Climate Smart Cocoa: Building a Resilient Cocoa Production System in Ghana

by

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climate change and variability, climate smart agriculture, environmental parameters, barriers to adoption, change theory, extension education.

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Abstract

The Study is a three-paper article dissertation. The purpose of the first paper is to examine smallholder farmer's perception of climate change in cocoa production in Ghana. The study employs shifts in environmental parameters—rainfall, temperature, and the duration of wet and dry seasons—to assess farmers' perceptions of climate change. The purpose of this study was to examine farmers' perceptions to climate change and their relationship with socioeconomic and institutional factors. A systematic random procedure was used for this study. Multiple regression analysis and descriptive analysis including frequencies, percentages, means, standard deviations, and correlations were done. The findings indicated that most farmers observed variations in rainfall, temperature, and the duration of wet and dry seasons. Farmers' perceived changes in climate corresponded with weather data from the study district. Farming experience and gender demonstrated a notable correlation with farmers' climate change perceptions. Farmers strongly agreed to be interested in learning about farm-level adaptation practices to climate change. Farmers also strongly agreed to take risks by changing their current farming practices to adopt climate change adaptive practices.

The second paper examines smallholder farmers' perception of climate-smart agricultural practices as an adaptation practice to climate change in Cocoa production. The research employs Rogers' (2003) Diffusion of Innovations theory and the Theory of Planned Behavior to explain the socioeconomic and institutional determinants influencing the adoption of climate-smart agricultural practices among cocoa farmers. A systematic random procedure was used for this study. Descriptive analysis including frequencies, percentages, means, standard deviations, and binary logistic regression were done. The majority of the farmers in this study were male (62,2%), have secondary education (47.2 %) and were between the age of 45-59 years old. Most

farmers have received training (93%), were members of farmer groups (92%) and have access to extension services (98%). The findings further show that gender, education and training positively and significantly influence farmers' adoption of climate-smart agricultural practices in the study communities.

The third paper discusses an advisory paper focusing on the adoption of drip irrigation in Haiti, as a climate-smart technology. This paper is a conceptual framework paper employing Roger (2003) Diffusion of Innovation theory to explain the sets, challenges, and benefits to adopting drip irrigation for vegetable farmers in Haiti.

Keywords: Climate Change Perception, Cocoa (*Theobroma cacao*), Management Practices, Climate-Smart Agriculture, Extension Support, Socioeconomic Factors

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your love and support during my childhood, and for believing in me. I will always be grateful for your legacy and the role you played in shaping my life.

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List of Abbreviations

CSA	Climate Smart Agriculture
CC	Climate Change
IPCC	Intergovernmental Panel on Climate Change
USGCRP	U.S Global Change Research Program

Introduction to the Dissertation: Three Papers on Cocoa Production in Ghana

Climate change and variability is a global issue with unprecedented consequences worldwide. Its projected outcomes are life-changing and life-altering (World Bank, 2015; IPCC, 2021). The World Bank (2015) report estimated that an additional 100 million people will have to survive below the poverty level because of consumption losses caused by climate change by 2030. The U.S Global Change Research Program (USGCRP) report also projected that the number of lands consumed by wildfires will increase by 30 percent due to climate change (USGCRP, 2018). Similarly, IPCC's sixth assessment report (2021) projected a rise in disease risks across warming levels.

Climate change significantly impacts the agricultural industry, including cocoa production. Despite this, the industry itself plays a substantial role in contributing to greenhouse gases that drive climate change (Lynch et al., 2021). The agrifood systems contribute to one-third of global anthropogenic greenhouse gas emissions (Crippa et al., 2021). *The cultivation of cocoa is linked to climate change, primarily due to deforestation and land clearing. Additionally, the environmental ramifications arising from the production of chocolate contribute to climate change, thereby exerting a net negative carbon footprint*[1]. As cocoa production impacts the climate, climate change has consequences for producers (Schroth et al. 2016; Ameyaw et al. 2018; Cilas & Bastide 2022).

Ghana's cocoa industry engages approximately 800,000 smallholder farm families, contributing over 2 billion annually to foreign exchange earnings (Ghana Commercial Bank (GCB), 2022). Cocoa is the number one export crop in Ghana contributing to 3.5% of the country's GDP and 25% in export receipts (B&FT News, 2023). Ghana is also the second largest

[1] https://www.news-medical.net/health/Impact-of-Chocolate-on-our-Climate.aspx

global cocoa producers, jointly contributing to supplying over half of the world's demand for raw cocoa with Côte d'Ivoire (Leissle, 2018). Ghana's cocoa production, a highly valued global commodity, serves as a crucial raw material for the billion-dollar chocolate industry, significantly influencing economic growth and poverty alleviation (Breisinger et al., 2008; Wessel & Quist Wessel, 2015)

Smallholder farmers, predominantly located in Africa, face heightened vulnerability to climate change and variability, given their dependence on rain-fed agriculture for both livelihood and sustenance (Challinor et al., 2007; World Bank, 2009; Connolly-Boutin & Smit, 2016). Smallholder farmers exhibit limited capacity to adapt to the impacts of climate change, rendering them more vulnerable to its effects. As of March 2024, the price of cocoa has surged, doubling since the beginning of the year and reaching a level twice as high as the previous record. The cost per metric ton has risen from $4200 to $9000, reflecting a 4.4% increase since the start of 2024 (Blomberg, 2024; Reuters, 2024). This significant price escalation can be attributed to various factors, including reduced production from West African family farms, the effects of climate change, illicit smuggling of cocoa beans, prevalence of diseases, and the complexities of the futures market (Reuters, 2024; Bloomberg, 2024).

Consequently, smallholder farmers within the cocoa supply chain are particularly affected, as they often receive the lowest compensation, thereby struggling to sustain a viable livelihood. To bolster support for its smallholder farmers, the government of Ghana has raised the farmgate prices of cocoa for the 2023/2024 crop season. The new price stands at GHS 20,943.84 (USD 1,821) per ton and GHS 1308.99 (98.79) per 64kg bag of cocoa beans, marking a significant historical increase of 63.6% compared to the previous season's rate of GHS 800 (60.38) per bag (Ghana Post, 2023).

Combating climate change impacts also requires a comprehensive approach of adaptation and mitigation strategies. Adger et al. (2005) contend that enhancing the adaptive capacity of a system amplifies its resilience and capability to effectively cope with and adjust to the impacts of climate change. Mabe et al. (2012) emphasized that implementing adaptation strategies at the farm level effectively mitigates the detrimental impacts of global warming on food production farms. Hassan & Nhemachena (2008) underscored that effective adaptation to climate change enables farmers to achieve food security, high income, and livelihood security.

Dissertation Organization

The dissertation introduces three papers. The first paper focuses on smallholder cocoa farmers in Ghana, exploring their perceptions of climate change, climate change impact on cocoa farms, factors influencing perceptions, and farmers' decisions to adopt climate change management practices.

Dissertation paper 2 examines cocoa farmers' perceptions of climate-smart agriculture, highlighting adopted practices, extension service support, and the connection between socioeconomic and institutional factors, and the adoption of climate-smart agriculture practices.

Dissertation paper 3 discusses an advisory paper focusing on the adoption of drip irrigation in Haiti, as a climate-smart technology. While this paper is independent of papers 1 and 2, it is intricately connected in its examination of how technology is adopted and disseminated within a given system. Furthermore, it utilizes the adoption and diffusion theory to elucidate the process by which drip irrigation can be embraced in Haiti over time.

The conclusion will provide a summary of the three studies and practical implications of the findings from the various studies.

References

Adger, W. N., Arnell, N. W., & Tompkins, E. L. (2005). Successful adaptation to climate change across scales. *Global Environmental Change*, *15*(2).https://doi.org/10.1016/j.gloenvcha.2004.12.005

Ameyaw, L. K., Ettl, G. J., Leissle, K., & Anim-Kwapong, G. J. (2018). Cocoa and climate change: Insights from smallholder cocoa producers in ghana regarding challenges in implementing climate change mitigation strategies. *Forests*, *9*(12). https://doi.org/10.3390/f9120742

Breisinger, C., Diao, X., Kolavalli, S., & Thurlow, J. (2008). *The role of cocoa in ghana's future development*. In Ghana Strategy Support Program (GSSP), Background Paper No. GSSP 0011, International Food Policy Research Institute.

Bloomberg News. (2024, March 28). *K*itkat, cadbury egg makers feel pain of record high cocoa prices. By Catelli, A., & Compoli, K.

Connolly-Boutin, L., & Smit, B. (2016). Climate change, food security, and livelihoods in sub-saharan africa. *Regional Environmental Change* 16 (*2*). https://doi.org/10.1007/s10113-015-0761-

Crippa, M., Solazzo, E., Guizzardi, D, Monforti-Ferrario, F., Tubiello, F. N., & Leip, A. (2021). Food systems are responsible for a third of global anthropogenic ghg emissions. Nature Food, 2, 198-209.

Challinor, A., Wheeler, T., Garforth, C., Craufurd, P., & Kassam, A. (2007). Assessing the vulnerability of food crop systems in africa to climate change. *Climatic Change*, *83*(3). https://doi.org/10.1007/s10584-007-9249-0

Cilas, C., & Bastide, P. (2020). Challenges to cocoa production in the face of climate change and the spread of pests and diseases. *Agronomy*, *10*(9). https://doi.org/10.3390/agronomy10091232

Ghana Commercial Bank. (2022). *Sector industry analysis: 2022 cocoa sector report*. GCB Strategy & Research Department, Accra, Ghana.

Hayford, K. (2023, September 29). Ghana pegs farmgate cocoa price at ghs 1308 for 2023/24. Ghana Post.

Hassan, R. M., & Nhemachena, C. (2008). Determinants of african farmers' strategies for adapting to climate change: Multinomial choice analysis. *African Journal of Agricultural and Resource Economics*, *2,* 83-104

IPCC. (2021). *Climate Change 2021: The Physical Science Basis*. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 2391 pp. doi:10.1017/9781009157896.

Leissle. K. (2018). *Cocoa*. John Wiley & Sons.

Lynn, J., & Peeva, N. (2021). Communications in the ipcc's sixth assessment report cycle. *Climatic Change*, *169*(1–2). https://doi.org/10.1007/s10584-021-03233-7

Lynch, J., Cain, M., Frame, D. & Pierrehumbert, R. (2021). Agriculture's contribution to climate change and role in mitigation is distinct from predominantly fossil CO2-emitting sectors. *Frontiers in Sustainable Food System,4,* 518039.

Mabe, F.N., Sarpong, D.B., & Osei-Asare, Y. 2012. Adaptive capacities of farmers to climate change adaptation strategies and their effects on rice production in the northern region of Ghana. *Russian Journal of Agricultural and Socio-Economic Sciences*, *11*(11).

Reuters News. (2024, March 14). *Exclusive: African cocoa plants run out of beans as global chocolate crisis deepens*. [Maytaal, A. & Akalaare Adombila, M. (eds)].

Schroth, G., Läderach, P., Martinez-Valle, A. I., Bunn, C., & Jassogne, L. (2016). Vulnerability to climate change of cocoa in west africa: Patterns, opportunities and limits to adaptation. *Science of the Total Environment*, *556*. https://doi.org/10.1016/j.scitotenv.2016.03.024

The Business and Financial Times (B&FT). (2023, February 14). *Deregulation of the cocoa industry*.

The World Bank. (2015). *Rapid, climate-informed development needed to keep climate change from pushing more than 100 million people into poverty by 2030*. The World Bank.

The World Bank. (2009). *Making Development Climate Resilient*. A World Bank Strategy for Sub-Saharan Africa. In Report No. 46947-AFR.

USGCRP. (2018). *Impacts, risks, and adaptation in the united states: Fourth national climate assessment, volume II* [Reidmiller, D.R., C.W. Avery, D.R. Easterling, K.E. Kunkel, K.L.M. Lewis, T.K. Maycock, and B.C. Stewart (eds.)]. U.S. Global Change Research Program, Washington, DC, USA, 1515. doi: 10.7930/NCA4.2018

Wessel, M., & Quist-Wessel, P. M. F. (2015). Cocoa production in west africa, a review and analysis of recent developments. *NJAS - Wageningen Journal of Life Sciences*, 74-75. https://doi.org/10.1016/j.njas.2015.09.001

Dissertation Paper One

Smallholder Cocoa Farmers' Perception of Climate Change And Variability In Ghana

Abstract

Climate change and variability issues worldwide impact human livelihood, socioeconomic activities, and food security. In Ghana, climate change affect cocoa (*Theobroma cacao*) production and impact smallholder farmers livelihood. Cocoa depends on specific rainfall and temperature to produce its maximum yield so changes in these environmental parameters will impact cocoa yield, affect cocoa trees, and increase pest and disease incidence. This study employs shifts in environmental parameters—rainfall, temperature, and the duration of wet and dry seasons—to assess farmers' perceptions of climate change. The purpose of this study was to examine farmers' perception of climate change and their relationship with socioeconomic and institutional factors. A systematic random procedure was used for this study. Multiple regression analysis and descriptive analysis including frequencies, percentages, means, standard deviations, and correlations were done. The findings indicated that most farmers observed variations in rainfall, temperature, and the duration of wet and dry seasons. Farmers' perceived changes in climate corresponded with weather data from the study district. Farming experience and education demonstrated a notable correlation with farmers' climate change perceptions. Farmers strongly agreed to being interested in learning about farm level adaptation practices to climate change. Farmers also strongly agreed to taking risk through changing their current farming practices to adopt climate change adaptive practices.

