	Commodities with domestic production
$f \epsilon F$	Factors
$i \epsilon INS$	Institutions (domestic and the rest of the world)
$i \epsilon INSDNG (\subset INSD)$	Domestic nongovernmental institutions
$h \epsilon H (\subset INSDNG)$	Households

Equations parameters

Cpi	Consumer price index
$cwts_c$	Weight of commodity c in cpi
ica_{ca}	Quantity of c as intermediate input per unit of activity a
$icd_{cc'}$	Quantity of commodity c as trade input per unit of c' produced and sold domestically
$ice_{cc'}$	Quantity of commodity c as trade input per exported unit of c'
$icm_{cc'}$	Quantity of commodity c as trade input per imported unit of c'
$int\ a_a$	Quantity of aggregate intermediate input per activity unit
iva_a	Quantity of value-added per activity per unit
mps_i	Base saving rate for domestic institutions i
α_a^a	Efficiency parameters in the CES activity function
α_a^{va}	Efficiency parameters in the CES value-added function
α_a^{ca}	Shift parameter for the domestic commodity aggregation function
α_c^q	Armington function shift parameter
α_c^i	CET function shift parameter
β^a	Capital sectoral mobility factor
β_{ch}^a	Marginal share of consumption spending on marketed commodity c for household h
δ_a^a	CES activity function share parameter
δ_{ac}^{ac}	Share parameter for domestic commodity aggregation function

δ_{cr}^{q}	Armington function share parameter
v_{f}	Capital depreciation rate
mps_{01}	0-1 parameter with 1 for institution with potentially fixed direct tax rates
pwe_{c}	Export price (foreign currency)
$shif_{if}$	Share for domestic institution *i* in income of factor f
$shif_{ii'}$	Share of net income *i'* to *i*
ta_{a}	Tax rate for activity a
$tins_{i}$	Exogeneous direct tax rate for domestic institution *i*

Equation parameters

$tins_{0,1}$	0-1 parameter with 1 for institution with potential fixed direct tax rates
tm_{c}	Import tariff rate
te_{c}	Export tariff rate
tq_{c}	Sale tax rate
ta_{a}	Tax rate for activity a
δ_{cr}^{t}	CET function share parameter
δ_{fa}^{va}	CES value-added function share parameter for factor f in activity a
γ_{ch}^{m}	Subsistence consumption of marketed commodity for household h
θ_{ac}	Yield of output c per unit of activity a
ρ_{a}^{a}	CES value-added function exponent
ρ_{c}^{ac}	Domestic commodity aggregation function exponent
ρ_{c}^{q}	Armington function exponent
ρ_{c}^{i}	CET function exponent
η_{fat}^{a}	Secor share of new capital

Exogenous variables

$fsav$	Foreign saving
mps_{i}	Marginal propensity to save for domestic nongovernment institution
pwm_{c}	Import price in foreign currency
pwe_{c}	Export price in foreign currency
$qdst_{c}$	Stock change quantity
qfs_{f}	Quantity supplied of factor
qg_{e}	Government consumption demand for commodity
$qinv_{e}$	Base-year quantity of private investment demand
$trnsfr_{if}$	Transfer from factor f to institution *i*
$wfdist_{fa}$	Wage distribution factor for facto for factor f in activity a

