

UNIVERSITY FOR DEVELOPMENT STUDIES

IMPACT OF CONSERVATION AGRICULTURE TECHNOLOGY ADOPTION ON
SMALLHOLDER INCOME AND FOOD SECURITY IN THE UPPER EAST REGION OF
GHANA

SOLOMON DERY BOTEE

(UDS/MEC/0006/20)

2024



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THESIS SUBMITTED TO THE DEPARTMENT OF AGRICULTURAL AND FOOD
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REQUIREMENT FOR THE AWARD OF MASTER OF PHILOSOPHY DEGREE IN

AGRICULTURAL ECONOMICS

JULY, 2024



DECLARATION

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

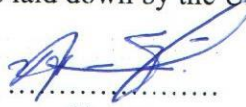
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ID: (UDS/MEC/0006/20)


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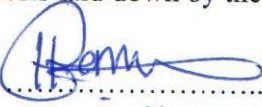
Professor Joseph Agebase Awuni
(Principal Supervisor)


.....
Signature

21-07-2025
.....
Date

I hereby declare that the preparation and presentation of the thesis was supervised following the guidelines on supervision of thesis laid down by the University for Development Studies.

Name: Dr Abdul-Hanan Abdallah
(Co-Supervisor)


.....
Signature

04/08/2025
.....
Date

I hereby declare that the preparation and presentation of the thesis was supervised following the guidelines on supervision of thesis laid down by the University for Development Studies.

Professor. Benjamin Anang-Tettey
(Head of Department)


.....
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ABSTRACT

Technology adoption has been low in developing countries due to the cost, but also because people prefer to wait and observe the benefits and risks before adopting. For the most part, Conservation Agriculture Technologies (CAT) are noted for promoting sustainable agriculture by preserving the soil and also mitigating climate change effects. For this reason, CA technology has gained global recognition and recommendations for increasing farm productivity and has the potential to help in the achievement of the Sustainable Development Goals, particularly goals 1, 2, 12 and 13. Yet empirical studies examining the impact of CA technologies on the livelihood outcomes of smallholder farmers are limited despite the policy relevance of such studies in Africa. This study therefore examines the factors that could account for the adoption of CA technologies and its potential impact on the incomes and food security of smallholder farmers in the Upper East region of Ghana. The study used cross-sectional data from 471 farmers selected through a multi-stage sampling technique. The data analysis was done using the multinomial endogenous switching regression with selectivity correction. The results showed that variables such as farm distance, plot size, credit access, durable assets, household size, CAT training, and distance to the district MoFA offices have a significant impact on smallholder adoption decisions. The results suggest that farmers who adopt single practices tend to experience low incomes. For those who adopted only zero tillage ($Z_1R_0C_0$), only crop rotation ($Z_0R_1C_0$), and cover cropping only ($Z_0R_0C_1$), incomes dropped significantly per hectare respectively for all single adoption. However, the adoption of multiple practices showed an average decrease in household income for ($Z_1R_1C_0$) and ($Z_0R_1C_1$) compared to the single adoption. Results for ($Z_1R_0C_1$) paired reveal increased income per hectare. In terms of food security, the results show that adoption of both single and multiple practices increases the dietary diversity of score households. Results of Average Treatment Effect on the Treated (ATT) reveal an increase in annual farm household income per hectare as well as increased dietary diversity score points for ($Z_1R_1C_1$) respectively relative to non-adopters. The study recommends the adoption of multiple conservation practices as it increases the returns to adoption in terms of income and food diversity. Policymakers must therefore retool the district Extension agents to intensify the campaign on conservation agricultural practices to ensure that farmers adopt multiple packages that promote sustainability, food safety, and long-term overall benefits to the farmer and society.



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DEDICATION

This work is dedicated to my immediate family especially my beloved wife Mary-Magdalene Samari, the children, Jordan, Kylian and Thelma for their love, support and understanding shown me right from the beginning to the end of this thesis. To my first siblings Roland Botee, Samson Botee and Enock Botee. I forever remain internally grateful for your support and prayers throughout my academic journey.



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ACRONYMS

ARMS:	Agricultural Research Management Survey
ATT:	Average Treatment on the Treated
ATU:	Average Treatment of the Untreated
AIS:	Agriculture Innovation System
AUC:	African Union Commission
CAT:	Conservation Agriculture Technology
CSA:	Climate-Smart Agriculture
CSIR:	Council for Scientific and Industrial Research
CRI	Crop Research Institute
CNTA:	Center for No-Tillage Agriculture
DFID:	Department for International Development
DANIDA:	Danish International Development Agency
EA:	Enumeration Area
ECA:	Economic Commission for Africa
ESR:	Endogenous Switching Regression
FANTA:	Food and Nutrition Technical Assistance
FAO:	Food and Agriculture Organization
GDP:	Gross Domestic Product
GMA:	Ghana Meteorological Agency
GOG:	Government of Ghana
GSS:	Ghana Statistical Service
GACS:	Ghana Agriculture Census Survey
GASIP:	Ghana Agricultural Sector Investment Program



HFCS:	Household Food Consumption Score
HDDS:	Household Dietary Diversity Score
HLPE:	High Level Panel of Experts
IFAD:	International Fund for Agricultural Development
IFPRI:	International Food Policy Research Institute
IFC:	International Finance Corporation
IDT:	Innovation Diffusion Theory
MNL:	Multinomial Logit
MoFA:	Ministry of Food and Agriculture
MoFA-SRID:	Ministry of Food and Agriculture- Statistics, Research and Information Directorate.
MESR:	Multinomial Endogenous Switching Regression
RUM:	Random Utility Model
SSA:	Sub-Saharan Africa
SARI:	Savanna Agriculture Research Institute
SRI	Soil Research Institute
TLU:	Tropical Livestock Units
UN:	United Nations
USDA:	United States Department of Agriculture
UNDP:	United Nation Development Programme
USAID:	United States Agency for International Development
WB:	World Bank
WFP:	World Food Programme
WHO:	World Health Organization

CHAPTER ONE

INTRODUCTION

1.1 Background

The recent decline in food crop productivity across sub-Saharan Africa (SSA) have largely been caused by climate variability leading to long periods of dry spell, rising temperatures, and droughts which are unfavorable to most crops. The situation has ignited policy debates about the role of conservation agriculture technology adoption in countering the effect of the changing weather. It is also revealed that over 85% of farmers, mostly smallholders, rely on traditional farming practices with minimal soil disturbance (FAO, 2016). This according to data from the Food and Agriculture Organization (FAO), accounts for the modest gains in crop production (FAOSTAT, 2020). This suggest that a wide spread adoption of conservation agriculture practices could reverse the current decline in food production.

According to the FAO (2013), smallholders are small farm managers constituted by crop farmers, fishers, pastoralist, forest keepers and operating in a defined piece of land from less than 1 hectare to 10 hectares (FAO, 2013). Family-based smallholder farmers are characterized by family focused on management and maintenance of the household unit with assistance from primarily own family labor to harvest crops and use part of their own farm output (FAO, 2013). The term smallholder farming for Ghana in some way covers the poor resource farmers, resource constraint in terms of available low capital and animals, accessibility to inputs, and land size holding (Andersen & D'Souza, 2012; Chamberlin, 2007).

Even though, the elusive smallholder definition is harder to quantify qualitatively and precisely, definitions continue to be elusive in finding in the literature a working definition to apply in Ghana and globally (Chamberlin, 2007). To have focal thematic domains entails landholding scale, wealth status, direction of market and level of risk exposure (Chamberlin,



2007). Ghana's Budget for the Medium-Term Expenditure Framework Program of the Ministry of Food and Agriculture 2024–2027 states that Ghana agriculture is predominantly smallholder scale and that farm-owning farmers produce approximately 90% of less than 2 hectares of land (MoFA, 2024). The smallholder farmers were by this study characterized as encompassing all categories of crop-producing households ranging from food to cash crops and livestock. This is important as the farmer's choice of CA technology they undertook are directly resulting from the type of group formed (FAO, 2020a).

But food production growth in SSA nations like, Nigeria, Kenya, and Ethiopia are far below their population growth rate, and there are no exceptions to Ghana's situation, constituting a threat to food security (OECD-FAO, 2016). It is caused, to some extent, by traditional methods of production and ineffective managerial practices by smallholder farmers (Chauvin et al., 2012). Traditional farming, while productive to some degree, also brings about soil erosion and decline in its productivity over time (Knowler and Bradshaw, 2007). Human interventions, the soil type, climate, management, and all other interventions only worsen the problems (Hoque et al., 2017; Gupta et al., 2019).

Addressing the failures of traditional agricultural technology practices calls for conservation agriculture technology adoption which has become the most favored option. Conservation agriculture technology adoption involves soil erosion prevention and accumulation of soil organic matter in the soil as core agendas towards achieving sustainable crop production compared to conventional agriculture (Polidoro et al., 2021; Sousa et al., 2020). All of the three low-cost CAT concepts of least soil tillage, Small-scale farmers can benefit from practices like soil surface cover and crop rotation, making these techniques accessible to them. (Thierfelder et al., 2013).



There is proof that CA technology uses increases smallholder farmers' production and income as well as reduces working hours (Byamungu, 2018; Brown et al., 2021; Selvakumar & Sivakumar, 2021; Jatz et al., 2020). In an attempt to conserve our resources, we have been encouraging the application of conservation farming practices. Environmentally founded and stimulating CAT practices enhanced agricultural productivity (Kassam et al., 2009). Low-tillage CA technology systems improve water infiltration and anti-water loss, thus improving the quality of the soil (Derpsch et al., 2014; Thierfelder et al., 2009).

The development of policies to promote CA technology acceptance and scaling in Ghana and elsewhere becomes more feasible when researchers understand farmers' adoption attitudes and CA technology's effects on livelihood outcomes like income and food security (Derpsch et al., 2014). Hence, soil degradation and erosion prevention through the implementation of soil conservation practices, including CA technology is crucial for enhancing and preserving agriculture productivity, farm income, and quality of food in agroecosystems (Bagheri et al., 2022).

1.2 Problem Statement

The UN's 2022 sustainability report uncovered several problems that are currently being faced globally today and the most prominent among them was the COVID-19 pandemic's effects, war, and weather-related disasters playing a paralyzing role on nutrition and food security, well-being, and learning. In its progress report on the action that has been taken where decades of work aimed at eliminating hunger and poverty have been erased and priorities of focus in attainment of the SDGs and making monumental progress, unprecedented by 2030 is achieved (progress report on the SDGs, 7 July 2022). The UN system's multilateral agencies also reported nearly 690–783 million people across the globe living in acute hunger in 2022—at a



mean of 122 million higher than before the covid-19 pandemic (WHO, UNICEF, FAO, IFAD, & WFP, 2023).

In addition, the 2017 African Union progress report of Accelerated Agricultural Development of the Malabo Statement of 2014 showed that Ghana and other Sub-Saharan African nations have to employ more percentage of lands that can be cultivated to implement conservation agriculture for the purpose of improving agricultural productivity (AU, 2018). Nevertheless, the levels of adoption are low since ignorance of applying the practice, poor infrastructure, and non-support by the government still dominate (Sun et al., 2020; Gyawaly & Karki, 2021).

Also, Ghana's annual household income and expenditure survey report revealed 15.1 million of Ghana's population of 30.8 million people or close to 49% of Ghana's population to be food insecure during Q1, of 2022, while a rough estimate of 50% of Ghana's population was food insecure (GSS, AHIE, 2022). Moreover, Economic Commission for Africa estimated Ghana's population growth between the years 2015 and 2025 to be 2.7% (Economics & Social Affairs Department, 2015), this disparity between population growth and food production needs to be addressed.

Despite Governments' and international agencies' efforts over the last four decades, unnormal climatic oscillations which are compounded by the severity of land degradation have been characterized in terms of crop loss to yield, fertility loss to soil and pasture loss to pastoralist in Bolgatanga (Yiran et al., 2012, 2022; 2013a; Owusu et al., 2013). Rain and climatic variability due to climate change, such as excess rain causing leaching from the topsoil and loss of soil nutrients, calls for the application of conservation agriculture technology (CAT) packages that are usually zero or reduced tillage, cover crop, and legume rotation to mitigate its impacts. The agricultural sector, the actual sector of an economy, directly contributes to the gross domestic product of most economies and sustains the livelihood of almost 2.5 billion



people across the globe (FAO, 2016). Despite all these efforts and contributions made by the sector, in the year 2020 alone, 690 million people across the globe went hungry with little to no food (FAO et al., 2020).

Ultimately, to address the problems described in underdeveloped countries like Ghana where food insecurity is also caused by other elements including climate change crises, smallholder farmers must use conservation agricultural technologies (CAT) in an attempt to improve agriculture productivity. This research aims to offer a more practical insight assessment of the effect of CA technology adoption on income and food security among smallholders in Ghana's Upper East region's where high poverty incidence and low technology/innovation penetration ratio (GSS, PHC 2021). Lastly, application of climate-resilient sustainable agriculture technology strengthens farmers' resilience to the impacts of climate change, productivity, income, and Safety of food and thus household well-being, in line with the SDG 1, 2, 12, & 13 targets by 2030 (Acheampong et al., 2022).

1.3 Research Questions

The research thus seeks to determine the extent to which the application of different CA technology options affects smallholder farm livelihoods in northern Ghana. This is particularly stated in the following research questions:

1. Factors that affect and hinder smallholder farmers in the Upper East region from implementing conservation agriculture technologies?
2. What is the response of the Upper East Region smallholder farmers in terms of Income and Food security to adopting conservation agricultural technology?



1.4 Research Aims

The overall research objective was to determine the impact of adopting CAT among farmers in Upper East region of Ghana, and specifically, by smallholder farm households on their livelihood. The research was supported by the following specific research objectives:

1. Quantify the factors influencing the adoption of farming technologies for conservation by smallholder farmers in the Upper East, Ghana.
2. Analyze how the adoption of conservation agriculture has affected income levels and diet quality of households in farming communities in the Upper East Region.

1.5 Rationale for the Study

The latest estimates indicate that approximately 20,000ha of Ghana's fertile lands, in the Upper East Region, are being encroached by desertification, and doubled once more in the most recent decades due to unsustainable anthropogenic activities (EPA, 2023). The Region is part of the Sudan savanna ecozone, where the land demand for agricultural production is immense, with more than 90% of farmers possessing less than 2ha (Yiran et al., 2022). Empirical evidence indicates that most smallholder farmers rely on land for survival (Atubiga and Atubiga, 2022). However, land degradation adds to these smallholder farmers' vulnerability index in the Upper East Region (Owusu, 2012). As such, adoption of conservation agricultural technology in a bid to preserve arable land for cultivation is a relevant issue for this research. Sustainable solutions aim at promoting conservation agriculture technology adoption to meet carbon sequestration needs which support climate-smart agriculture as it addresses smallholder farmers' needs during climate change adaptation and food security efforts (Kassam et al., 2021). Rural farming households and communities can expand their farm land use capacities through conservation agriculture techniques (Kassam et al., 2021).



Smallholder farmers have not, in general, taken up conservation agriculture technology at levels that are considerable (Derpsch 2005; Garcia-Torres et al. 2003; Fowler & Rockstrom 2001; Hobbs 2006). The study looks to establish the necessity to assist smallholder farmers' production, since the Upper East region of Ghana is where considerable poverty rates of about 58% and low rates of technology adoption are recorded between 30% and 40% (GSS, 2021). This research demonstrates how CAT adoption affects farm household incomes and food reserves which will address existing literature gaps and inform development policy and poverty reduction strategies.

1.6 Organization of the study

The study material is organized into five chapters. Background to the study, statement of the problem, and defining the purpose statement, research questions and the rationale and organizational framework, defining terms used in the research are addressed in Chapter One. The second Chapter examines the research topic through literature review concerning factors that influence adoption and characteristics of farmers who adopt conservation agricultural technology. Smallholder farmers are driven to adopt CA technology because of their demographic factors. The third chapter explains the research methodology used to conduct the study, for instance, study sample population, sample size, methodology, research location, sampling method and procedure, study instrument, and data collection. Chapter four contain data analysis, Results, and debate are presented. Last chapter comes with the summary, conclusions, and policy implications in Chapter five.



CHAPTER TWO

LITERATURE REVIEW

2.1 Chapter Outline

Literature review of this Chapter uses concepts and theories on the topic of research, i.e., effect of adoption of conservation agricultural technologies among smallholder farmers livelihoods (thereby annual household income and food self-sufficiency). Chapter two of literature review further expounds the right comprehension of CA technology adoption concepts according to available literature.

2.2 The Concept of Agriculture Technology Conservation

Adoption of conservation agriculture technology (CAT) is an integration of farming principles for sustainable land management. Three of the fundamental principles that are central to CA technology adoption are discussed by Corsi and Muminjanov (2019) as:

- (i). Minimum soil tillage, e.g., no-tillage, minimum-tillage, or direct seeding, and all of these are referred to as zero-tillage (ZT);
- (ii). Cover crops, residues, or intercrops as permanent soil cover to minimize erosion and enhance the soil's health; and
- (iii). Rotation cropping as a means to manage weeds, disease and pests.

More details, with examples relating to conservation agriculture technology usage ranging from minimum tillage to soil surface cover to legume-intercrop rotation, are available with CA approaches from Dorothy and Bernard (2019) cited from Kaumbutho and Kienzle (2007) and Bradshaw and Knowler (2007). It is therefore, proper for this scientific treatment that has accorded CA technology adoption with the term Unifying label, integrated agricultural water management practices to create efficiency in agricultural crop production, according to the



proclamation of some authors. In reference to the principles of CAT, Ferdinand and Baret (2021) Classified those in the category of permanent minimum soil disturbance, permanent residue covers with soils, and crop species diversity tested and used abroad and thus, standardized it as international CA technologies in order to be differentiated with the conventional farming systems. The term conservation agriculture technology, however, has been differently interpreted by scholars and organizations giving rise to differing definitions for its components (Ambler et al., 2020). Other practices, however, supplement the adoption and sustainability of CA technologies characterized primarily by their pillars; Scopel et al. (2013) and Hauswirth et al. (2015) note that it is this ease in adopting those pillars that enables the creation of diversified cropping systems to cater to local constraints and farmer needs.

Besides, CA technology includes no tillage, minimum tillage, and direct seeding practices in the field of farming (Erenstein, 2003; Erenstein et al., 2008b). No-tillage means the planting of crops in unploughed fields, while minimum tillage is restricted to accidental disturbances on tillage land to save them from degradation in performance (Kassam et al., 2009). Direct seeding avoids soil movement and keeps soil structure intact, thereby creating an approach toward sustainable agriculture (Vishal, 2021). Maintenance of soil cover through permanent or permanent cover plants and residue mulching should be counted as among the most crucial CAT (Conservation Agriculture Technologies) traits (Vishal, 2021). Minimum recommended mulching as a proper cover with cover crop ranges not less than 30% of the field for the proper control of soil erosion (FAO, 2017; FAO, 2020a; 2020b). Mulching refers to the application of organics or inorganic substance to the soil cover for agricultural production and soil health care for sustainable agriculture purposes (Kader et al., 2017a; Chakraborty et al., 2018).

Diversification in cropping system constitutes the third pillar of CA technology: it guarantees water use efficiency, minimization on pest and disease incidence, and enhancing soil fertility (FAO, 2014). To achieve this diversity, the application of crop rotation, cropping association,



and intercropping are utilized (FAO, 2020a; 2020b; Corsi & Muminjanov, 2019). Besides the management of soil erosion, conservation agriculture technology includes anti-compaction practices such as low-traffic and windbreaks to ensure soil structural stability and soil intactness (Corsi & Muminjanov, 2019). These practices in general, ensure the sustainability and longevities of the farming system operated under utilization of CA technology. Adoption of CA technology is generally a response to information-need for problem-solving in agricultural sustainability that involves concepts encompassing low disturbance to the soil, soil cover, as well as diversification between crops. Its applicability under varying agroecological conditions makes it a point of focus in combating the degradation of the environment and improving farm household agricultural efficiency.

2.2.1 International Perspective of Conservation Agriculture Technology

Conservation agriculture initially emerged as a measure against soil erosions in the USA, Brazil, Argentina, and Australia where it has been practiced on over one million hectares as of current information exists (Friedrich et al., 2012; Derpsch, 2005). Brazil has continued to be the best-known example of a successful conservation agriculture Programme that has been encouraged by farmers (Friedrich et al., 2012). Thereafter, the private and public sectors, research organizations, agricultural think tanks on food policy, farmer groups and networks, NGOs and civil societies, and volunteer associations joined to form innovative and dynamic mechanisms that actively contributed towards disseminating the technology (Friedrich et al., 2012; Derpsch, 2005). CA systems are applied on approximately 106 million hectares of cultivated land in the world each year, with no tillage (Derpsch, 2005). All these forms of sustainable agriculture remain to be standardized by Agri-development plans or supported by the necessary policies and institutions in the majority of countries except some countries



including Brazil, Argentina, Uruguay, Kazakhstan, China, Kenya, Tanzania, Lesotho, Malawi, the United States, Canada, Australia, and the Republic of South Africa.

In all, the extent of adoption under CA systems remains restricted: approximately 7% of the area planted with tillage (Derpsch, 2005; Friedrich et al., 2012). Yet, during the years 1990 to the current year, the net area that has augmented the use of technology under CA globally remains consistently at approximately 5.3 million hectares per year, mostly in the Americas, Australia, and New Zealand (Derpsch, 2005; Friedrich et al., 2012).

2.2.2 Conservation Agriculture Technology Overview in Ghana

Over the years, Ghana has witnessed the impacts of the contribution CA technologies on the production performance of the commodity and the need to harmonize other farm programs, particularly in the northern regions of the country towards the adoption of conservation agricultural technology (CAT) (Derpsch, 2005). Yet, no such programs are definitively effective to increase the adoption of technologies in CA, owing to infrequent evaluations. But soil erosion was challenging the Government's signature program Planting for Food and Jobs (PFJ) the most, and thus sustainable conservation of soil had to be promoted for crop cultivation (MoFA, 2020). Initiatives like Sasakawa Global 2000 during 1986-2003 in Ghana were focusing on improving utilization of improved seed varieties by small farmers and sustainable technology like zero tillage and minimizing burning of farm plots for effective crop production (Derpsch & Friedrich, 2009). Yet farmers continue to find it challenging to adopt these technologies (Derpsch & Friedrich, 2009).

Follow-up projects, for instance, the DANIDA-financed Savannah Resources Management Project, highlighted soil covering for long intervals and land stewardship. Establishment of the Toase-based Centre for No-Till Agriculture, CNTA, in the Ashanti region in Ghana also allowed for on-farm training of the farmers concerning CA innovations and witnessing its





advantage in soil organic nutrients on the farm. Extramural financing, for instance, the USAID Feed the Future Agricultural Technology Transfers, has been set up to bring CAT concepts to farmers with a specific focus on cover crops, intercropping, and residues to leave behind. This has been the case with the World Bank financed Sustainable Land and Water Management Project which has concentrated its attention on CA technology adoption by farmers with respect to land degradation and biodiversity loss. Within the national context, projects such as the Climate Change Resilience subcomponent of the Ghana Agricultural Sector Investment Program (GASIP) were to be devoted to climate change resilience awareness and collaboration to ensure the adoption of CA technology, through extension services reaching the smallholder farmer. GASIP promoted an extension strategy that has a strong educational component to farmer training on salient CA principles; those include minimum soil disturbances, continuous cover of soil, and rotation of crops.

Conservation Agriculture Technology (CAT) is known for its contribution to sustainable food systems, yet the level of adoption and intensity in Ghana and sub-Saharan Africa is woefully low (FAO, 2020a). This calls for further investments in farms into soil conservation measures, with the presence of the national plans and programs of the donor organizations. Filling the gap, nonetheless, must be done to enable CA techniques to be carried to the limit in increasing agricultural productivity and resilience in northern Ghana and the nations at large.

2.2.3 Historical Development of Conservation Agriculture Practices in Ghana

Farmers in Ghana experienced a devastating fire in 1983 that burned massive amounts of crops like cash crops including cocoa and oil palm plantations. This led to some of the farmers to abandon their farms. They thus also diverted their attention from these plantation crops such as oil palm and cocoa to that of food crops like plantain, maize, and cassava, and used the slash-and-burn technique and rotation farming in plowing the land as the primary land-preparation

technique (Boahen, 2002). Crop rotation was no longer cost-effective enough to sustain land fertility due to population growth and its resultant impact on the environment (Boahen et al, 2007). The adverse impacts of the use of the slash-and-burn practice began to be realized, with enhanced weed pressure, huge loss of nutrients in the soils, farm erosion, and general loss of productivity (Davies et al, 2014).

At first, this was possible with little pressure on land, and thus farmers could cultivate fertile land without an immediate danger of sustainability (Boahen et al., 2007). As the population expanded, the consequences of slash-and-burn on environmental impacts became increasingly apparent, and it became impossible to maintain soil fertility through changing cropping patterns. Effects like enhanced weed burden, loss of soil nutrients, erosion, and reduced productivity started to be seen (Boahen et al., 2007).