Keywords: Climate Change Perception, Cocoa (*Theobroma cacao*), Management Practices

Introduction

Climate change and variability issues worldwide impact human livelihood, socioeconomic activities, and food security (Amajath-Babu et al., 2016; Clarke et al., 2012; Romiew et al., 2010). Climate change encompasses ongoing and anticipated alterations in weather patterns, temperatures, rainfall patterns, and ecological impacts, driven by the sustained rise in greenhouse gas emissions (World Meteorological Organization, 2020). Climate change and variability impacts in Africa are projected to affect about 25%-42% of species' habitat and food and non-crop losses (McClean et al., 2005).

In Ghana, smallholder farmers in the tropical cocoa belt face heightened vulnerability to climate change due to poverty, limited infrastructure, lack of access to technical and financial support, hindering investments in climate-resilient agriculture, and reliance on rainfed agriculture (Adimassu & Kessler, 2016; Donatti et al. 2018; Holland et al. 2017). Ghana's cocoa industry engages approximately 800,000 smallholder farm families, contributing over 2 billion annually to foreign exchange earnings (Ghana Commercial Bank (GCB), 2022). Ghana's cocoa production, a highly valued global commodity, serves as a crucial raw material for the billion-dollar chocolate industry, significantly influencing economic growth and poverty alleviation (Breisinger et al., 2008; Wessel & Quist Wessel, 2015).

Despite cocoa's valuable contribution worldwide and particularly to Ghana, it encounters challenges, notably climate change (Jamel et al., 2021). Cocoa (*Theobroma cacao*), a sensitive plant, thrives under specific climatic conditions, necessitating temperatures ranging from 21-23°C and annual rainfall between 1,000-2,500 mm for optimal yield. A change in environmental parameters will impact cocoa yield, income, and productivity, thus affecting smallholder livelihood and food security (Cilas & Bastide, 2020). In the bid for smallholder farmers to increase production and improve their livelihood, they clear extensive forest lands causing a substantial negative implication on forest lands leading to increase deforestation (Cilas & Bastide, 2020). Deforestation contributes highly to climate change especially in cocoa production which thrive under shade trees. The Guardian news in May 2023 confirmed that 26,000 hectares out of 193,000 hectares (13.5%) of deforestation in Ghana are linked to cocoa production. Climate change and variability enhance cocoa disease spread, such as swollen shoots and black pod diseases (Kosoe & Ahmed, 2022).

Addressing climate change and variability requires a comprehensive approach involving both adaptation and mitigation strategies. Mitigation involves the reduction of greenhouse gas emissions to alleviate the effects of climate change through deliberate human interventions (IPCC, 2014B). One of the key challenges in mitigation efforts involves accurately quantifying carbon sequestration and effectively identifying methods for reducing emissions (Schnetzer, 2016). Adaptation involves modifying behavior and adjusting in response to current and projected climate change impacts and anticipated vulnerabilities (FAO, 2021). Adaptation responses are frequently interconnected across local, regional, and national levels. Farmers' adaptive capacity to climate change differs based on their unique characteristics, leading to disparities in their resilience levels (Mabe et al., 2012). Fostering adaptive capacity via farm-level climate management practices is key to attaining climate action and food security goals, especially for smallholder farmers.

Previous studies (Meldrum et al., 2018; Antwi-Agyei et al., 2021; Jamal et al., 2021) have revealed that farmer's perception of climate change informs farming decisions and determines the adoption of adaption measures. Yet understanding farmers' climate change perception is still scant especially, in Ghana. Jamal et al. (2021) stressed that smallholder cocoa farmers can engage in adaptation practices only when they can discern changes in climatic conditions. Given the location-specific nature of adaptation practices and the global significance of cocoa production, particularly to the economy of Ghana, it is crucial to assess farmers' perceptions of climate change and the factors influencing these perceptions. This research may contribute to a better understanding of practices and processes needed for adoption (Lindner et al., 2016)

Purpose of Study and Objectives

The purpose of the study was to assess smallholder cocoa farmers' perception of climate change and variability in Ghana. Specifically, the objectives of the study are:

1. Examine cocoa farmer's perception of ongoing climate change and variability in comparison with observed trend in climatic data records of the study area.

2. Determine individual and institutional factors that affect cocoa farmer's perception of climate change.

3. Assess cocoa farmers' decisions to adopt adaptive measures.

Literature Review and Theoretical Issues

Climate Change and Farmers' Perception

Climate change perception involves intricate psychological elements, including knowledge, beliefs, attitudes, and concerns about the occurrence of climate change (Whitmarsh & Capstick, 2018). Perception is molded by individuals' characteristics, experiences, cultural and geographic context in which they live (van der Linden, 2015; Whitmarsh & Capstick, 2018). Perception is inherently subjective, and individuals within the same community may construct diverse views of climate change, even when experiencing identical weather conditions (Simelton et al., 2013). Perceptions of climate change are impacted by the use of disciplinary knowledge and understanding literacy (Clemons, et al., 2018). Measuring climate change perception and finding its determinants is complex and requires several approaches.

Some studies in Africa have measured farmers perception of climate change based on their perception of changes in climate or weather-related variables, including rainfall changes, temperature, and precipitation (Amadou et al., 2015; Ameyaw et al., 2018; Antwi-Agyei et al., 2021; Kosoe & Ahmed, 2022). Findings from these studies revealed farmers' perceptions of climate change, citing irregular rainfall, high temperatures, and variable rainfall amounts. Kosoe & Ahmed's (2022) research on climate change effects on cocoa farms, for instance, emphasized a weighted average index (WAI) of 2.07, indicating that most respondents perceived climate changes, particularly in rainfall patterns.

Factors Influencing Perception of Climate Change

Climate perception is shaped by various factors, including age, farming experience, education, social networks, and access to weather information (Roncoli et al., 2002). These elements significantly contribute to individuals' awareness of climatic conditions and their ability to adopt appropriate adaptation measures (Maddison, 2006). According to Atangana et al. (2014), climate change perception is closely linked to sociocultural factors such as gender, age, education, and labor. Uddin et al. (2017) found that education, family size, farm size, farming experience, and training significantly influence Bangladeshi farmers' perception of climate change. Abdul-Fatah Alidu et al. (2022) further highlighted that institutional factor, such as weather information, play a crucial role in shaping producers' perceptions of climate change.

Niles and Mueller (2016) argued that a strong correlation persists between climate change, concerns about its implications, and producers' decisions to adopt climate change management practices. This correlation remains significant irrespective of the accuracy of individual perceptions and historical climatic trends.

Method

Overview of Study Area

The study was conducted in Birim North district, located in the Eastern region of Ghana, with an approximate population of 78,907. About 74% of the district's labor force is involved in agricultural activities. Cocoa is one of the main cash crops grown in the district. Other cash and food crops include oil palm, citrus, maize, and cassava. New Abirem is the capital town (Figure 1), among thirty-three municipalities and districts. Positioned in the country's forest belt, the district encounters significant precipitation, featuring a dual-maxima rainfall pattern: the first season spans late March to early July, and the second occurs from mid-August to late October. The district receives an average annual rainfall ranging from 1,500mm to 2,000mm. Temperature fluctuations are observed, with an average minimum of 25.2 degrees Celsius and a maximum of 27.9 degrees Celsius, coupled with a year-round relative humidity of approximately 55-59 percent.

Sample

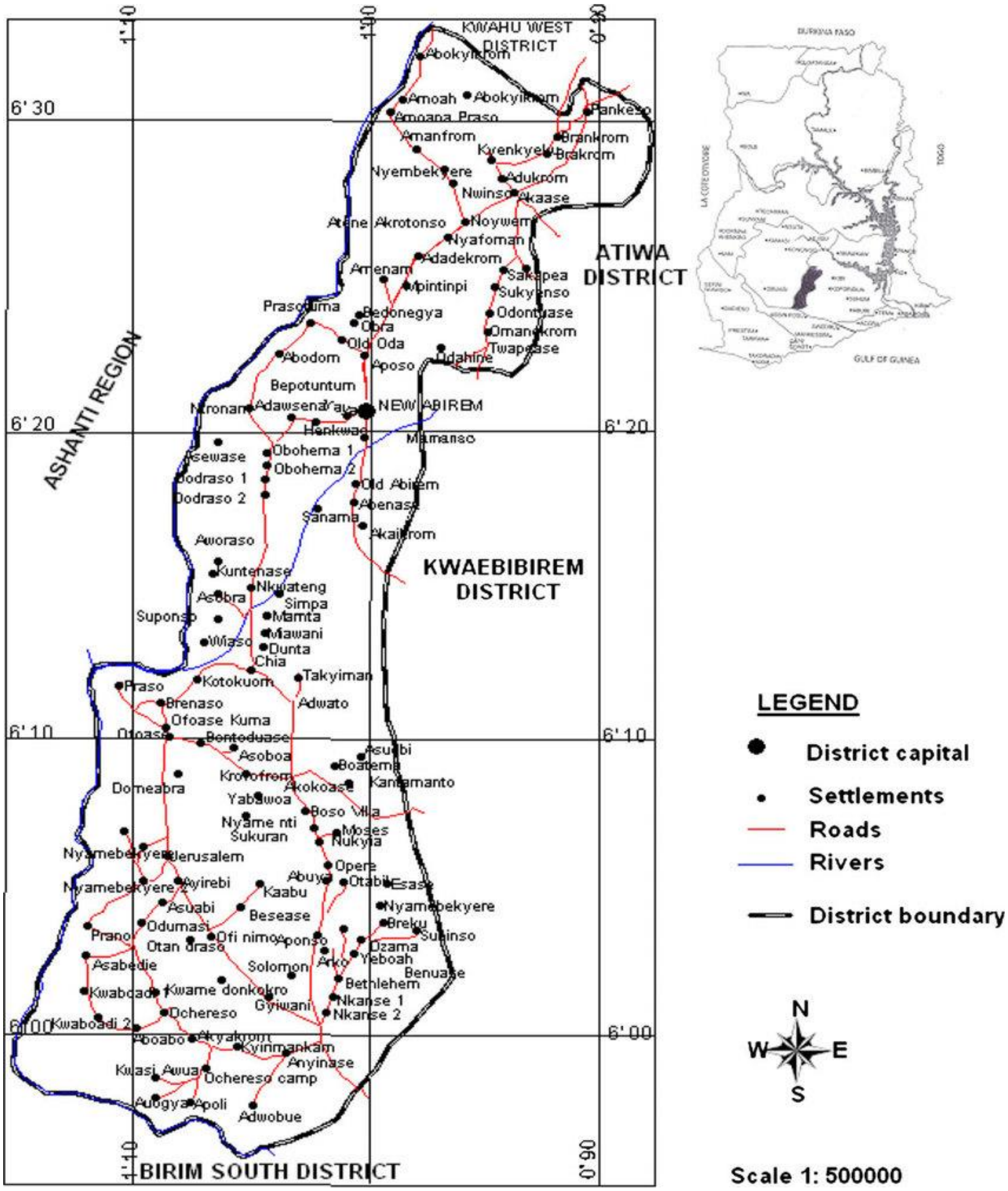
The target population for this study was adult cocoa producers with membership in the Ghana Cocoa and Extension Division in Birim North District, Ghana. Birim North has been identified by the Ministry of Food and Agriculture (MOFA), Ghana, as one of the major cocoa production areas (MOFA, 2020).

Nine communities from the district were selected based on their intensive cocoa farming activities. Agricultural extension officers from the district's Cocoa Health and Extension division suggested these communities as focal areas of cocoa production. Information on cocoa farmers in each community was obtained from the extension division, and farm families were-selected using a systematic random procedure that ensured a woman was a member of each sample household. The farmers were then invited to partake in the survey by extension officers and other farmers. One hundred and six cocoa farmers were interviewed. The intended sample size was initially set at 150; however, the achieved response rate was 70%, with a total of 106 responses obtained. Potential factors contributing to this outcome include constrained time for data collection, data collection occurring during the rainy seasons when farmers were difficult to reach, and challenging road conditions. Caution is warranted against generalizing the findings beyond the sample that was drawn due to potential nonresponse error (Lindner, 2002; Lindner et al., 2001).

Data Collection

Data collection and analysis adhered to the ethical principles of research with human subjects, following approval from the Institutional Review Board (IRB). Questions were prepared in English using Kobo toolbox software, while the interviews were conducted in the local language, Twi, with the help of enumerators who spoke the language fluently. A total of 106 face-to-face interviews were conducted in June 2023 with at least five interviews in each selected community. Interviews were conducted at both participants' homes and on farms and lasted 40 to 60 minutes (Figure1.1). Climatic data for the study area were also collected from the Ghana Meteorological Agency for 2013-2022. Data were utilized to compare perceptions of climate change with climatic records.

Figure 1.1 *District in Relation to the Country as a Whole and the Ocean and Adjacent Nations*[2]



The questionnaire used to collect data for this study was designed and delivered through Kobo toolbox (Appendix A) in a face-to-face interview. The survey instrument contained closed-

[2] https://www.researchgate.net/figure/Map-of-Birim-North-District-Assembly_fig1_285417044

ended questions, structured into three different sections: (1) knowledge about climate change related to changes in environmental parameters; (2) perception of climate change impact; (3) perception about farmer decisions about adaption strategies, and sociodemographic characteristics (age, gender, level of education and farming experience).