Endogenous variables

AWF_{ft}^{a}	Average capital rental rate in time period t

$LADJ$	Investment adjustment factor
EG	Government expenditure
EH_h	Consumption spending for household
EXR	Exchange rate (local currency per unit of FCU)
$QINT_a$	Quantity of aggregate intermediate input
$QINT_{ca}$	Quantity of commodity c as intermediate input to activity a
$QINV_c$	Quantity of investment demand for commodity
QM_{cr}	Quantity of imports of commdotity c
QE_c	Quantity of exports of commodity c
QA_a	Quantity of activity a
PA_a	Activity price in unit gross revenue
$GSAV$	Government saving
QF_{fa}	Quantity demanded of factor f from activity a
QH_{ch}	Quantity consumed of commodity c by household h
QHA_{ach}	Quantity of household home consumption of commodity c from activity a for household h
PM_{cr}	Unit price of capital in period t
PQ_c	Import price in domestic currency
PVA_a	Composite commodity price
PX_c	Value-added price factor income per unit of activity
$PXAC_{ac}$	Aggregate producer price of commodity a
QA_a	Producer price of commodity a for activity a
QD_c	Quantity of activity
QE_{ct}	Quantity sold domestically of domestic output
QQ_c	Quantiy of goods supplied to domestic market
QVA_a	Quantity of aggregate value-added
PD_c	Demand price for commodity produced and sold domestically
PE_{cr}	Supply price for commodity produced and sold domestically
$PINTA_a$	Export price in domestic currency
PK_{ft}	Aggegrate intermediate input price for activity a
QX_c	Aggregate quantity of domestic output of commodity
$QXAC_{ac}$	Quantity of output of commodity c from activity a
$TRII_{ii'}$	Transfer from institution i *' to i*
WF_f	Average factor price
YF_f	Factor f income
YG	Government revenue
YI_i	Domestic nongovernment institution income
YIF_{if}	Income to domestic institution *i* from factor f
K_{fat}^{a}	Quantity of new capital by activity a for the period t

Production and price equations

$$QINTA_{ca} = ica_{ca} * QINTA_a \quad (1)$$

$$PINTA_a = \sum_{cC} PQ_c * ica_{ca} \quad (2)$$

$$QVA_a = \alpha_a^{va} * \left(\sum_{f \in F} \delta_f^{\alpha} * (\alpha_{fa}^{vaf} * QF_{fa})^{-\rho_a^{va}}\right)^{\frac{1}{\rho_a^W}} \quad (3)$$

$$W_f * \overline{WFDIS_f T} = PVA_a * QVF_a * \left(\sum_{f \in F} \delta_f^{\alpha} * (\alpha_{fa}^{vaf} * QF_{fa})^{-\rho_a^{va}}\right)^{-1} * \delta_f^{\alpha} * (\alpha_{fa}^{vaf})^{-\rho_a^{va}} * (QF_{fa})^{-\rho_a^{va}} \quad (4)$$

$$QF_{fa} = \alpha_{fa}^{van} * \left[\sum_{f' \in F} \delta_{ff'a}^{van} * QF_{f'a}^{-\rho_{fa}^{va}n}\right]^{\frac{1}{\rho_{fa}^{van}}} \quad (5)$$

$$W_{f'} * WFDIST_{f'a} = W_f * WFDIST_{fa} * QF_{fa} * \left[\sum_{f' \in F} \delta_{ff'a}^{van} * QF_{f'a}^{-\rho_{fa}^{van}}\right]^{-1} * \delta_{ff'a}^{van} * QF_{f'a}^{-\rho_{fa}^{van}-1} \quad (6)$$

$$QVA_a = iva_a * QA_a \quad (7)$$

$$QINT_a = inta_a \times QA_a \quad (8)$$

$$PA_a * (1 - ta_a) * QA_a = PVA_a * QVA_a + PINTA_a * QINTA_a \quad (9)$$

$$QXAC_{ac} = \theta_a * QA_a \quad (10)$$

$$PA_c = \sum_{c \epsilon C} * PXAC_{ac} * \theta_{ac} \quad (11)$$

$$QX_c = \alpha_c^{ac} * \left(\sum_{a \epsilon A} \delta_{ac}^{ac} * QXAC_{ac}^{-\rho_c^{ac}}\right)^{-\frac{1}{(\rho_c^{ac}-1)}} \quad (12)$$

$$PXAC_{ac} = PX_c * QX_c * \left(\sum_{a \epsilon A} \delta_{ac}^{ac} * QXAC_{ac}^{-\rho_c^{ac}}\right)^{-1} * \delta_{ac}^{ac} * (QXAC_{ac})^{\rho_c^{ac}-1} \quad (13)$$

$$PE_{cr} = pwe_{cr} * EXR - \sum_{c' \epsilon CT} * PQ_c * ice_c \quad (14)$$

$$QX_c = \alpha_c^t * \left[\sum_t \delta_{cr}^t * QE_{cr}^{\rho_c^t} + \left(1 - \sum_t \delta_{cr}^t\right) * QD_c^{\rho_c^t}\right]^{\frac{1}{\rho_c^t}} \quad (15)$$