With the rising pressure on the demand for land, most farmers were forced out of their options with no choice but to abandon the old shifting cultivation technique. On the appeal by government to switch over to new methods, entities such as the SARI, C.R.I., and S.R.I. into agricultural research based in northern Ghana carried out on-farm demonstrations with some of the conservation agriculture technologies like minimum tillage, mulching, and cover crop utilization (Davies et al., 2014).

These CA techniques were first tested within experimental stations and then moved to on-farm plots for testing and possible roll out, with the overall goal being to identify replacement technologies that would be able to maintain high yields without exacerbating either the problems caused by soil fertility decline or environmental degradation (Davies et al., 2014).

The most widely used conservation agriculture technology practiced among the small-scale farmers in Ghana, according to Boahen et al (2005), include:

- Direct Planting



- Minimum Tillage
- Lane Cropping
- Cover Crops
- Crop Rotation
- Improved short-season fallow with leguminous cover crops,
- Permanent cover with plantation.

In these systems, plants' crops are cut with a machete or cutlass, rather than being burned to clear land. The biomass dries and becomes mulch and acts as a mulching material for direct maize planting. Planting labor is conducted by hand using a dibbler, a staff for planting, or cutlass, and for controlling weeds, hand-weeding using a cutlass or handheld hoe (Boahen et al., 2005).

With direct planting and minimum tillage, the soil is cut, and not more than 30cm of regrowth is maintained. The leftover is applied across the land surface before planting, ideally by a rich in protein maize variety (Boahen et al., 2005).

2.2.4 Study Operationalized Definition of Conservation Agriculture

The primary drawbacks of scientific studies on adoption are that focus on CA technology practices are not very well contextualized (Michler et al., 2019). As much as Global CA systems usually have three basic CAT pillars, they are used to a very large degree differently by place since farm methods vary and there are a number of various environmental and ecological specifics (Corbeels et al., 2014).

Therefore, in this research, the following three crucial constructs have been theoretically conceptualized to operationalize smallholder farmers' adoption of CA technology on a plot basis (FAO, 2011). (i) reducing soil loss through low to zero-tillage, (ii) retention of soil cover



via cover crops, crop residue management, intercropping and mulching, (iii) diversification through crop rotation/diversification. In this study, the CA technology working definition simply defines the research location as smallholder farmers who embrace or apply any one of the three CA technology pillars or principles outlined in this study.

2.3 Study Gap

Even though extensive portions of studies conducted within SSA nations has quantified the effect of CA technology adoption and employed diversified results variables such as labor demand, food security, agricultural production, and income for families including (Amondo et al., 2019; Marennya et al., 2020; Oduniyi & Chagwiza, 2021; Adam & Abdulai, 2022; Gebremariam & Wunscher, 2016; Manda et al., 2016; Teklewold et al., 2013b; Zakaria et al., 2019). These works such as Wudineh et al. (2023) quantified determinants of rural households' income diversification in Ethiopia's highlands. Boimah et al. (2018) expected CA impact on use of inputs and farm productivity in northern Ghana under minimum-tillage, maize-legume rotation and application of organic-inorganic fertilizers to maize monocrop utilizing three CA practices. Nevertheless, none of these studies determined the relationship between farm household crop sale incomes based on crops' production and food security implications of CA technology adoption. This research tied the three basic pillars/principles of adoption of CA technologies to family annual income in farm enterprise and food security of households applied not just to one crop as done by most authors in literature but to all principal staple crops including vegetables under research topics.

2.4 Theoretical and Conceptual Framework.

Adoption of technology in farming is necessitated by various reasons rooted in technology adopted as well as the overall socio-cultural as well as political environment. This study is



primarily based on conservation agriculture technology (CAT) theory of technology adoption underpinned by inventiveness of diffusion theory, (AIS) Agricultural Innovation System theory, (AHM) Agricultural Household Model, and (RUM) Random Utility Model.

The (IDT) Theory of Innovation Diffusion accommodates farm household decisions based on demographic traits such as age, marriage, number of family members, and schooling level. Random Utility Model (RUM) implies that farm household and CA technology adoption decisions are based on farm household goals and scarcity of resources. The RUM holds that consumers are rational and decision making are based on the grounds of anticipated utility.

Theory of (AIS) Agricultural Innovation System explains the determinants of farmers' technology adoption for cultivating crops as an external institutional and policy level.

Making use of the utility maximization theory to support the justification of the research, the study is concentrated on the choice of taking up one or a set of CA technology practices and farmers' adoption behavior is what is particularly aimed at for in the study. Random utility theory is used, referencing literature that is available in trying to find the theory of CA technology adoption among farm households. Farm households would adopt CA technology practice if the net benefit is more than zero according to random utility theory.

Using alternatives, households aim to maximize the utility of their spending decisions (Green, 2008). Agents using random utility theory are likely to select one from a set of options, which is defined as $C = \{C_1, \dots, C_m\}$. Let π stand for the Combination of $\{1, \dots, m\}$, which is a linear order $[C_\pi(1) \rightarrow C_\pi(2) \rightarrow \dots \rightarrow C_\pi(m)]$ by nature. A preference order distribution is produced by the linear order Random Utility $(X_1, \dots, X_m)$ as;

$$P_r(\pi/\theta') = P_r(X_\pi(1) > X_\pi(2) > \dots > X_\pi(m))$$

The fact that all the choice sets of every agent are mapped to an actual sequence of real numbers and they also monitor preference intensity as a benefit of cycle-free RUMs. Systematic and



painstaking (V_{im}) as well as error term components with randomness e_{im} , consider one, i , utility function as $U_{im} = V_{im} + e_{im}$

$V_{im} = X_{im} b_{im}$, where (V_{im}) is the systematic component and is a linear function of specified variables, such as individual or particular qualities.

$$U_{im} = X_{im} b_{im} + e_{im}$$

The person I select is m if $U_{im} > U_{ij} \forall j \neq m$. Given that alternative one's projected utility is higher than alternative Two's, there is a good chance that it will be selected. Written correctly in this order: C

Make forecasts of the chances that an otherwise randomly drawn farm family chooses one of these specific or alternate CA technology package choices, we distribute over the (e) into a multinomial Probit or logit estimate model. Ghanaian rural farm families, just like in any other developing nations, will think through a number of appropriate technologies impact to livelihood while choosing agricultural ventures. The choice will be made with an objective of attaining the highest anticipated usefulness for the family farm, as highlighted in a paper by Kassie et al (2015). The paper demonstrates that CA acceptance is based on net return and on maximizing expected utility.

The CA technology of interest, including low or zero tillage, residue retention, and rotation, is assumed to be utilized by these respondents as farm household heads. They would be categorized as non-adopters ($Z_0 R_0 C_0$) with no ZRC integrated and all other or full adopters ($Z_1 R_1 C_1$) with eight (8) combination of ZRC configurations if a farm household would expect socio-economic benefit given that the expected net benefit was under socioeconomic conditions and other farm level and farmers resources, socio-economic and institutional factors along with farm level circumstances, farmer resource endowment and other factors) suggesting that the potential farm household could have expected policy capture.



These factors are plausibly defined as (socioeconomic and institutional factors, farm-level circumstances, farmer resource endowment) indicating their capacity to adopt their policy choice along with maximal net returns. As a single resource constrained utility maximizing individual, farmer, I will adopt one CA practice of zero-tillage ($Z_1R_0C_0$) solo, crop rotation ($Z_0R_1C_0$) solo and cover cropping ($Z_0R_0C_1$) solo, or two CA combinations of zero-tillage and crop rotation ($Z_1R_1C_0$), cover cropping and crop rotation ($Z_0R_1C_1$), and reduced tillage with cover cropping ($Z_1R_0C_1$), and not incorporating any other CA ($Z_0R_0C_0$) which is the base category of all three CA package ($Z_1R_1C_1$) if probability $P=U_{iA}-U_{iN}>0$.

P is a latent factor for differential variance with respect to non-adoption (U_{iN}) and benefit from adoption (U_{iA}). According to Singh et al.'s (1986) neo-classical microeconomic model, farm household consumption and production in representative rural economies of least developed countries with imbalance between factor market and output. The theoretical framework of the study suggests that the use of Conservation Agriculture Technology (CAT) practices would increase the income and the level of food security of the farming family. Determining the variants that would cause the farmers to adopt the particularly CA technology by implication, to the livelihood level, including food independence and higher income, was the research focus.

This study incorporates CA technologies such as cover cropping, zero tillage, and crop rotation. Food autonomy of farmers at the household level and revenue from crops are likely to increase because of these conservation agricultural technologies that enhance collaboration among agricultural value chain actors. Implementation of CA technology has been predominantly centered on enhancing farm productivity for respective farming systems in Ghana (Ambler et al., 2020). Farmers will most likely ramp up the amount of farm output and redirect the food supply, beyond producing surpluses that would be sold in an attempt to complement the consumption of food variety (Nyikahadzoi et al., 2012; Mango et al., 2015).



This suggests that household dietary diversity can have a direct and significant impact of adopting CA technology, holding other factors constant. In addition, household diet can be indirectly improved through CA technology adoption by using the proceeds from selling surplus crop output to purchase additional inputs for future production. This research, therefore, also anticipates that the Food self-sufficiency and (HDDS) Household Dietary Diversity Score will be higher among CA technology adopters at the four research sites as an indicator of food stability among rural farm households.

The application of CA technology in this research implies that smallholder farmers' ability to implement CA practices is conditioned by a set of farm-level factors (shape, size, productivity), socio-economic and institutional factors, farmers' asset endowment, and environmental and biological issues (i.e., weather, rainfall patterns, and drought) as exogenous shocks. The study, based on this analysis has the presumption that farmers indeed receive information regarding CA procedures from extension agents, (FBOs) Farmer-Based Organizations, and by way of CA training and farm field demonstration but may not be able to apply it on farms what they learn through such training owing to uncertainty, risk considerations, and the time elapse for repeated adoption before productivity gains become evident. Farmers must be provided with information about CA approaches, but information alone will not suffice. Farm families will utilize their knowledge, skills, and embrace CA technology only if the projected returns far exceed the cost of adoption.

Finally, in the event that farmers have little knowledge to implement CA practices, they may as well suffer negative shocks in their early years of adoption, which would reduce production gains and undermine confidence in CA innovation and thus, may result in dis-adoption in subsequent years. CA technology adoption can be brought in by two channels: access to credit and training that farmer acquire in CA. First, CA training acquaints farmers with new knowledge of innovations, thus raising their awareness of CA practices and the uncertainty of



adoption. Second, availability of finance or credit to farmers would help them have resources to buy CA machinery like seeding machines, jabbers, and dibblers that are expensive, hence the expense of adopting the CA technology will be less than the gain.

If the fields of the farmers appear to be more favorable and productive due to the adoption of CA technology, farmers will be encouraged to adopt the practices, thereby increasing farm household incomes and food security. The conceptual model had assumed that these variables were potentially influencing farmers' adoption of conservation agricultural technology for a greater crop yield either directly or indirectly, while institutional variables and social networks served as intermediaries between the two channels.

2.5 Impact of CA Technologies Adoption Practices on Farm Household Income

Literature exists with empirical evidence that indicates yields can have a positive impact on Ghana's CA technology adoption, but only on experimental farms (Ambler, 2020; Erenstein, 2003). Smallholder farmers' main expectations for direct livelihood outcomes at the farm level are an increase in farm revenue and food security for rural households (Ngaiwi et al., 2022; Acheampong et al., 2022). In 2014, the contribution of Kunta Shula et al. research to the maize yield of the crop and farm household income by crop rotation/MT. From their study, although both methods optimized maize production, MT did not contribute to the increased gross income from crop sales of farmers in Zambia. Wekesah et al. (2019) concluded that income, workload, employment opportunities, health and risk, and household food security are increased among women as soon as they adopt CA technology.

Osewe et al. (2020) research approximated the household Demand for labor and net crop per capita of household income contribution to Tanzania's southern region's minimum-tillage (MT) welfare impacts. Based on their findings, per capita net crop household income was improved by minimum tillage and they added that decoupling household labor demand has been



substantial, enabling members of the family to engage in other non-farm activities for purposes of additional income and revenue generation. According to a study on the implementation of CA technology in South Africa by Oduniyi, Chagwiza & Wade (2022), farmers who simply practiced crop diversification reported an income improvement of 50.32%, or \$806.11 USD, and those who only practiced crop diversification with minimum tillage reported an income improvement of 46.01%, or \$593.62 USD. Additionally, there is a proof that farmers' income increased by 60.31% (\$996.88 USD) when they adopted minimum tillage and crop choice combined (Oduniyi, 2021; Chagwiza & Wade, 2022).

Smallholder maize farmers using CA techniques would have suffered losses in the counterfactual scenarios if they hadn't. For example, when Farmers didn't embrace some of the CA practices, e.g., Crop diversification and minimum tillage practices and farmers' income could have increased by (\$366.19 USD) if they had practiced only minimum tillage (Oduniyi, Chagwiza, & Wade, 2022). Again, farmers' incomes improved without reference to whether they practiced crop diversification. When treated independently or when separately combined with low tillage practices, crop diversification with minimum tillage increased agricultural income by a base of (\$430.90 USD) and (\$858.05 USD), respectively (Oduniyi, Chagwiza, & Wade, 2022). In Wordofa et al. (2021), the authors stated that higher adoption levels of agricultural technology practices methods in Eastern Ethiopia increased household income from agricultural production by a mean of \$824.42 USD per year per household. According to data presented by Oduniyi, Chagwiza, and Wade (2022), farmers who engaged in low tillage, diversification of crops, or a combination of both performed better than non-practitioners.

Issahaku and Abdulai (2020) and Abdulai and Huffman (2014) established very impressive growth rates of crops and reductions in poverty levels for the Ghanaian CA-technique-implementing farmers. But, meanwhile, Boimah et al. (2018) obtained no effect by the use of CA technology on maize yield but instead argued about its negative impact on profit. For



instance, Boimah et al. (2018) findings revealed significant negative mean differences between minimum tillage and maize-legume rotation farmers with low profit versus relative non-adopters by a mean effect of GHS-1015/ha. As per Corbeels et al. (2014) study, where CA technology adoption was reported to have a significant adverse effect on adopters' and non-adopters' profit. Addison et al. (2022) employ a two-stage BGF model to estimate the causal effect of the adoption of specific technologies on farm net revenue in Ghana. Addison et al. (2022) conclude that, on average, the adoption decreases the rice income inequality among the participants by 0.207 points and conclude that technology adoption in farming has equalizing effects. Apart from that, evidence suggests that women rice farmers' income gap decreases by 0.265 points as they adopt new rice technologies from 0.582 to 0.317 (Addison et al., 2022). Wiredu et al. (2015) results had shown that Ghana's rice productivity income was positively correlated with new rice technological advances. Apart from the above empirical evidences, another empirical evidence of how CSA technology adoption affects maize yield and net farm returns in Ghana indicates that zero-tillage and row planting are factors that contribute to decreasing maize production by 80 kg/acres and 94kg/acres respectively due to the fact that smallholder farmers never embrace zero-tillage and row planting (Asante et al., 2024).

An innovation such as embracing CSA technology, in this case, using row planting to develop crop cultivation in agriculture, is observed to be extremely positive for net farm income, with the largest effect of not embracing it being GHS 643/acre (Asante et al., 2024). The highest total gain from all of the CSA technology options to gain in net farm income was realized under the adoption of row planting and zero-tillage, which are two of the three alternatives adopted, with GHS 2078/acre in the absence of adoption (Asante et al., 2024). Maximum net farm income gain is achieved when all three combinations of the CSA technologies are adopted by GHS 815/acre (Asante et al., 2024).



2.6 Impact of CA Technologies Adoption Practices on Household Food Security

Review of the literature on theoretical and empirical evidence of conservation agriculture technology adoption impact resulted in Veronesi, Di Falco and Yesuf (2011); Asafu-Adjaye (2018); Manda et al. (2016) arriving at these findings. A study on food insecurity among rural farm households in the 10 regions of Ghana showed that 76% of the farm households were at the acceptable level of food consumption. Additionally, 19% and 6 % of the households were at the borderline and poor level of food consumption, respectively (Acheampong et al., 2022). Looking at the above findings, the research identified that these types of household's experiences greater levels of food scarcity. The principal food crops in Ghanaian cuisine are grains, root crops, and local vegetables, which are often eaten every day by both urban and rural populations (Acheampong et al., 2022).

A study in Zimbabwe and Malawi has shown that farmers who adopt CA technologies tend to have higher food consumption scores, albeit not significantly higher than their counterparts who have not yet adopted the technologies (Mango et al., 2017). For instance, CA technology adoption lowered treated farmers' food consumption score by 2.05. Although in Mozambique, compared to where there was a positive impact, there was an increment in implementor food consumption score by 5.486 points when applying CA technology and it was statistically significant (Mango et al., 2017). Other than that, Asante et al. (2024) used multinomial ESR to estimate the adoption of various climate-smart agriculture technologies among smallholder farmers, their determinants, and effects on maize output and farm net returns in Ghana. Adoption of zero-tillage and adoption of any one of the drought-tolerant maize varieties increased production by 153 kg/ha, while adoption of all the technologies in the package to the maximum intensified the impacts on the yields by 548 kg/ha.



Besides, Ali et al. (2022) assessed the effect of CSA adoption on food safety among farm families in central Ethiopia through MESR methods. The difference between treated farm households and non-treated farm households was statistically significant. Conservation agriculture and soil fertility management adoptees had, on average, score a 2.34 more FCS points compared to their counterparts, with a reduction in food consumption score by 7.58 points. In addition, the rise in mean FCS among adopters was 34.39 points with soil fertility management through small-scale irrigation and conservation agriculture techniques and a loss of 32.67 points for non-adopters (Ali et al., 2022). Adoption of conservation agriculture technology and soil fertility management also reported, on average, an increase of 0.22 points in HDDS, while, compared to non-adoption of the same technology, the HDDS decreased by 1.99 points (Ali et al., 2022).

Early planting and field preparation were identified as the primary factors affecting the availability of food in a Zambian study of CA women farmers (Nyanga et al., 2012). Grain production, food security in the household, consuming three meals a day, variety of foods, and affording sufficient food to last them until the subsequent planting season were all cited by women who had engaged in CA in Zimbabwe (Hove & Gweme, 2018).

2.7 Complementarities between CA Technologies Adoption

As depicted by Dumanski and coauthors (2006), one significant advantage of CA technology, is the farmers continued embracing of additive methods aimed at increasing agricultural production. CA experts highlight the fact that farmers need to embrace and undertake all three aspects (i.e., surface soil cover, crop rotation, and minimum tillage). Scientists contended that even though conservation agriculture (CA) technology like legume rotations are best suited for phosphorus fertilization, they remain unfertilized (Waddington et al., 2007; Zingore et al., 2007). Therefore, through enhanced supply of phosphorus-based fertilizers at a greater level of



availability to farmers, they would gain more from legume rotations, and this would be reflected in the higher maize yields arising from cereal-legume rotations (Thierfelder & Wall, 2010b).

In a bid to rectify soil nutrient imbalance and provide adequate biomass in the CA system, additional nutrients must be employed. Organic soil fertilizers also comprise manures and composts that are generally mixed with mineral fertilizer in smallholder production systems, e.g., in CA systems (Ito et al., 2007; Rusinamhodzi et al., 2013). Nevertheless, if cattle or other animals' manure is present in the paddocks or fields, then that may be utilized as organic fertilizer to mix with mineral fertilizer (Rusinamhodzi et al., 2013). Besides, abiotic stresses like drought, salt, and poor soil health are other determinants of SSA crop productivity, where the technology adoption of CA would be possible. Seed is therefore, a significant farm input whose gene potential places a limit on the performance as well as yield of the crop (Cromwell, 2009).

Experiment has proven that crop resistance to biotic and abiotic stress is predominantly governed by genes (Almekinders & Louwaars, 1999). Of specific interest to CA systems are those cultivars that have proven resistant to biotic and abiotic stress factors. Crop residue on the field creates a more humid microclimate on the soil surface that can enhance the risk of bacterial and fungal leaf disease. This has serious consequences for crop yields. The use of resistant tolerant varieties thus provides the most effective and economic disease control able to maintain foliar diseases at bay in CA systems (Thierfelder et al., 2015c). Resistant hybrids reduce loss of crop, are longer in duration, and use fewer objectionable chemicals on public health and the environment (Nelson et al., 2011). Whereas, if there is cattle or other animal manure in the paddocks or fields, then it can be utilized as organic fertilizer to blend with mineral fertilizer (Rusinamhodzi et al., 2013).



Besides, abiotic stresses like drought, salt, and low fertility soils are other determinants of SSA crop productivity, where the technology adoption of CA would be possible.

Once more, the stand and Plant population are crucial parameters of effective crop establishment and final crop yield (Thierfelder et al., 2018). Seeds must be seeded via mulch when seeding an animal traction or tractor-seed powered CA system. It serves to measure the extent to which a seeding technology is effective and suitable for any CA system having crop residues, stubbles, or living mulch on the field (Thierfelder et al., 2018). Agroecology plays an important role in determining the target plant population for crops (e.g. cropping management used, rain, and soil conditions). Spacings for legumes of crops with CA technologies can also be useful, such as when Malawian farmers were found to be manually planting some rows that were spaced between normal row spacings of 75-90 centimeters (Thierfelder, 2013b).

Research also shows that most legume crops such as soybean and groundnuts, have increased crop yield with increased high-density population in farm field (Thierfelder, 2013b). For example, in an intervention of the Sasakawa Global 2000 project, rows were planted with close plant population spacings of 75cm and 25cm apart in a row (Ito et al., 2007; Vincent et al., 2002). This was in addition to the ideal conservation agriculture technology (CAT) practice, but improved crop yield, especially in Malawi, to the extent it is now the most widely planted plant spacing technology in Malawi (Ngwira et al., 2013). In the case and adoption of CAT, crops are planted on flat beds instead of annual ridges, and so it is possible to have less tight spacing (between rows) than if traditional ridge tillage technology was used. The reason being is that, even though there would generally be less yield of crops, farmers prefer weeding on such fields that have more space.

Since weeds can lower crop yields by as much as 90%, weed control is an important agronomic operation (Nair et al., 2009). Microenvironmental transitions introduced by the use of CA



innovations may also affect what kind of weeds will subsequently germinate (Grant et al., 1989). However, niche differentiation of the type of weeds application of a blend of organic amendments with varying qualities is capable of limiting competition among weeds and crops (Radosevich et al., 1997). Malawi trials, for instance, proved that, provided weeds were weeded manually in good time, weed control using herbicide yielded as much as the weed-free plots (Nyagumbo et al., 2016). In such a scenario, Farmers can be aided in the initial stage of changing from traditional agronomic practices to the regime of CA techniques while utilizing herbicides in limited extent. However, farmers should be properly guided for procedure for using and applying them in a safe manner.

2.8 Determinants of Conservation Agriculture Technology Adoption

Numerous researches across the world have been studying the determinants of Climate Smart-Agriculture (CSA) technology adoption by smallholder agricultural systems (Anuga et al., 2019; Diro et al., 2022). There are typically two strands which have been debated within the literature. Literature initially treats the adoption of agricultural technology at a micro-level (Manda et al., 2020a; 2018; Ehiakpor et al., 2021; Guo et al., 2023), i.e., type of crop or rows to plant. The second strand, research involves adoption drivers of new farming technologies or innovations by smallholder farmers (Ehiakpor et al., 2021; Bese et al., 2021; Antwi-Agyei and Amanor, 2023; Jones et al., 2023; Makate et al., 2018).

Several such previous studies have explored the effect of single CSA technology adoption on outcomes of interest including agro-input use, labor requirement, crop production, poverty, etc. (Manda et al., 2016; Ng'ombe et al., 2017; Martey et al., 2020). Sheikh (2003) discovers that the most significant determinants of adoption of zero tillage technology are individual characteristics, including education level, number of tenants, readiness for new technology, risk, and encouragement for technology-induced price enhancement.





Implementation and severity of utilization of CA technologies in Zambia were examined to exhibit a series of elements affecting the adoption of CA methods. For instance, living within a district that was advocated to use less tillage and the seasonal rains were a limitation to the intensity and adoption of minimum tillage based on a survey using panel data (2010-2014) that were collected for crop production forecasting (Ngoma et al. 2016). Aslan et al. (2014) utilized Survey of Rural Agricultural Livelihood (RALS) data that were collected during the cropping seasons of 2004 and 2008 to examine minimum tillage disturbance and adoption of crop rotation. To them, economic status, extension services, rainfall variability, and agroecological conditions among others drive the adoption of CA practices. Farmers who adopt CA technologies gain technically as nitrogen surplus is reduced environmentally based on other studies (Abdulai, 2016; Abdulai; Abdulai, 2017).

Age and demography also have a very important influence on agricultural technology adoption. Smallholder old farmers will tend to have less interest in adopting new technology due to perceived cost, expected benefit, and perceived utility of the particular technology (Okello et al., 2019). For example, Manda et al. (2018) had established socioeconomic determinants of farm-level and institutional determinants that influence improved maize varieties adoption by Zambian farmers. Extension and seed availability, gender, labor, and location are among the determinants affecting farmers' adoption of drought-tolerant maize varieties in Ghana, as identified by Martey et al (2020). In Zimbabwe, the intensity and level of adoption of CA technology are determined by the agroecological location of the specific farmland, education, and institutional factors (Mazvimavi & Twomlow, 2009; Pedzisa et al., 2015b).