Figure 21.2 Researcher Interviewing Farmer on Cocoa Farm

The interview questions about farmer perception and their adaptive intent were designed by adopting and modifying Ameyaw et al. (2018) and Walker's (2020) instruments. Likert scale questions were utilized. A team of three Auburn University professors assessed and revised the questionnaire for content validity. Additionally, extension officers in the study area reviewed and adjusted terminology or answer choices to align with the context in the local community. The Cronbach's alpha coefficient was computed for climate perception and adaptive decision (Cronbach, 1951). A reliability coefficient of .70 is acknowledged as acceptable, however lower thresholds have been used (Santos, 1999). The reliability levels for each scale are presented in Table 1.1.

Table 1.1 *Reliability Test*

Scale	Number of items	Cronbach's alpha
Climate change (Temperature)	2	0.79
Climate change (Precipitation)	2	0.62
Decision to Adopt Adaptation Measures	4	0.59

Measures

Dependent Variables

Farmer perception of climate change. These parameters were assessed to elucidate farmers' perceptions regarding alterations in rainfall (precipitation) and temperature patterns. The measure used was Stayed about the Same= 0, Decreased =1 and Increased =2. A set of four Survey items was examined, 2 set of questions for precipitation and 2 set of questions for temperature. The preamble and actual survey questions are presented in Appendix 2.

Independent Variables

Socioeconomic Characteristics: age, education, farming experience and gender. The inclusion of these factors was grounded in previous literature on climate change perception (Ameyaw et al., 2018; Asare-Naumah & Botchway, 2019).

Institutional Characteristic

The institutional characteristic is access to weather information (Table 1.2).

Table 1.2 *Description of Variables Used in the Ghana Cocoa Farmers Study, Ghana Data, 2023*

Variables	Description of Variables
Dependent (Perception of Climate Change)	
Temperature	Decreased= 1, Stayed Same = 0, Increased=2
Precipitation	Decreased = 1, Stayed Same= 0 Increased=2
Independent	
Education	Respondent Years of Schooling
Age	Age in years
Gender	Female=0, Male =1
Farming Experience	Total Number of Years of Farming
Access to Weather Information	Receive Weather Info (Yes=1, No=0)

Analysis

In the process of data cleaning, errors stemming from data inconsistency were identified and rectified. Descriptive analysis such as frequencies, percentages, and means were utilized to summarize participants' perceptions of their climatic changes, their decision to adopt adaptive management practices, and their individual and institutional characteristics. Additionally, multiple regression was used to determine the factors affecting smallholder farmers' climate change perception. Data were analyzed using SPSS. Multiple regression is employed to estimate the association between farmers' perception of climate change and the individual and institutional characteristics of the respondents.

The model is represented as:

$$Y = \beta o + \beta_1 X_1 + \beta_2 X_2 + \ldots\ldots\ldots \beta_b X_b + \varepsilon$$

where Y = Dependent variable; β = coefficient of the constant term; $\beta_1 - \beta_b$ = coefficients of the explanatory variables; $X_1 - X_b$ = explanatory variables, and ε = error term.

Thus, the regression model for the study is:

Farmer perception of climate change (Y) = $\beta_0 + \beta_1$Gender + β_2Education + β_3 Framing experience + $_4\beta$ Age + β_5Access to weather information + ε

Hypotheses

H_0: There is no significant effect of cocoa farmers' individual and institutional characteristics on farmers perception of climate change.

These further imply that all regression coefficients are equal to zero.

H_0: $\beta_1 = \beta_2 = \beta_3 = \beta_4 = \beta_5 = 0$

H_1: There is a significant effect of cocoa farmer's individual and institutional characteristics on farmers perception of climate change.

$H_{1:}$ $\beta_1 \neq \beta_2 \neq \beta_3 \neq \beta_4 \neq \beta_5 \neq 0$

The study also used the Mann-Kendall test (Mann, 1945; Kendall, 1975) to explore climatic trends from meteorological data obtained for the study area. The Mann-Kendall test assumes random and independent ordering of meteorological data (Chepkoech et al., 2018; Jaiswal et al., 2015). It was employed to test the hypothesis of no climate trend, using rainfall and temperature proxies. Previous studies (Ameyaw et al., 2018; Baffour-Ata et al., 2021) successfully applied the Mann-Kendall trend test to assess temperature and precipitation trends in other regions of Ghana, facilitating comparisons between individual farmers' experiences and the broader community's observations.

Findings

Descriptive Statistics of Variables in the Study

Table 1.3 presents the variables observed in the sample of Ghanaian cocoa farmers. The results indicate that, among the interviewed farmers, 62.2% were male, while 37.7% were female, highlighting cocoa farming as a male- dominated activity. Approximately 73.3% were household heads, with a majority (50%) in the 45-59 age group. Educational levels ranged from basic (28.3%) to secondary education (47.2%) to tertiary (6.6%) and no formal education (17.9%). The results also indicated that a significant majority of respondents possessed over 16 years of farming experience (62.3%), earned a monthly average income within the range of GHC 900-200 (77-172 USD) (41.5%), and identified cocoa farming as their primary income source (75.5%). Additionally, about 46.2% of respondents owned cocoa farms exceeding 5 acres.

Table 1.3 presents findings on participants' institutional characteristics, their access to weather information. The results revealed about 90% of the participants had access to weather information, primarily, 53% of respondents indicated that their information source was from the media (TV/radio), and about 20.8% use their personal observation to access weather information.

Table 1.***3*** *Descriptive Statistics of Variables Used in the Analysis in the Analysis, Ghana Data, 2023.*

Variables	Category	*f*	%
Dependent			
Temperature	Increased	94	88.7
	Decreased	9	8.5
	Stayed Same	3	2.8
Rainfall	Increased	19	17.9
	Decreased	76	71.7
	Stayed Same	11	10.4
Length of Wet Season	Increased	17	16.0
	Decreased	81	76.4
	Stayed Same	17	16.0
Length of Dry Season	Increased	75	70.8
	Decreased	21	19.8
	Stayed Same	10	9.4
Independent			
Gender	Female	40	37.7
	Male	66	62.3
Age	18-29	2	1.9
	20-44	30	28.3
	45-59	51	50
	Over 60	21	19.8
Education	Basic	30	28.3
	Secondary	50	47.2
	Tertiary	7	6.6
	No formal Education	19	17.9
Farming Experience	6-10 years	15	14.2
	11-15years	25	23.6
	Over 15 years	66	62.3
Access to Weather Information	No	16	15.1
	Yes	90	84.9

Objective 1.1: Farmer Knowledge and Perception of Climate Change on Cocoa Farm

Table 1.3 showed the descriptive statistics of farmers knowledge and perception of climate change as influenced by variations in rainfall, temperature, length of dry season and wet season. Respondents asserted that there have been changes in climatic patterns over the last ten years. Approximately 66% of farmers reported an increase in temperature, while 71.7% observed a decline in rainfall patterns. Approximately 76.4% of farmers indicated a reduction in duration in the wet season, and approximately 70.8% reported an increase in the duration of the dry season.

Participants Perception on the Impact of Climate change on Cocoa Farms

Almost all farmers, 103 out of 106 (97.1%), indicated a worry about the change in climate on their cocoa farms. Of the worried respondents, a large number of respondents 26.4% were concerned about the reduction in cocoa yield, 23.4% were worried about the high mortality rates of their cocoa trees, 21.1% about the impact on their cocoa income, and 15.1% about the heightened occurrence of pests and diseases (Table 1.4).

Table 1.4 *Distribution of Participants Perception on Impact of climate Change on Cocoa Farm, Ghana Data, 2023*

	Responses	
	f	%
Low Yield from Cocoa	89	26.4
High Mortality Rates of Cocoa trees	79	23.4
Low Income from Low Yield	71	21.1
High incidence of Pest and Diseases	51	15.1
Food Crop Loss Due to Drought	47	13.9
Total	337	100.0

Note. Total is not equal to N (106) because of multiple responses of participants.

Participants Knowledge on the Causes of Climate Change

Table 1.5 shows that approximately 44% of respondents indicated that changes in climate parameters were caused by deforestation through illegal logging and expansion of land for cocoa production followed by approximately 26% of farmers who believed climate change is caused by slash and burn agriculture (traditional agriculture).

Table 1.5 *Distribution of Participants Knowledge of the Causes of Climate Change, Ghana Data, 2023*

	Responses	
	f	%
Deforestation (Illegal Logging)	87	43.5
Slash and Burn Agriculture	51	25.5
Use of Wood Fuels	30	15.0
Full-Sun Cocoa Plantation	28	14.0
Caused by a Curse	4	2.0
Total	200	100.0

Note. Total is not equal to N (106) because of multiple responses of participants.

Climatic Data Trend of Study Area

As part of objective one on farmers perception of climate change, the study sought to compare results from farmers perception with climatic data of the study area. Climatic data was obtained from the weather station in the study district for a period of ten years (2014-2022).

Temperature

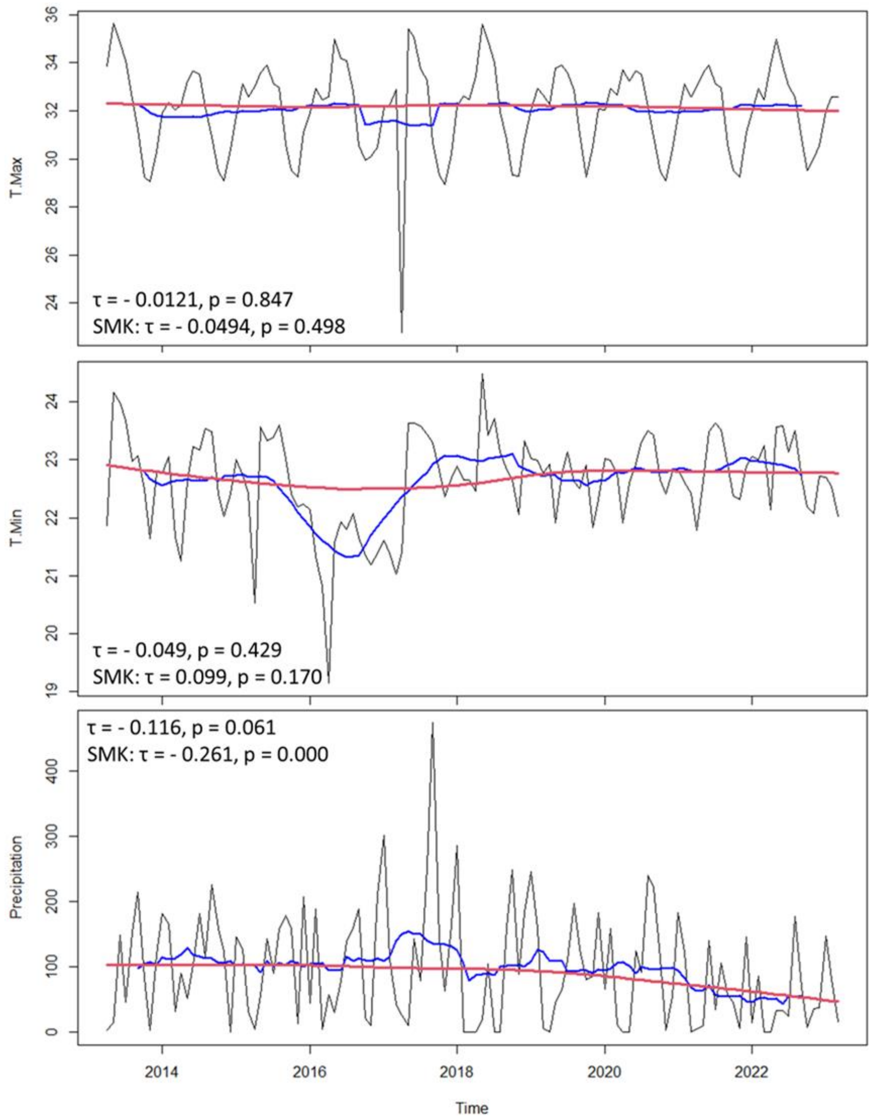
The findings revealed that the maximum temperature for the study area stayed about the same with a slight increase in the minimum temperature over the ten-year period. The mean temperature recorded over the span of a decade varies between 22.6 °C and 32 °C for minimum and maximum values, respectively, exhibiting no significant upward trend (Figure 1.3).

Precipitation

Based on data from 2013 to 2022, overall precipitation and seasonal rainfall have slightly decreased. The Seasonal Mann-Kendall Tests (SMK) further unveiled a diminishing trend in seasonal precipitation for rainfall ($\tau = 0.261$, $p = 0.00$) (Figure 1.3).

Figure 1.3

Monthly Trend Analysis of Precipitation in mm, Maximum and Minimum Temperature at the Birim North District Weather Station



Objection 1.2: Factors Affecting Participants Perception of Climate Change

The second objective examines the link between socioeconomic, institutional factors and farmers' perception of climate change. Table 1.6 depicts correlations between dependent and independent variables. Significant associations were found between climate change perception and socioeconomic factors (gender, education, farming experience, and access to weather information) at $p < .05$ and $p < .01$ levels. Detailed examination of these associations is conducted in the multiple regression analysis.

Table 1.6 *Pearson Correlation of Study Variables, Ghana Cocoa Farmers, Data 2023*

	Age	weather info.	Gender	Edu.	Farming Exp.	Temp.	Rainfall	Wet Season	Dry Season
Age	--								
Weather information	0.12	--							
Gender	.19*	.23*	--						
Education	-0.03	-0.10	-0.13	--					
Farming Exp.	.63**	0.18	.38**	0.14	--				
Temperature	0.05	-0.17	-0.05	0.17	-0.11	--			
Rainfall	0.08	0.04	-0.05	-0.03	0.13	-.20*	--		
Wet season	0.04	.23*	-0.09	-0.17	0.13	-.24*	.45**	--	
Dry season	0.03	-0.14	0.11	.19*	-0.07	.66**	-.30**	-.22*	--
N	106								

Note.*p<0.05; **p<0.01

Table 1.7 shows the coefficient and standard errors and standardized beta for the multiple regression analysis of the study variables. The R^2 of the regression model is 0.12 which implies that 12% of the variation of the dependent variable (farmers perception in the changes in precipitation is explained by the independent variables (socioeconomic and institutional factors).