$$\frac{QE_c}{QD_c} = \left(\frac{PE_c}{PD_c} * \frac{1 - \sum_t \delta_c^t}{\delta_c^t}\right)^{\frac{1}{\rho_c^t - 1}} \quad (16)$$

$$QX_c = QD_c + QE_c \quad (17)$$

$$PX_c * QX_c = PE_c * QE_c + PD_c * QD_c \quad (18)$$

$$PM_c = pwm_c * (1 + tm_c) * EXR + \sum_{c^t \epsilon CT} PQ_c * icm_c \quad (19)$$

$$QQ_c = \alpha_c^q * \left[\sum_t \delta_{ct}^q * QM_{ct}^{-\rho_{cr}^q} \left(1 - \sum_t \delta_{ct}^q\right) * QD_c^{-\rho_c^q}\right]^{-\frac{1}{\rho_c^q}} \quad (20)$$

$$\frac{QM_{ct}}{QD_c} = \left(\frac{PD_c}{PM_c} * \frac{\delta_c^q}{1 - \sum_t \delta_{ct}^q}\right)^{\frac{1}{1+\rho_c^q}} \quad (21)$$

$$QQ_c = QD_c + QM_c \quad (22)$$

$$PQ_c * (1 - tq_c) * QQ_c = PD_c * QD_c + \sum_t PM_{ct} * QM_{ct} \quad (23)$$

$$PQ_c * (1 - tq_c) * QQ_c = PD_c * QD_c + \sum_t PM_{ct} * QM_{ct} \quad (23)$$

$$cpi = \sum_t PQ_c * cwts_c \quad (24)$$

Institutional a incomes and domestic equations

$$YF_f = \sum_{a\epsilon A} WF_f * WFDIST_{fa} * QF_{fa} \quad (25)$$

$$YIF_{if} = shii_{if} * YF_f \quad (26)$$

$$YI_i = \sum_{f\epsilon F} YI_i + \sum_{i\epsilon INSDNG} TRII_{if} + trnsfr_{igov} * cpi + trnsfr_{irow} * EXR \quad (27)$$

$$TRII_{if} = shii_{if} * (1 - mps_i) * \left(1 - tins_{if}\right) * YI_i \quad (28)$$

$$EH_h = \left(1 - \sum_{i\epsilon INSDNG} shii_{ih}\right) * (1 - mps_h) * (1 - tins_h) * YI_h \quad (29)$$

$$PQ_c * QH_{ch} = PQ_c * \gamma_{ch}^m + \beta_{ch}^m * \left(EH_h - \sum_{c'} PQ_{c'} * \gamma_{c'h}^m\right) \quad (30)$$

$$QINV_c = LADJ * qinv_c \quad (31)$$

$$EG = \sum_{i\epsilon C} PQ_c * QG_c + \sum_{i\epsilon INSDNG} trnsfr_{igov} * cpi \quad (32)$$

$$YG = \sum_{i \epsilon INSDNG} tins_i * YI_i + \sum_{i \epsilon F} tf_f * YF_f + \sum_{a \epsilon A} tva_\alpha * PVA_\alpha + QVA_\alpha + \sum_{i \epsilon A} ta_\alpha PA_\alpha * QA_\alpha + \sum_{c \epsilon CMNR} tm_c * pwm_c * QM_c * EXR + \sum_{c \epsilon CE} te_c * pwe_c * QE_c\, EXR + \sum_{c \epsilon C} tq_c * PQ_c * QQ_c + \sum_{f \epsilon F} YF_{govf} * trnsfr_{govrow} * EXR \quad (33)$$