Gender dynamics also determine the extent of adoption, with research indicating that male-headed farmers stand a better chance of adopting new technology compared to female-headed ones (Murage et al., 2015; Michalscheck et al., 2018).

Also, women farmers consult family members as a key source of information and new technologies like zero-tillage (Jafry, Ahamad and Poswal, 2006; Jafry, 2007; Joshi et al., 2007b). Unlike female-headed households, the most educated among them graduating from higher secondary schools having a greater propensity for using paddy rice residues than male-headed households, none of the male heads being educated (Sharna et al., 2022). Possessing more productive assets, the probability of a female-headed household to retain paddy rice residues. On the other hand, it was also true for livestock integrated households; rice-fish culture, male-headed households had a higher likelihood of adopting residue retention (Sharna et al., 2022).

The probability of farmers accepting CSA practices relies significantly on household head education level, access to extension services, and knowledge of weather, alongside FBO membership, as posited by research carried out by (Issahaku and Abdulai, 2020; Zakaria et al., 2020; Wu et al., 2023). Bandeira & Rasul (2006) support that farmer groups and social capital are the initiators to follow Soil Conservation Practice SCP constituting 20% of overall farmers in Zimbabwe adopted all three phases (Chiputwa et al., 2011). If the soil is not tilled under low tillage and residues are kept, crop rotation can be an efficient means of managing pests, diseases, and weeds, since it disrupts the cycle of infection from crop to crop. Crop rotation appears to be the most basic method that links all the other CA technologies (Abrol, PACA, 2009).

Due to the detrimental effects on credit availability and zero-tillage adoption, farmers who receive credit for farming are no longer in need of zero-tillage because they can now afford more inputs for other systems (Ngaiwi et al., 2022). Additionally, it was determined that the proximity of a farm to an individual's residence promoted the application of agroforestry, intercropping, and zero-tillage. Where the distance. Those closest, farmers, are urged to adopt



all the practices (Ngaiwi et al., 2020). When using conservation tillage, farmers tend to split into groups of technology and implement the elements in phases. They are most at ease with the initial one, followed by the following elements subsequently (Mazvimavi & Twomlow, 2009).

Ayel et al. (2018) studied the determinants of adoption of row planting in Ethiopia. The most significant factors of row planting adoption were the size of the farm, family labor, training, the membership of associations, livestock ownership and the education status of the head of household. In line with Makate et al. (2019), access to extension services, marital status, credit, experiences, and dwelling status were the chief determinants for adopting varying CSA innovations, e.g., conservation agriculture techniques, improved legumes, and drought-tolerant maize varieties among Malawian and Zimbabwean smallholder farmers. Different sustainable practices vary in adoption due to factors such as farm income, perceptions of soil fertility, experience, field demonstration and group membership, land ownership, market distance, and credit availability, including (improved maize varieties; maize-legume rotation; animal manure.

Farmers have adapted to available technologies based on the availability of their resources (Anderson and Giller, 2012; Giller et al., 2009). Farmers can, however, overcome constraints and still implement CA technologies on very small plots of land (Anderson and D'Souza, 2014; Arslan et al., 2014). Agronomists advise that, in reason, farmers weigh cases of Minimal Tillage (MT) use against benefits expected, costs paid, and risks taken. Fear of erosion with maize or cotton and perceptions of risk are minimal on low-lying areas with little tillage which makes productive degrading land possible with MT, which may have additional benefits. Labor availability is also an incentive to cotton farmers for minimum tillage in some but not all areas in eastern Zambia (Abdulai & Abdulai, 2017).



As D'Emden et al. (2008) put it, the more educated and knowledgeable out-growers are regarding zero tillage practice, the higher the probability of their undertaking this technological conduct. From empirical research on farmers' protection behavior in Northern Australia, moral norms explain farmers' behavior more than do social, economic, or cost elements (Greiner et al., 2011). Labor capacity has a negative and significant effect on the adoption and utilization of the technology, according to Chiputwa et al. (2011) empirical findings on zero-tillage. In Zambia, Baudron et al. (2007) hypothesized that if labor-saving technologies were available and affordable, more farmers would use them, including fewer tillage systems.

Chiputwa et al. (2011) discovered a negative relationship between disposable income of the family and technology adoption and concluded that such families with more disposable income will have fewer chances to adopt zero-tillage than those with low disposable income, who have a high likelihood of adopting and using no-tillage intensively. In contrast, zero-tillage would be more economically viable for poorer farmers to adopt, while richer farmers have larger finance to pay for their ability to pay to use tractors and other agricultural machinery. This side, hire rates on equipment are expensive (Chiputwa et al., 2011). According to Haggblade and Tembo (2003), farmers adopting zero-tillage as compared to conventional tillage practice would be saving up to 75% of operations per hectare. Unlike the few farmers, majority of farmers have a very low access to both machinery and input supply, hence, leading to automatic delay planting, which is likely to affect crop production in the long run (Boahen, 2002).

The requirement for introducing new labor-saving technology like zero-tillage in cattle rearing operations rises as there is an increase in the size of the herd through management goals. Domestic labor becomes increasingly restricted, and restriction thereof will eventually result in labor-saving technologies such as using herbicides, weed wipers, sprayers, minimum/reduced tillage systems, and direct seeding technology, though each has a cost and



might not be within budget reach and accessibility for most farmers. Among them is perhaps that one family had cattle since it is an anchor investment, a better way of accumulating wealth or a source of liquidity (Tizale, 2007).

Furthermore, a significant empirical analysis variable was the number of tropical family-sized livestock keeping units; that is, the number of farm animals owned, hurts attitudes toward agroforestry adoption but a positive impact on intercropping, cover crops, and crop rotation. This shows that livestock ownership is a factor of influence on the said practices (Ngaiwi et al., 2020). Empirical evidence has revealed that the higher the demand for crop farms in terms of animal manure, the higher the likelihood of crop rotation, cover crops, and multiple cropping. But animal dung can be used on plowed land essentially for soil fertility improvement for cropping purposes. Nevertheless, all these findings corroborate (Ndeke et al., 2021), who concluded that cow ownership is a good predictor of higher technology adoption.

The level of soil fertility has been discovered to significantly influence the adoption of zero-tillage but negatively influence the adoption of mulching (Ngaiwi et al., 2020). The adoption of recovery measures is determined by soil fertility, and recovering the fertility of the soil is one way to achieve that using zero-tillage. Therefore, low fertility soils will make a farmer switch to zero-tillage from mulching. The innovation can improve soil fertility and, consequently, livelihoods and food adequacy by reducing tillage (Ngaiwi et al., 2020). Mulching adoption is once again hampered by soil fertility, but zero-tillage adoption is greatly aided by it (Ngaiwi et al., 2022). Seed and fertilizer use have increased as a result of Ghana's zero-tillage initiative farmers were forced to acknowledge that the only way to fully benefit from the zero-tillage system was to implement it in its entirety. The region's smallholder farmers must transition to conservation agriculture (Wall, 2007; Erenstein et al., 2012; Giller



et al., 2009) mainly because different patterns of rainfall variability and soils have varying effects on the relative strength and weakness of reduced tillage (Baudron et al., 2012; Giller

Adoption of zero tillage is primarily determined by the farmer's land conditions regarding SLOPE, SANDY, and CLAY. If the farmer has clay or sandy land, the farmer will adopt zero tillage (Derpsch, 2005). Bohlinger et al. (2006) in abstracts of most sources summarized that Brazilian farmer who originally had medium-textured soils initiated zero-tillage, and the approach has worked best in 10% to 70% clay soils in sloppy land.

2.9 The Concept of Food Security

Food security is understood qualitatively and measured subjectively (Peng et al., 2019). Although its definition came to fruition during the early phases of the 1950s, the terminology and what is understood by a word like this will vary from one place to another and the context in which it was used (Merriam-Webster, 2023; Babu et al., 2014). Initially, world food challenges are more often than not acknowledged even as they were (Ahmad, 2023) and most definitions made by various researchers and institutions as to this end have been founded on a similar reasoning since this concept emerges (Kuwornu et al., 2013) starting with the prime World Food Conference in 1974.

The term food security first emerged at the World Conference on Food in 1974 as reflecting the availability at any moment in time of adequate world supplies of basic foods in necessary quantities for an increasing level of food intake and in order to counteract variations in production and price (FAO, 1974). A one-day joint FAO/WHO meeting held in Rome in 1992 made it clear that hunger and malnutrition in all its forms must be overcome in an age when the knowledge and resources are available, making it possible to eliminate this human disaster and that access to adequate nutrition is a right to all human beings. Smith and Maxwell (1992).



As awareness about the causes and consequences of food security/insecurity has grown, so too have the numerous definitions that have evolved over the years. Food security is also found to be dynamic and multi-dimensional as various authors including but not limited to sociologists, agriculturists, political scientists, nutritionists and economists have provided different definitions in different contexts at different times (Maxwell, 1995; Bickel et al., 2000). For example, Smith Pointing and Maxwell write in the early 1990s that, there is no single definition of (food security or food insecurity) but rather rich tapestry of inter-related strands which are tailored to suit the needs and interests of particular users (Smith, Pointing and Maxwell, 1993, p. 136).

According to Béné (2020), food security is when households and individuals have enough money to buy enough food. About 630 million people experienced food insecurity in 2021 in the USA, and an estimated genotypes of 441 million in the world (Coleman-Jensen et al, 2021). Food security refers to the even, continuous access to sufficient food for an active healthy life (FAO, 2013). Operationalizing food security is where everyone has regular physical, social and economic access to sufficient safe food (Committee on World Food Security, 2012). Hayes (2021) defined food access as a person's regular access to sufficient food for active, healthy lives for every member of the household at any time throughout the year. By the receipt of packets of entitlements—farm produce, cash, foodstuff or inventory of assets, and/or state programs, so that people, when in stress, will be capable of maintaining proper nutrition intake for health (Benson et al., 2022).

Lastly, conventional indicators of food security are the total stocks of foods, generally related with the availability, access, and adequacy of food (FAO, 2020a; 2020b), and Busch & Lacy (1984). These sort of concerns for other defining elements like sufficient foods, and preferred foods are themselves highly subjective in nature and their applications differ very widely in a



broad range of situations (Coates, 2013). According to the Committee on World Food Security (1974); Béné, (2020); Coleman-Jensen et al. (2021); Hayes, (2021); FAO, (2020a; 2020b) and Busch & Lacy (1984), all are in perfect agreement highly with the third objectives of this study. With the overwhelming majority of definitions set in literature. Household vulnerability is intended to be part of food security, irrespective of socioeconomic status.

2.9.1 Food Security Dimensions

Food availability, food access, food utilization and food stability are the four dimensions to food security, as researched and published upon by other organizations and researchers (Lovendale, 2005; Yarid, 2001). Jrad et al. (2010) classified literatures into five food security dimensions—supply stability, availability, accessibility, utilization, and food and nutrition safety. Household and national food security rely mainly on having food. Food availability is simply another way of referring to the extent to which there are sufficient quantities and quality food in a region (FAO, IFAD, & WFP, 2013). Yet, the argument presented in the literature is that despite adequate production volumes and supply consistency being a requirement, economic issues like poverty reduction and expanding economic opportunity are also pivotal in terms of food availability (George, 1999).

Food access is the ability of individuals, households, and communities to provide a sufficient quantity of food from a variety of sources for a healthy diet through domestic production, purchase, exchange, and food aid (WFP, 2012; FAO, IFAD, & WFP, 2013). Physical and economic characteristics influence an individual's ability to access food. Physical access is controlled by infrastructure and, in addition to this, conflict and border closure, whereas economic access is controlled by household expenditures, food price levels, and access to social support systems (IFPRI, 2015).





Food access is the ability to secure, get hold, access sufficient food both in quality and quantity, to support all the year-round nutritional needs of all family members (Jonsson and Toole, 1991), and food access by all refers to adequate food to stay productive and healthy (Pinstrup-Andersen, 2009). Capacity of family members to provide themselves with healthy stocks and regular access to the minimum quality and quantity of food to lead healthy, productive lives (UN, 1990), and hence, all will gain from the physical, economic, and social access to a safe and adequate quantity of healthy, wholesome food appropriate to their food preference and dietary need leading to active and health-maintaining life (WFP, 2009b).

Food utilization here is the capacity to gain proper nutrition and energy from food as an action of trying to live a healthy life (WFP, 2012). Food utilization has two-sided elements of anthropometric estimates of malnourishment and health, hygiene, and quality indicators of foods. Food insecurity that occurs due to shocks or accidents at the period of recurrent occurrences is avoided through guaranteeing everybody food availability the entire year through (FAO, IFAD, & WFP, 2013). Even when there is food available for consumption, shocks like seasonal food shortages shouldn't compromise households' food security (FAO, 2014).

2.9.2 Food Security Determinants

In food security, several variables interact to define the capacities of households to ensure sufficient provision of access to healthy food. Income changes, income inequality, land endowment, yield of crops, and other socio-economic variables are stated to significantly influence food security (Maetz, 2013; Laborde et al., 2013). The wealthier and better-off households spend less percentage of their income on food, thus are less sensitive to price shocks (Laborde et al., 2013). Yet the influence of income towards food security is complex, albeit also differs according to wealth and personal taste (Tabatabai, 2013).

Empirical studies have concentrated on macro-level demand-side and supply-side determinants of national food security patterns. Feleke et al. (2005) explained the demand-side factors' roles in forecasting food security outcomes. Future studies need to be conducted because there has not been decisive evidence about demand-side variables of food security determinants (Carter et al., 2010; Herath et al., 2014). Babatunde et al. (2007) explained how younger household heads can be paid more and gain labor benefits. Arena & Anyaeji (2010) discovered older household heads tend to be more food secure. Alpizar et al. (2020) also emphasized the influence of education and age on food insecurity among smallholder farmers.

The household food security also depends on gender relations. Research like Nyanga et al. (2012) and Hove & Gwene (2018) had documented the benefits of Conservation Agriculture (CA) programs for women's food security in Zimbabwe, but there were losses of food diversity through which CA suppressed intercropping, as evidenced by Nyanga et al. (2012). Maxwell et al. (2000) documented inequality in income and access to land among female-headed and male-headed households, and this affected the status of women in food security. Other factors that influence household food security include family size, education, farm size, and credit availability; farm size and education are positively associated with food security (Dick et al., 2023); household size can be either positive or negative depending on the circumstances (Osman, 2015; Tsegay, 2009) credit availability can both encourage and discourage food security outcomes and household welfare is impacted by credit availability through a variety of channels (Diagne and Zeller, 2001; Acheampong et al., 2021).

Lastly, a household's food security is also increased by farming experience. According to Acheampong et al. (2022), better food security conditions in northern Ghana were positively correlated with farming experience. Similarly, Oluyole et al. (2009) found that food security in Nigeria was positively correlated with farming experience. All things considered, these



findings demonstrate how socioeconomic, demographic, and environmental factors intersect to influence household food security outcomes, necessitating context-driven interventions to effectively combat food insecurity.

2.9.3 Ghana's Food Security Trajectory

Food security continues to be a major issue in Ghana, but in two forms. Even though exports of horticultural crops have increased, while production stagnation in food crops is aggravating food insecurity (Wolter, 2009). Though there have been an episodic experiences of food insecurity, mostly in Ghana's northern regions, overall food security in Ghana has been relatively unchanged. In the 1983 drought in West Africa, people went to a typical source of foods, including using unripe bananas as a supplement for plantains, which aren't usually on Ghanaian diets (Kuwornu et al., 2013). Yet even in the present time, the majority of the populace has limited access to adequate and high-calorie food, a fact that has been brought forward by a World Food Programme 2009 survey, which spread to vulnerable populations such as cash crop farmers and unskilled laborers (Biederlack & Rivers, 2009).

As required by Ghana's Ministry of Food and Agriculture (2017), the government of Ghana has launched several initiatives to address these issues and improve food self-reliance, particularly through rapid agricultural growth transformation development programs. However, food security in northern Ghana is still threatened by elements like seasonal variations in local production, unpredictable rainfall patterns, and growing food costs (Nyanteng et al., 2003). They are further exacerbated by the region's low soil fertility and persistently high unemployment rates, which compromise food security.

2.9.4 Measurement of Food Security

Food security measurement is a strong determinant of stakeholders' activity selection in policy formulation. Throughout history, intervention activities have sought to address food



availability to a large extent, and as a result, interventions like food aid and the improvement of agricultural productivity levels have been introduced. Sen's 1981 argument to target food access, however, should be to redirected stakeholders' action to anti-poverty programs, food price stabilization, and social protection policy implementation. Multiple techniques have been used to measure food security with the most frequently used being the Household Consumption and Expenditure Surveys (HCESs), Household Dietary Diversity Score (HDDS), Food Consumption Score (FCS), Coping Strategies Index (CSI), and the Household Food Insecurity Access Scale (HFIAS). As stated by the FAO (2014), these instruments correspond with the major dimensions of food security which are; availability, access, utilization, and stability of adequate amounts of food that are safe and quality for a healthy living.

The HCES framework is concerned about the availability of food and collects data on finances, expenditures on food, and consumption, but is criticized because of the difficulty in standardization across borders as well as ignoring away-from-home food consumption (FAO, 2014). Income calming and risk management approaches, or consumption calming, are distinguished in the literature. Income smoothing refers to the efforts made by households to diversify their sources of income to protect against risk. In the face of food shocks or financial hardship, households may purchase food or obtain it through alternative means to sustain food intake (World Bank, 2000). Household Dietary Diversity Score (HDDS) is frequently employed to estimate the socioeconomic status of the household based on the intake of 12 food groups—grains, starches, vegetables, fruits, meat, eggs, fish, legumes, dairy products, fats, sugar, and condiments within the past 24 hours (Charamba et al., 2023). HDDS ranks among the most frequently employed indicators to provide an estimate of household dietary diversity in the literature (FANTA, 2003; Swindale & Bilinsky, 2009; Funmilola & Patricia, 2014).

Dietary diversity, as suggested by Lorenzana and Sanjur (1999) and (Hatloy et al., 1998), is the foods or diets eaten by members of a household at any particular time. It is also defined by



the Food and Agriculture Organization (2011) as having numerous varieties of foods at the household level, and is widely used as an index that is employed to quantify nutrient adequacy in one's diet. The Household Dietary Diversity Score (HDDS) is most commonly used to measure dietary diversity. It is calculated against the diversity of the food consumed by the household during 24 hours. Household Dietary Diversity is defined by Dop, Kennedy, and Ballard (2011) in terms of having a low (≤ 3 food groups), medium (4–5 food groups), and high (≥ 6 food groups) dietary diversity level. HDDS contains 12 food groups in total. A household's ability to consume variety foods is measured by its dietary diversity level. Both dietary diversity and socioeconomic level and household food self-sufficiency are positively associated with it, based on empirical evidence (Hatloy et al., 2000; Hoddinot & Yohannes, 2002).

For seven consecutive years, HFCS has determined the household's dietary patterns and nutritional profiles. HFCS does have a particular cutoff point when it is a matter of determining whether or not it is splitting enough levels of vitamin intake, but these are quite arbitrary (Leroy et al. 2015). Of very useful significance, the FCS considers just household food variety without accounting for intrahousehold disparity of nutrient intake Vhurumuku, (2014). The HDDS and HFCS indicators are utilized to determine food utilization Vhumuruku, (2014). The Household Coping Strategies Index (HCSI) is an easy household food security measure that is not so difficult to carry out. CSI controls for behavior irrespective of what individuals do when they cannot access enough food. At its most basic level, tracking the CSI score change shows whether or not a household food security status is improving or deteriorating. The Household Coping Strategy Index is also used in measuring frequency of food consumption and According to the literature review, there is no universal CSI because every country, territory, and location has distinct cultural norms and coping mechanisms that are used when experiencing food insecurity (Jones et al., 2013; Leroy et al., 2015). Because measurement tools of CSI are subject



to variability, they are primarily used as a comparable variable tool with localized emphasis (Jones et al., 2013).

Strategies of coping have been used as a response to adverse conditions or shocks. (Devereux, 2001). Even coping strategies that have been strategically used, in a sense that involving steps individual households (with unclear circumstances) take in order to manage their spending or acquire additional income so that they can respond to their needs for basics needs such as food, and shelter. Clothing and shelter as per the findings of Staring & Snel (2001). Coping strategies are the actions that households take in an attempt to survive when they encounter unforeseen stress related to their means of subsistence (Frank, 2000). Donald (2008) has described coping strategies as ex-post responses that are aimed at mitigating the shock of food scarcity. Coping strategies are employed by families to mitigate the shock of food insecurity. Through borrowing food, receiving assistance from relatives and friends, hunting, collecting wild fruits and vegetables from the forests, picking unripe fruits, or sending members of the household to be fed outside; curtailing adults' intake to subsidize infants or young children (Mjonono, Ngidi & Hendrik, 2009). Therefore, household coping approaches are dissimilar in every way concerning wealth, assets, education, and worldview of the household heads (Maxwell et al., 2003).

Though they vary in type to accommodate particular households based on available resources, coping strategies are typically shared by households within same community (Devereux, 2001).

With the primary goal of quantifying food access at the household level over the previous 30 days (Coats et al., 2007), the HFIAS tool was created with characteristics similar to those of the FEIS and HFSSM (Ballard et al., 2013; Charamba et al., 2023). Thus, the study uses HDDS to gauge food security at the household level since the third objective of the study deals with economic access to food consumption by households and a unit of measurement at household



level fits better with the concept of food security (FAO, 2011). Although HDDS and FCS offer exceptionally closely related information, their utilization has been defended by the need to cross-check with other studies and broaden the scope of the results. One of the justifications for the HDDS is that it is easy and clear to respondents, even though the module cannot capture intra-household food distribution (Swindale & Bilinsky, 2006). To the extent that this restriction may be resolved, other instruments to measure all elements of food security, along with individual- and household-level food security, are proposed and developed by food researchers and food policy think tanks, thus, providing a consideration for intra-household food consumption inequalities.



CHAPTER THREE

METHODOLOGY

3.1 Chapter Outline

The study's methodology section in this chapter covers the following topics: population of interest, sample size, sampling techniques, study design, data collection tools, validity and reliability tools, analytical framework, ethical considerations, and empirical models from the literature.

3.2 The Study Design

The study used a cross-sectional study design with a categorical treatment variable that was most appropriate for a multinomial endogenous switching regression model. Cross-sectional study design records the outcome of interest and measures the causal association between a dependent variable and explanatory variables as they correspond to a given population at one point in time (Alenezy et al., 2020). The cross-sectional study design enables individual farmers to choose between various alternative practices of CAT, in which the risk of potential bias is likely to be most pronounced owing to self-selection from unobserved determinants of choice. This meant that when the farmers self-select into one or more of the other options, and the researcher wishes to examine the effect of such choices, having controlled for likely confounding factors which are tied to the choice itself. Cross-sectional study design is preferable, compared to other research approaches due to it being flexible since the researcher does not require following the subject over time. Moreover, cross-sectional design has no or limited ethical issues since it does not involve interference (Wang and Cheng, 2020).

There are two types of cross-sectional studies. Firstly, we have the Descriptive cross-sectional studies, and secondly, the Analytical cross-sectional studies. While the former provides description of events which co-occur at one time point, the later measures exposers and outcome



association. Cross-sectional studies, in practice, use both types of design aspects in data classification. Similar to any other model, identification of the strength and weakness of a research design is a good foundation for a design option. One strength of cross-sectional design is based on

1. It's capacity to organize multiple outcomes and exposer;
2. Suitable for descriptive analysis and hypothesis testing;
3. Data for all variables is gathered once from two or more disparate groups (Setia, 2016).

But some of the disadvantages of cross-sectional design are that:

1. Design is prone to response and misclassification bias due to recall bias because of it;
2. It becomes difficult to conclude that outcome preceded exposer in time or exposer was result of outcome;
3. Association found might be hard to interpret

Most important reason for a design suitable for a MESR model is that:

1. There has to be more than one treatment group (CAT choice set), meaning that the treatment variable should not be more than binary i.e. such as treatment and control but rather comprise more than one distinct category participants can select from.
2. The choice in each category would likely be influenced by unobservable characteristics that can, in turn, influence the outcome variable and thus have an endogenous switching procedure to eliminate the bias.