The regression analysis revealed a statistically significant relationship ($p > .05$) between independent variables (socioeconomic and institutional factors) and dependent variable (perception of climate change -precipitation). The findings suggest that farming experience has a statistically significant impact on farmer perception of precipitation. For every one unit of change increase in farming experience, there would be a 56% increase in farmers perception in changes in precipitation. Gender also plays a major role in the perception of climate change (precipitation). However, gender revealed a negative and statistically significant relationship with perception of climate change. Males were less likely to perceive a change in precipitation in the study area. Access to weather information showed a positive sign for precipitation, implying that a one unit increase in access to weather information could increase the probability of respondents' observation on the changes in these climatic parameters, although it was not significant.

Table1.7 *Multiple Regression Coefficients of Sociodemographic and Institutional Factors on Farmers Perception on Climate Change Based on Changes in Climate Pararmeters, Ghana Data 2023.*

	Precipitation			Temperature		
	B	*SE*	*ß*	*B*	*SE*	*ß*
Constant	2.19*	0.65		2.00*	0.54	
Gender	-0.57*	0.25	-0.25	0.32	0.22	0.17
Education	0.19	0.29	0.07	0.22	0.25	0.09
Age	-0.32	0.17	-0.22	0.36	0.25	0.18
Farming Experience	0.56*	0.19	0.37	-0.21	0.18	-0.17
Access to Weather Information	0.39	0.25	0.15	-0.1	0.22	-0.05
R^2		0.12			0.06	
Adjusted R^2		0.07			0.01	
F-Value		2.56*			1.23	
N		106			106	

Note. *P< .05

Objective 1.3: Farmers Decision to Adopt Management Practices to Climate Change

Table 1.8 and table 1.9. revealed adaptation management decision of respondents grouped under learning and knowledge seeking and risk taking and experimentation. Table 1.6 revealed that about two-thirds of respondents (77.6%) strongly agreed to Item “Interested in learning farm level agricultural practices that will help me cope with climate change impacts” with a (*M* = 4.77, *SD* = 0.60). Interpretations of the scores were based on Lindner’s (2024) convention for Likert-type scales.

Table 1.8 *Distribution of Farmers Learning and Knowledge Seeking*

	Strongly Disagree		Disagree		Neither Agree nor Disagree		Agree		Strongly Agree			
	f	*%*	*f*	*%*	*f*	*%*	*f*	*%*	*f*	*%*	*M*	*SD*
Interested in learning farm level agricultural practices that will help me cope with climate change	0	0	0	0	0	0	24	22.6	82	77.6	4.77	0.60

Note. Scale: 1=Strongly Disagree, 2=Disagree, 3=Neither Agree nor Disagree, 4=Agree, 5=Strongly Agree

Under the risk taking and experimentation scale, approximately 62.3% of respondents (*M* = 4.62, *SD* = 0.49) strongly agreed to “I am willing to change my current practices to cope with changes in weather” and 60.4% of respondents (*M* = 4.60, *SD* = 0.49) strongly agreed to “I am willing to try new agricultural technologies and practices if other farmers are using it. A little over half of the participants (51.9%) “intent to adopt management practices if the government provides support” (*M* = 4.40, *SD* = 0.80).

Table 1.9 *Distribution of Farmers' Risk-taking and Experimentation*

	Strongly Disagree		Disagree		Neither Agree nor Disagree		Agree		Strongly Agree			
	f	*%*	*f*	*%*	*f*	*%*	*f*	*%*	*f*	*%*	*M*	*SD*
I am willing to change my current practices to cope with the changes in weather	0	0	0	0	0	0	40	37.7	60	62.3	4.62	0.49
I am willing to try new Ag. technologies and management practices if other farmers are using it	0	0	0	0	0	0	42	39.6	64	60.4	4.60	0.49
I intent to adopt climate management practices if the government grant support	2	1.9	2	1.9	3	2.8	44	41.5	55	51.9	4.40	0.80

Note. Grand Mean is 4.54 and Grand SD is 0.423. 1=Strongly Disagree, 2=Disagree, 3=Neither Agree nor Disagree, 4=Agree, 5=Strongly Agree

Discussions, Conclusions and Recommendations

The first objective was to examine farmers' perception of climate change based on changes in environmental parameters such as temperature, rainfall, length of dry season and length of wet season. Findings showed that farmers perceived changes in climatic patterns in the study district, evidenced by the increase in temperature, changing rainfall patterns, decreased in length of wet season and increased length of dry season. Studies by Antwi-Agyei et al. (2021), Kosoe & Ahmed (2022) and Kwakye-Ameyaw (2018) confirmed these changes in rainfall and temperature in various regions of Ghana. Weather data from the study district revealed a slight increase in temperature over a period of ten years (2013-2022). Also, overall precipitation and seasonal rainfall exhibited a slight decrease in pattern for the same period although it was not statistically significant. Although the trend analysis from the weather data for the period of 2013 to 2022 collaborated with farmers perception of climatic parameters of the study area, it would have been a more accurate in description and comparison if data were obtained as far back from the 1980’s. Nevertheless, the accurate recognition of rising temperature and diminishing rainfall by cocoa farmers illustrates their capacity to discern alterations in weather patterns and adapt their farming practices accordingly (Niles & Mueller, 2016).

The majority of farmers (97.1%) expressed concerns regarding climate changes affecting their cocoa farms. Specifically, they articulated a worry about reduced cocoa yields and increased mortality rates among their cocoa trees. These concerns have been raised previously by Anning et al. (2022), Bunn et al (2018), Kwakye-Ameyaw et al. (2018) and Rainforest Alliance (2019). About 43.5% and 25.5% of farmers indicated deforestation and slash and burn agriculture respectively as a probable cause of climate change. The Guardian News (May 2023) confirmed that confirmed that 26,000 hectares out of 193,000 hectares (13.5%) of deforestation in Ghana are linked to cocoa production. Deforestation and burning of trees and food crops releases more carbon dioxide in the atmosphere which contributes to climate change. According to a report by Annika Dean in Climate Council News (August 2019), the average global loss of tropical forests (deforestation) during the period from 2015 to 2017 resulted in an annual contribution of approximately 4.8 billion tons of carbon dioxide.

The second objective of the study was to determine the relationship between socioeconomic and institutional factors on perceptions of climate change. The results revealed that majority of the respondents were male exemplifying cocoa farming as a male-dominated activity. Most farmers were above the age of 45 years and had a secondary education. Approximately 62.3% of respondents have over 16 years of farming experience. About 90% of farmers reported having access to weather information, with the media identified as their primary source for obtaining such information. About 90 % of farmers had access to weather information and indicated the media as their main source of weather information.

The results revealed farming experience has a relationship on farmers' climate change perception. Farmers with longer farming experience were more likely to predict changes in the length of wet season. Overall, farming experience is an important determinant of smallholder farmers climate change perception. Gender also revealed a negative relationship with perception of climate change. Males were less likely to perceive changes in precipitation than females. Although access to weather information was not a significant factor, it showed a positive impact on climate change perception. Meaning that when access to weather information is increased there is a probability of farmers perceive climatic changes. Partey et al (2018) posited that when cocoa farmers have access to climate information, they are able to plan and adopt farming practices that will improve their adaptation to climate change.

Objective three of the study looked at the perception of farmers decision to adopt management practices to climate change. Farmers decision was grouped into two: their learning and knowledge seeking and their risk and experimentation. About 62.3% of smallholder farmers were interested in learning about farm level agricultural practices that will help them cope with climate change. The majority of smallholder farmers further stated that they were willing to take a risk and experiment by changing their current practices to cope with the changes in weather, by trying new agricultural practices to climate change if other farmers are using it and adopting climate management practices if get some type of government support. As farmers perceive the changes in climate, the causes of these changes and the implications on their cocoa farms, they were more likely to learn, take risk and experiment with management practices that will help them to adapt against future negative impacts.

Identifying smallholder cocoa farmers perception to climate change and the socioeconomic and institutional factors that impact their perception is critical in the design of adaption strategies and policies that are local context specific and foster effective implementation especially among rural cocoa farmers. Furthermore, the indigenous knowledge of farmers, derived from their extensive years of cocoa farming experience and their decisions regarding adaptation, should be considered in the formulation of climate adaptation strategies at the farm level.

References

Adimassu, Z., Kessler, A. (2016). Factors affecting farmers' coping and adaptation strategies to perceived trends of declining rainfall and crop productivity in the central Rift valley of Ethiopia. *Environmental System Research*, *5*, 1. https://doi.org/10.1186/s40068-016-0065-2

Alidu, A.F., Man, N., Ramli, N.N., Mohd Haris, N.B., & Alhassan. A. (2022). Smallholder farmers access to climate information and climate smart adaptation practices in the northern region of Ghana. *Heliyon*, 8.

Afriyie-Kraft, L., Zabel, A., Damnyag, L., 2020. Adaptation strategies of Ghanaian cocoa farmers under a changing climate. *Forest Policy Economics*, *113*,102115.

Amadou, T., Falconnier, G. N., Mamoutou, K., Georges, S., Alassane, B. A., François, A., Michel, G., & Benjamin, S. (2022). Farmers' perception and adaptation strategies to climate change in central mali. *Weather, Climate, and Society*, *14*(1). https://doi.org/10.1175/WCAS-D-21-0003.1

Ameyaw, L.K., Ettl, G.J., Leissle, K., & Anim-Kwapong, G.J. (2018). Cocoa and climate change: insights from smallholder cocoa producers in ghana regarding challenges in implementing climate change mitigation strategies. *Forests, 9* (12), 742. https://doi.org/10.3390/f9120742

Amjath-Babu, T., Krupnik, T.J., Aravindakshan, S., Arshad, M., & Kaechele, H., (2016). Climate change and indicators of probable shifts in the consumption portfolios of dryland farmers in sub-saharan africa: implications for policy. *Ecological Indicators*, *6*, 830-838, https://doi.org/10.1016/j.ecolind.2016.03.030

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

Anning, K.A., Ofori-yeboah, K., Baffour-Ata, F., & Owusu, G. (2022). Climate change manifestations and adaptations in cocoa farms: Perspectives of smallholder farmers in the adansi south district, ghana. *Current Research in Environmental Sustainability*, *4*,100196. https://doi.org/10.1016/j.crsust.2022.100196

Asare-Nuamah, P., & Botchway, E. (2019). Comparing smallholder farmers' climate change perception with climate data: the case of adansi north district of ghana. *Heliyon*, *5*(12).https://doi.org/10.1016/j.heliyon.2019.e03065

Baffour-Ata, F., Antwi-Agyei, P., Apawu, G. O., Nkiaka, E., Amoah, E. A., Akorli, R., & Antwi, K.(2021). Using traditional agroecological knowledge to adapt to climate change and variability in the upper east region of ghana. *Environmental Challenges*, *4*, 100205.

Breisinger, C., Diao, X., Kolavalli, S., Thurlow, J. (2008). *The role of cocoa in ghana's future development*. Ghana Strategic Support Group (GSSP). Background Paper No. GSSP 0011, 24.

Campbell, B.M., Thornton, P., Zougmor´e, R., van Asten, P., & Lipper, L. (2014). Sustainable intensification: what is its role in climate smart agriculture. *Current Opinion in Environmental Sustainability*, *8*, 39-43.

Cilas, C., & Bastide, P. (2020). Challenges to cocoa production in the face of climate change and the spread of pests and diseases. *Agronomy*, *10* (9), 1323. https://doi.org/10.3390/agronomy10091232.

Clarke, C., Shackleton, S., Powell, M. (2012). Climate change perceptions, drought responses and views on carbon farming amongst commercial livestock and game farmers in the semiarid Great Fish River Valley, eastern Cape province, South Africa. *African Journal of Range Forage Science*, *29*(1), 13-23, https://doi.org/10.2989/10220119.2012.687041

Clemons, C., Lindner, J. R., Murray, B., Cook, M. P., Sams, B., & Williams, G. (2018). Spanning the Gap: The Confluence of Agricultural Literacy and Being Agriculturally Literate. *Journal of Agricultural Education*, *59*(4), 238-252. https://doi.org/10.5032/jae.2018.04238

Cronbach, L. J. (1951). Coefficient alpha and the internal structure of tests. Psychometrika 16,297-334.https://doi.org/10.1007/BF02310555

Chepkoech, W., Mungai, N. W., Stöber, S., Bett, H. K., and Lotze-Campen, H. (2018). Farmers' perspectives: impact of climate change on African indigenous vegetable production in kenya. *International Journal of Climate Change Strategy and Managemen*t, *10*, 551-579.DOI: 10.1108/IJCCSM-07-2017-0160

Dohmen, M.M., Noponen, M., Enomoto, R., Mensah, C., & Muilerman, S. (2018). *Climate-smart agriculture in cocoa: A training manual for field officers, accra, ghana*. World Cocoa Foundation and The Rainforest Alliance.