System constraints and macroeconomic closures

$$QQ_c = \sum_{\alpha \epsilon A} QINT_{ac} + \sum_{h \epsilon h} QH_{ch} + qg_c + QINV_c + qdst_c \quad (34)$$

$$\sum_{\alpha \epsilon A} QF_{fa} = QFS_f \quad (35)$$

$$YG = EG + GSAV \quad (36)$$

$$\sum_{tc \epsilon CMN} pwm_c * QM_{cr} = \sum_{tc \epsilon CEN} pwe_{ct} * QE_c + \sum_{i \epsilon INSD} trnsfr_{ct} * fsav \quad (37)$$

$$\sum_{tc \epsilon CMN} mps_i * (1 - \overline{tins_i}) * YI_i + GSAV + EXR * fsav = \sum_{c \epsilon C} PQ_c * QINV_c + \sum_{c \epsilon C} PQ_c * qdst_c \quad (38)$$

$$AWF_{ft}^a = \sum_a \left[\left(\frac{QF_{fat}}{\sum_{a'} QF_{fa't}} \right) * WF_{ft} * wfdist_{fat} \right] \quad (39)$$

$$\eta_{fat}^a = \left(\frac{QF_{fat}}{\sum_{a'} QF_{fa't}} \right) * \left[\beta^\alpha \left(\frac{WF_{ft} * wfdist_{fat}}{AWF_{ft}^a} - 1 \right) + 1 \right] \quad (40)$$

$$\Delta K_{fat}^a = \eta_{fat}^a * \left(\frac{\sum_c PQ_{ct} * qinv_{ct}}{PK_{ft}} \right) \quad (41)$$

$$PK_{ft} = \sum_c PQ_{ct} * \frac{qinv_a}{\sum_{c'} qinv_{ct}} \quad (42)$$

$$QF_{fat+1} = QF_{fat} * \left(1 + \frac{\Delta K_{fat}^a}{QF_{fat}} - vf \right) \quad (43)$$

$$QFS_{ft+1} = QFS_{ft} * \left(1 + \frac{\sum_a K_{fat}}{QFS_{ft}} - vf \right) \quad (44)$$

Appendix B: S U R V E Y I N F O R M A T I O N

REGION: …… ☐☐ DISTRICT:…… ☐☐	LOCALITY: …….. ……
CLUSTER: …… ☐☐☐☐ HOUSEHOLD: ……. ☐☐	NAME OF HEAD OF HOUSEHOLD: ……..……..
ECOLOGICAL ZONE: …… ☐ GPS COORDINATES: ☐☐	HOUSEHOLD CONTACT(S): ……..……2……
	DATE: ☐☐☐☐☐☐☐☐
	Start Time:……

SECTION 1: HOUSEHOLD ROSTER. THESE QUESTIONS ARE FOR IDENTIFYING HOUSEHOLD MEMBERS

SEX Male.....1 Female..2	2 How old is NAME in completed years?	Has (NAME) ever attended school? Yes.....1 No.....2	What is the highest level of education (NAME) has attained? None.....0 Kindergarten..1 Primary.....2 JSS/JHS.....3 SSS/SHS/Voc/ Tech/Comm...4 Tertiary …..5	Number of years of schooling	12 YEARS OR OLDER				10 What is (NAME'S) religious denomination? No religion.....1 Catholic.....2 Protestant.....3 Islam.....6 Traditionalist.…..7 Other (specify)….9	To which ethnic group does (NAME) belong?	Housing arrangement /ownership Owner occupied…1 Family house…2 Rented house…3 Living with someone…4
					Can (NAME) read a phrase/ sentence in English or French? **(SHOW FLASHCARD)** Yes, English...1 Yes, French…2 Yes, both……3 No.....4	What is (NAME'S) present marital status? Married.....1 Consensual Union..2 Separated/Divorced.....3 Widowed.....4 Never Married....5	Household size	Number of years of farming			