The study needed more precise information about the study participants such as variables that have the potential to influence their category selection and the outcome variable of interest. Creswell (2009) contended that the selection of the research design is to a great extent subject to the research hypothesis, research questions, purpose of study and phenomenon under study. The purpose of this study was to investigate the impact of different categories of CA technology



adoption on household income and food security. In regard to the reality that CA technology adoption is no longer innovative in Ghana but traceable to the 1980s. CA technologies to be investigated under this study are cover crops, crop rotation, and zero-tillage. Each of the aforementioned technologies is defined by the study as follows:

No-till or zero-till land and soil cropping method with low disturbance of soil with intact residual crop residue still present on the surface at the farm soil for a number of cropping season or seasons; Crop Rotation: Least unrelated rotation within one and same field arranged in pairs with high residue crops, grasses and/or legumes (USDA-NRCS, 2018); and Cover Crops: Inter-season cover between cash cropping to be prepared for conservation purposes, complementary for reducing topsoil runoff, increase and improvement of soil health and incorporation of organic matter. These CA technological practices were selected due to the fact that they react to on-farm conservation activities at the farm level (Canales et al., 2023). Through detailed understanding of the CA technologies used by farmers to plant crops for the sake of identifying structural and systematic causes of productivity. Case study, ex-post factor, and experimental study are the most common research methods used in quantitative studies (Hakansson, 2013).

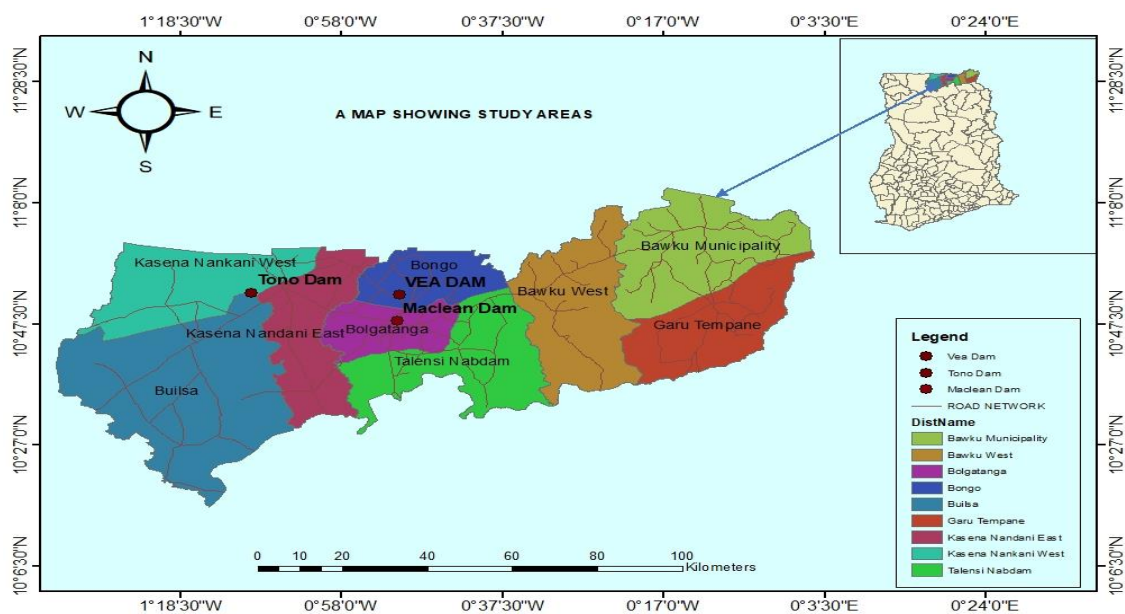
3.3 Study Area

As per the 2012 Ghana Statistical Service estimations, the Upper East Region can be found between latitudes 10°30'N and 11°10'N as well as longitudes 00°02'E and 10°33'W. To the south, it is bordered by the republic of Togo, with The Upper West Region to the east, and Burkina Faso to the North and West. It has an area of 8842 sq.km (3414 sq mi), constituting about 3.7% of the total land area of Ghana, with a total population density standing of 150 people/kilometer (MOFA, 2020; Ghana Survey Dept., 2020). The topography is rolling and, in some places, the slopes are under 1% while most of the region has slopes between 1% and 5%. Still, the region does experience moderate to severe gully and sheet erosion.



A cross-sectional sample survey was conducted among smallholder farmers in the Upper East Region, to examine the use of various conservation agricultural technologies aimed at improving productivity. The study focused on four administrative districts: Kassena Nankana East, Bongo, Talensi, and Nabdam. These districts are predominantly rural and are widely recognized for their agricultural activities (MoFA, 2020). The rationale for selecting these specific districts lies in their representation of both intensive and extensive agricultural practices within the region (MoFA, 2020). Additionally, the presence of NGOs and research institutions actively supporting farmers in these areas further justified their strategic inclusion in the study (MoFA, 2019). Therefore, these districts did appear to have been treated or intervened (Group) in a way to sustain their activity. The control group consisted of non-adopters of CA technology were selected from the sample. Studies established a general decline in farm production brought about by inefficient farming management methods among farmers. As agriculture farming is the dominant rural economy of northern Ghana, a low yield per unit of production increases the farmers' vulnerability. This means that welfare and food security are indirectly negatively impacted.

Figure 3.1 A Map showing study areas in the Upper East region highlighted with dots



Source: Researchers Construct: 2022.

3.4 Data Sources

The study utilized both primary and secondary data sources. Primary data were collected through interviews and focus group discussions with small-scale farmers who were invited to participate in the research. Secondary data were obtained from credible institutions, including the Ministry of Food and Agriculture (MoFA) and the Ghana Statistical Service (GSS). Unpublished and published theses, conference discussion papers, research papers, journals released by well-established and popular publication houses of Web of Science journals like Scopus, Springer, Elsevier, Taylor and Francis, Research Gate, and SAGE publications were utilized to undertake the literature review.

3.5 Data Collection Methodology

The data collection process was done via structured questionnaires in the survey process. A cross-sectional study in which data were obtained for a particular point in time for two or more different populations (Setia, 2016). Data for this study were collected from 1,358 plots and 471 farm households within northern Ghana, specifically in the Upper East Region between May and July 2022. Bongo, Kassena Nankana East, Talensi, and Nabdam districts were the selected districts in the region in Upper East Region where the survey was conducted. Field Enumerators were locally trained with language-proficient in data collection, conducted and completed a detailed household survey consisting of observation and personal interview.

Smallholder farmers' cross-sectional survey questionnaires were used to gather data, which helped to clarify how farmers' adoption of conservation agricultural technologies affected their livelihood outcomes. To assist in verifying the product and input prices, secondary data from MoFA were also requested for validation for the survey. The entire data set also contained the outcome variables utilized in this study: food self-sufficiency, household annual crop income,



and various CA practices. The study's analysis enables the control of both observable and unobservable factors for variations in non-adoption among farmers in the four districts.

The normative family data were founded on the socioeconomic traits like the size of the family, age, gender, and education level. Information on expenditures, income, and crop yields in terms of the use of CA practices were also gathered.

3.6 Data Collection Instruments

The respondents were dispense using semi-structured questionnaires. The key variables in the data from the respondents among the quantitative data are both open-ended and closed-ended questionnaires. Questionnaires were aimed to collect data from the respondents regarding the purposes of the study:

1. What characterize smallholder farm households in Upper East Region as far as the adoption of CA technology is concerned?
2. How does farm household income influence CA technology adoption?
3. How would household food security be impacted by the use of CA technology? The questionnaires were segmented into seven (7) sections and sub-divisions (i.e., A, B, C, D, E, F, G, sections) where each section was meant to collect data for the study from household heads.

For example, Section A recorded the nature of commodities that made up of straightforward domestic demographic factors such as (age, sex, level of education, size of household in persons, marital status, and number of economically active persons in the household. Section B was also divided into four sections based on farm-level factors. Such items that were captured under this section are (size of plot, percentage area covered by CA technology, farm to homestead distance, experience of the farmer in years, and land preparation method).



In order to increase farm output, the latter portion of this section discusses questionnaires such as input application, which includes information on the quantity of seeds planted, the amount of fertilizer and pesticides used, and the cost of inputs. Families' use of farm labor, including whether they hire, or share labor, as well as the cost of labor is covered in the latter portion of this section. However, part four recorded questions like how many crops were harvested, how many were lost, how many were sold, how much they were sold for, how far it was to the nearest market, how much it cost to transport, and how many crops were bought to ensure the family had food security. Institutional determinants such as access to credit, extension services, health care, and support from non-governmental organizations, and membership in farmers' social networks or farm-based organizations are covered in Section C. What kind of CA training farmers obtained if any?

Data on farm plot size, percentage of area covered by zero-tillage, residue retention, and crop rotation and production received from each one of the targeted locations of land were also collected. Section F captured household income and expenditure questions in modules. Module one captured questions such as off-farm and on-farm income, agricultural income, and origin of wages of agricultural laborers captured from respondents.

The second modules focus on weekly household expenses and household cash inflows, household assets such as (livestock units and all types of long-term assets were collected from the questionnaires. Finally, Section G comprises farm household-level food self-sufficiency questionnaires based on the Household Dietary Diversity Score (HDDS) indicator, which is adapted from the Food and Agriculture Organization's (FAO) design for assessing household food security. The HDDS module serves as a reliable and easy-to-implement proxy measure for evaluating the variety of foods consumed by households over the previous 24-hour recall period. It captures food intake across 12 food groups (FAO et al., 2023; FAO, 2017). Section G of the questionnaires employs the framework presented in literature and reports by credible



organizations such as (FAO, 2008; WFP, 2009b; Mango et al., 2014; Makate et al., 2016; Swindale & Bilinsky, 2006) in collecting food security indicators' data (i.e., HDDS) for measuring household food security, such as HDDS calculation templates within the questionnaire. The HDDS questionnaire facilitated the collection of data on all foods consumed by a household in the previous 24 hours. Each food group is assigned a score of 1 if it was consumed during this period, and 0 if not. The HDDS comprises 12 food groups, and dietary diversity is categorized as low (≤ 3 food groups), medium (4–5 food groups), or high (≥ 6 food groups). Evidence suggests that household dietary diversity is positively associated with food security and socio-economic status (Hoddinott & Yohannes, 2002; Hatloy et al., 2000).

The study employed Kobo Collect Toolbox, an open-source, web-based platform for field data collection developed as a humanitarian initiative at Harvard's Brigham and Women's Hospital. This tool facilitated efficient data gathering in the field. Collected data could be exported in Excel format and subsequently imported into statistical software packages such as Stata, SPSS, or other software for analysis. Data entry time was saved after data collection was completed using the Kobo collect toolbox. Each enumerator's Android phone was also downloaded and install with the Kobo-collect Toolbox app and questionnaires for the household survey were uploaded on the Kobo Toolbox for data collection.

3.7 Determination of Sample Size

The study used a sample size of 471 farmers. The sampling approach used was multistage with purposive in certain cases and random in others. The study population covered farming households in the Upper East Region; includes the four districts discussed above. Secondary data concerning the population of the area were taken from the household survey report of the Population and Housing Census (GSS, 2021), and Farmers' secondary data from secondary sources such as the Ghana Agricultural Census Report 2018 for crop-farming households



correspondingly for the four districts respectively (GSS, GAC, 2018). The approach developed by Taro was used to figure out the quantity of samples (1967, p. 886), which is commonly applied under the assumption of simple random sampling without replacement and without adjustments for population variability. This method is particularly useful when the researcher has limited prior knowledge about the population or study objects (Ryan, 2013; Ariola, 2006).

The sample size was calculated at a 95% confidence level, with a margin of error (p) set at 0.05, using the formula provided by Taro Yamane (1967: p. 886) as shown below in eqn 1.

$$n = \frac{N}{1+N(e)^2} \quad (1)$$

By applying the approach developed by Taro (1967, p. 886), the sample size was determined. In this formula, n denotes the number of samples, N is the population size, (e)² is the error term, and 1 is unity. In 2018, the Upper East Region had a total of 213,644 households, with 186,859 agricultural households and 26,785 non-agricultural households (GSS, GAC, 2018). Applying the formula, the initial sample size (n) was calculated to be 399. However, to account for potential design effects during data collection, this number was increased to 480. After the survey period, 471 completed questionnaires were returned, reflecting a 99% response rate. The data distribution was as follows: 26% of the data came from Kassena Nankana East and Talensi districts, which together represented 52% of the total dataset, while Nabdam and Bongo districts contributed 25% and 22%, respectively. The remaining 1% of data consisted of 9 questionnaires, which were excluded due to time constraints and monetary limitations.

$$n = \frac{186,859}{1+186,859(.05)^2} = 399 \quad (2)$$

3.8 Sampling Techniques

Drawing from previous studies that reported low crop production and productivity in districts with food security concerns, I used the multiple sampling stages method to select the districts



and villages for the study. The districts were purposively selected based on food security considerations (GSS, 2021). Within these districts, farm households were randomly selected from designated enumeration zones. The overall Update on Population and Housing Census by Ghana Statistical Service for Districts and Regions (GSS, PHC, 2021) provided the enumeration areas (EAs) for the study. A minimum of 25 farm household members were sampled from each district, with two EAs purposively selected per district using a proportional sampling technique. In total, 471 farm household members were interviewed over a three-month period, from May to July 2022, as detailed in Table 3.1 below.

Table 3. 1 A Table Showing the distribution of communities by households and districts contacted for the survey

District	No of EAs	Name of Community	No of Household Contacted
Bongo	2	Adaboya	25
		Tindongo	25
		Feo	28
		Bongo-Beo	29
Talensi	2	Tongo	30
		Bare	30
		Yameriga	31
		Balungu	30
Nabdam	2	Pelungu	30
		Domolgo	30
		Yakoti	30
		Zoog	30
Kassena N. East	2	Yog Bania	30
		Gia	31
		Bonia	31
		Korania	31
Total	8	16	471

Source: Researchers Construct 2022.s



3.9 Data Analysis

By the end of the survey, 474 sample farm households were covered. It was necessary to clean and edit the data in order to find any missing or invalid information, duplicate entries, and any kind of ambiguity or inconsistency in the information that the respondents had supplied. In order to explain why smallholders, choose a specific CA solution, mistakes that were made and found were documented in the determinants that affect farmers CA technology adoption. After cleaning, zero-tillage and minimum-tillage data were combined into one, and residue retention was updated to incorporate cover crops as the primary agronomic practice.

Those terms which carried the same meaning but were phrased differently were reconciled to allow the software to easily translate the information into measurable and tabulated format. Moreover, computation for certain end variables like farm income necessitated quantities of the output realized. Nevertheless, that crucial information was not available for some of the farm households, thus such questionnaires were excluded. Upon loss of some of the questionnaires, 471 were left and imported into Stata version 14.0 to be analyzed and results for this study.

Multicollinearity is a common occurrence in regression analysis that may be a serious problem with the validity of the model parameter estimates. If linear relationships between two or more variables within a data set, then there exists multicollinearity. Multicollinearity presents in the signs of the beta's for $(i=1, 2, 3, K)$ can be erroneous and contrary to the sign of correlation between the respective explanatory variables (Wiley and Sons, 2010). The betas will have humongous standard errors, hence humongous sampling variability. This renders the coefficient unreliable and reduces their precision. Despite this, the indicators of the regression remain accurate even when there is multicollinearity (Wiley and Sons, 2010, ch3, P-131). The model remains significant even when there is multicollinearity, though the variables in the model remaining insignificant. Diagnosis of multicollinearity needs model diagnosis. Most



frequently used diagnosis in the literature is testing the correlation matrix of the explanatory variables. Since correlation is not collinearity, multicollinearity can be present even when all the correlations are low. Thus, the utilization of correlation

- i. Matrix R are not sufficient cure,
- ii. Determinant of R (detR) is nearer to 1,
- iii. Variance Inflation Factor (VIF) is used to cure multicollinearity for independent variables (Wiley and Sons, 2010) as indicated in the dataset of the study below.

Table 3.1. 1 Multicollinearity Diagnostic Test for Independent Variables

Variable	VIF	1/VIF
Household Size	1.59	0.631
Educational level	1.47	0.679
Active workforce	1.46	0.685
Annual Income	1.41	0.710
Farmer Experience	1.25	0.800
Farm Distance	1.18	0.850
Plot Size	1.15	0.866
Distance to Market	1.13	0.883
Distance to MoFA	1.07	0.939
Mean VIF	1.30	

Source: Field Survey July, 2022

Observed from table 3.1.1 above, VIF data values indicate that there is no indication of multicollinearity in data set. High level of multicollinearity between the respective explanatory variable and other model variables is indicated when VIF has a value greater than 10. Moderate



level of multicollinearity is represented by VIF of 1 and 5 and, for sure, greater than 5 VIF indicates a probable issue of high level of multicollinearity suggesting remedies to the management of multicollinearity.

The research applied a three-step ordinal scale multinomial logistic regression (MNL) model. Initially, the model calculated the factors influencing farmers' adoption or non-adoption decisions regarding specific practices of CA technology including zero-tillage (Z), crop rotation (R), and cover cropping (C), alongside with non-adoption as a reference category among the other seven CA technologies. The second phase applied a selectivity-corrected multinomial endogenous switching regression (ESR) to model the outcome equations. In the last stage, the study estimated the difference in mean of food security and income outcomes between CA adopters and non-adopters of Conservation Agriculture (CA) practices, which is referred to as Average Treatment Effect (ATE), specifically focusing on those farmers who adopted CA technologies.

3.9.1 Estimating the impact of CA adoption on household income and food security

The treatment effect models most frequently cited in the literature regarding the simultaneous estimation of several adoption decisions, their impacts on an individual's livelihood, include the Multivalued Treatment (MVT) model, the Multinomial Endogenous Treatment Effect (METE) model, and the Multinomial Endogenous Switching Regression (MESR) model.

As it is the case with some of the matching techniques like the MVT model and Multinomial Propensity Score Matching (MNPS), these models rely on Conditional Independence Assumption (CIA). So, these models fail to overcome one of the most prominent challenges of selection bias due to unobservable elements. Nevertheless, such models are more preferable to instrumental variables, especially, models like MESR and METE are more ideal because they do not require the use of instrumental variables for estimation, making the task of identifying



suitable instruments less challenging. Nevertheless, MESR and METE to some extent accept unobservable elements, but only if one applies an exclusion restriction—known as the IV approach—which is not always straightforward to find. Aside from this, the MESR model is particularly well-suited for estimating the ATT, while the METE model is easier to use but can only estimate ATE. This research applies the MESR model estimations.

The biases of both the observed and the unobserved variables are further addressed by the MESR model. The application of the MESR model is facilitated by the argument of other writers that, in contrast to other multinomial models, the MESR is still a suitable refinement of the result equation, particularly for population result estimation, even if the Independent Irrelevant Assumption (IIA) condition is not met (Bourguignon et al., 2007). The MERS model excels at monitoring individual practices, which is one of its most important advantages. The MESR model also captures the interaction of covariates across various adoption alternatives (Wu & Babcock, 1998). It serves to identify the determinants of both joint and individual adoption of Conservation Agriculture (CA) practices and assesses their impacts on household income and food security. In this study, a farmer who adopts none of the three CA practices is categorized as a non-adopter, denoted as ($Z_0R_0C_0$). Adopters, on the other hand, a farmer fall into one of seven possible categories based on their combination of adopted practices:

- (1) Zero-tillage only ($Z_1R_0C_0$)
- (2) Crop rotation only ($Z_0R_1C_0$)
- (3) Cover cropping only ($Z_0R_0C_1$)
- (4) Zero-tillage and crop rotation ($Z_1R_1C_0$)
- (5) Crop rotation and cover cropping ($Z_0R_1C_1$)
- (6) Zero-tillage and cover cropping ($Z_1R_0C_1$)
- (7) All three practices zero-tillage, crop rotation, and cover cropping ($Z_1R_1C_1$)



The eight combinations of CA technologies are all mutually exclusive. A farmer thus selects one of these eight different possibilities in farm production in pursuit of his or her optimal expected utilities or revenues.

Therefore, all the factors of CA technology adoption have to be simulated at the same time. This is an assumption because CA technology will do much more for crop yield if all the three principles are packaged together (Ter Arest et al., 2019) and marketed as a single package (Jew et al., 2020). Partial adoption of CA techniques has been shown to result in less than full CA. This calls for a model with the ability to handle all the CA factors.

For every CA technology option, the MNLS predicts a unique continuous latent variable. According to Verbeek (2008), it is argued that, a common random utility model in which every alternative's utility as a linear function of observed attributes and an error term as well. It is also believed under economic theory that farmers choose one or several technologies to maximize their utility. This would mean that adopting whatever the package that is being adopted is worth more to the farmer than other packages. However, the utility realized through the adoption of the agricultural technology is only observed indirectly and not the technology decision itself, thus one can make an assumption of random utility model that suggests conditional expectation under assuming farmers' choice.

For each adoption option, the higher the score, the more likely a farmer (individual i) is to choose that particular alternative (j). The model specification is presented below:

$$U_{i,j} = X_i\beta_j + \varepsilon_{i,j} \quad (3)$$

In the model, $X_i\beta_j$ represents the interaction between the predictors and their associated parameters for alternative j , while ε_{ij} denotes the stochastic error term, which is independently and identically distributed (iid.) following a type-1 extreme value distribution. Equation (3) consists of two components: the deterministic part ($X_i\beta_j$), which captures observable



influences, and the latent stochastic part (ε_{ij}), which accounts for unobserved factors affecting the choice. Deterministic component is an unobservable variable quantified in terms of observable household variables e.g., (age, sex, size of household, assets' ownership, head of household's education level, plot size, soil's PH). Stochastic component encompasses all other significant variables relating to farm household decision-making which do not take an observable form e.g., (natural propensity of farmers, natural assets, and capacity). Farm household's value of following decisions among alternative CA adoption choices is uncertain, yet decision among adoption choices is sure. For farm household i , choose CA strategy j if that achieves a greater expected benefit in comparison to some other alternative if:

$$y_i^* = X_i\beta + e_i, \quad y_i = 1 \text{ if } y_i^* > 0 \text{ (adoption)} \quad (4)$$

$$y_i = 0, \quad \text{if } y_i^* \leq 0 \text{ (non-adoption)} \quad (5)$$

Where; y_i^* is farmer i 's unobservable non-measurable variable; X_i represents all dimensions of any given farmer; β represent estimated parameters; and e_i is error. For ease of use, multinomial logit is best but equally guilty of the generally erroneous independent irrelevant assumption IIA. Repeatedly, type-1 extreme value generates errors that are identical yet independent. In general, IIA assumes that when one adds or removes one unrelated alternative in/out of consideration, one's relative ranking of the unrelated alternative as against the others should remain unaltered. It is possible that computers can calculate the maximization of the likelihood function directly for even a very large number of alternatives since probability of choice in a multinomial logit is very simple.

Computer-simulated logit will be closer to the target in comparison with Probit. Both models are the same but with different distributions for the error term. Similarly, MNL predictors are the same across all the alternatives but with different coefficients. This description applies for only the independent variables in estimation like the respondents' income, gender, and age.



The MESR model is based on the assumption of an independently identically normal distribution probability of the error terms as follows from (Teklewold et al., 2013a, Zhou et al., 2020; Ma et al., 2022b; and McFadden, 1973), the model is specified below as follows:

$$P_{i,M} = P_r(\sigma_{i,M} < 0/X_i) = \frac{\exp(X_i\gamma_M)}{\sum_{K=1}^M \exp(X_i\gamma_K)} \quad (6)$$

Here, $P_{i,M}$ is farmer i 's choice of CA technology M . X_i is the observed variables vector accounting for home plot and area factor; γ_M is the scale of the forecasting parameters. In the second step, there is a significant need to determine the interaction of the set of exogenous variables and the result variables (food security, family income) which is tested based on the OLS (Ordinary Least Squares) model variables for the selected ones abbreviated as γ . CA, i.e., non-adoption-based category ($Z_0R_0C_0$), is measured as $M=0$ having either pairing abridged as ($M=1, 2, \dots, 8$). The feasible equation for any regime is expressed in (7a) and (7b) following:

$$\text{Regime 1: } Q_{i,1} = \gamma_{i,1}\alpha_1 + \omega_{i,1} \quad \text{if } I = 1 \quad (7a)$$

$$\text{Regime 2: } Q_{i,2} = \gamma_{i,2}\alpha_M + \omega_{i,2} \quad \text{if } I = M \quad (7b)$$

Where i is farmer's choice of adopting a specific CA technology; Q_i is farmer M i 's corresponding variable; an exogenous vector variable for which γ_i has been adjusted in the equation; α_1 and α_M are to be estimated parameters; $\omega_{i,1}$ and $\omega_{i,2}$ are white noises. Interestingly, the outcome variables serve as stepping stones to achieving SDG 1 & 2 objectives that among other goals seek to eliminate poverty, an eco-friendly solution to hunger eradication, and food security at the cost of not compromising upon the amenities of the ecosystem. So, the UN-Sustainable Development Goal Agenda 2030 defines that in order to achieve this, crop productivity must be increased, while CA methods and revenues must be effectively transferred (UN-SDG, 2015). If at the initial stage using an observed covariate vector is given by δ_i , then equations (8a) and (8b) can reduce the observed selection bias. Hence, errors in equations (7a)



and (7b) and in equation (6) errors would be correlated when identical non-observable variables, i.e., farmers' incentives and capacity to use CAs technology at equal points in time impact the use of CAs by farmers, while also influencing endogenous variables.