Donatti, C.I., Harvey, C.A., Martinez-Rodriguez, M.R., Vignola, R., & Rodriguez, C.M. (2018). Vulnerability of smallholder farmers to climate change in central america and mexico: Current knowledge and research gaps. *Climate and Development*,1-23. doi:10.1080/17565529.2018.1442796

FAO. (2021). *Climate-smart agriculture case studies*. https://doi.org/10.4060/cb5359en

Ghana Commercial Bank. (2022). *Sector industry analysis 2022 cocoa sector report*. Strategy and the Research Department.

Ghana Statistical Service. (2014). *2010 population and housing report: District analytical report, birim north district, ghana*. International Development Cooperation

Holland, M.B., Shamer, S. Z., Imbach, P., Zamora, J. C., Medellin Moreno, C., Hidalgo, E. J.L., Donatti, C. I., Martínez-Rodríguez, M. R., & Harvey, C. A. (2017). Mapping adaptive capacity and smallholder agriculture: applying expert knowledge at the landscape scale. *Climatic Change*, *141*(1). https://doi.org/10.1007/s10584-016-1810-2

Jamal, A. M., Antwi-Agyei, P., Baffour-Ata, F., Nkiaka, E., Antwi, K., & Gbordzor, A. (2021). Gendered perceptions and adaptation practices of smallholder cocoa farmers to climate variability in the central region of ghana. *Environmental Challenges*, *5*, 100293.

Jaiswal, R.K, Lohani, A.K., Tiwari, H.L. (2015). Statistical analysis for change detection and trend assessment in climatological parameters. *Environmental Process*. https://doi.org/10.1007/s40710-015-0105-3

Kendall, M.G. (1975). *Rank Correlation Methods*, 4th ed.; Charles Griffin: London, UK.

Kosoe, E., & Ahmed, A. (2022). Climate change adaptation strategies of cocoa farmers in the Wassa east district: Implications for climate services in Ghana. *Climate Services*, 26. https://doi.org/10.1016/j.cliser.2022.100289

Kumi, E., Daymond, A.J., 2015. Farmers' perceptions of the effectiveness of the Cocoa Disease and Pest Control Program (CODAPEC) in Ghana and its effects on poverty reduction. *American Journal of Experimental Agriculture*, *7*(5), 257-274.

Lindner, J. R., Murphy, T. H., & Briers, G. E. (2001). Handling Nonresponse In Social Research. *Journal of Agricultural Education*, *42*(4), 43–53. https://doi.org/10.5032/jae.2001.04043

Lindner, J. R. (2002). Handling of nonresponse error in the Journal of International Agricultural and Extension Education. *Journal of International Agricultural and Extension Education*, *9*(3), 55-60. https://www.researchgate.net/publication/237569094_Handling_of_Nonresponse_Error_in_the_Journal_of_International_Agricultural_and_Extension_Education#fullTextFileContent

Lindner, J. R., & Lindner, N. (2024). Interpreting Likert type, summated, unidimensional, and attitudinal scales: I neither agree nor disagree, Likert or not. *Advancements in Agricultural Development*, *5*(2), 152-163. https://doi.org/10.37433/aad.v5i2.351

Lindner, J. R., Rodriguez, M. T., Strong, R., Jones, D., & Layfield, D. (2016). Research priority area 2: New technologies, practices, and products adoption decisions. *American Association for Agricultural Education national research agenda*, 2020, 19-27.

Mabe, F. N., Sarpong, D. B., & Osei-Asare, Y. (2012). Adaptive capacities of farmers to climate change adaptation strategies and their effects on rice production in the northern region of Ghana. *Russian Journal of Agricultural and Socio-Economic Sciences*, *11*(11), 9-17.

Mann, H.B. (1945). Non-parametric tests against trend. *Econometrica*, *13*, 163-171.

Maddison, D. (2006). The perception of and adaptation to climate change in Africa. CEEPA Discussion Paper (10).

Meldrum, G., Mijatović, D., Rojas, W., Flores, J., Pinto, M., Mamani, G., Condori, E., Hilaquita, D., Gruberg, H., & Padulosi, S. (2018). Climate change and crop diversity: farmers' perceptions and adaptation on the bolivian altiplano. *Environment, Development and Sustainability*, *20*(2). https://doi.org/10.1007/s10668-016-9906-4

McClean CJ, Lovett JC, Küper W, Hannah L, Sommer JH, Barthlott W, Termansen M, Smith GF, Tokumine S. & Taplin J. (2005). African plant diversity and climate change. *Annals of the Missouri Botanical Garden*, *92*(2), 139-152.

Ministry of Ghana (MOFA). (2011). *Birim North*. https://mofa.gov.gh/site/sports/district-directorates/eastern-region/223-birim-north

Niles, M. T., & Mueller, N. D. (2016). Farmer perceptions of climate change: Associations with observed temperature and precipitation trends, irrigation, and climate beliefs. *Global Environmental Change*, 39. https://doi.org/10.1016/j.gloenvcha.2016.05.002

Nunoo, I., Darko, B.O., Owusu, V. (2015). Restoring degraded forest landscape for food security: Evidence from cocoa agroforestry systems, Ghana. In: Enhancing food security through forest landscape restoration: Lessons from burkina faso, brazil, guatemala, vietnam, ghana, ethiopia and philippines, 122.

Jamal, A.M., Antwi-Agyei, P., Baffour-Ata, F., Nkiaka, E., Antwi, K., Gbordzor, A. (2021). Gendered perceptions and adaptation practices of smallholder cocoa farmers to climate variability in the central region of ghana. *Environmental Challenges*, *5*, 100293.

Romieu, E., Welle, T., Schneiderbauer, S., Pelling, M., & Vinchon, C. (2010). Vulnerability assessment within climate change and natural hazard contexts: revealing gaps and synergies through coastal applications. *Sustainability Science*, *5*, 159-170.

Roncoli, C., Ingram, K., & Kirshen, P. (2002). Reading the rains: Local knowledge and rainfall forecasting among farmers of burkina faso. *Society and Natural Resources*, *15*.

Santos, J. R. A. (1999). Cronbach's Alpha: A tool for assessing the reliability of scales. *Journal of Extension*, *37*(2), Article 2TOT3. https://www.joe.org/joe/1999april/tt3.php

Shaftel, H. (2020, August 31). *The causes of climate change*. Washington DC: National Aeronautics and Space Administration. https://climate.nasa.gov/causes/

Simelton, E., Quinn, H. C. Batisani, N., Dougill, A.J., Dyer, J.C., Fraser, E.D.G., Mkwambisi, D., Sallu, S., & Stringer, C.L. (2013): Is rainfall really changing? Farmers' perceptions, meteorological data, and policy implications, *Climate and Development*, 37-41. DOI:10.1080/17565529.2012.751893

Walker, T. (2020). Climate Variability Adaptive Capacity: Perceptions of Alabama Farmers.Dissertation, Auburn University, Auburn Alabama.

Uddin, M. N., Bokelmann, W., & Dunn, E. S. (2017). Determinants of farmers' perception of climate change: A case study from the coastal region of bangladesh. *American Journal of Climate Change*, *6* (1). https://doi.org/10.4236/ajcc.2017.61009

van der Linden, S. (2015). The social-psychological determinants of climate change risk perceptions: Towards a comprehensive model. *Journal of Environmental Psychology*, 41. https://doi.org/10.1016/j.jenvp.2014.11.012

World Meteorological Organization. (2020). *Climate*. https://public.wmo.int/en/our-mandate/climate.

Whitmarsh, L., & Capstick, S. (2018). *Perceptions of climate change*. In S. Clayton & C. Manning (Eds.), Psychology and climate change: Human perceptions, impacts, and responses 13–33. Elsevier Academic Pres

Dissertation Paper Two

Assessing Cocoa Farmers' Perception of Climate-Smart Agriculture

Abstract

Cocoa (*Theobroma cacao*) holds substantial importance for Ghanaians as it serves as a vital crop, contributing to food security, income generation, employment opportunities, the production of industrial raw materials, and resources aimed at poverty reduction (Peprah, 2015). Climate-smart agriculture (CSA) is an approach introduced by the Food and Agriculture Organization to improve farm productivity and enhance food security while protecting the environment (Lipper et al., 2014). Climate smart agriculture is local and site context-specific and is focused on farm-level implementation (FAO, 2013). The study used the Rogers (2003) theory and theory of planned behavior to explain socioeconomic and institutional factors that influence the adoption of climate smart agriculture practices among cocoa farmers. A systematic random procedure was used for this study. Descriptive analysis including frequencies, percentages, means, standard deviations, and binary logistic regression were done. The majority of the farmers in this study were male (62,2%), have secondary education (47.2 %) and were between the age of 45-59 years old. Most farmers have received training (93%), were members of farmer groups (92%) and have access to extension services (98%). The findings further show that gender, education, training and membership in farmer groups positively and significantly influence farmers' adoption of climate smart agricultural practices in the study communities.

Keywords: Climate-smart agriculture, cocoa (Theobroma cacao), Extension, Institutional factors, Socioeconomic factor

Introduction

Cocoa (*Theobroma cacao*) holds substantial importance for Ghanaians as it serves as a vital crop, contributing to food security, income generation, employment opportunities, and resources aimed at poverty reduction (Peprah, 2015). In addition to sustaining the livelihoods of millions of smallholder farmers, cocoa serves as the primary raw material for the multibillion-dollar global chocolate industry. The consistent expansion of the confectionery chocolate market into a global industry, valued at approximately 106 billion dollars in 2017 (Voora et al., 2019), is contingent upon the traditional cocoa production carried out by smallholder farmers, particularly in West and Central Africa. While cocoa is originally indigenous to South America, notably utilized as a form of currency among ancient Aztec communities (Coe & Coe, 2007), it has evolved into a pivotal economic resource for growers in Ghana and Cote d'Ivoire. Ghana ranks as the second-largest global producer of cocoa, following Côte d'Ivoire.

Hence, ensuring the sustained production of high-quality cocoa beans holds paramount significance for the millions of smallholder family farmers and the global consumer base of chocolate. Approximately two decades ago, the Ghanaian government implemented various interventions, such as extension information dissemination, the Cocoa Disease and Pest Control (CODAPEC) program, the Cocoa Hi-tech initiative program, remunerative producer prices, and a bonus payment scheme (Teal et al., 2004). These programs, particularly the Cocoa Hi-tech initiative, functioned as catalysts for growth and output enhancement. They achieved this by promoting the intensive use of fertilizers to restore soil fertility, applying pesticides on cocoa, and adopting improved planting materials to enhance cocoa productivity (Oppong, 2014; Onuamah et al., 2013) and drop poverty level (Vigneri & Kolavalli, 2018). Nevertheless, it was accompanied by challenges such as biodiversity loss, pollution, environmental degradation, and a lack of sustainability (Scherr & McNeely, 2008; Ramachandran, 2007). Recently, the government of Ghana has raised state-guaranteed prices by a total of 63% to raise income standards and tackle crop smuggling to neighboring countries (Confectionary News, 2023).

Climate-smart agriculture (CSA) is an approach introduced in 2010 by the Food and Agriculture Organization to enhance agricultural output and ensure food security while preserving the environment (Lipper et al., 2014). Practices and technologies related to CSA offer the potential for triple-win by concurrently advancing food security, income generation, climate change adaptation, and greenhouse gas mitigation (Campbell et al., 2014). Given that Climate-Smart Agriculture (CSA) is a new integrated approach, a site-specific assessment is imperative to identify agriculturally suitable practices that effectively address the impact of climate change (FAO, 2013). Ajibade & Eche (2017) further revealed that profitable and environmentally-friendly agricultural practices like climate-smart agriculture if integrated into farm production will improve smallholder production.

CSA strategies are local and site context-specific and are focused on farm-level implementation (FAO, 2013). Porter et al. (2014) reported an estimated 15% to 18% improvement in farmer yields when they adopted good agronomic practices at the farm level. Because of the triple win CSA is known to provide to farmers, development agencies and cocoa processors have ramped up their financial and technical support to scale CSA effectively in recent years. For about two years, the World Bank supported 30 African countries in building resilience to climate change through CSA projects worth US $ 2.5 billion (The World Bank Group, 2019). Additionally, CARE and Cargill have supported cocoa farmers' resilience to climate change impacts and farmer incomes in West Africa by empowering farmers to develop climate-smart agriculture and agroforestry practices by training agricultural extension officers.

Despite government and international support to scale up CSA in Africa, little is known about climate-smart agriculture practices among smallholder cocoa farmers, especially in Ghana.

Purpose of Study and Objectives

The purpose of this study was to explore cocoa farmers' perception of climate-smart agriculture practices in Ghana. Specifically, we sought to:

1. Identify farmers' perception and adoption of climate-smart practices on cocoa farms.
2. Explore farmers' extension service support and training.
3. Determine socioeconomic and institutional factors influencing the adoption of climate-smart practices.

Literature Review and Theoretical Framework

Knowledge/ Perception of Climate Smart Agriculture Practices

Rogers' (2003) adoption and diffusion of innovation theory is used for anticipating farmers' perception and adoption of climate-smart agriculture practices. Innovation can be defined as a concept, practice, or object perceived as novel by an individual or another unit of adoption. Innovation is an idea or practice perceived as new by an individual or another unit adoption (Rogers, 2003). Rogers also posited that technologies or practices may not be entirely new to meet the definition and dynamics of innovation because old practices could be repacked and reintroduced. Climate-smart agriculture is a set of innovations adopted in a social system to build resilience to climate change impacts. Climate-Smart Agriculture (CSA) practices are additionally grounded in the existing experience and knowledge base of sustainable agricultural development practices (Wheeler & von Braun, 2013). New ideas and innovations diffuse through the social system over time.