SECTION 2: ECONOMIC ACTIVITY: CURRENT ECONOMIC ACTIVITY STATUS AND TIME USE OF SECONDARY JOB

WAGE/SALARY		DOMESTIC WORK		FARM ENTERPRISE			VOLUNTARY WORK	
2 During the past 7 days, did [NAME] work for a wage, salary, commission, or other pay (incl. in kind) for someone who is not a member of your household (e.g. an enterprise, the government, another individual), for at least an hour? **INCLUDE 'BY DAY' WORK** YES.....1 NO……2 (>>Q4)	3 During the past 7 days, how many hours did [NAME] work for a wage/salary? **NOTE: EXCLUDE** **I. HOURS PAID FOR BUT NOT WORKED** **II. MEAL BREAK** **III. COMMUTING TIME** HOURS	4 During the past 7 days, did [NAME] work as a domestic worker for a wage, salary, commission or any payment in cash or in kind for someone who is a member of your household, for at least an hour? **INCLUDE 'BY DAY' WORK** YES……...1 No……2 (>>Q6)	5 During the past 7 days, how many hours did [NAME] work for a wage/salary? HOURS	6 During the past 7 days, did [NAME] work on a farm owned or rented by a member of your household, either in cultivating crops or in other farming tasks, such as raising livestock or fishing, for at least an hour? YES……..…1 NO…….....2 (>>Q9)	7 During the past 7 days, how many hours has [NAME] done on this farm or other agricultural work for the household? HOURS	8 Are the products obtained from this activity on the farm mainly intended for sale or barter or family use? Only for sale/barter……1 Mainly for sale/barter but some for own/ family use….....2 Mainly for own/family use but some for sale/barter……..3 Only for own/family use….4	19 During the past 7 days, did [NAME] do any voluntary work for someone who is not a member of [NAME's] household, without any pay for at least one hour? Yes…….....1 No…….2 (>>Q21)	20 During the past 7 days, how many hours did [NAME] work on this activity? HOURS

continued

NON-FARM ENTERPRISE			FAMILY HELP IN NON-FARM ENTERPRISE			NON PRODUCTIVE AGRIC		APPRENTICESHIP WORK	
9 During the past 7 days, did [NAME] run/manage a non-farm enterprise of any size owned by the household for at least an hour? *Examples: trader, shop-keeper, barber, dressmaker, carpenter or taxi driver* Yes….1 No…..2 (>>Q12)	10 During the past 7 days, how many hours have [NAME] worked in the non-farm enterprise? HOURS	11 Are the products/services obtained from this activity on the non-farm enterprise mainly intended for sale or barter or use by the household? Only for sale/barter..1 Mainly for sale/barter but some for own/ family use...2 Mainly for own/family use but some for sale/barter…….3 Only for own/family use…….4	12 During the past 7 days, did [NAME] help/work in a non-farm enterprise of any size owned by someone in the household, for at least an hour? Yes……...1 No.....2 (>>Q15)	13 During the past 7 days, how many hours did [NAME] help/work in the non-farm enterprise? HOURS	14 Are the products/services obtained from this activity on the non-farm enterprise mainly intended for sale or barter or use by the household? Only for sale/barter……1 Mainly for sale/barter but some for own/ family use……...2 Mainly for own/family use but some for sale/barter…3 Only for own/family use…….4	15 During the past 7 days, did [NAME] catch fish, prawns, wildlife or collect any other food for sale or own use for at least one hour? Yes, mainly or only for sale/barter……1 Yes, mainly or only for own/household use……..….2 No……..…3 (>>Q17)	16 During the past 7 days, how many hours did [NAME] do this activity? HOURS	17 During the past 7 days, did [NAME] work as an apprentice even if it was for at least one hour? **(PROBE)** Yes, received pay..1 Yes, had to pay…..2 Yes, did not receive pay and did not pay…3 No……..…..4 (>>Q19)	18 During the past 7 days, how many hours did [NAME] work as an apprentice? HOURS