Therefore, here the selection bias is not evident, which might lead to selection biased estimates unless selection bias is controlled. Following the equation (6) estimation, selectivity correction terms are estimated within MESR framework and then added into equation (8a) and (8b) to counter the unobserved selection bias given below:

$$\text{Regime 1: } Q_{i,1} = \gamma_i \alpha_1 + \delta_1 \lambda_1 + \omega_{i,1} \quad \text{if } I = 1 \quad (8a)$$

$$\text{Regime 2: } Q_{i,M} = \gamma_i \alpha_2 + \delta_2 \lambda_2 + \omega_{i,2} \quad \text{if } I = M \quad (8b)$$

Where Q_i and γ_i have previously been defined elsewhere in equations (7a) and (7b); λ_1 and λ_2 are used to control for unobserved selection bias by using selectivity correction terms; δ_1 and δ_2 are error terms between equations in error in (6), (8a) & (8b). In multinomial choice scenarios, for every given possible alternative CA combination, a single M-1 selectivity-correction term. Use of OLS in second-stage estimation makes efficiency and consistency easier to achieve and is used to calculate the extent to which the estimator would deviate from the actual population parameter in event that the sample size was taken to infinity. Validity of MESR model estimate requires at least one of variables utilized through instrumentation to be included in MNL model in X_i but not in the γ_i in the results equation. In achieving model consistency, distance to MoFA office and training in CA have been utilized as IVs. and without hypothesizing effect of IVs over outcome of interest (i.e., food sufficiency and household's annual income).

In order to verify the authenticity of IVs, a falsification test was necessary and had to be carried out (Liu et al., 2021; Ma et al., 2022a; and Pizer, 2016). The total income from the sale of all



crops, livestock holdings, rental income from all movable assets, capital and equipment, and agricultural wages—all in Ghana cedis—was used to calculate the annual household income.

By comparing the expected means for a particular package, the third method aims to estimate the average treatment on the treated farmer sample (ATT) by equating it across the model. To determine whether an innovation is appropriate for farmers, average treatment effect estimation has been widely used (Rosenbaum, 2002). Due to its capacity to estimate a counterfactual using adopter and non-adopter features, the selectivity correction multinomial endogenous switching regression (MESR) model was used to choose the ATT groups in the study following (Kassie et al., 2015).

However, it should be pointed out that if self-selection bias were absent, adopter farm households might be allocated a counterfactual outcome of interest, such as the mean outcome for non-adopters with the same observable features. There is some debate in the literature, though, on how to estimate treatment effects. The average treatment effect (ATE) has according to some authors been described as not being a good impact measure since it fails to account for a multitude of observed and unobserved outcome determinants in different adoptions (Kassie et al., 2015; Teklewold et al., 2013). Others think that while ATE corrects for the influence of non-adopters, it just accounts for the difference in expected outcomes between the treatment and control groups, which is not a problem for policy interventions (Teklewold et al., 2013; Heckman, 1977; Kassie et al., 2015). Heckman et al. (1997) proposes the average treatment effect on the treated ATT because it is the only one that takes the treatment group result into account in this particular context. Because the causal effect of CA adoption on total household income and food security is the outcome variables, the conditional expectation of outcome variables of CA adopting households (observed) are expressed as equations (9a) and (9b):



$$E(Q_{i,2}/I = 2) = \gamma_i \alpha_2 + \delta_2 \lambda_2 \quad (9a)$$

$$E(Q_{i,M}/I = M) = \gamma_i \alpha_M + \delta_M \lambda_M \quad (9b)$$

CA adoption outcome variable if they had not adopted counterfactuals, is operationalized as:

$$E(Q_{i,1}/I = 2) = \gamma_i \alpha_1 + \delta_1 \lambda_2 \quad (10a)$$

$$E(Q_{i,1}/I = M) = \gamma_i \alpha_1 + \delta_1 \lambda_M \quad (10b)$$

Observe that equations (9a) and (9b) are true interest result of wanting in the model (i.e., food self-sufficiency and income for farm families, and related standard deviations) that the sample is experiencing in order to become adopters and equations (10a) and (10b) are hypothetical interest result of wanting. The average treatment effect (ATT) is estimated through conditional expectations. Thus, the ATT between equations is stated as (9a) - (10a) or (9b) - (10b) as stated in equation (11) below.

$$ATT = E[Q_{i,2} / I = 2] - E[Q_{i,1} / I = 2] = \gamma_i (\alpha_2 - \alpha_1) + \lambda_2 (\delta_2 - \delta_1) \quad (11)$$

ATT estimates the adoption outcome variable with respect to their counterfactual treatment variables based on such farm families not having adopted the CA technology unless they received one randomly. If assignment has heterogeneous effect and is non-random, then ATT and ATE will not be equal, i.e., ATE averages over the gains in the non-treatment units. While ATT reflects on the treatment effect on the treatment outcome in a randomly chosen population with treated attributes. To the right of equation (11) the first term (γ_i) defines the estimated difference between the average outcome variable receiving the same features and of not receiving them. On the other hand, endogeneity resulting from unobserved heterogeneity and selection bias are managed by the second factor (λ_2) on the far-right side of the equation. Impact assessments are made simple with experimental-based treatment analysis. But applying cross-sectional observation data in this study, observing the observed effect itself is very cumbersome



task. The task is to find the counterfactual result for the same family but under the condition that they hadn't applied the CA technology.

3.9.2 Description of the variables used for the analysis

This research measured CA agrotechnological practice adoption to present zero-tillage, rotation and cover crop as the two or more combinations of CA practices with potential to shift the livelihood effects of small-scale farmers like income and food security. Apart from that, literature has used variables under the farm technology adoption and have grouped them into three. Independent variables to adopt CA technology which are expected to have positive livelihood effects (i.e., farmers' income, food availability) on the adopters are (zero-tillage, crop rotation and cover cropping) and quantified them in terms of farmer's adoption area for each CA practice in hectares. Furthermore, autonomous evocative variables are listed and coded as count continual variables. These include farmer socio-demographic variables, such as head of household age, farm experience, education level, experiences, family size, farm size, labour force to farm distance, MoFA office distance, and weekly market distance. Farm households (marriage status, gender, and FBO membership) are the third independent explanatory variables included in the descriptive analysis. These factors are assessed and quantified as categorical variables. Anang et al. (2022), Anang (2020), and Abdul-Hanan et al. (2014) used the same demographic household variables to examine the factors that influence the adoption of CSA and SWC farm technologies to crop yield in northern Ghana. These explanatory variables collectively explained the farmers' choice to adopt CA technology to crop yield. Table 3.2 below lists the descriptive characteristics and measures that were employed following analysis of this study.



Table 3. 2 Descriptive variables used for the analysis

Variables	Description	Measurement
<u>Dep Variables</u>		
Zero-tillage	Adoption of zero-tillage	Number in hectares (Continuous)
Crop rotation	Adoption of crop rotation	Number in hectares (Continuous)
Cover cropping	Adoption of cover cropping	Number in hectares (Continuous)
<u>Indep Exp Variable</u>		
Age	Age of the household head	Number in years (Continuous)
Sex	Gender of household head	1 if household head is male and 0 otherwise binary (Categorical)
Marital status	HH marital status	If HH is married/single/divorce/widowed/separated (Categorical)
FBO membership	Membership to farmer group	1 if farmer belong to farm group, and 0 otherwise binary (Categorical)
Educational level	HH educational level	Number of years of formal schooling (Continuous)
Household size	People within the household	Number of household members (Continuous)
Farmer experience	Years of farming experience	Number in years (Continuous)
Extension access	Contact with extension agent	1 if contacted 0 if otherwise (Binary)
Farm distance	Distance from home to farm	Distance in kilometers (Continuous)
Distance to MoFA	Distance to MoFA office	Distance in kilometers (Continuous)
Plot size	Total land area cultivated	Number in hectares (Continuous)
Active workforce	Family labor in agriculture	Total active labor force (Continuo)
Credit access	Access credit for farming	1 if yes and 0 otherwise (Binary)
Total Livestock	Total livestock holdings	Number of TLU Number (Continuous)
<u>Outcome variables</u>		
Farm income	Annual income from farm	Amount in GHS (Continuous)
Food security	Household dietary diversity	1 if food diversity, and 0 otherwise (Binary)

Source: Researchers' Constructs July, 2022



3.9.3 Description of the explanatory variables used for the analysis

According to this study, smallholder farm households' adoption of HH is influenced by three types of explanatory variables:

1. It was discovered that demographic characteristics including age, sex, the number of household members, and the head of the family's educational attainment had a favourable effect on the adoption of CA technology and, consequently, household income and food security;
2. Institutional factors, including credit, extension, and land turner;
3. Socioeconomic factors, including farm plot size, farm income, off-farm and non-farm income, durable assets, input availability, total livestock holding in (TLU), distance from farm plot and market, and FBO membership; and (2).

X₁; Household head age is being computed based on household head's years and hence continuum scale variable (Baidu & Adesina, 1995). Crop rotation, intercropping, and low tillage and mulching have all been demonstrated to benefit from family head age (Tufa, et al., 2023). It will take positive or negative impact.

X₂; It refers to the head of household sex. CA strategies project female farmers experienced enhanced grain output, enhanced food security in terms of accessing three meals a day, enhanced diet (Hove & Gwene, 2018). A dummy variable, it accepts 0 for feminine and 1 for masculine (FAO, 2011). It was designed to have direct and indirect effects on household food security and income.

X₃; Educational level is necessary in achieving food consumption diversity at home. Education level should improve capacity and potential of information processing on CA more and thus lead to, financial and availability of food (Kotu et al., 2017; Acheampong et al., 2021; Dick et al., 2023). It is then believed that educated household heads in the farm decrease chances of



poor and borderline FCS but enhance chances of good class of consumption food (Ngema et al., 2018). It is an interval variable, and it is measured as years of formal education. Education variable will have a positive impact on food security and income.

X₄; Farm size: CA technology is a block-level activity whose impact on adopting technology is beneficial because a farmer with large farm blocks can revert to experimenting using different technologies to try and optimize yield and food security. Greater plot area enables farmers to experiment various CA practices at the same time on an equal area of land, farmers will get low return and low risk on conventional practices (Tufa et al., 2023). Plot size is also measured in a unit of hectares (Akudugu et al., 2012).

X₅; Household size: Variable that changes and suggests the number of people dwelling and consuming within a compound as family. Large household size is expected by the research to create more economically active farm labor force per (Jayne et al., 2015; Osman, 2015). It is expected to be a source of contribution to food autarky and household earnings.

X₆; Farm Distance: proximity of distance-to-distance proximity is designed to affect or deter extent of farmers' time on crops, and affect or deter extension contacts. Measurement variable with measurement in kilometers. Negative and positive impact is designed to be induced by this variable to variable of interest.

X₇; Farm to market distance is farm to market center quantitative variable in kilometers. Farmers have easier access to transportation and other support services the closer their farm is near a road or market centre. As a result, the study assumed that the variable may affect adoption and outcome factors in a variety of ways.

X₈; FBO: Farm-based organisations are social networks that connect farmers with sellers of inputs and extension agents. FBOs also purchase agricultural inputs in bulk for members to resell in return, giving members access to economies of scale. This dummy variable has the



values 1 for farmers who are FBO members and 0 for those who are not. It is anticipated that it will significantly improve the outcome factors.

X₉; Credit access: Inability to access credit is one of the largest rural farmers experiences in technology use in agriculture (Balana et al., 2020). It is a imaginary variable and it is 1 if the farmer is credit accessible and 0 if otherwise. credit accessibility was previously discovered to be positively correlated with secure food security and moderate food security (Ehiakpor et al., 2020; Acheampong et al., 2021; Mustapha et al., 2016) but negatively correlated with acceptable food group (Aidoo et al., 2013). On this premise, credit access variable is expected by the study to have a mixed effect.

X₁₀; Land turner: land ownership is still a major hurdled among rural farmers (Maxwell & Wiebe, 1998), and most of rural farmers cultivate their farm land according to the trend of own land by inheritance, lease, hired, or purchased land. For instance, signing land leases influence farmers choice in utilizing conservation tillage (Si et al., 2021). Land fragmentation may possibly limit agriculture efficiency, production and high cost (Xu et al., 2021).

X₁₁; Total Livestock: Farm animal livestock ownership that produces waste such as poultry waste and cattle dung is utilized for livestock integration to land and manure. Livestock compete with the crop residues in a type of feed resulting in the unreliability of crop residues in being utilized for mulching (Tufa et al., 2023). It is measured in terms of numbers as tropical livestock units. Tropical livestock units are the conventional units which enable summation of various livestock cohorts and species livestock by use of coefficient first computed on liveweight basis. Units of reference to be employed when calculating TLU (=1 TLU). There is also other conversion scale provided for the remaining species, e.g., Cattle were taken to have mean weight 175kg with 0.7 TLU per head; Sheep and Goats 0.1 TLU per head; Pigs 0.2 TLU per head; Horse 0.8 TLU per head; Mules 0.7 TLU per head; Asses 0.5 TLU per head; Chicken



0.01 TLU per head (FAO, 2013). The study anticipated TLU to yield positive and negative results.

X₁₂; Long-term assets(log): Assets owned by the household are leading measures of poverty reduction (Nancy et al., 2011). Well-being of households in farms is determined by the ability to own and command assets. Additionally, asset ownership brings about increased assets for households to command resources (Doss et al., 2020). A continuous variable expected in the study to play a positive role in household adoption decisions. As household wealth increases, it is easy to convert it into cash to purchase farm equipment to experiment with new farming practices (Acheampong et al., 2022). Assets' value reflects the significance of family wealth, reflects that more affluent household heads tend to utilize CA (Dalton et al., 2014). The factor is likely to have positive effects.

X₁₃; CA training: Farmers receive farm information from various sources and can learn from MoFA under extension Programmes on improved income and food security (Kimathi et al., 2021). For this reason, those farmers who received training in improved CA innovations have a greater tendency to adopt CA compared to farmers who did not receive exposure to improved training. It is an imaginary variable that returns 0 otherwise and 1 if the farmer has received CA training. It should be positively correlated with income and food security.

X₁₄; CA Knowledge: Knowledge of CA technology potentially improves attitudes of farmers towards its adoption. Knowledge further influences how easy with which farmers perceived the technology to be adopted to suite their local settings, the more likely to adopt (Ramasubramaniyan et al., 2016). Knowledge of CA is measured as qualitative binary categorical variable as Yes=1 if farmer has knowledge in CA, and No=0 if not. This variable is expected to generates both positive and negative association with CA technology adoption.



X₁₅; CA Perception: Farmers attitude towards the adoption of the technology is negatively affected by perceived risk (Wandji et al., 2012). Farmers perception of a new innovation is a requirement for adopting to use (Mwangi and Kariuki, 2015). Develop variable that will most likely have negative and positive effect on CA technology adoption.

X₁₆; Physical distance between MoFA office and farm-plot enables extension agents and farmers to converse and share new concepts and is a continuous variable that will have both positive and negative impacts on the adoption of CA.

Table 3,3 below showed the a priori expectation of the variables that the study population thought had an effect on smallholder farm household CA technology adoption. It also indicates a picture of the assumed determinants of the independent explanatory variables for use in the analysis as well as unit of measurement in applying conservation agriculture technology and its estimated contribution to household livelihood indicators such as income as well as food self-sufficiency in the study area.



Table 3.3 A Table illustrating the variables that affect Household CA technology Adoption

Variables	Description	Measurement	A priori Expectation
X ₁	Age household head	Years	+/-
X ₂	Sex_household head	Binary male=1,0 female	+/-
X ₃	Marital status household head	S/M/W/D/S	+/-
X ₄	Educational level	Years	+
X ₅	Farmer experience	Years	+
X ₆	Farm distance	Kilometers	+
X ₇	Household Size	Number of persons living	+
X ₈	FBO status	Binary Yes=1, No=0	+
X ₉	Extension service access	Binary Yes=1, No=0	+
X ₁₀	Credits access	Binary Yes=1, No=0	+
X ₁₁	Plot size	Hectares	+/-
X ₁₂	Distance to MoFA office	kilometers	+
X ₁₃	Distance to markets	kilometers	+
X ₁₄	CA training	Binary Yes=1, No=0	+
X ₁₅	Land turner	Own/leased/trust	+
X ₁₆	Tropical Livestock Units	Counts	+
X ₁₇	Durable Assets	Counts	+
X ₁₈	Active Workforce	Counts	+
X ₁₉	Annual income	Ratio/count	+
X ₂₀	Slopes	Steep/Flat/undulating	+/-

Source: Researcher's Construct July, 2022

These hypothesis variables herein will be prone to guarding or repel farm household CA technology adoption for Long-term cultivation of crops with the intent of enhancing smallholder farmers' revenue and food variety in Ghana's Upper East region.



CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Chapter Outline

The subsection includes adoption outcomes determinants and determinants of household income and food security implications. Nominal annual household income of the research area, food crop yield, cropping system food self-sufficiency, summary statistics of farm households, perception determinants to embrace CA technology, and effect of CA practice and adoption effect on income and food security are classified under demographic determinants but are mere groundwork to CA practice adoption effect and impact on income and food security.

4.1.1 Descriptive Results

The sample structure by marital status, sex, household head education level, and household size were examined. Descriptive statistics were employed to depict the impact of farm household demographic determinants in Table 4.1 below.

Table 4.1 Descriptive Statistics of Districts, Residence, and Sex of household's head

District of Respondents	Sex of Household Head		Frequency
	Female	Male	
Bongo	20	87	107
Kassena Nankana East	27	96	123
Nabdam	9	111	120
Talensi	17	104	121
Frequency	73	398	471

Source: Field Survey July, 2022.

Table 4.1 had previously shown respondents' frequency distribution by sex and district in the study as follows: There were (20) females accounting for approximately 19% of the farm household heads and (87) males accounting for approximately 81% from a sample of 107 farm



households. In Kassena Nankana East (27) women were said to account for about 22% of farm household heads, and (96) household heads were represented by men for 78 % of the total 123 farm household surveyed for the survey, Nabdam district was isolated (9) women holding a negligible proportion of about 7.5% and (111) male head of household holding a larger proportion of about 92.5% totaling 120 farm households surveyed.

Talensi district represented (17) female headed households since 14% of the small holders were females while (104) males since 86% heads of farm household were out of a total of (121) out of 471 observations. The overall finding is that, of the 471 observations, male household heads have the highest percentage of farmers who have embraced CA technology farming practices in the four study regions (398, or 84%), while female farmers have the lowest percentage (73) of farmers. Descriptive statistics that produce continuous variables with mean and standard deviation from field surveys are represented by the values in table 4.2 below.

Table 4.2 Summary Statistics indicating continuous variables of Households

Variables	Obs	Mean	Std. Dev	Min	Max
Age	471	48.531	12.426	23	83
Farm distance	471	1.947	1.556	1	6
Distance to MoFA	471	1.826	1.107	1	9
Distance to market	471	1.728	0.816	1	6
Educational level	471	4.735	5.559	0	22
Farmer experience	471	21.894	10.486	2	50
Household size	471	6.113	2.696	1	25
Plot size	471	5.389	4.471	1	25
Active workforce	471	4.212	2.088	1	12
Annual income	471	9372.066	13185.16	200	97500

Source: Field Survey July, 2022



Table 4.2 above showed continuous variables of summary statistics indicating the minimum and maximum values as well as the mean and standard deviation of farm households in the survey. Sample farmers' age averaged approximately 49 years. Active working age among farm household in the study was 23 years minimum and 83 years maximum, showing the active working age range of household agricultural labor in the study. As research by (Zakaria et al., 2020) indicates, it reflects the age of farmers in their productive years is the most appropriate for agricultural production. The 12-year standard deviation shows the deviation range from the mean of CA technology adopters of farmers and non-adopters was 23 years minimum and 83 years maximum. Farm distance on average was 1.9 kilometers and a standard deviation of 1.5 kilometers, least of 1 kilometer and 6 kilometers highest. Average to MoFA was 1.8 kilometers, a standard deviation of 1.1 kilometers, least of 1 kilometer and the highest of 9 kilometers. Though the distance farmers travel to reach market points in order to get inputs and sell crops registered a mean average of 1.7km and Standard deviation of 0.8km. Educational level achieved by farmers on average registered 5 years with standard deviation of 6, ranging from 0 to 22 years of education. Farmer Experience in years reports on average 21 years' experience with a standard deviation of 10.4 ranging between 2 to 50 years. Farm household size reported the average number of persons living together and sharing meals together and utilizing other household amenities within a compound as 6 persons with a minimum of 1 and a maximum of 25 persons in a household. Plot size has an average value of 5ha/farmer, a standard deviation value of 4.4ha, low value of 1ha and a high value of 25ha in observation. Active Workforce involved in family labour was 4 members on average, standard deviation of 2.0, lowest of 1 and highest of 5 active members contribute towards family own labour requirement. The mean annual income for each family head polled was GHS 9372.066, with a standard deviation of 13185.16. The least and largest amounts were GHS 200 and GHS 97500, respectively.



Additionally, descriptive statistics report from Table 4.2.1 to Table 4.2.10 and Table 4.3.1 to Table 4.3.3 below, are provided in the context of Adopters and Non-Adopters, an independent mean t-test was further conducted in Stata. Using t-test statistics to understand how each of these socio-economic variables influence the adoption and non-adoption of CA technologies amongst farm households in the study. T-test is an inferential statistic, employed to establish if there are two groups with a difference in the means that would be termed as significant, if the treatment has an effect on the population of interest (Bevans, 2023). A p-value primarily reveal the mean difference by probability if in reality there is no difference in the population, while the t-value show the magnitude of the difference between the two groups (Bevans, 2023).

Table 4.2.1 Descriptive Statistics for Continuous Variable Age

Adoption CA	Obs	Mean	Std. Err	Std. Dev	t- value	D.f	95%. Conf	Interval
Non-adopters	63	48.921	1.673	13.278	0.267	469	45.577	52.265
Adopters	408	48.471	0.692	12.306			47.273	49.668
Combined	471	48.531	0.573	12.426			47.406	49.656
Diff		0.4500	1.683				-2.859	3.759

Source: Field Survey July, 2022 $p < 0.05$, $p > 0.05$ $p\text{-value} = 0.7894$

Findings of table 4.2.1 are placed in the perspective of adopters' and non-adopters'. Descriptive statistics also found out the mean age of adopting and non-adopting farm household heads was around 49 years by approximation alongside with their respective Standard Errors of 0.69 and 1.67 for respective groups representing the young farmers on average represent half of the smallholder farmers' population which are in the active working ages and adopt CA technology in this study. Overall, conclusion is that, the male heads of households constitute with the greatest number of farmers who applied CA technology farming practice in the four study locations with the largest percentage of 84% or (398) farmers and female farmers with smallest



percentage with (73) farmers with 16% of the 471 observations. Descriptive statistics of farm distance that create continuous variables with mean and standard deviation from field surveys are represented by the values in table 4.2.2 below.

Table 4.2.2 Descriptive Statistics for Continuous Variable Farm Distance

Adoption CA	Obs	Mean	Std. Err	Std. Dev	t- value	D.f	95.% Conf	Interval
Non-adopter	63	2.333	0.181	1.437	2.126	469	1.971	2.695
Adopters	408	1.887	0.078	1.567			1.735	2.040
Combined	471	1.947	0.717	1.556			1.806	2.088
Diff		0.446	0.210				0.338	0.858
Source: Field Survey July, 2022 $p < 0.05$, $p > 0.05$						p-value = 0.0340		

Table 4.2.2. above showed the average mean distance farmers walks from home to the farm daily across all households for non-adopters was 2.3 kilometers with a Standard Error of 0.18 kilometers, as against an approximately 1.9 kilometers for adopters with a Standard Error of approximately 0.08 kilometers. The mean difference between the research population's adopters and non-adopters for farm distance was roughly 0.45km, which was statistically significant. A t-test statistic-derived p-value of $p = 0.0340 < p = 0.05$ indicates that the average between the two groups (i.e., adopters and non-adopters) is statistically significant and that the null hypothesis must be rejected. Explanatory variable distance to farm therefore significantly influences farmers adoption and non-adoption of CA technology in the study population.



Table 4.2.3 Descriptive Statistics for Continuous Variable Distance to MoFA

Adoption CA	Obs	Mean	Std. Err	Std. Dev	t- value	D.f	95.% Conf	Interval
Non-adopter	63	2.619	0.204	1.621	6.363	469	2.211	3.027
Adopters	408	1.703	0.047	0.950			1.611	1.796
Combined	471	1.826	0.051	1.107			1.726	1.926
Diff		0.916	0.144				0.633	1.198

Source: Field Survey July, 2022 $p < 0.05$, $p > 0.05$

$p\text{-value} = 0.0000$

Table 4.2.3 above report the descriptive statistics for continuous variable distance to MoFA office. The mean distance between farm plot to MoFA office in a bid to reach extension advisory services was 2.62 kilometers for non-adopters and 1.70 kilometers for Adopters. A standard Error of 0.20 kilometers and 0.04 kilometers respectively for the two groups. This means that distance to MoFA office positively impact farmers decision to adopt CA technology. This implies that adopters on average have a farther distance of about 3 kilometers in traveling to MoFA office in accessing extension services, while non-adopters have a distance of about 2 kilometers in traveling to accessed MoFA offices. The technology adoption in most cases is under the accessibility of farmers to extension services and to information. A mean difference of 0.9 kilometers between adopting and non-adopting farm households of CA technology. T-test statistic with computed $p\text{-value} = 0.0000$ which is below $p = 0.05$, implies that we reject null hypothesis and concludes that no difference in mean between adopters' and non-adopters' distance to MoFA in sample population is significant. Variable distance to MoFA office is having positive significant impact on farmers CA technology adoption in survey Population.