Climate change practices emerge as recommendations and possibilities presented by the agricultural knowledge and information system that provides a context for farmers to learn about and use these tools (Anuga et al. 2019). The innovation-decision process comprises five stages: knowledge, persuasion, decision, implementation, and confirmation (Rogers, 2003). In the Knowledge stage, the farmer becomes aware of the innovation and gradually becomes interested in adopting it based on interactions like farm visits and training. Rogers (2003) emphasized that farmers will adopt technology or practices such as climate-smart agriculture when they know or are aware of such practices and their benefits.

Gwambene et al. (2015) study on climate-smart agricultural practices (CSA) in Tanzania indicated that most farmers were unaware of CSA practices, and those who were adopting CSA practices did not understand the reason for practicing them. In Setshedi & Modirwa's (2020) investigation on climate-smart agriculture in South Africa, findings showed that a significant number (75.9%) of small-scale farmers exhibit low level of knowledge regarding climate-smart agriculture. This indicates a considerable knowledge gap that needs to addressed to ensure small-scale farmers possess the proper information to assist them in making decisions.

In contrast, Kassa and Abdi's (2022) research on climate-smart agriculture practices (CSA) in Ethiopia indicated that about 96.5% of farmers were knowledgeable about CSA, understanding its definition and functions, while 3.5% were not aware of it. Ouedraogo et al. (2019) further found explained that, despite high awareness (87%) of agroforestry as a climate-smart agricultural practice in Mali, only 21.40% of farmers adopted this practice, indicating a gap between awareness and adoption. Agricultural extension services play a vital role in technology transfer and education across the entire agricultural supply chain (Anaeto et al., 2012). Olorunfemi et al. (2019) found that approximately 84.5% of extension agents conveyed knowledge regarding climate-smart agricultural practices, contributing to the adoption of these practices.

Climate-smart Agricultural Practices in Cocoa Production

Asare (2014) highlighted climate-smart agricultural (CSA) practices, including mulching using cleared weeds during land preparation to enhance soil organic carbon, and planting hybrid seedlings for improved yield and disease resistance. Further, the authors identified adhering to recommended fertilizer regimes to enhance cocoa growth and soil carbon stocks, and recommended pesticide application for control of black pods, fungal diseases, and pests affecting cocoa as CSA practices in cocoa production. The author elaborated that permitting natural regeneration and planting shade trees results in moderate carbon sequestration and the mitigation of greenhouse gas emissions.

Bunn et al. (2019) added that diversifying cocoa production by intercropping with food crops like palm oil, peanuts, yam, etc. can reduce climate shock risk to household income. Akrofi-attianti et al. (2018) confirmed that cultivating non-cocoa crops, particularly food crops, alongside cocoa provides households with heightened access to food resources and additional income in comparison to traditional farming methods. The author explained that agroforestry in cocoa farms boosts on-farm carbon stocks, reduces greenhouse gas emissions, and offers additional income through carbon credits in national REDD+ programs. Additionally, the authors added that pruning enhances cocoa growth, reduces pests and diseases, ensuring healthier and more resilient cocoa.

Factors that affect the Adoption of Climate Smart Practices

Theory of Planned Behavior (TPB) (Ajzen, 1991) anticipates how farmers make decisions about using technologies such as climate-smart agriculture (Hyland et al., 2018). The theory of planned behavior (TPB) is a socio-psychological model whose theoretical foundation is based on understanding human behavioral intention and how that intention transforms into specific behaviors. Ajzen (1991) added that TPB is open to including any explanatory constructs to explain the variance in intention and behavior more significantly. Diverse factors have been associated with the adoption of technologies across a range of studies in CSA. For example, socioeconomic characteristics (age, gender, education, family size), institutional (i.e., market access, extension services, training, and social groups) have been shown to influence the adoption of CSA technologies (Anning et al. 2022; Jamal et al. 2022; Kassa & Abdi, 2022). Kassa & Abdi (2022) revealed that education correlated with the adoption of climate-smart agriculture in Ethiopia. In Ghana, Anning et al. (2022) also revealed that education and age significantly influenced the adaptation strategies to climate change such as use of mulch and crop diversification among cocoa farmers. Anning et al. (2022) further identified gender as a significant influence on the planting of hybrid varieties by farmers on their cocoa farms. Jamal et al. (2021) substantiated that, based on their research, a majority of male farmers prefer drought-tolerant cocoa varieties compared to their female counterparts. Nonetheless, these preferences are context-dependent, varying with location and technologies evaluated.

Social learning has emerged as a pivotal way for predicting behavioral shifts toward the adoption of sustainable practices (Schusler et al., 2003; Stone, 2016). Social learning theory posits that the interaction among social actors promotes the exchange of knowledge and modification of behaviors (Bandura & Walters, 1977). Mekonnen et al. (2018) argue that the presence of social networks, including farmer groups and cooperatives, is crucial for facilitating social learning within communities. These networks enable the sharing of knowledge, encourage individual participation, and foster interactions at the farm level (Murro & Jeffery, 2008).

Ngwira et al. (2014) study on adoption on conservation practices in Malawi show a correlation between participation in farmer group and the adoption of these practices. The authors implied that smallholder farmers within farmer groups engage in mutual interactions and share knowledge and experiences informally, establishing trust which tends to increase adoption of practices.

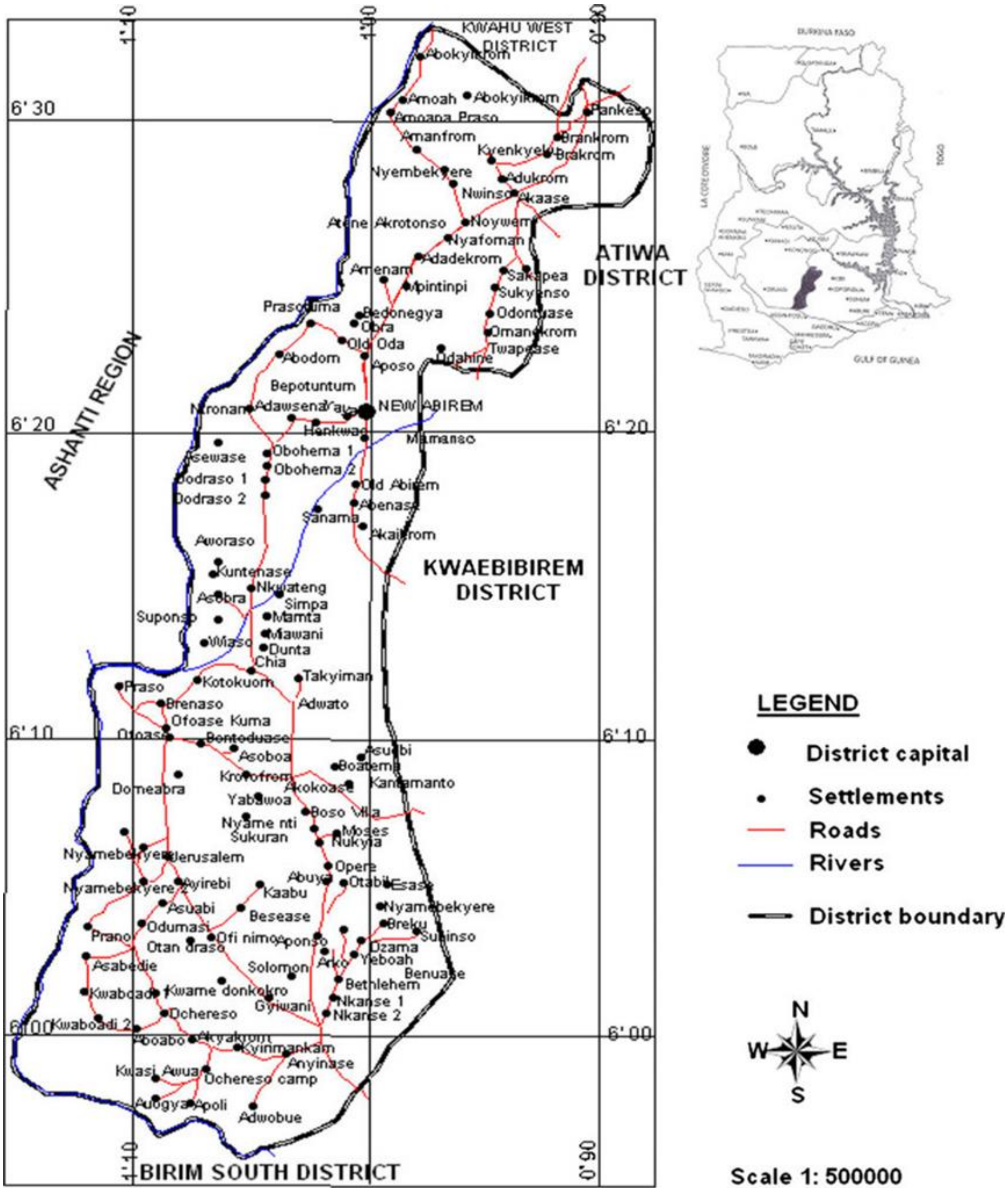
Additionally, farmer training has been associated with the adoption of technologies such as CSA (Jellason et al., 2020; Ouedraogo et al., 2019). For example, Jellason et al. (2020) study on understanding the impacts and barriers to CSA practices in Nigeria identified a relationship between training organized by extension agents and the adoption of CSA practices. Ouedraogo et al. (2019) study on the uptake of climate-smart agricultural practices in Mali further revealed a correlation between training and the adoption of drought-resistant hybrid seedlings by 15%.

Methods

Overview of Study Area

The study was conducted in Birim North district, located in the Eastern region of Ghana, with an approximate population of 78,907 (Ghana Statistical Service, 2014). About 74% of the district's labor force is involved in agricultural activities. Cocoa is one of the main cash crops grown in the district. Other cash and food crops include oil palm, citrus, maize, and cassava. New Abirem is the capital town (Figure 1), among thirty-three municipalities and districts. Positioned in the country's forest belt, the district encounters significant precipitation, featuring a dual-maxima rainfall pattern: the first season spans late March to early July, and the second occurs from mid-August to late October. The district receives an average annual rainfall ranging from 1,500mm to 2,000mm. Temperature fluctuations are observed, with an average minimum of 25.2 degrees Celsius and a maximum of 27.9 degrees Celsius, coupled with a year-round relative humidity of approximately 55-59 percent.

Figure 32.1 *District Relation to the Country as a Whole and to the Ocean and Adjacent Nations*[3]



Sample

The target population for this study was adult cocoa producers with membership in the Ghana Cocoa and Extension Division in Birim North District, Ghana. Birim North has been

[3] https://www.researchgate.net/figure/Map-of-Birim-North-District-Assembly_fig1_285417044

identified by the Ministry of Food and Agriculture (MOFA), Ghana, as one of the major cocoa production areas (MOFA, 2011).

Nine communities from the district were selected based on their intensive cocoa farming activities. Agricultural extension officers from the district's Cocoa Health and Extension division suggested these communities as focal areas of cocoa production. Information on cocoa farmers in each community was obtained from the extension division, and farm families were-selected using a systematic random procedure that ensured a woman was a member of each sample household. The farmers were then invited to partake in the survey by extension officers and other farmers. One hundred and six cocoa farmers were interviewed. The intended sample size was initially set at 150; however, the achieved response rate was 70%, with a total of 106 responses obtained. Potential factors contributing to this outcome include constrained time for data collection, data collection occurring during the rainy seasons when farmers were difficult to reach, and challenging road conditions. Caution is warranted against generalizing the findings beyond the sample that was draw due to potential nonresponse error (Lindner, 2002; Lindner et al., 2001).

Data Collection

Data collection and analysis adhered to the ethical principles of research with human subjects, following approval from the Institutional Review Board (IRB). Questions were prepared in English using Kobo toolbox software, while the interviews were conducted in the local language, Twi, with the help of enumerators who spoke the language fluently. A total of 106 face-to-face interviews were conducted in June 2023. At least five interviews in each selected community. Interviews were conducted at both participants' homes and on farms and lasted 40 to 60 minutes (Figure1.1). Climatic data for the study area were also collected from the

Ghana Meteorological Agency for 2013-2022. Data were utilized to compare perceptions of climate change with climatic records.

The questionnaire used to collect data for this study was designed and delivered through Kobo toolbox (Appendix 2) in a face-to-face interview. The survey instrument contained closed-ended questions, structured into three different sections: (1) knowledge and adoption of climate climate-smart agriculture; (2) Training and Extension Support (3) and sociodemographic, farm characteristics (age, gender, level of education and farmer group membership).

The interview questions about the climate smart practices were designed by adopting and modifying information from a Rainforest Alliance training manual for cocoa field officers in Ghana (Dohmen et al., 2018), which discussed climate smart cocoa practices and their benefit to the environment. A team of three Auburn University professors assessed and revised the questionnaire for content validity. Additionally, extension officers in the study area reviewed and adjusted terminology or answer choices to align with the context in the local community.

Measures

Dependent Variables

Climate smart agriculture practices (CSA) is the dependent variable. These were measured to explain farmers' adoption of climate-smart practices in cocoa production**.** Adoption of Climate Smart Practices was measured by counting "yes" responses to a series of farm management steps: Clearing without Burning, Use Hybrid cocoa seedlings, Agroforestry with timber trees, Intercropping with food crops, Inorganic Fertilizer, Manure/compost tea, Integrated Pest Management and Pruning. Responses were: Yes = Adopted, No = Not Adopted. The preamble and actual survey questions are presented in the Appendix section.