6	8		9
The sector of (NAMS's) main secondary job?	How much is (NAME's) payment for this secondary job? IF NAME HAS NOT YET BEEN PAID ASK: What payment does (NAME) expect? What time does this payment cover? **(MOST RECENT)**		Does (NAME) receive any payment for this work in the form of goods and services?
	AMOUNT GH¢	TIME UNIT **TIME UNIT** Hour.....1 Day.....2 weeks.....3 Two weeks...4 Months.....5 Quarter……6 Half Year.....7 Year…….8	Yes.....1 No.....2 (>> 11)

continued

Continued

1	2	3	4	5	Whom did you mainly do this for?	Location At
During the past 7 days, what were your total hours of work in your economic activities?	**THE TOTAL NUMBER OF HOURS IS:** Less than 40 hrs……1 40 hrs or more…….2 (>> 5)	Was (NAME) available for additional hours of work in the past seven days? Yes……1 No……2	Was (NAME) willing to work for additional hours in the past seven days? Yes……1 No……2	How many hours would (NAME) have liked to work during the past week?	Self …1 Household…2 Work…3 Friend..4 Charity..5 Community…6 Child…7 Other (specify)...8	home…1 Someone's house…2 School, college…3 Workplace…4 Other…5 Travelling/ moving…6
	Less than 40 hrs……1 40 hrs or more…….2 (>> 5)	Yes……1 No……..2	Yes…….1 No……..2 (>> 6)			

9	10	12	13	12	13	14
Did you spend any time during the day looking after children? Yes….1 No…...2 (>>Q12)	During the past 7 days, how many hours has [NAME] looked after children? HOURS	Did you spend any time during the day taking care of adult persons? Yes……..1 No.....2 (>>Q15)	During the past 7 days, how many hours did [NAME] take care of an adult person? HOURS	Did you spend any time during the day taking care of a sick person/s? Yes……...1 No.....2 (>>Q15)	During the past 7 days, how many hours did [NAME] take care of sick person/s? HOURS	Was yesterday a typical day for you? Only for sale/barter……1 Mainly for sale/barter but some for own/ family use……...2 Mainly for own/family use but some for sale/barter…3 Only for own/family use…….4

SECTION 3: ACCESS TO INFORMATION AND OTHER SERVICES

1 Does (NAME) own a computer (desktop, laptop, tablet or similar (not GSM)? (**MULTIPLE RESPONSES)** Yes.....1 No.....2	2 Has (NAME) used a computer (desktop, laptop, tablet or similar (not GSM) from any location in the past three months? Yes.....1 No.....2	3 Does (NAME) own a mobile phone? Yes.....1 (>> 5) No.....2	4a Have you used a mobile phone (including GSM tablets) in the past three months? Yes.....1 No.....2	4 Does (NAME) have access to the internet from any location in the past 3 months? Yes.....1 No.....2 (>> 5)	5 Has (NAME) used the internet from any location in the past 3 months?? **SELECT ALL THAT APPLY** Yes on mobile phone/tablet…..1 Yes on a computer at home……..2 Yes on a computer at the workplace/school…3 Yes at Internet Café/Youth centre/ICT……..4 Other (specify)….5	6 Does (NAME) participate/have participated in agricultural training? Yes.....1 No.....2	7 Does (NAME) have access to market information services? Yes.....1 No.....2	8 Does (NAME) have access to community information services?? Yes.....1 No.....2	9 Does (NAME) have access to extension services?? Yes.....1 No.....2	Does NAME have accessible roads to the various farmlands? Yes.....1 No.....2	10 Does (NAME) have access to information on output price?? Yes.....1 No.....2	11 The average number of neighbours engaged in CSA practices NUMBER

SECTION 4: AGRICULTURE LAND, LIVESTOCK, EQUIPMENT AND ASSETS

What is the size of your farm? HECTARES	5 Is the farm owned by the Holder? Yes, with deed…..….1 Yes, without deed……...2 No…….…3 (>> 8)	6 Does the holder have the right to sell the farm or use it as collateral security? Sell…….1 Security…..2 Both……...3 No right….4(>> 8)	8 How did (HOLDER) obtain the land? Bought……..…1 Rented for cash or in-kind……...2 Sharecropped by h/hold……...3 Use free of charge…4 Distributed by village/family…..…5 Inherited……6>>11

continued

Type of Crop	Maize	Millet	Sorghum	Rice	Other cereals	Yam	Cassava	potato	Other tubes	Pepper	Garden eggs	okra	tomato	Other vegetables	cocoa	coffee	Other cash crops	Pineapple	Watermelon
Quantity (in bags)																			
The amount realized in the Previous Season (GH cedis)																			