Table 4.2.4 Descriptive Statistics for Continuous Variable Distance to Market

Adoption CA	Obs	Mean	Std. Err	Std. Dev	t- value	D.f	95.% Conf	Interval
Non-adopter	63	1.619	0.114	0.906	1.141	469	1.391	1.847
Adopters	408	1.745	0.040	0.802			1.667	1.823
Combined	471	1.728	0.038	0.816			1.654	1.802
Diff		-0.126	0.110				-0.343	0.091

Source: Field Survey July, 2022 $p < 0.05$, $p > 0.05$

p-value = 0.2544

Averagely, adopters and non-adopters' mean distance from homestead to the market centers to obtain inputs was 1.62 kilometers and 1.75 kilometers respectively. This translates to the fact that farmers on average traveling a distance of approximately 2 kilometers to market centers to buy simple farm inputs and sell their produce. The Standard Error of 0.11 kilometers and 0.04 kilometers for the non-adopters and adopters respectively in the survey. However, the mean difference in distance to market for adopters and non-adopters is -0.1 kilometers of CA technology adoption between the two sample groups. The t-test statistic = 0.2544 above $p = 0.05$ outcome fail to reject the null hypothesis, and infer that the mean difference between the variable distance to market for the CA technology adoption is not statistically significant among the two sample groups. Therefore, farmers' CA technology usage is not affected or has no effect by distance to market.



Table 4.2.5 Descriptive Statistics for Continuous Variable Educational Level

Adoption CA	Obs	Mean	Std. Err	Std. Dev	t- value	D.f	95%. Conf	Interval
Non- adopters	63	3.937	0.569	4.515	-1.125	469	2.799	5.074
Adopters	408	4.858	0.282	5.697			4.303	5.412
Combined	471	4.735	0.256	5.559			4.231	5.238
Diff		-0.921	0.752				-2.399	0.556

Source: Field Survey July, 2022 $p < 0.05$, $p > 0.05$

$p\text{-value} = 0.2211$

Educational level attainment between non-adopters' and adopters' households in the survey recorded an average mean of approximately 4 and 5 years of formal schooling respectively. Approximately, 0.57 and 0.28 survey's standard Error recorded for both non-adopters and adopters. A negative mean difference of -0.9 for both groups respectively. Indicating that within the observation, farm households least years for formal schooling among non-adopters and adopters was just a year difference. A t-test statistic of calculated $p\text{-value} = 0.2211$ greater than Because $p = 0.05$ indicates that we do not reject the null hypothesis, we may infer that the survey's mean difference between non-users and adopters of CA technology is not statistically significant. The variable educational level of farmers has no significant impact on CA technology adoption between the two groups.



Table 4.2.6 Descriptive Statistics for Continuous Variable Household Size

Adoption CA	Obs	Mean	Std. Err	Std. Dev	t- value	D.f	95%. Conf	Interval
Non- adopters	63	6.698	0.433	3.439	1.858	469	5.832	7.565
Adopters	408	6.022	0.126	2.555			5.773	6.271
Combined	471	6.113	0.124	2.696			5.868	6.357
Diff		0.676	0.364				-0.039	1.392

Source: Field Survey July, 2022 $p < 0.05$, $p > 0.05$

$p\text{-value} = 0.0637$

The mean number of individuals per household was 6 persons on average for both non-adopters and adopters respectively. Suggesting that there are no significant difference in household size between non-adopters and adopters. Having a Standard Error of 0.43 and 0.13 for non-adopters and CA technology adopters respectively. Mean difference of 0.67. A t-test statistic $p\text{-value} = 0.0637 > p = 0.05$ indicates that we cannot reject the null hypothesis and draw a conclusion that household size mean difference is not statistically significant between adopters and non-adopters of CA technology among sample population. Hence, household size does not affect farmers adoption of CA technology among two groups in the observation.



Table 4.2.7 Descriptive Statistics for Continuous Variable Farmer Experience

Adoption CA	Obs	Mean	Std. Err	Std. Dev	t- value	D.f	95%. Conf	Interval
Non- adopters	63	26.254	1.384	10.988	3.591	469	23.487	29.021
Adopters	408	21.221	0.508	10.256			20.222	22.219
Combined	471	21.894	0.483	10.485			20.944	22.843
Diff		5.033	1.402				2.279	7.788

Source: Field Survey July, 2022 $p < 0.05$, $p > 0.05$

$p\text{-value} = 0.0004$

Mean number of years of farm experience seen in sample were 26 and 21 years among non-adopters and adopters respectively with Standard Error of around 1.38 years and 0.51 years respectively. Difference between years of experience in farming was 5 years among adopters and non-adopters. t-test statistic $p\text{-value} = 0.0004$ is less than $p = 0.05$ and hence null hypothesis is rejected i.e., CA technology adoption is influenced by years of experience in agricultural business, we can see that the difference in means is significant statistically. Thus, years of experience a farmer gains have significant positive effect on household CA technology adoption between two groups.

Table 4.2.8 Descriptive Statistics for Continuous Variable Plot size

Adoption CA	Obs	Mean	Std. Err	Std. Dev	t- value	D.f	95%. Conf	Interval
Non- adopters	63	7.397	0.586	4.654	3.888	469	6.225	8.569
Adopters	408	5.078	0.216	4.366			4.653	5.503
Combined	471	5.389	0.206	4.471			4.984	5.793
Diff		2.318	0.596				1.147	3.490

Source: Field Survey July, 2022 $p < 0.05$, $p > 0.05$

$p\text{-value} = 0.0001$

The mean plot size of non-adopters and adopters according to the survey is approximately around 7.40 hectares for non-adopters and 5.08 hectares for adopters, people whose mean error was 0.59, whereas non-adopters' was 0.23. The sample population's mean difference between adopters and non-adopters is 2.3/ha. Since the null hypothesis was rejected and the t-statistic value and its p-value = 0.0001 are less than $p=0.05$, it can be concluded that the mean difference in plot size between adopters and non-adopters is statistically significant. The explanatory variable plot size thus significantly contributed towards CA technology adoption among the aforementioned said study populations.

Table 4.2. 9 Descriptive Statistics for Continuous Variable Active Workforce

Adoption CA	Obs	Mean	Std. Err	Std. Dev	t-value	D.f	95%. Conf	Interval
Non- adopters	63	2.873	0.222	1.764	-5.648	469	2.429	3.317
Adopters	408	4.419	0.102	2.059			4.219	4.619
Combined	471	4.212	0.962	2.059			4.023	4.401
Diff		-1.546	0.274				-2.084	-1.008

Source: Field Survey July, 2022 $p<0.05$, $p>0.05$

$p\text{-value} = 0.0000$

Table 4.2.9 recorded on average, an active workforce of 2 members for non-adopters and 4 active members for adopters per household. A standard Error of 0.22 and 0.10 members constituting the active family workforce for non-adopters and adopters respectively. Implying that adopters of CA technology have more active family labor force compare to non-adopters. The mean difference is -1.5 between adopters and non-adopters. t-test statistics with p-value = 0.0000 less than $p=0.05$ represent rejection of null hypothesis, and that the mean difference between the CA technology adopters and non-adopters is significant statistically. Hence the



variable household active workforce reflects own family labor capacity has significant impact on CA technology adoption between the two groups.

Table 4.2.10 Descriptive Statistics for Continuous Variable Annual Income

Adoption CA	Obs	Mean	Std. Err	Std. Dev	t-value	D.f	95%. Conf	Interval
Non-adopters	63	4201.73	646.20	4129.07	-3.38	469	2909.99	5493.47
Adopters	408	10170.43	685.95	13855.47			8821.98	11518.87
Combined	471	48.53	0.573	12.43			47.41	49.66
Diff		0.45	1.68				-2.86	3.76

Source: Field Survey July, 2022 $p < 0.05$, $p > 0.05$

$p\text{-value} = 0.0008$

Table 4.2.10 report the descriptive statistic of mean and standard Error, standard deviation, showed that on average, the mean annual income farm households earned was GHS 4201.73 and GHS 10170.43 for non-adopters and adopters respectively. Indicating that adopting households earned as much as three times the income of non-adopter's farm households' heads on average per year. With their corresponding standard Errors of 646.2023 and 685.9482 respectively. A t-test statistic $p\text{-value} = 0.0008$, less than $p = 0.05$, indicates that we reject null hypothesis and conclude that the difference in means for adopters and non-adopters of CA technology in the population sample is statistically significant. Thus, the explanatory variable annual income has a positive significant effect on household CA technology adoption in both groups. Household incomes indicated a considerable difference between the high and the low-income individuals in all districts. It is possible because farmers have sunk so much money in agriculture and in the favorable-to-crops CA practice versus their peers who don't invest and provide more inputs to the CA practice



Table 4.3 Descriptive Statistic Showing Categorical Variables for Adopters and Non-adopters

Variables	Obs	Mean	Std. Deviation	Min	Max
Sex	471	0.845	0.362	0	1
Marital status	471	2.342	0.799	1	5
FBO member	471	0.626	0.484	0	1

Source: Field Survey July, 2022

According to the discovery of the aforementioned Table 4.3, the farm household male-headed own more than half of the smallholder farmers under the sample survey with a mean of around 80% out of a total number of observations of 471 reporting a higher gender difference between male-headed and female-headed farm household households which have implemented CA practice in the survey, whereas that of the latter own a paltry mean of 20% of farm household with a standard deviation of 0.36.

Table 4.3.1 Descriptive Statistics for Categorical Variables Sex

Adoption CA	Obs	Mean	Std. Err	Std. Dev	t-value	D.f	95%. Conf	Interval
Non-adopter	63	0.873	0.423	0.336	0.659	469	0.788	0.958
Adopters	408	0.841	0.018	0.366			0.805	0.876
Combined	471	0.841	0.017	0.362			0.812	0.878
Diff		0.323	0.049				-0.064	0.129

Source: Field Survey July, 2022 $p < 0.05$, $p > 0.05$

$p\text{-value} = 0.5103$

Table 4.3.1 above report the descriptive statistics for household head sex with corresponding means and Standard deviations and errors for the survey group's CA technology adopters and non-adopters. On average, the mean of sex for non-adopters was 0.87 relative to 0.84 for adopters. For non-adopters, relative standard error is 0.02; for adopters, it is 0.42. For sex group of household heads, the difference between the mean of both groups is 0.32. Null hypothesis will not be rejected if t-test statistic $p\text{-value} = 0.5103$ is more than $p = 0.05$, indicating that the



mean difference between males and females is not statistically significant. This indicates that there is no effect of male-headed and female-headed household on CA technology adoption for the survey.

Table 4.3.2 Descriptive Statistics Categorical Variable Marital Status

Adoption CA	Obs	Mean	Std. Err	Std. Dev	t- value	D.f	95%. Conf	Interval
Non- adopters	63	2.222	0.092	0.728	1.278	469	2.039	2.406
Adopters	408	2.360	0.040	0.808			2.282	2.439
Combined	471	2.342	0.368	0.799			2.269	2.214
Diff		-0.138	0.108				-0.350	0.074

Source: Field Survey July, 2022 $p < 0.05$, $p > 0.05$

$p\text{-value} = 0.2020$

Table 4.3.2 reported the marital status of respondents which showed the mean average of 2.22 for non-adopters and 2.36 for adopters of CA technology household heads being married. A corresponding Standard Error of 0.09 and 0.04 respectively out of the 471 observations. The result indicated a mean difference of -0.1 between the groups. The t-test statistic with $p\text{-value} = 0.2020$ which is larger than $p = 0.05$ provides do not reject the null hypothesis, i.e., statistical difference between non-adopters and adopters group is negligible. Therefore, farmers CA technology adoption doesn't depend significantly on marital status.



Table 4.3.3 Descriptive Statistics for Variable Farm Based Organization

Adoption CA	Obs	Mean	Std. Err	Std. Dev	t- value	D.f	95%. Conf	Interval
Non- adopters	63	0.317	0.059	0.469	-5.613	469	0.199	0.436
Adopters	408	0.674	0.023	0.469			0.683	0.720
Combined	471	0.626	0.022	0.484			0.582	0.670
Diff		-0.357	0.064				-0.481	-0.232

Source: Field Survey July, 2022 $p < 0.05$, $p > 0.05$

$p\text{-value} = 0.0000$

Table 4.3.3 reported the descriptive statistic for farmers belonging to Farm Based Organization. FBO association of farm households recorded on average, a mean value of 0.32 for non-adopters and 0.67 for adopters from the observation. A Standard Error of approximately 0.06 and 0.02 respectively for farmers belonging to farm-based organization. A mean difference of -0.36 between the two groups. The t-test statistic of a $p\text{-value} = 0.000 < p = 0.05$ indicates that the null hypothesis is rejected and there exists a statistically significant difference between the mean of adopters and non-adopters. The explanatory variable FBO association thus has positive significant effect on farmers CA technology adoption in the observation.

Descriptive outcomes indicating frequency distribution of non-adoption and adoption status of study farm households are presented in the below table 4.4.

Table 4. 4 Descriptive Results Showing Respondent's CA Adoption and Non-adoption

Respondents	Frequency	Percent	Cumulative
No	63	14.01	14.01
Yes	408	85.99	100.00
Total	471	100.00	

Source: Field Survey July, 2022.

When asked if they had adopted any CA practices in crop production, as shown in Table 4.4 above, 63% of farmers, or 14.01% of the total, responded negatively, meaning they had not adopted any CA practices, whereas 408 farmers, i.e., nearly 86% of the total number of farmers, replied positively that they implemented one or more CA practices during the previous crop season of the study region. Frequency distribution of different CA categories as per field data for implementation of one or more CA techniques followed by farm families of the study region is provided in the following table 4.5.

Table 4.5 Descriptives of Different CA Categories of Adoption

CA Categories	Description	Frequency	Percent	Cumulative
Z ₀ R ₀ C ₀	non-adoption	66	14.01	14.01
Z ₁ R ₀ C ₀	Zero-tillage	50	10.62	24.63
Z ₀ R ₁ C ₀	Rotation	53	11.25	35.88
Z ₀ R ₀ C ₁	Cover cropping	53	11.25	47.13
Z ₁ R ₁ C ₀	Zero-tillage/Rotation	54	11.46	58.60
Z ₁ R ₀ C ₁	Zero-tillage/Cover crops	54	11.46	70.06
Z ₀ R ₁ C ₁	Rotation/Cover crops	56	11.89	81.95
Z ₁ R ₁ C ₁	Zero-tillage/Rotation/Cover	85	18.05	100.00
Total		471	100.00	

Source: Field Survey July 2022: Note! Zero-tillage and Minimal-tillage data were merged after data cleaning.

For Z₀R₀C₀ adoption only; (66) farmers were seen adopting approximately 14.01%. Exclusive CA practice of Z₁R₀C₀ only was with an adoption by (50) farmers covering approximately 11%. Exclusive cover cropping (Z₀R₀C₁) and single crop rotation (Z₀R₁C₀) adoption was (53) farmers respectively covering approximately 11.25%. About 11.89% of the responders, or 56 farms, double adopted two CA methods, i.e., Z₀R₁C₁. There was space for 54 farmers in (Z₁R₁C₀) and (Z₁R₀C₁), which accounted for roughly 11.46% of the total. The full CA package had a considerable number of adopters accounted for with (85) farmers accounting for approximately 18.05%. In line with earlier research (Donkoh, et al., 2019; Adzawla et al.,



2020), Many believe that because multiple approaches work well together, a combination of CSA activities is the best way to lessen the effects of climate change. This implies that farmers select technology autonomously at their own will to which they can adjust their level and capacity to meet their local conditions. A descriptive statistic of the frequency distribution of the main crops that farm households are now cultivating during the 2020–2021 cropping season can be found in Table 4.6 below.

Table 4.6 Descriptive Statistic distribution of Major crops cultivated by households

Crop Cultivated	Frequency	Percent	Cumulative
Maize	82	17.41	17.41
Rice	103	21.87	39.28
Millet	62	13.16	52.44
Sorghum	60	12.74	65.18
Soyabean	14	2.97	68.15
Cowpea	19	4.03	72.19
Groundnuts	24	5.10	77.28
Cotton	10	2.12	79.41
Vegetable leafy	20	4.25	83.65
Pepper	12	2.55	86.20
Tomatoes	13	2.76	88.96
Garden eggs	52	11.04	100.00
Total	471	100.00	100.00

Source: Field Survey, July 2022.

With 103 farmers producing 22% of the total crops, rice was the most common grain staple crop. Maize producers produced 82, or 17%, millet producers produced 62, and sorghum producers produced 60, or 13%. For farm families, legumes like soybeans (14), cowpeas (19), and groundnuts (24), yield 5%, 4%, and 3%, respectively. 52 farmers produced garden eggs, 20 produced leafy vegetables, 13 produced tomatoes, and 12 produced peppers, which



accounted for 11%, 4%, and roughly 3% for each of the vegetables, respectively. Cotton, a cash crop grown by just 10 farmers, or 2% of 471 observations, had the lowest harvest rate.

4.1.2 Factors Influencing adoption of CA Practices Among Farm Households.

The main goal of this study was to explore the determinants of the adoption of conservation agriculture technologies among smallholder farmers in the Upper East. The multinomial logit estimation from the extended MESR model's initial findings, are presented in Table 4.7, identify variables of interest upon which the choices of smallholder farmers regarding adopting CA technology hinge. These results show a set of factors determining various dimensions of adoption of CA technology.

It is here that findings concerning the determinants that affect farmers' adoption decision are presented. The practices come under 7 levels. Farmers at level one is lone adopters who have embraced cover crops ($Z_0R_0C_1$), crop rotation ($Z_0R_1C_0$), or zero-tillage ($Z_1R_0C_0$). Or a combination of two of CA practices such as zero-tillage and rotation ($Z_1R_1C_0$), zero-tillage and cover crops ($Z_1R_0C_1$), and the combination of rotation and cover cropping ($Z_0R_1C_1$), or all three CA technology package ($Z_1R_1C_1$).



Table 4. 7 Multinomial logit estimates for Factors influencing CA Technology adoption

VARIABLES	Z ₁ R ₀ C ₀	Z ₀ R ₁ C ₀	Z ₀ R ₀ C ₁	Z ₁ R ₁ C ₀	Z ₁ R ₀ C ₁	Z ₀ R ₁ C ₁	Z ₁ R ₁ C ₁
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Sex	-1.561 (1.694)	-2.103 (1.707)	-2.104 (1.701)	-0.629 (1.686)	-1.704 (1.710)	-1.051 (1.714)	-1.048 (1.668)
Age	-0.007 (0.041)	-0.028 (0.041)	0.001 (0.041)	0.036 (0.040)	-0.008 (0.041)	0.006 (0.041)	0.009 (0.040)
Educational level	-0.031 (0.102)	0.001 (0.100)	0.020 (0.100)	-0.003 (0.200)	0.036 (0.100)	0.006 (0.100)	0.027 (0.100)
Plot Size	-0.142 (0.097)	-0.194** (0.096)	-0.087 (0.096)	-0.095 (0.094)	-0.146 (0.092)	-0.097 (0.094)	-0.123 (0.092)
Household size	-0.311* (0.159)	-0.228 (0.151)	-0.195 (0.162)	-0.196 (0.144)	-0.188 (0.149)	-0.219 (0.152)	-0.348** (0.152)
Farm Distance	-1.581*** (0.357)	-1.336*** (0.333)	-1.860*** (0.352)	-1.759*** (0.341)	-1.208*** (0.333)	-1.779*** (0.347)	-1.593*** (0.330)
Distance to Mkt	-0.297 (0.412)	-0.288 (0.438)	0.346 (0.367)	-0.006 (0.401)	0.332 (0.370)	-0.061 (0.413)	0.351 (0.367)
Farm Based Organization	1.380 (1.053)	1.382 (1.039)	2.328** (1.051)	1.450 (1.029)	0.329 (1.027)	1.509 (1.036)	0.975 (1.003)
Credit	-5.766***	-6.518***	-5.649***	-5.077***	-5.558***	-7.078***	-5.563***

	(1.457)	(1.453)	(1.434)	(1.402)	(1.431)	(1.484)	(1.387)
Land turner	-0.152	0.062	0.127	0.106	-0.155	-0.016	-0.058
	(0.255)	(0.245)	(0.255)	(0.248)	(0.249)	(0.252)	(0.243)
Total Livestock	-0.053	-0.034	-0.036	-0.124**	-0.072	-0.058	-0.113**
	(0.044)	(0.026)	(0.031)	(0.058)	(0.049)	(0.048)	(0.051)
Log of Durable Assets	1.563**	1.743***	1.356**	1.450**	1.645***	1.715***	1.332**
	(0.610)	(0.607)	(0.606)	(0.603)	(0.609)	(0.605)	(0.598)
CA training	1.683	2.676**	1.293	1.422	1.521	1.989	2.425**
	(1.223)	(1.311)	(1.231)	(1.195)	(1.200)	(1.226)	(1.190)
Knowledge CA	-1.553	-2.183	-2.123	-2.489	1.269	-2.050	-1.339
	(1.866)	(1.853)	(1.965)	(1.825)	(1.945)	(1.841)	(1.823)
Perception CA	-0.103	0.696	0.491	0.216	-0.532	0.396	0.879
	(0.747)	(0.625)	(0.590)	(0.585)	(1.081)	(0.589)	(0.562)
Distance MoFA	0.938***	0.789**	1.129***	1.053***	1.042***	0.876***	0.971***
	(0.320)	(0.318)	(0.320)	(0.312)	(0.314)	(0.314)	(0.307)
Kassena Nankana East	0.778	-2.396	15.96	1.491	0.994	-0.375	0.639
	(1.849)	(1.960)	(607.7)	(1.862)	(1.820)	(1.864)	(1.821)
Nabdam	-0.766	-0.420	14.47	0.283	1.136	-1.918	0.821
	(1.830)	(1.792)	(607.7)	(1.863)	(1.783)	(1.873)	(1.804)

Talensi	-3.451*	-3.715**	16.61	0.462	-15.89	-0.675	-0.626
	(1.803)	(1.648)	(607.7)	(1.551)	(508.6)	(1.537)	(1.517)
Constant	-0.877	-2.537	-18.09	-4.376	-5.741	-4.222	-2.640
	(4.452)	(4.397)	(607.7)	(4.294)	(4.495)	(4.373)	(4.253)
Joint test of instruments:	44.47**						
$\chi^2(28)$							
Observations	471	471	471	471	471	471	471

Source: Field Survey July, 2022. Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

The second phase of the study focused on farmers that implemented two CA practices: zero tillage and crop rotation ($Z_1R_1C_0$), zero tillage and cover crops ($Z_1R_0C_1$) and crop rotation and cover crops ($Z_0R_1C_1$). Farmers who have adopted all three CA farming practices ($Z_1R_1C_1$) are covered under the third category. As shown by the multinomial logit model, the model utilized examined the explanatory variables influencing the adoption of any of these collections of CA technologies by farmers. The statistical model fit is highlighted by a joint chi-squared test, rendering the explanatory variables statistically significant. Thus, the statistically significant measure of the model explains the explanatory variables utilized in justifying their usage; otherwise, they are to be deleted.

Table 4.7 results determine farm distance, access to credit, value of the durable goods, and distance to the nearest MoFA office as significant determinants of farmers' adoption choices under all of the seven combinations. Farm distance was significant at 1% due to the fact that the a priori expectation hypothesis had presumed. It is employed to signify that having one more kilometer of farm distance lowers the chances of the farmer adopting all the three conservation agricultural technologies. It also assumes that farmers with homesteads at faraway places from farms are not as likely to possess all 7 conservation technologies as those with homesteads at nearby places. This agrees with Ngaiwi et al. (2022) where they also noted that at near distance, it had a very important and positive effect on agroforestry, intercropping, and zero-tillage adoption.

Nonetheless, a reduction in the distance to MoFA offices contributes positively to the adoption of CA technology. i.e., distances to MoFA offices have an increased rate of adoption for any CA practice. A presence of nearness to the Ministry of Food and Agriculture office facilitates frequent extension-farmer contact and exposure to agricultural extension, and thus increases the adoption rate of CA technologies by smallholder farmers. The finding confirms to the a priori expectation of the study because extension agents are the central figure of information



provision to smallholder farmers. Farm household awareness of CA is, to a greater degree, the outcome of exposure to extension agents, and therefore the greater the adoption potential of CA technology adoption with exposure to extension. As previously demonstrated by the research studies of Anang et al (2020) who also came to similar findings in northern Ghana. For example, Anang (2022) found that adoption of CSA practices is linked with use of agricultural extension services.