Independent Variables

The independent variables are socioeconomic characteristic: age, gender and education and institutional factors are training and farmer group membership. The reason for including these variables is based on literature information from studies such as Kassa & Abdi (2022), Musafiri et al. (2022) and Samoura et al. (2023).

Table 2.1 *Reported Use of Climate Smart Practices, Ghana Data 2023*

Variables	Description of Variables
Dependent	
Hybrid Seedling	Yes =Adopted, No= Not Adopted
Agroforestry with Timber Trees	Yes =Adopted, No= Not Adopted
Clearing Without Burning	Yes =Adopted, No=Not Adopted
Inorganic Fertilizer	Yes =Adopted, No= Not Adopted
Manure/Compost Tea	Yes= Adopted, No=Not Adopted
Integrated Pest Management	Yes= Adopted, No= Not Adopted
Intercrop with Food Crop	Yes= Adopted, No= not Adopted
Pruning	Yes= Adopted, No= Not adopted

Analysis

In the process of data cleaning, errors stemming from data inconsistency were identified and rectified. Descriptive analysis such as frequencies, and percentages was used to summarize the study variables on participants' perceptions of climate smart agriculture, adoption of these practices, extension services support and their individual, and farm characteristics. In addition, we assessed the relationship between socioeconomic (age, gender, education) and institutional factors (training and farmer group membership) on the adoption of CSA practices by smallholder cocoa farmers using Binary logistic regression.

Data were analyzed using SPSS. Binary logistic regression analysis was employed to examine the correlation between farmers' adoption of climate-smart agriculture practices and their socioeconomic and institutional characteristics. Binary logistic regression was selected due to the binary coding (0, 1) of the dependent variables.

The model is represented as:

$$Y = \beta o + M_1X_1 + M_2X_2 + \ldots\ldots\ldots M_bX_b + \varepsilon$$

where Y = Dependent variable; β = coefficient of the constant term; $M_1 - M_b$ = coefficients of the explanatory variables; $X_1 - X_b$ = explanatory variables, and ε = error term.

Thus, the regression model for the study is:

Adoption of climate smart practices (Y) = β_0 + M_1 Member of Farmer group + M_2Training + M_3 Age + M_4 Gender + M_5 Education +ε

Hypotheses

H_0: There is no significant effect of socioeconomic and institutional factors on adoption of climate smart agricultural practices. This implies that all regression coefficients are equivalent to zero.

H_0: $M_1 = M_2 = M_3 = M_4 = M_5 = 0$

H_0: There is a significant effect of socioeconomic and institutional factors on adoption of climate-smart agricultural practices.

H_1: $M_1 \neq M_2 \neq M_3 \neq M_4 \neq M_5 \neq 0$

Results

Characteristics of Respondents

Table 2.3 presents the variables observed in the sample of Ghanaian cocoa farmers. The results indicate that, among the interviewed farmers, 62.2% were male, while 37.7% were female, highlighting cocoa farming as a male- dominated activity. Approximately 73.3% were household heads, with a majority (50%) in the 45-59 age group. Educational levels ranged from basic (28.3%) to secondary education (47.2%) to tertiary (6.6%) and no formal education (17.9%). The results also indicated that a significant majority of respondents possessed over 16 years of farming experience (62.3%), earned a monthly average income within the range of GHC 900-200 (77-172 USD) (41.5%), and identified cocoa farming as their primary income source (75.5%). Approximately 46.2 % of respondents owned cocoa farms greater than 5 acres and about 38.7 % had joint ownership for their cocoa land.

Table 2.2 *Personal Characteristics of Smallholder Farmers, Ghana Data, 2023*

Gender		*f*	%	Income		*f*	%
	Female	40	37.7		Below 900	36	34
	Male	66	62.3		900-2000	44	41.5
Age	18-29	2	1.9		Above 2000	26	24.5
	20-44	30	28.3	Farm Size	< or equal to 1 acre	2	1.9
	45-59	51	50		> 1 < 3acres	15	14.2
	Over 60	21	19.8		> 3 < 5 acres	40	37.7
Education	Basic	30	28.3		> 5 acres	49	46.2
	Secondary	50	47.2	Land Ownership	Owner	26	24.5
	Tertiary	7	6.6		Joint Ownership	41	38.7
	No formal Edu.	19	17.9		Rent/Lease	28	26.4
Farming Experience	6-10 years	15	14.2		Inheritance	11	10.4
	11-15 years	25	23.6	Head of Household	No	28	26.4
	Over 16 years	66	62.3		Yes	78	73.6

Note. N is 106

Objective 2.1: Farmers' Perceptions and Adoption of Climate Smart Agriculture Practices

The first objective of the study was to explore farmers' perception of climate smart agriculture specifically to "whether they have heard the word before" and "whether they understood what the term CSA means." The first objective also identifies CSA practices used by respondents on their cocoa farm. Frequency and percentages were used to show the distribution of participants knowledge and adoption of CSA.

Participants were asked if they had "heard the word climate-smart agriculture." Of the 106 respondents, 63 (59.4%) revealed they had heard the word climate-smart agriculture. However, out of the 63 who have heard the word, 24.5% understood what it meant and 34.9% did not know what it meant (Table 2.3).

Table 2.3 *Distribution of Participants Who Have Heard the Word CSA and Who Know the Meaning, Ghana Data, 2023.*

	f	%
Heard the Word CSA		
No	43	40.6
Yes	63	59.4
Know the Meaning of CSA		
Yes	26	24.5
No	37	34.9
Have not heard and Don't Know the Meaning	43	40.6

Note. N is 106

Table 2.4 reports findings on the adoption of climate smart practices in cocoa production. The findings showed that 82% of the smallholder farmers practice clearing of their lands (manual weeding) without burning during land preparation. About 81% of the smallholder farmers use high-yielding, disease, and pest-resistant hybrid seedlings for planting. Approximately 76 % of the participants have adopted growing timber trees with their cocoa production, a term known as agroforestry. The majority (87%) practiced intercropping with food crops such as palm nuts, yams, and legumes with their cocoa production. About 77 % used inorganic fertilizer on the cocoa farms while a handful (30%) adopted the use of manure or compost on their cocoa farm. All of the 106 respondents interviewed are using the recommended pesticide dosage on the farm and were involved in pruning.

Table 2.4 *Reported Use of Climate Smart Practices, Ghana Data, 2023.*

		f	%
Clearing Without Burning	Yes	87	82.1
	No	19	17.9
Hybrid Seedling	Yes	86	81.1
	No	20	18.9
Agroforestry With Timber Trees	Yes	80	75.5
	No	26	24.5
Intercropping with food crops	Yes	92	86.8
	No	14	13.2
Use of Inorganic Fertilizer	Yes	82	77.4
	No	24	22.6
Use of Manure and Compost	Yes	32	30.2
	No	74	69.8
Use of Right Pesticide dosage	Yes	106	100
	No	0	0
Pruning	Yes	106	100
	No	0	0

Note. N is 106

Motivation to Adopt Climate Smart Agriculture

About 38 % of the participants revealed they will adopt climate-smart agriculture practices to increase farm income and yield, approximately 31 % to reduce pest and disease incidence on their farms, and about 23 % to protect their farms from future climate change impacts (table 2.5).

Table 2.5 *Participants Motivation to Adopting Climate Smart Agriculture Practices, Ghana Data 2023*

	f	%
Increase Farm Income and Yield	103	38.1
Reduce Pest and Diseases on My Farm	83	30.7
Protect My Farm from Future Impact to Climate Change	63	23.3
Increase Household Security	21	7.8
Total	270	100.0

Note. Total is not equal to N because of multiple responses from respondents.

Objective 2.2: Extension Advisory Service Support and Training

Objective two of the study is to explore extension service support and training for smallholder farmers within the study district.

Table 2.6 shows the distribution of participants (*n*=106) by their support to extension service. Almost all the participants (97%) have access to extension service and farm visits. Approximately 59 % indicated extension agents have visited their farm more often (more than 3 times) in the last 6 months. The majority of respondents (53%) said they were very satisfied with the overall support provided by extension services. However, 27% indicated a desire for additional training on climate-smart agriculture in the Birim North District.

Table 2.6 *Extension Access and Support, Ghana Data 2023.*

		f	%			*f*	%
Access to Extension Service				Farmer Needs from Extension agents			
	Yes	103	97.2		Visit Farm	70	24.6
Times of Visit in 6 Months					More Info. on the Risk of CC	67	23.5
	Never	0	0		More Training on CSA	77	27.0
	Once	3	2.3		Farm Incentives	71	24.9
	Two or Three Times	41	38.7		Total	285	100
	More Often	62	58.5				
Satisfaction with Extension Agents Support	Very Satisfied	56	52.8				
	Satisfied	49	46.2				
	Neither	1	0.9				
	Dissatisfied	0	0				
	Very Dissatisfied	0	0				

Note. Total for farmer needs from extension agents is not equal to N (106) because of multiple responses by respondents.

Table 2.7 show findings on farmer training and future training of participants. About 88% of participants have attended training on climate smart agriculture practices. About 87% reported that these trainings were offered by the extension division of the Ghana Cocoa Board. Out of the

12 % who have never attended a CSA training, about 11% indicated they would definitely attend a CSA training if it were offered.

Table 2.7 *Distribution of Climate Smart Agriculture Training, Ghana Data, 2023*

		f	%
Training			
	Yes	93	87.7
	No	13	12.3
Attend Future Training			
	Definitely Yes	12	11.3
	Probably Yes	1	0.9
	Might or Might Not	0	0
	Probably Not	0	0
	Definitely Not	0	0
	Received CSA Training Before	93	87.7

Note. N is 106

Objective 2.3: Socioeconomic and Institutional Factors Influencing Adoption of Climate Smart Agricultural Practices (CSA)

The study's third objective was to assess the impact of socioeconomic and institutional factors on the adoption of Climate-Smart Agriculture (CSA) practices among smallholder farmers, using Pearson correlations and Binary Logistic Regression.

Correlations

Table 2.8 displays the correlations between the dependent and independent variables. Six out of the eight dependent variables (CSA practices) were used in the correlation and regression analysis because the two variables (use of integrated pest management and pruning) did not show variations in respondents' responses. Overall correlations between adoption of climate smart agricultural practices and socioeconomic and institutional factors were low with the highest degree of correlation, r (106) = 0.39, $p < .01$ observed between training and adoption of agroforestry by respondents on their cocoa farms. Followed by correlations between education and clearing without burning on cocoa farms by respondents, r (106) = 0.35, $p<.01$. The comprehensive examination of these associations is conducted in the regression analysis.

Table 2.8 *Pearson Correlation Matrix of Study Variables, Ghana Data, 2023.*

	Without Burning	Hybrid	Manure	Agroforestry	Intercrop	Inorg. fertilizer	Training	Farmer Grp	Age	Edu.	Gender
Without Burn	--										
Hybrid Seedling	.24*	--									
Manure	0.19	.20*	--								
Agroforestry	-0.20*	0.07	-.29**	--							
Intercrop	.34**	-0.11	-0.05	-0.03	--						
Inorganic Fertilizers	-0.07	-0.08	.26**	-.31**	-0.01	--					
Training	-0.02	.27**	-0.07	.39**	-0.15	-0.13	--				
Farmer Grp	0.12	0.03	0.14	0.10	0.01	0.12	.28**	--			
Age	-0.14	0.12	-0.02	.20*	-0.01	0.09	.26**	0.17	--		
Education	.35**	.24*	0.09	0.08	-0.04	-.20*	.27**	0.10	-0.04	--	
Gender	.24*	.32**	0.15	0.03	-0.00	.21*	.26**	0.12	.19*	.21*	-

* Correlation is significant at the 0.05 level.
** Correlation is significant at the 0.01 level.

Socioeconomic and Institutional Factors on Adoption of Climate Smart Practices

Table 2.9 shows the results from the binary logistic regression analysis. Binary logistic regression assessed the relationship between socioeconomic and institutional factors and the adoption of climate-smart agricultural practices among smallholder farmers. The results from the are presented in table 2.9. Table 2.9 shows the coefficient and the standard error which are in parenthesis. The model shows a significant level and a good fit at p <.05 level for the various CSA practices. The results show R^2 values of 0.36,0.25, 0.22, 0.25 and 0.1 indicating that the variance of adoption of CSA practices are accounted for by socioeconomic and institutional factors.

Based on the results, gender had a positive and significant effect on farmer's likelihood to adopt clearing their lands without burning, planting of hybrid seedlings and the application of inorganic fertilizers on their farms. The findings implies that males are more likely to adopt clearing without burning, hybrid seedlings and inorganic fertilizer by 17%, 16% and 16% respectively, all things being equal. Gender was found to be a determining factor in the adoption of CSA practices and was found statistically significant at 5% level. The findings also reveal education as a determining factor on the adoption of CSA practices at 5% significance level. As education increases, ceteris paribus, the probability of adopting clearing cocoa lands without burning by 22%. The results also suggest age as a determining factor in the adoption of CSA practices at 5% significance level. As the age increases, ceteris paribus, the probability of adopting CSA practice manual clearing without burning decreases by 23%. The older the farmer the less likely to adopt CSA practices.

The findings additionally indicated that both training had a positive and statistically significant impact on the adoption of agroforestry. An increase in training is associated with a higher likelihood of farmers adopting agroforestry practices by 24%, all things being equal. Also, when farmers participate in farmer groups, the likelihood of adopting the manual clearing without burning and the use of inorganic fertilizer on their farms increases by 16% respectively even though it was not statistically significant.