6 What was the main outlet of sale? Pre-harvest contractor…...1 Farm gate buyer…….2 Market trader…….3 Consumer……..4 State trading organ……..5 Coop…….6 Other (specify)…….....7	8 What was the value of the sales through this outlet? VALUE (GH¢)	9 How promptly were you paid? Paid before harvest…..…...1 At the time of. Sale.....2 Within 1 week of the sale…...3 Within 1 month of the sale…...4 Over 1 month…….5	11 Apart from the main outlet, what value did (HOLDER) sell through other outlets? VALUE (GH¢)	Has any member of the household owned any livestock or engaged in fishing/fish farming activities during the past 12 months? Yes……...1 No……2

31. Has any member of the household owned any agricultural equipment in th[ ]12 months? Yes….1 No…2

TYPE OF AGRICULTURE EQUIPMENT/IMPLEMENT	Tractor	Plough	harvester	Animal drawn equipment	Spraying machine	Irrigation
Does any member of the household own any……? No.....0 Yes.....1						
What would be the total value of … if it/they were sold now? in GhC						

SECTION 5: FIELD PRACTICES, INPUTS AND EXPENSES OF CLIMATE-SMART AGRICULTURE

Climate-smart agriculture practices	Does NAME practice.....? Yes …1 No…0	How many times does NAME do/use…..?	How much was spent in cash and in kind on…..? Amount in GH¢	What proportion of …does NAME practice on the farm?	Is …… … obtainable in this community any time during the year when you needed it? Yes….1 No…..2
Improved certified seed					
Improved planting materials					
Seed dibbling					
Broadcasting					
Row planting					
Transplanting					
Sow at stake					
Manure for fertilizing					
Inorganic fertilizers					
Pesticide/insecticide					
Selective herbicide/weedicide					
Irrigation					
Crop diversification					
Agroforestry					

SECTION 6: INPUT DELIVERY SYSTEM AND CONTRACT PREFERENCES OF FARMERS

Does NAME have a sale/harvest based on a preharvest contract? Yes …1 No…0	Did a buyer contract the household to grow the crop?	Is there any land owned by the household, but rented out or sharecropped	What is the area of land rented out or sharecropped to another household	The agreed upon is…for CSA practices Money…1 Inputs….2	Who does NAME normally sign the contract with? Wholesaler 1 Industry 2 Market queen 3 Other 4	Which part of the harvest is covered by the contract? 0 1 Less than 1/2 2 About ½ 3 More than 1/2 4 All 5	Is the price settled before or after the harvest? Before 1 After 2	what was the source of seed used in the last major season? 1- All from own harvest or gifts 2- All purchased or bartered 3- Some own harvest or gifts, some	Imagine you have a choice between the following two options: OPTION 1: You receive a small CSA package. OPTION 2: You receive a large CSA package.	How much did your household pay for seed/ CSA practices that was purchased and planted in the last major season?	Was any seed or fertilizer or pesticide provided on credit to this household for this crop? 1- Yes, seed 2- Yes, fertilizer	What proportion of farms does NAME use CSA inputs? Less than 1/2 1 About ½ 2 More than 1/2 3 All 4

								purchased or bartered	Which option do you prefer?		3- Yes, pesticide 4- No	

SECTION 7: FINANCIAL INCLUSION

1 Does NAME have access to a formal financial institution? Yes …1 No…0	2 Does (NAME) have a bank account or is contributing to a loan/savings scheme? Yes…….1 No……...2	3 Does NAME use a formal bank account? Yes …1 No…0	4 Does NAME have mobile money account? Yes …1 No…0	5 Does NAME receive mobile payments? Yes …1 No…0	6 Does NAME apply for a loan? Yes …1 No…0	7 Do you have an insurance policy/cover? Yes.....1 No.....0

Continued

8 Is there anyone else who is/ is not a household member to whom this household has sent money or goods in the past 12 months outside this household? Yes ……1 No ……..2 (>>skip)	10 During the past 12 months, has this household received or collected money or goods from any other individual? Yes, cash…….1 Yes, goods……..2 Yes, both cash/goods..3 No ……4	12 What was the total amount of cash this household received from this individual during the past 12 months? AMOUNT (GH¢)	13 What was the total value of food received from this individual during the past 12 months? VALUE (GH¢)	What was the value of other goods (non-food items) received from this individual during the past 12 months? VALUE (GH¢)