Also, access to credit reduces with the use of all CA practices. In other words, farmers who access to farm credit will have declining adoption levels for all conservation agriculture technologies. This may perhaps be because the farmers had to repay their credit early enough and hence compelled them to adopt other, environment-degrading approaches so that they can repay their loan on time. These results coincide with earlier works by Gao et al. (2017; 2019) and Ngaiwi et al. (2020; 2022), in which all the above studies established that credit was a constraining factor to farmers' adoption of CA technology.

Adoption of all CA practices is positively related to permanent assets. That is farmers adopt conservation agricultural practices where their household possesses more permanent assets, perhaps because they can invest in the appropriate technology and soil conservation methods. These results align with those of Akinbile et al. (2007) that established farmers' use of farm technology to promote sustainable crop production strengthens household asset development.

Smallholder farm households have less space to adopt zero-tillage alone, crop rotation, and cover crops ($Z_1R_1C_1$) than large-sized ones because farm household size is also found to be inversely related to all adoption categories, zero-tillage adoption alone, and simultaneous adoption of zero tillage, crop rotation, and cover crops ($Z_1R_1C_1$). In addition, the size of the farm plot indicates that the use of crop rotation ($Z_0R_1C_0$) decreases only when the farm grows in size.





This would imply that it is less likely to adopt crop rotation among the small plot farmers than among the big plot farmers. According to the a priori assumptions of the study. Similar to most studies in literature (e.g., Anang, 2022; Abdul-Hanan et al., 2014; Menale, 2010). For instance, Anang (2022) found that farmers with small farm size have lower probabilities of adopting the CSA practices. Abdul-Hanan et al. (2014) rationalized that farm size was strongly significantly associated with the adoption of soil and water conservation (SWC) practice by formulating the assumption that a farmer with larger farm size would possess higher technology adoption than his/her counterparts. Menale (2010) verified that the farm size and adoption of various CA practices had a positive correlation because it is one of the factors that mitigates the liquidity constraint of adopting the practice. This followed research by Ngaiwi et al. (2020; 2022) whose research concluded that the size of a farm owned by an individual farmer positively affected adopting zero-tillage techniques.

Furthermore, FBO membership is highly interested in the adoption of cover cropping alone. Farmer group membership increases access to farm extension and better access to farm inputs, hence exploiting economies of scale in the purchase of inputs in bulk quantities. Acheampong et al. (2021) found that farm households under community institutions have a higher likelihood of using climate-smart agricultural technology in food crop cultivation in all of Ghana's ten administrative regions. To assist Wu's (2022) finding as well, which indicated farm households under cooperative institutions have a higher likelihood of using new agricultural technology, with increased crop yield.

Lastly, socio-economic and environmental issues have crucial roles to play in the adoption of CA technology, and in enhancing multi-dimensionality of farm decision-making susceptible to the smallholder farmers. Socio-economic and environmental knowledge intervention is most critical in guaranteeing sustainable practice of agriculture, resulting in enhanced farmers' livelihoods, for example, income and food security.

The research is concerned primarily with adoption of Conservation Agriculture technology by Upper East Region smallholder farmers. We do not present results of selective tests of farm household income and food security. Estimation results are presented as supporting material in Appendix A as Table 4.8 and Table 4.9 for farm household income and food security. See Appendix A.

4.1.3 ATT Impact Results of CA Adoption Practices on Household Income.

Table 4.10 shows the Average Treatment Effect (ATE) of MESR on actual and hypothetical farm revenue depending on the use of Conservation Agriculture Technology (CAT). The difference between the outcome variables (income) of farm households that adopt CA and those that do not is used to calculate the ATT. With an effect size coefficient, a positive ATT in the table below shows that the corresponding CA category improves the desired results. However, a negative ATT indicates that as the intended effect rises, CA technology adoption is decreasing.

Table 4.10 ATT Impact Estimates on Outcome Variable Household Annual Income

1. CA Choice	2. Outcome		3. Difference (ATT)
Household income	Adoption	Non-adoption	Coeff/t-values
$Z_1R_0C_0$	632.269 (224.221)	6144.153 (1751.616)	-5511.884 (2206.751)***
$Z_0R_1C_0$	2817.608 (698.733)	4622.293 (1751.616)	-1804.685 (2070.046)**
$Z_0R_0C_1$	2727.17 (385.798)	4534.015 (1751.616)	-1806.845 (2148.057)**
$Z_1R_1C_0$	2974.095 (677.212)	4344.253 (1751.616)	-1370.158 (2087.296)**
$Z_0R_1C_1$	3549.421 (765.832)	4144.032 (1751.616)	-594.611 (2311.874)*
$Z_1R_0C_1$	3774.095 (522.012)	3261.012 (1751.616)	513.0824 (1784.043)



$Z_1R_1C_1$	4348.982	3803.230	545.752
	(945.344)	(1751.616)	(2068.156)*

*Square bracket values are stand and errors, and *, **, *** denote 10%, 5%, and 1% significance levels, respectively. Note that the reference category for this analysis is non-adoption of all three CA categories.*

Table 4.10 values above are some of the reasons why farm household CA technology adoption is statistically significant and negative with respect to household income, particularly for the single adopters. For zero-tillage only ($Z_1R_0C_0$), it is negatively correlated with the treated household income. The negative -5511 coefficient to adopt zero-tillage only reflects that there is reduction in household income by GHS 5511/ha. This finding agrees with Asante et al. (2024) who estimated the impact of adoption of CSA technology on maize yield and farm net value in Ghana and found that row planting or zero-tillage both decrease maize production by a significant amount of 80kg/acre and 94kg/acre respectively if there are poor zero-tillage practices. Contrary to the findings of prior studies (e.g., Khonje et al., 2018; N'gombe et al., 2017; Manda et al., 2016; Ngwira et al., 2012) all of which had documented significant positive CA technology adoption with productive asset accumulation and income effects on farmers' maize and other crops, credited the enhancement of maize and other crops production to CA uptake among farmers. Supporting Wordofa et al. (2021) evidence, they found that greater CA technology utilization in Eastern Ethiopia achieved greater (\$ 824.42 USD) mean yearly household income for non-users.

When crop rotation is implemented solely by farm families ($Z_0R_1C_0$), the result is a negative association with farm income of -1804/ha, or a loss in farm household income of GHS1804/ha. According to data published by Baiyegunhi et al. (2022), Nigerian farmers who exclusively adopted crop diversification had the lowest income of N1547/ha. Additionally, the cost of using cover crops alone ($Z_0R_0C_1$) on family farm income is only GHS1806 per hectare.



Addison et al.'s (2022) causal estimates, in measuring respondents' net farm income effect by adoption of farming technologies, warranted that the adoption lowers respondents' rice income inequality in Ghana by 0.207 points on average. However, Nkala et al. (2012) found that income was positively linked with the adoption of CA technology when conducting their research on how adoption of CA technology influenced the livelihoods of farmers in central Mozambique.

These results are very conclusive by research. For instance, Oduniyi, Chagwiza & Wade, (2022) explained that farmers who advocated for diversification of crops using minimum tillage or farmers who advocated for diversification of crops only achieved their incomes improved by 50.32% or the amount of (USD 806.11) and 46.01% or (USD 593.62) agricultural income respectively. Diversification has only one adopter, and the outcome indicates drastic farm income growth (Oduniyi, Chagwiza & Wade., 2022). In this case, the combination of $Z_1R_0C_1$ adopters benefit the most in terms of income of some GHS 513/ha but not statistically in manner but the outcome according to Asante et al. (2024) led to improvement in net farm income through technology under CSA technology when two out of three technology options are implemented e.g., adoption of zero-tillage and row planting increase net farm income by an amount of GHS 2070/acre compared to non-adoption. This concurs with results in experiments conducted by Nkala et al. (2011a) to determine the impact of CA technology adoption, whereby it's being highly correlated with increased yield but with no side effects when conducted through either with CA cover crop or CA crop rotation tillage. $Z_1R_1C_0$, zero-tillage crop rotation, recorded lowest GHS -1370/ha, and also resulted in income decline by farmers owing to embracing a combination of crop rotation and zero-tillage and thus highlighted technology choice complementing to be blended in an endeavor towards realizing optimum benefits from adoption (Nkala, 2012). Other studies by Boimah et al. (2018) created a high negative mean difference between maize-legume rotation practice adopters and lowest



profit adopters and non-adopters by mean impacts of GHS -1015/ha. In addition to Corbeels et al. (2014) whose results provide that CA technology adoption greatly reduces farm income between adopters and non-adopters by this result findings. For all the three CA technologies that were adopted, the results indicated substantial increase in income by approximately GHS 545/ha which means adopters of all the three CA practices have more income from crops per hectare.

As would be anticipated, Asante et al. (2024) report that net farm income significantly improved when the three CSA technology are packaged into bundles, income improved by GHS 815/acre. As would be anticipated, Abdulai and Huffman, (2014); Abdulai and Issahaku, (2020) all reported considerable increase in crop production and poverty decline among farmers using CA technology on farm yield in northern Ghana. This means that whenever farmers embrace bundles of conservation technologies, there are significant opportunities for the incomes to rise significantly. In most situations, the implication of the income outcomes is that CA technology adoption is not necessarily constrained to grow farm household incomes annually, particularly in the short term despite the fact that the environment benefits in terms of conservation agricultural technologies exist. The results reveal heterogeneity effects of the uptake for each of the CA technologies. Crop rotation is best, with cover cropping ranking second with the worst being zero as found in this study.

4.1.4 ATT Impact Results of CA Adoption on Household Food Diversity

Table 4.10 below displays the Average Treatment Effect on the Treated (ATT) of the third-stage MESR estimate of the effect of CA technology adoption on household food security. The estimates displayed here represent statistically significant variations in food security as measured by the Household Dietary Diversity Score (HDDS) between CA adopters and non-adopters. Based on the variety of food types that are readily available and divided into 12 food



groups for 24-hour recall, HDDS provides a qualitative description of food consumption in farm households (FANTA, 2003).

Table 4.11 Impact of CA Adoption Practices on Household Food Security

Variable	CA status	Outcome		Difference (ATT)
Food Security		Adoption	Non-adoption	Coeff/t-values
HDDS	Z ₁ R ₀ C ₀	7.192 (0.294)	7.197 (0.227)	0.005 (0.365)
	Z ₀ R ₁ C ₀	7.424 (0.343)	7.973 (0.385)	-0.549 (0.518)
	Z ₀ R ₀ C ₁	7.226 (0.279)	6.843 (0.311)	0.383 (0.418)*
	Z ₁ R ₁ C ₀	7.116 (0.257)	6.904 (0.353)	0.211 (0.438)
	Z ₀ R ₁ C ₁	7.283 (0.259)	8.234 (0.412)	-0.951 (0.486)**
	Z ₁ R ₀ C ₁	8.165 (0.299)	7.569 (0.411)	0.596 (0.512)**
	Z ₁ R ₁ C ₁	8.501 (0.430)	7.186 (0.218)	1.316 (0.454)***

Values in brackets denote standard errors, and *, **, and *** represent significance at 10%, 5%, and 1% respectively. Note the reference category for this analysis is non-adoption of all three CA categories.

Adoption effects on the basis of a degree of food diversity reveal that CA technology adoption overall such as the adoption of zero-tillage alone contributed to increased food diversity at household levels in not very significant but a positive manner. Crop rotation alone, however, has highly significant gains in food diversity. For most of the conservation technology adopters, evidence suggests that crop rotation and zero-tillage adopters have a greater food diversity amongst themselves relative to non-adopters within their respective categories. The cover



cropping and crop rotation adopters have lower food diversity amongst themselves relative to non-adopters. Compared to non-adopters, there is evidence that the three conservation technology adopters have better dietary diversity among themselves. This is consistent with existing research (e.g., Mango et al., 2017; Acheampong et al., 2022; Asante et al., 2024) that demonstrated that using all three CSAs in accordance with the correct protocols may boost farm household income and food security, as well as improve welfare and reduce rural poverty.

Among CA practices adopted by single farmers, cover cropping only ($Z_0R_0C_1$) is most and strongest correlated with household dietary diversity score of 0.383 points higher among adopters and non-adopters. Further findings of Aweke et al. (2021) indicating adopting households of high-tech Agri-tech have mean 1.22 higher HDDS score than non-adopters. According to Maseko et al. (2023) ATT, users of cover crops had maize yield increases of 19.5% and 25.3% for the 2018–2019 season compared to areas without cover cropping adoption. Impact studies on the effects of conservation agriculture on household food security by Hailu et al. (2014), Kuntashula et al. (2014), and Nkhoma et al. (2017) confirm to this.

Additionally confirming results from the Mango et al. (2017) study that showed a notable improvement of 5.486 points in the Food Consumption Score of treated farmers in Mozambique. In line with Ali et al. (2022) in Central Ethiopia findings, they discovered adopters of conservation agriculture technology and soil fertility management increased mean HDDS by 0.22 points although statistically it had no variation from non-adopters reducing HDDS by -1.99 points which are indicators of the contribution of adoption of conservation agriculture technology towards household food security in line with Addai et al. (2023) findings ATT from northern Ghana show high propensity score of farmers on average adopting agricultural technologies significantly higher 257.1 percentage points for rice production and 74.5 percentage point for HDDS than non-adoption. Crop rotation only adoption ($Z_0R_1C_0$) is



negatively but statistically insignificantly correlated with household food security and is related to a 0.549-point decrease in household dietary diversity score. As expected by the hypotheses of Mango et al. (2017) estimates reduced the food consumption score by 2.05 points among treated Zimbabwe farmers. Note that HDDS and FCS are equivalent and interchangeable at the household level as a dietary diversity measure (Maxwell et al. 2013).

Among the conservation agriculture practices and intercropping methods being developed, zero-tillage after cover cropping ($Z_1R_0C_1$) is statistically significant with a positive correlation to household dietary diversity by 0.596. HDDS is 0.596 units greater in adopters of the zero-tillage technology and subsequently covered cropping compared to non-adopters. As per Chiputwa et al. (2011); Wekesseh et al. (2019); and Mango et al. (2017) who demonstrated a statistically significant food consumption score change of the Zimbabwean, Kenyan and Mozambican CA technology adopters respectively showing enhanced protein consumption score among the adopters.

Joint implementation of cover cropping and crop rotation ($Z_0R_1C_1$), however, is statistically and negatively significant for HDDS by -0.951 points and thus explains the fact that joint implementation of cover cropping and crop rotation at farm plot level reduces by 0.951 points in HDDS. This aligns with Aslan, (2014) whose view was that CA technology adoption has the potential to reduce Zambia's heterogeneity of yields. This finding is unique from other literature review study (e.g., Setsoafia et al., 2022; Acheampong et al., 2021; Wekesah et al., 2019) whose results were all in line with the statement that farm household food security status improved when they adopt CA. This conforms to the results of the Baudron et al. (2007) case study that did record some of the features of CA technology like (minimum/zero tillage, cover cropping and rotation diversification) to have made their individual contributions towards fostering the fertility of soils and consequently crop yields.

Lastly, adoption of the whole package of CA technology like zero-tillage, rotation and cover



cropping (Z₁R₁C₁) has with very high significance effects on household dietary diversity score with effect size of 1.315 points. The discovery that farm families who had adopted the full CA package have higher dietary food diversity intake is one whose discovery was consistent with FAO advice to farmers to adopt full CA technology package of minimum/zero tillage, cover crops and diversification through crop rotation, if they were to achieve any potential benefit from CA technology package (FAO, 2017). The conclusion of this study concurs with other recent studies by Setsoafia et al. (2022); Oduniyi and Chagwiza, (2021); Amadu et al. (2020) that the adoption of several conservation agriculture technologies with the same effect on the farm performance, productivity, and crop yield than the adoption of a single CA technology. Generally, empirical findings reveal the multi-dimensional effect of various CA technology practices to household food security under varying circumstances. The evidence is warranted in establishing the contribution of package adoption of CA technologies to household-level food security over selective adoption.



CHAPTER FIVE

SUMMARY, CONCLUSIONS AND POLICY RECOMMENDATION

5.1 Chapter Outline

This Chapter introduces the summary outcomes of the study, conclusions, research and policy recommendations, and future research recommendations in the field of individuals who are interested in starting and advocating for an effective intervention strategy.

5.2 Summary

The major goals of this thesis are to analyze the effects of CA technology adoption (i.e., zero-tillage, crop rotation and cover cropping) on farm household income and food security. Multistage sampling design was applied to select respondents to be interviewed. The answers were gathered by using a survey of 471 farm households for the analysis. The effects of CA technology adoption on the livelihood indicators in households such as income and food security were predicted using a multinomial endogenous switching regression.

MESR model was used here since it has the ability of controlling endogeneity and examining how adoption by individuals and groups of farmers applying different CA practices affects income and food security. Findings of this study indicate that institutional, exogenous, and socio-economic farmer profile are the drivers of farmer adoption of CA technology. In particular, demographic and social household characteristics (e.g., farm-to-household distance, education, age, gender, and household size), plot-level characteristics (e.g., land slope and topography, and plot location), drive household choice to adopt different CA practices.

ATT implications on impact achieved had they adopted CA practice single and combined differential effects. Surprisingly to all, adoption of ($Z_1R_0C_0$) lowers household yearly income by GHS 5511/ha and HDD score by 0.005 points) respectively than the based category. $Z_0R_1C_0$



(adoption of crop rotation only) lowers household yearly income and diet diversity score to (GHS1804/ha and lower diet-diverse score by 0.549 points) respectively than the based category. Adoption effect of cover cropping by $Z_0R_0C_1$ only led to mixed outcomes, thereby lowering household income and dietary diverse score by (GHS 1806/ha and HDDS score by 0.383 points) from the based category.

ATT plans of the adoption of the other CA technologies like the bundle of ($Z_1R_1C_0$, $Z_0R_1C_1$, $Z_1R_0C_1$ and $Z_1R_1C_1$) that complement one another may have impacted farm household income and food security differently by (GHS-1370/ha loss of income with a more adoption of $Z_1R_1C_0$ increased the diversified diet in the HDD score by 0.211 points compared to the based category by -0.951 points decreases dietary-diverse HDDS score for adoption of $Z_0R_1C_1$ compared to the based category is equivalent to annual loss in farm household income of GHS594.61/ha. Compared to the based group, farm household income rose by GHS 513.08/ha, corresponding to a 0.596-point gain in the household dietary-diverse score for adopting $Z_1R_0C_1$ option.

As per this study, ATT evidence also indicates that household income would be raised above the based category by GHS 545.75/ha, equivalent to a positive HDDS score value of 1.315 points for $Z_1R_1C_1$ adoption. This implies that farm households would attempt to enhance household dietary diversity through the purchase of additional food products using the excess cash received from selling surplus crops.

5.3 Conclusions

The key objective of the present study was to find out and analyze the role played by the adoption of conservation farming methods in increasing farm household revenues and increasing the food diversity levels of farmers in Ghana's upper east region. The ordinal scale multinomial logit model, or (MNL) model, was utilized to an expectation to attain the key objective of the present study, which is identifying the determinants that affect the CA



technology of agricultural production systems to some extent. In order to address the second and third objectives individually, the ATT difference-in-mean impact was employed through a multinomial ESR. In this research, the most frequent CA technology farming practices among farmers were witnessed to be crop rotation, reduced/zero-tillage, and cover crops in greater percentages. The practices also enhanced the extent of farm households' food security. Key positive policy determinants that affect CA technology adoption were FBO membership, HDDS, CA training and accessibility of MoFA office facilitating farmer-extension contact. HDDS comprised food sufficiency and food diversity at the household level from farm outcome and CA technology practices of the application in farm activity.

It is proven through the study that; such variables whose influence was opposite to adoption of CA and yields should be given the highest priority as in the end it will be an effort towards realization of effects of smallholder livelihood such as income and diversity of food for family farmers. Lack of study was faced in not having a chance to view all the 480 data which had initially rested upon time and finances constraints. Initial magnitude of large data in future studies of the application of conservation agriculture technology for models' convergence development and net welfare effect estimation of variables will be encouraged.

Total outcomes differed by their effects of CA technology practices on farm household production of crops. Implying that adoption of the CA technologies cannot be substituted by household income increase and food security after adoption but benefits are arising while adopting new package of the CA technologies in an entire package.

5.4 Policy Recommendations

- i. The empirical results of the study serve as the building block for subsequent policy recommendations.
- ii. From a broader level, the outcomes had indicated that conservation agriculture



technology would improve income and food security among small-scale farmers. Based on the survey conducted in four districts in the Upper East region covered in the study, as well as overall in Ghana, the results likewise affirm the critical need to advance CA Practices as livelihood-enhancing technology.

- iii. In accordance with the research findings, rural farm households that adopted over one package of CA technology saw higher farm income and food diversity than those who adopted a single package of CA technology.
- iv. In order to maximize the use of the CA package, CA interventions such as (Z₁R₀C₁ and Z₁R₁C₁) which have been shown to be effective in order to produce income and improve food security for the smallholders need to be scaled up and expanded. They need to be addressed as a package and not separately.
- v. Farmer-extension access was found to be one of the key factors in having a positive influence on the adoption level of CA technologies among the smallholder farmers. The policymakers should go back to the district MoFA extension officers to scale up the conservation agriculture practice campaign in a manner that farmers embrace various packages that offer sustainability, food security and net gain to the farmer and society with the collaboration of extension officers towards attaining 2030 SDG goals of (1, 2, 12, and 13).
- vi. Farm-Based Organization has generally positive effect on CA adoption among farm households. FBO associations offer entry points to extension service and sale and purchase of farm inputs in bulk to members and hence economies of scale to some extent.
- vii. A recommendation for future research with high data volume to examine the impact of Multiple CA adoption on crop yield and rural food security among smallholder farmers.



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APPENDIX A

Table 4. 8 MESR Selectivity results for household farm income

Variables	Outcome (Household income)							
	Nonadopter (0)	Z ₁ R ₀ C ₀ (1)	Z ₀ R ₁ C ₀ (2)	Z ₀ R ₀ C ₁ (3)	Z ₁ R ₁ C ₀ (4)	Z ₁ R ₀ C ₁ (5)	Z ₀ R ₁ C ₁ (6)	Z ₁ R ₁ C ₁ (7)
Age	0.055 (0.046)	-0.037 (0.161)	0.032 (0.051)	0.044 (0.053)	0.013 (0.060)	0.044 (0.040)	0.053 (0.086)	0.056 (0.039)
Sex	-0.199 (0.941)	-2.715 (4.246)	-5.981* (3.483)	1.921 (1.850)	-1.581 (3.680)	-1.603 (2.956)	-4.305 (3.268)	3.896*** (1.492)
Marital status	-0.460 (0.439)	0.568 (0.899)	-2.683 (1.674)	0.681 (1.120)	-0.647 (1.527)	-1.209 (1.029)	-0.836 (3.148)	1.153 (0.823)
Level of education	-0.016 (0.084)	0.256 (0.286)	0.199** (0.083)	0.072 (0.077)	0.118 (0.085)	-0.040 (0.114)	0.048 (0.102)	0.050 (0.042)
Farmer experience	-0.073 (0.053)	-0.025 (0.249)	-0.110 (0.149)	-0.022 (0.047)	-0.050 (0.104)	0.014 (0.034)	-0.124 (0.112)	0.009 (0.064)
Farm distance	0.312* (0.164)	-2.183 (1.756)	0.675 (0.480)	0.040 (0.282)	0.350 (0.718)	-0.663** (0.323)	0.699 (0.648)	-0.105 (0.477)
Household size	0.060 (0.115)	0.806 (0.580)	0.197 (0.307)	0.436*** (0.138)	-0.058 (0.338)	-0.635*** (0.213)	0.611** (0.278)	0.078 (0.285)
Credit access	3.378 (5.317)	-3.529 (8.187)	-0.635 (1.667)	-0.271 (0.410)	0.327 (0.938)	1.245 (0.971)	0.041 (1.662)	0.053 (0.553)
Distance to markets	0.623*** (0.214)	0.955 (1.429)	-0.132 (0.506)	0.244 (0.438)	1.025 (1.045)	0.913* (0.509)	0.625 (0.827)	-0.731* (0.435)
Landholding	0.104 (0.073)	-0.016 (0.361)	-0.140 (0.095)	-0.089 (0.080)	0.020 (0.216)	0.185 (0.147)	-0.428** (0.209)	-0.004 (0.064)
Livestock assets (log)	0.021 (0.465)	1.340 (0.893)	0.575 (0.509)	0.097 (0.201)	0.313 (0.756)	-0.557 (0.366)	0.639 (0.821)	0.868*** (0.157)
Durable assets (log)	0.075 (0.268)	-1.0754 (1.497)	0.501 (0.628)	0.763** (0.341)	-0.507 (0.683)	0.627 (0.797)	1.333 (0.885)	0.193 (0.302)

Source: Field Survey, July 2022.

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

Table 4. 9 MESR Selectivity Results for household food security

Variables	Outcome (household food security)							
	Nonadopter (0)	Z ₁ R ₀ C ₀ (1)	Z ₀ R ₁ C ₀ (2)	Z ₀ R ₀ C ₁ (3)	Z ₁ R ₁ C ₀ (4)	Z ₁ R ₀ C ₁ (5)	Z ₀ R ₁ C ₁ (6)	Z ₁ R ₁ C ₁ (7)
Age	-0.018** (0.007)	0.012 (0.012)	-0.000 (0.009)	0.023** (0.010)	-0.004 (0.018)	0.006 (0.018)	-0.005 (0.014)	0.024*** (0.006)
Sex	0.192 (0.456)	0.138 (0.307)	0.210 (0.787)	0.569 (0.616)	-0.383 (1.026)	-0.040 (1.103)	-0.535 (0.602)	0.689 (0.438)
Marital status	0.137 (0.135)	-0.001 (0.206)	-0.019 (0.318)	0.006 (0.350)	-0.187 (0.378)	0.144 (0.430)	-0.188 (0.195)	0.039 (0.222)
Level of education	-0.003 (0.016)	0.020 (0.023)	0.006 (0.014)	0.016 (0.018)	-0.004 (0.012)	0.002 (0.051)	0.007 (0.016)	0.026** (0.011)
Farmer experience	0.011 (0.007)	-0.035** (0.014)	-0.002 (0.011)	-0.021** (0.010)	-0.021* (0.011)	-0.010 (0.019)	-0.005 (0.018)	-0.009 (0.012)
Farm distance	-0.044** (0.020)	-0.130 (0.204)	0.018 (0.243)	-0.046 (0.085)	-0.018 (0.195)	0.0130 (0.143)	-0.162** (0.082)	0.020 (0.058)
Household size	0.015 (0.028)	0.061 (0.053)	-0.017 (0.062)	0.074 (0.070)	-0.037 (0.075)	-0.020 (0.125)	-0.011 (0.053)	0.045 (0.039)
Credit access	0.061 (0.380)	-0.057 (0.226)	0.322 (0.317)	-0.022 (0.105)	0.062 (0.125)	-0.013 (0.505)	0.042 (0.092)	-0.037 (0.106)
Distance to markets	0.0323 (0.060)	0.059 (0.120)	0.144* (0.085)	-0.034 (0.148)	0.261* (0.158)	0.145*** (0.052)	0.102 (0.157)	-0.238*** (0.072)
Landholding	-0.001 (0.011)	-0.003 (0.020)	-0.025 (0.042)	-0.026 (0.023)	0.040 (0.066)	0.025 (0.038)	0.023 (0.033)	-0.016 (0.016)
Livestock assets (log)	-0.040 (0.072)	0.118 (0.113)	0.024 (0.166)	0.002 (0.089)	-0.068 (0.140)	-0.061 (0.220)	-0.020 (0.077)	-0.103*** (0.037)
Durable assets (log)	0.019 (0.043)	0.028 (0.123)	0.037 (0.123)	0.081 (0.094)	0.0173 (0.167)	-0.097 (0.140)	-0.090 (0.090)	-0.028 (0.043)

Source: Field Survey July, 2022.

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

APPENDIX B

STRICTLY CONFIDENTIAL

IMPACT OF CONSERVATION AGRICULTURE TECHNOLOGY ADOPTION AMONG SMALLHOLDER FARMERS IN NORTHERN GHANA

Household Survey Instruments:

Instruction: Please Enumerators conduct the interview with household head/or the wife of HH

Hello morning/afternoon.....Am a student of UDS, I am conducting research on Conservation Agricultural Technology Adoption among smallholder farmers in Northern Ghana precisely in Kassena Nankana East Municipal, Bongo, Nabdam and Talensi districts in the upper east region. Thank you for having granted me permission to interview you.

I would like to assure you that I will stick to all ethical codes and conducts with regards to conducting research as stated in my introductory letter.

Survey ID:

Questionnaire number..... Enumerator's Name.....

Date of interview..... Time.....

Location:

I. District..... IV. District Code.....

II. Community..... V. Community ID.....

III. Household head Name..... VI. GPA Code.....

SURVEY QUESTIONNAIRES.

SECTION A: Background Information/ Demographic Characteristics:

S/ N	ID	DESCRIPTION.	1	2	3	4	5	6	7	8	9	1	1
A1	Sex	1=Male, 0= Female										1	0
A2	H/head	1= Male, 0= Female											
A3	Marital status	1.Single 3. Divorce 5. Separated 2.Married 4. Widowed											
A4	Age of H/head	Indicate household head age?											
A5	Edu level	How many years of formal schooling by household head.											
A6	H/head Experie	How many years of farming experience											
A7	Distanc e	How many (km) of distance do you cover from home to farm?											
A8	Househ old size	Number of persons in one compound											



		Total number of household members													
A9	Dep Ratio	What is the dependency ratio of your household?	Children < 6 years	Children > 10-15 years	Adults from 16-50 years	Adults Above 60 years									
#															

SECTION B: PART I. Farm /Plot Level characteristics and other activities

Plot ID	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12
	What is the total size of this plot?	What portion of the land has been cultivated?	What is the status of the remaining portion? Code B3	If rented how much would you receive in cash/kind? Code B4	What crops were cultivated on this plot in last season? Code B5	Where is the farm located? Code B6	What is the distance of the farm from your home? (No of min walking) Code B7	What is the level of soil fertility on this plot over the last 10 years? Code B8	How did you obtain the plot/gain right to farm on it? Code B9	How long have you been farming this land?..... Code B10	How did you prepare your land? Code B11	How much did it cost you to prepare this farm? Code B12
	Size	Units of measure Codes B1										
1.												
2.												
3.												





4.												
5.												
6.												
Codes B1		Codes B3		Codes B5		Codes B6		Codes B8		Codes B9		Code B11
1.Hectare 2.Acre. 3. Poles		1.Allow land to fallow 2.Give out to someone else to farm 3.Rent it		1.maize 2. rice 3. millet 4.sorghum 5.soyabea 6.Cowpeas 7.Gr. nuts 8.Cotton 9.Vegetabl 10.Pepper 11.T/toes 12.Gd. egg		1.Around the home 2.Outside home but within same community 3.Outside home located in different community		1.Infertile 2.Increase in fertility 3.Same fertility 4.Decrease in fertility		1.Owner 2.Purchase 3.Least/hir e 4.Allocate d free of charge 5.Rent/tena nt from decease family member 6.Begged 7.Borrowe d 8.Other (specify)		1.Tracto r 2.Droug ht animal 3.Hand

PART II: Information about your Farm Input Application during the 2020/2021 Season

Please provide information about your input application during the season.

Plot ID	B13	B14	B15	B16	B17	B18	B19	B20	B21	B22
	Indicate the quantity of seeds you apply on this farm? (kg)	Indicate the seed variety you applied on this farm?	Where did you obtain the seeds, you planted on	If bought, what was the quantity bought for this	How much was the cost of the seeds you bought on	Did you apply fertilizer on this farm? 1= Yes 0= No	If yes what type, did you apply on this	What was the quantity apply? (kg).	What was the price per bag?	Did you apply pesticide? 1=Yes 0= No

		Codes B14	this farm? Code s B15	farm? (kg)	this farm?		farm? Cod e B19			
1.										
2.										
3.										
4.										
5.										
6.										
Othe rs										
Codes B14				Codes B15			Codes B19			
0. Local seeds 1. Improved certified seeds				0.Own storage 1.Input dealer 2.Market purchae 3.local seed producer 4.Extention officers 5. NGO. 6.Aggregators 7. SARI/CSIR			1.Fertilize NPK (15.15.15) 2.Ammonium sulphate 3.Fert 23.10.5 (Activyva) 4.Other compound fertilizer 5.Urea 6.Phosphate. 7. Sulfan 8. Inoculant 6.Others specify.....			

Plot ID	B23	B24	B25	B26	B27	B28	B29	B30	B31	B32
	Which type did you apply? Cod e B23	How many quanti ties did you apply farm? (liters/ kg)	How much did the pestici des cost you?	Did you apply weedici des? 1= Yes 0= No	If,yes what type of weedici des did you use? CodesB 26	What quan tity of liters did you appl	How much did it cost for the weedici des? (GHC) ...	Did you appl y gree n man ure on this plot? 1=Y es 0= No	Did you apply anim al manu re on this farm ? 1= Yes, 0= No	Did you apply comp ost on this farm ? 1=Y es, 0= No
1.										

2.										
3.										
4.										
5.										
6.										
Oth ers										
Codes B23						Codes B26				
0.None 4. Fungicides 1.Powder/condemn 5. Tintani 2.Sarosate 6. Others..... 3.Insecticide						0.None 3. Fungicide 1.Condemn 4. Tintani 2.Glyphosate 5. Others				

PART III: Farm Labor information.

Kindly tell me about your farm labor requirement for the 2020/2021 season.

Own labor			Contract labor				Cooperative labor		
B33	B34	B35	B36	B37	B38	B39	B40	B41	B42
Did you used family labor during the 2020/2021 cropping season? 1=yes 0=no	If yes how many ?	Kindly thick the numbe r of days spend on the farm?	did you use hired labor on your farm ? 1=yes 0=no	If yes how many ?	How many days did you spen d on your farm ?	What was the total cost for hired labor ?	Did, you use labor from cooperative s last season? 1=Yes 0=No	If yes how man y were they ?	If yes how many days did you use them on your farm ?

PART IV: Crops Harvesting, threshing and Marketing Details.

Plot ID	B43		B44	B45		B46	B47	B48	B49	B50	B51	
	Kindly indicate quantity of crops you harvested on this plot last season?		Did you experience crop losses during harvesting on this field? 1=yes 0=no	what quantity of crops were lost in total?		Did you sell any of your crops? 1=yes 0=no	What was the quantity sold since harvest in 2020/2021	How much did you sell most of the crops per unit?	What was the distance to the nearest market for (km).	Indicate the cost of transporting farm produce to the market?	Did you incur any additional cost at the market? If any kindly indicate?	
	No	Measurement units Code B43		#	Unit of measurement Codes B45						0/1	Amount
1.												
2.												
3.												
4.												
Codes B43						Codes B45						
1.kg bag 5. Tubers 2.Mini bag 6. Bowls 3.Maxi bags 7. Others (specify) 4.Basin						1.Hectare 2.Acre 3.Poles.						



Plot ID	B52						
	Please tick 1=yes 0=no if you bought any crop for H/Hold consumption during this year						
	B53	B54	B55	B56	B57	B58	B59
	If yes kindly indicate the crop	What was the quantity of crops you bought? Codes B54	How much was the price of those crops?	What was the nature of the crop? Codes B56	Did you conduct a market survey before buying? 1=Yes 0=no	What was your main reason for buying? Codes B58	Please indicate where you buy most of the crops from? Codes B59
1.							
2.							
3.							
4.							
Codes B54		Codes B56		Codes B58		Codes B59	
1.kg bag 2.Bowls. 3.Mini bag 4.Maxi		1.Staple crops 2.Cash crop 3.Livestock		1.Supplement stocks 2.when crop price decrease/falls 3.Expectation of future crop price increase		1.On the farm 2.Community market 3.Aggregators	

SECTION C. Institutional Characteristics.

I would like to ask you about institutional factors that support your farming over the years.

Institutional Interventions/Support	1-Yes [] 0-No[]
C1. Do you belong to any FBO?	
C2. Did you ever receive extension services from any institution?	
C3. Did you ever receive health care from any health care services?	
C4. Get Support from NGO or Community Based Organization	
C5. Do you have access to credit from any financial institution?	
C6. How many times do you or any of your household members visit the hospital in every month?	

C7. Type of training received by farmers, organization conducting the training and crops grown under CA.

Types of training received under CA	Response 1=yes 0-No	Total
	(Variable Improves)	
Zero tillage		
Minimum tillage		
Bullock plough		
Tractor plough		
Mulching		
Cover cropping		
Farm waste management		
Erosion control structures		
No burning of residues		
Use of chemical fertilizer		
Use of manure/composting		
Green manuring		
Water conservation		
Irrigation		
Crop livestock integration		
Proper use of pesticides		
Which of the organization provided the training?	MoFA extension [] Researchers []	



SECTION D: Locational characteristics.

Please I would like to ask you about the locational characteristics of your farm plots

Plot ID		D1	D2	D3	D4	D5	D6	D7																
		What is the fertility level of the soil? Codes D1	What is the soil PH level of this land? D2	Percentage of nitrogen matter? Code: D3	Percentage of organic matter in this plot? Code D4	Available phosphorus mg/kg? Code D5	Texture of the soil? Code D6	Slope of the land? Code D7																
	Size	Units																						
1.																								
2.																								
3.																								
4.																								
5.																								
6.																								
Others																								
<table border="0"> <tr> <td>Codes: D1</td> <td>Code D2</td> <td>Code D3</td> <td>Code D4</td> </tr> <tr> <td>1. Averagely fertile</td> <td>1. 4.10-7 soil PH</td> <td>1. 0.00-0.14%</td> <td>1. 0.54-6.74%</td> </tr> <tr> <td>2. Moderately fertile</td> <td>2. 3.10-7 soil PH</td> <td>2.0.00-0.13%</td> <td>2. 0.54-6.73 %</td> </tr> <tr> <td>3. Poorly fertile</td> <td>3. 2.10-7 soil PH</td> <td>3. 0.00-0.12%</td> <td>3. 0.54-6.72 %</td> </tr> </table>									Codes: D1	Code D2	Code D3	Code D4	1. Averagely fertile	1. 4.10-7 soil PH	1. 0.00-0.14%	1. 0.54-6.74%	2. Moderately fertile	2. 3.10-7 soil PH	2.0.00-0.13%	2. 0.54-6.73 %	3. Poorly fertile	3. 2.10-7 soil PH	3. 0.00-0.12%	3. 0.54-6.72 %
Codes: D1	Code D2	Code D3	Code D4																					
1. Averagely fertile	1. 4.10-7 soil PH	1. 0.00-0.14%	1. 0.54-6.74%																					
2. Moderately fertile	2. 3.10-7 soil PH	2.0.00-0.13%	2. 0.54-6.73 %																					
3. Poorly fertile	3. 2.10-7 soil PH	3. 0.00-0.12%	3. 0.54-6.72 %																					
Code D5 1.0.00-3.62 mg/kg 2.0.00-3.61 mg/kg 3. 0.00-3.60mg/kg			Code D6 1.Clay 2.Sandy 3.Loom		Code D7 1.Flat 2.Steep 3.Undulating																			

Source: SARI/CSIR, 2018.

SECTION E: Conservation Agriculture Practices Among Smallholder Farmers.

Please provide information about Conservation Agricultural Technology Practices

Plot ID	E1	E2	E3	E4	E5
	What is structure of ownership of the plot of land you cultivate your crops? Code E1	What type of cropping system do you use? Code E2	Have you heard of /aware of/any knowledge about CA? 1=yes Code 0-No E3	What is your perception about Conservation Agriculture? Code E4	Do you adopt Conservation Agricultural practices? 1=yes 0-No Code E5
1.					
2					
3					
4					
5					
6					
CODES: Please use the codes below to the answer the questions in section E					
Code E1	Code E2	Code E3	Code E4	Code E5	
1.Own land	1.Mixed cropping	1= Yes	1.Makes farming easy	1= Yes	
2.Leased/hire	2.Mono cropping	0= No	2.Control weeds	0= No	
3.Family land	3.Crop rotation		3.Reduce labor and input cost		
4.Inheritance	4.Mixed and Mono cropping		4.Waste time		
5.Holding/trust					
6.Forest Reserve					

E6. If yes which of these CA practices, have you been using to cultivate your crops over the years? Please indicate the number from the table below.

Conservation Practices	Adoption/uses
	1=yes [] 0-No[]
Zero/Minimal soil tillage	
Cover crop/mulching/crop residue	
Crop diversification/rotation	
Soil water conservation	
Crop-livestock integration	
Integrated Pest Management (IPM)	
Fallowing	



Please provide information on the following C A Practices as a smallholder Farmer

Crop Season (2021/2022).										
Plot ID	E11	E12	E13	E14	E15	E16	E17	E18	E19	E20
	Indicate the number of plots you cultivate your crops on?	What was your farm preparation method used? Code E12	How many hectares/ acres is in each farm-plots?	Proportion of area for Zero tillage	Proportion of area for minimal soil tillage	Proportion of area for Cover crops/inter cropping?	Proportion of area for crop rotation	What Crop did you plant in each of the plot last season 2020/2021? Code E18	Have you ever used CA in that plot? 1-yes 0-No	What is the yield per ha/acre plot? (bags kg)
	Size	Units Ha/acre								
1.										
2.										
3.										
4.										
5.										
6.										
CODES:										
E11	E12	E13	E14	E15	E16	E17	E18	E19	E20	E21
1.kindly indicate the number of plots? 2.Indicate Size of the plot in ha/acre	1.Hand hoe 2.bullock plow 3.Tractor plow 4.Bullock ripping 5.Tractor ripping						1.Maize 2.Millet 3.Sorghu 4.Rice 5.Soyabea 6.G'nuts 7.Vegetabl 8.Onion 9.Pepper 10.Cowpe Others.....			



P l o t I D	E22	E23	E24	E25	E26	E27	E28	E29	E30	E31
	Did you own, rent/borrow the plot?	What is the soil type? Sandy, Stones, Loam/Clay	Did you do anything to reduce soil erosion from that plot?	How often do you normally weed that plot in a month?	Did you use Herbicide to spray that plot? 1-yes 0-No	Did you apply fertilizer/manure? Code E27	If yes how much qty of fertilizer/animal manure did used?	How much herbicide did you use (Liters/kg)	How much seeds did you use to plant (kg)	How many bags did you harvested from each plot?
	Size	Units								
1.										
2.										
3.										
4.										
5.										
6.										
CODES:										
E22	E23	E24	E25	E26	E27	E28	E29	E30	E31	
1.Own 2.Rent 3.Borrow	1.Sandy 2.Clay 3.Loam 4.Stones	Please state the type of erosion control measure	Kindly state the number of times you weeded the plot	1-yes 0-No	0. None 1.fertilizer 2.Manure	kgkgkgkg	litlitlitlit	kgkgkgkg	1.Mini bag(kg) 2.maxi bag (kg)	



Plot ID	E32	E33	E34	E35	E36	E37
	How do you normally manage crop's residues leftovers before planting? Code E32	Did animals graze on it? If it were grazed what quantity residues approximately were grazed?	Which farm machinery were used in the CA area? Code E34	What, is the color of the soil on your plot? Code E35	Which crop was your largest crop you harvested in the last season?	How many bags did you harvest from that in total for the season?
1.						
2.						
3.						
4.						
5.						
6.						
CODES:						
E32	E33	E34	E35	E36	E37	
1.Allow to decay	Please indicate	1.bulloc plow	1.Black	Please indicate on the column above	kg	
2.Animal Grazed on it		2.Disc plow	2.Brown		kg	
3.Use as Mulch		3.Harrow	3.white		kg	
		4.Ridgers	4.Ashes		kg	
		5.Tracto plow			kg	
					kg	

SECTION F: HOUSEHOLD INCOME AND EXPENDITURE INFORMATION.

Household Module Questionnaires for Income and Spending.

Kindly tick the boxes your yearly gross income from the activities in the table listed below:

Module 1.	Agricultural On-farm Income/Agric wage labour Source of income	GHC AMOUNT
F1.	Did you earn any income from farming in the last 12 months?	1 yes [] 0 []
F2.	Indicate the amount of money you got from sale of produce/crops last year? Pls indicate the amount in the right column	
F3.	Income from non-farm activities did you earned income in the last 12 months?	
F4.	Gifts and remittance	
F5.	Aid from NGOs/Govt	
F6.	Farm income earns from farm labor activities at Agric-wage rate	
F7.	Any other income earns (specify)	

Kindly indicate by 1=yes 0=no which of the following apply to your household?

	Household Liquidity/Cash Status	Response 1=Yes 0=No
F8.	Does your household usually save some food against lean season? 1-Yes 0-No	
F9.	Do household head usually save money against future emergencies?	
F10.	Does household head have a bank account?	
F11.	Does household head have other financial assets?	
F12.	Does household head often borrow money to meet Household expenditure?	

Kindly Provides Expenses Incur by you and your Household in a Month:

	Item	Expenses/GHC
F13.	What your household monthly expenditure on food items?	
F14.	How much is your monthly expenditure on non-food items?	
F15.	How much did spent (e.g., funerals, weeding, remittance, gifts in the last 12 months	



Kindly Provides information about your Household Livestock Units Holding Assets.

I would want you to tell me about household Tropical Livestock Units and assets Possession

F16.	Please indicate by 1=yes, 0=no if your household owned any of these animals?	Cattle	Sheep	Goat	Pigs	Poultry	Oxen/donkey	Others
		1=yes 0=No	1=yes 0=No	1=yes 0=No	1=yes 0=No	1=yes 0=No	1=yes 0=No	1=yes 0=No
F17.	If yes indicate the number of them your household own?							
F18.	Indicate, the total number that is your own?							
F19.	Did you sell some? If yes how many in all did you sell last year?							
F20.	How much was the selling price of these animals? (GHC)							
F21.	Did you buy any animals? If yes how many animals did you buy last year?							
F22.	How much did it cost you buy them? (GHC)							
F23.	Did you seek for veterinary services for them? 1=yes 0-No							
F24.	If yes how much did pay for							
F25.	vertinery services? What was the total expenses on vertnery services for the year?							



Kindly Provide Details of your Household Durable Items Easily Convertible into Money.

#	Assets.	Ownership of listed assets? 1=Yes 0=No	If, confirm indicate total number?	If you were converting these items into money now how much will you sell them at prevailing market price today? (GHC)
1.	Irrigation pump/kit			
2.	Thresher			
3.	Bullock/donkey			
4.	Tractor			
5.	Mechanized sheller			
6.	Knapsack			
7.	T.V set			
8.	Motorbike			
9.	Car/motor-king			
10.	Bicycle			
11.	Cellphone			
12.	Radio			
13.	Disc plough			
14.	Ridgers			
15.	Combine Harvester			
16.	House			
17.	Oxen Carts			
18.	Others.....			



SECTION G - HOUSEHOLD FOOD SECURITY QUESTIONNAIRES.

Household Food security

Dietary Diversity Score of Households (HDDS)

This section Adopted the FAO (2017) Food and Nutrition Technical framework (HDDS) to gauge household food self-sufficiency.

G1. Please describe the foods type (meals and snacks that you ate yesterday during the day and night whether at home or outside the home start with the first food eaten in the morning.

Breakfast	Snacks	Lunch	Snacks	Dinner	Snacks

Household level: Account for food eaten by individual members at home excluding food purchases outside of the home.

Kindly read from the list of foods in the box below tick 1 in the box if any member of your household ate the underlisted food, place a 0 if no one ate the food.

Food groupings/Categories	Tick
G2. Let me now ask you the type (s) of foods that you or any member of your household ate during the day and at night in the las 24-hours?	
(A) Eaten/ate any banku, TZ, rice, kenkey bread, indomie, biscuits or any other foods made from millet, sorghum, maize, Wheat or locally available grain.?	A.....
(B) Eaten/ate any potatoes, yam, maniac, cassava, or any other food from roots or tuber?	B.....
(C) Eaten/ate any vegetables (e.g., Alefu, cabbage, lettuce, carrots, 'bito leaf's)	C.....
(D) Eaten/ate any fruits (e.g., pawpaw, mangos, oranges, guava, pineapple, etc)	D.....
(E) Eaten/ate any beef, pork, goat, rabbits, bush meat, chicken, duck, other birds, liver, kidney, heart or organ meat	E.....
(F) Eaten/ate any eggs?	F.....
(G) Eaten/ate any fresh or dried or shellfish (e.g., catfish, salmon, tuna etc)?	G.....
(H) Eaten/ate any food made from beans (waakye, tupane) peas, lentils or nuts?	H.....
(I) Eaten/ate any Cheese, yoghurt, Milk, or other milk product?	I.....
(J) Eaten/ate any food made with oil, fat or butter?	J.....
(K) Eaten/ate any sugar or honey?	K.....
(L) Eaten/ate any other foods such as condiments, coffee, tea?	L.....

The HDDS indicator Computation Plan

HDDS (0-12)	Total number of food groups consumed by members of the household. Values for A through L are either 0 or 1 Sum (A+ B+ C+ D+ E+ F+ G +H + I+ J+ K+ L)
-------------	---



The first stage HDD variable is calculated for each household where value of this variable ranges from 0-12

The second stage HDDS indicator is calculated for the sample population

Average HDDS	Sum (HDDS)
	Total Number of Households

G3. Please read the list of foods, and use the codes below to answer the questions from the

Food Source Code G3:

- 1 Bought
2. Own farm produce
3. Traded goods/ services
4. Borrowed
5. Received as gift
6. Own resources
7. Food Aid





Solomon Dery Botee

**IMPACT OF CONSERVATION AGRICULTURE TECHNOLOGY
ADOPTION ON SMALLHOLDER INCOME AND FOOD SECURIT...**



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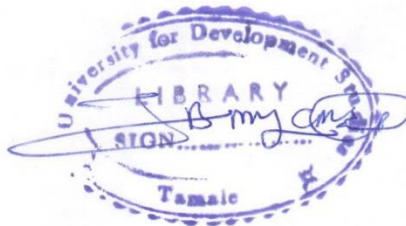
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