SECTION 8: WELFARE HOUSEHOLD EXPENDITURE (FOOD AND NON-FOOD ITEMS)

Item	Was anything spent by the HH on …… for the last 7 days? 0.no 1. yes	How much was spent on … for the last 7 days altogether? (Total in GH cedis)
Cereals and bread		
Meat: live, fresh, frozen, processed		
Poultry		
Fish: fresh, dried, fried		
Milk and milk products		
Eggs		
Oil and fats		
Fruits, fresh or canned		
Vegetables including potatoes and other tuber vegetables		
Sugar, jam, honey, syrups, chocolate and confectionery		
Food products not elsewhere classified - - *condiments and spices*		
Starchy staples		
Pulses and nuts		
Processed starchy staples		
Non-alcoholic beverages - - coffee, tea and cocoa		
Minerals waters, soft drinks and juices		
Alcoholic beverages, tobacco and narcotics - -spirits		
Wine		
Beer		
Tobacco		
Housing, water, electricity, gas and other fuels - - - other services relating to the dwellings		
Solid fuels		
Ice		
Furnishing, household equipment and routine maintenance - - non-durable household goods		
Non-durable products, appliances and equipment		
Health - - medical products, appliances and equipment		
Transport - - fuels and lubricants (household use and private cars)		

Maintenance, repair and other services		
Passenger transport by rail		
Passenger transport by road		
Passenger transport by sea and inland waterway		
Other purchased transport services		
Communications - - postal and telecommunication services		
Recreation and culture - - games of change		
Books		
Newspapers and periodicals		
Hotels, café and restaurants - - restaurants, café, take-aways and the like		
Canteens (workers/universities and schools canteen)		
Miscellaneous goods and services - - hairdressing salons and personal grooming establishments		
Appliances, articles and products for personal care		

Appendix C: Correlation Matrix of Objectives Two and Three

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1. csa	1.000																
2.preference	-0.007	1.000															
3.rental	0.099	0.073	1.000														
4.input	-0.051	-0.049	0.046	1.000													
5.commit	0.016	0.006	-0.129	-0.142	1.000												
6.age	0.044	-0.066	-0.083	0.030	0.031	1.000											
7.sex	-0.017	-0.244	0.009	-0.072	-0.003	0.139	1.000										
8.farmsize	0.162	0.175	0.195	0.059	0.032	0.004	-0.216	1.000									
9.farmgroup	-0.120	0.034	0.024	-0.017	0.051	-0.066	0.001	0.052	1.000								
10.maritat	-0.043	-0.146	0.001	-0.117	0.048	0.174	0.670	-0.151	0.044	1.000							
11.mkt_dist	-0.011	0.053	0.060	0.061	0.012	-0.020	-0.094	0.068	-0.009	-0.043	1.000						
12.farmdist	0.002	-0.064	0.007	-0.059	-0.027	-0.057	0.068	0.124	0.097	0.083	-0.067	1.000					
13.formallender	0.080	-0.077	-0.166	0.066	0.054	0.030	-0.032	-0.055	-0.029	-0.037	0.043	-0.090	1.000				
14.education	-0.044	0.038	0.071	0.050	0.063	0.110	0.025	0.073	0.010	0.027	-0.052	0.009	-0.011	1.000			
15.agricinfor	0.049	-0.062	-0.108	0.073	0.081	-0.089	0.004	-0.006	0.099	0.055	-0.015	0.059	0.174	-0.072	1.000		
16.MM	-0.037	-0.118	-0.065	0.090	0.117	-0.030	-0.003	-0.023	0.007	-0.003	0.014	-0.081	0.512	-0.002	0.222	1.000	
17.informallender	0.020	-0.101	-0.043	0.105	-0.007	-0.092	0.013	-0.013	0.002	-0.061	0.011	-0.067	0.418	-0.004	0.213	0.372	1.000