Table 2.9 *Logistic Regression of the Relationship Between Socioeconomic and Institutional Factors on Adoption of Climate Smart Practices, Ghana Data, 2023*

	Without Burning	Hybrid Seedling	Agroforestry	Inorganic Fertilizer	Manure
Training	-1.91	1.23	2.36*	-2.07	-1.19
	(-1.21)	(0.78)	(0.78)	(1.24)	(0.76)
Farmer Group	1.61	-0.67	-0.12	1.43	1.31
	(0.85)	(0.93)	(0.77)	(0.74)	(0.86)
Age	-2.29*	0.07	0.80	0.20	-0.21
	0.47	(0.66)	(0.55)	(0.59)	(0.52)
Gender	1.72*	1.56*	-0.55	1.59*	0.84
	(-0.67)	(0.62)	(0.60)	(0.55)	(0.52)
Education	2.21*	0.90	0.05	-2.28	0.56
	(-0.76)	(0.67)	(0.69)	(1.15)	(0.67)
Constant	3.60	-0.43	-1.74	2.71	-1.66
	(1.86)	(1.20)	(1.86)	(1.56)	(1.20)
Log Likelihood	67.10	78.51	97.63	91.00	118.35
Pseudo R^2	0.36	0.25	0.22	0.25	0.1
Prob > chi^2	<0.00*	0.00*	0.00*	0.00*	0.18
Chi-square (5)	21.47	16.94	16.53	18.46	7.67
N	106				

Note. Standard error in parenthesis. * p<.05

Discussions, Conclusions and Recommendations

The aim of the study was to explore cocoa farmers' perceptions of climate-smart agriculture practices. The study's first objective was to identify farmers' perception and adoption of climate smart agriculture practices. The study finds that more than half of participants (59.4%) were familiar with the term climate-smart agriculture; however, only 24.5% of those familiar with the term comprehend its meaning. A probable explanation is that climate-smart agriculture is a novel concept, particularly introduced and promoted in developing countries, especially among rural farmers. The findings also aligned with Gwambene et al. (2015) study in Tanzania, which indicated that most farmers who were adopting CSA practices did not understand the reason for practicing them and were unaware of what CSA means.

The study also identified seven climate-smart agricultural practices within cocoa production based on modifications from the Rainforest Alliance Training Manual for cocoa field officers in Ghana (Dohmen et al., 2018). The results show most smallholder farmers were clearing their lands without burning during land preparation, are using high-yielding, disease, and pest-resistant hybrid seedlings for planting, are growing timber trees with their cocoa production, a term known as agroforestry and are involved in intercropping their cocoa production with food crops such as palm nuts, yams, and legumes and are using inorganic fertilizer on the cocoa farms. All the farmers used the recommended pesticide dosage on their farms and were involved in pruning.

Although many farmers lack understanding of the term climate smart, the majority were adopting CSA practices on their cocoa farms. A plausible explanation is that farmers have been taught about the benefits of adopting farm-level management practices on yield, production, and environment without necessarily associating them with climate smart practices. Asare (2014) and Akrofi-Atitianti (2018) discuss the importance of these farm management practices (CSA) on yield and the environment. The study revealed the benefits of intercropping diverse non-cocoa crops, particularly food crops, including improved household access to food and additional income, coupled with a reduction in the extensification of forest lands. Moreover, the adoption of agroforestry practices contributes to increase in on-farm carbon stocks and diminished greenhouse gas emissions, presenting an additional avenue for household incomes through carbon credits in national REDD+ programs.

Most farmers in the study communities used mineral fertilizer instead of manure or compost, a probable explanation for the lower number (30%) of adoption of manure. Farmers were asked about their motivation factor for adopting CSA practices. Many farmers indicated that they would adopt CSA practices if their cocoa yield and production increases. Only a few farmers (23%) indicated they would adopt CSA on their cocoa if their farms would be protected from future impact to climate change.

The study's second objective was to explore extension service support and training among smallholder farmers. The results from the study revealed the significant representation of extension agents from government agencies like COCOBOD in the study district. Most farmers (97%) have access to extension service, and more frequent farm visits from extension agents in the last six months. The majority of farmers have attended training on CSA by extension agents. Farmers who have not yet attended CSA training indicated a willingness to attend future training if provided. Overall, farmers (99%) were satisfied with the support from extension service but revealed a need for more training on CSA practices.

Agricultural extension service centers on assisting farmers in making informed decisions regarding cocoa production to marketing by providing technical support, training, and other services. The cordial relationship between cocoa farmers and extension agents promotes trust and social learning and a willingness to invest time and resources toward implementing adaptation strategies to address climate change. in trying adaptation measures to climate change.

Objective three discusses the individual and institutional factors that influence CSA adoption on cocoa farms. Results from the binary logistic regression revealed gender as a determining factor in adopting CSA. Men are more inclined to embrace adoption of clearing of land without burning, planting of hybrid seedlings and application of inorganic fertilizer. The findings correspond to Jamal et al. (2021) study, which show that many male farmers opt for hybrid or drought-tolerant cocoa varieties compared to their female counterparts.

Education of farmers positively and significantly influence farmers' likelihood to adopt CSA practices (manual clearing without burning and use of manure). This finding collaborates with Anning et al (2022), who found education positively and significantly influence cocoa farmers' use of mulch and crop diversification (CSA practices) on their farms. The age of farmers negatively and significantly influenced farmers' likelihood to adopt CSA practices (manual clearing without burning). A plausible explanation could be that older farmers are set in their ways and find it difficult to change their practices to adopt new ones.

Regarding institutional factors, training positively and significantly influences the adoption of CSA practices, specifically, the use of agroforestry techniques (planting timber trees with cocoa production). This finding aligns with Jellason et al.'s (2021) study, which established a correlation between training facilitated by extension agents and the adoption of Climate-Smart Agriculture (CSA) practices in Nigeria, and, also consistent with Ouedraogo et al.'s (2019) study, which reveals a positive and significant correlation between training and adoption of CSA practices (planting of hybrid seedling) by 15% in Mali.

Also, farmer membership in associations showed a positive influence on the adoption of CSA practices like using inorganic fertilizers although it was not significant. This could imply that membership in farmer organizations facilitates knowledge sharing and interactions and increases farmers' access to knowledge on CSA practices and their importance. This finding collaborated with Ngwira et al. (2014) study, who found a relationship between farmer group membership and adoption of conservation practices in Malawi and also in line with Sanogo et al (2023) study, who found a positive relationship between membership in farmer cooperatives and the adoption of improved seed.

In conclusion, based on our findings, adoption of CSA practices especially local context specific practices in cocoa production are key to building resilience to climate change. Socioeconomic and institutional factors such as gender, education, training, and membership in farmer groups are relevant considerations in policy interventions regarding scaling CSA among smallholder farmers. The study highlights the need for extension agents to incorporate training programs and resources that are farmer centered and demonstrate the benefits of adopting CSA practices. Farmers should be engaged in the design of climate-smart agriculture training to help improve their capacity to understand the concept and the benefit to their cocoa production and the environment. Also, training opportunities should target both males and females and should be broadcasted by extension agents and farmer groups to create awareness and increase participation. This study also recommends that farmers' involvement in associations in the district be encouraged to promote social learning, trust, and adoption of CSA practices.

References

Anthony M. (2023, September 11). Ghana’s president raises cocoa farmgate price to combat smuggling and weak cedi. Confectionary News

Akrofi-Atitianti, F., Ifejika Speranza, C., Bockel, L., & Asare, R. (2018). Assessing climate smart agriculture and its determinants of practice in ghana: A case of the cocoa production system. Land, 7(1). https://doi.org/10.3390/land7010030

Anuga, S. W., Gordon, C., Boon, E., & Musah-Issah Surugu, J. (2019). Determinants of climate smart agriculture (csa) adoption among smallholder food crop farmers in the techiman municipality, ghana. *Ghana Journal of Geography*, *11*(1).

Anning, A. K., Ofori-Yeboah, A., Baffour-Ata, F., & Owusu, G. (2022). Climate change manifestations and adaptations in cocoa farms: Perspectives of smallholder farmers in the adansi south district, ghana. *Current Research in Environmental Sustainability*, *4*. https://doi.org/10.1016/j.crsust.2022.100196

Ajibade, L. T., & Eche, J. O. (2017). Indigenous knowledge for climate change adaptation in Nigeria. In *Indigenous knowledge systems and climate change management in Africa.*

Ajzen, I. (1991). The theory of planned behavior. *Organizational Behavior and Human Decision Processes*, *50*(2). https://doi.org/10.1016/0749-5978(91)90020-T

Asare, R.A. (2014). *Understanding and Defining Climate-Smart Cocoa: Extensions, Inputs, Yields and Farming Practices*; Natural Conservation Research Center—Forest Trends: Accra, Ghana.

Bunn, C., Läderach, P., Quaye, A., Muilerman, S., Noponen, M. R. A., & Lundy, M. (2019). Recommendation domains to scale out climate change adaptation in cocoa production in ghana. *Climate Services*, *16*. https://doi.org/10.1016/j.cliser.2019.100123

Bandura, A., & Walters, R. H. (1977). *Social Learning Theory* (Vol. 1). Englewood Cliffs, NJ Prentice-Hall.

Campbell, B. M., Thornton, P., Zougmoré, R., van Asten, P., & Lipper, L. (2014). Sustainable intensification: What is its role in climate smart agriculture? In *Current Opinion in Environmental Sustainability*, 8. https://doi.org/10.1016/j.cosust.2014.07.002

Clemons, C., Lindner, J. R., Murray, B., Cook, M. P., Sams, B., & Williams, G. (2018). Spanning the Gap: The Confluence of Agricultural Literacy and Being Agriculturally Literate. *Journal of Agricultural Education, 59*(4), 238-252. https://doi.org/10.5032/jae.2018.04238

Coe, S.D., & Coe, M.D. (2007). *The true history of chocolate*. London? Thames and Hudson.

Dohmen MM, Noponen M, Enomoto R, Mensah C, Muilerman S. (2018). *Climate-smart agriculture in cocoa: A training manual for field officers, accra, ghana*. World Cocoa Foundation and The Rainforest Alliance.

FAO. (2013). Climate-smart agriculture sourcebook. *Sourcebook on Climate-Smart Agriculture, Forestry and Fisheries.*

Ghana Statistical Service. (2014). *2010 population and housing report: District analytical report, birim north district, ghana*. International Development Cooperation.

Gwambene, B., Saria, J. A., Jiwaji, N. T., Pauline, N. M., Msofe, N. K., Mussa, K. R., Tegeje, J. A., Messo, I., Mwanga, S. S., & S.M.Y., S. (2015). Smallholder farmers' practices and understanding of climate change and climate smart agriculture in the southern highlands of tanzania. *Journal of Resources Development and Management*, *13*(B)

Jamal, A. M., Antwi-Agyei, P., Baffour-Ata, F., Nkiaka, E., Antwi, K., & Gbordzor, A. (2021). Gendered perceptions and adaptation practices of smallholder cocoa farmers to climate variability in the Central Region of Ghana. *Environmental Challenges*, *5*. https://doi.org/10.1016/j.envc.2021.100293

Jellason, N. P., Conway, J. S., & Baines, R. N. (2020). Understanding impacts and barriers to adoption of climate-smart agriculture (csa) practices in north-western nigerian drylands. *Journal of Agricultural Education and Extension*. https://doi.org/10.1080/1389224X.2020.1793787

Kassa, B. A., & Abdi, A. T. (2022). Factors influencing the adoption of climate-smart agricultural practice by small-scale farming households in wondo genet, southern ethiopia. *SAGE Open*, *12*(3). https://doi.org/10.1177/21582440221121604

Lipper, L., Thornton, P., Campbell, B. M., Baedeker, T., Braimoh, A., Bwalya, M., Caron, P., Cattaneo, A., Garrity, D., Henry, K., Hottle, R., Jackson, L., Jarvis, A., Kossam, F., Mann, W., McCarthy, N., Meybeck, A., Neufeldt, H., Remington, T., … Torquebiau, E. F. (2014). Climate-smart agriculture for food security. *Nature Climate Change*, *4*(12). https://doi.org/10.1038/nclimate2437

Lindner, J. R., Murphy, T. H., & Briers, G. E. (2001). Handling Nonresponse In Social Research. *Journal of Agricultural Education*, *42*(4), 43–53. https://doi.org/10.5032/jae.2001.04043

Lindner, J. R. (2002). Handling of nonresponse error in the Journal of International Agricultural and Extension Education. Journal of International Agricultural and Extension Education, 9(3), 55-60. https://www.researchgate.net/publication/237569094_Handling_of_Nonresponse_Error_i n_the_Journal_of_International_Agricultural_and_Extension_Education#fullTextFileContent

Lindner, J. R., & Lindner, N. (2024). Interpreting Likert type, summated, unidimensional, and attitudinal scales: I neither agree nor disagree, Likert or not. *Advancements in Agricultural Development, 5*(2), 152–163. https://doi.org/10.37433/aad.v5i2.351

Lindner, J. R., Rodriguez, M. T., Strong, R., Jones, D., & Layfield, D. (2016). Research priority area 2: New technologies, practices, and products adoption decisions. *American Association for Agricultural Education national research agenda, 2020*, 19-27.

Mekonnen, D. A., Gerber, N., & Matz, J. A. (2018). Gendered social networks, agricultural innovations, and farm productivity in ethiopia. *World Development, 105*. https://doi.org/10.1016/j.worlddev.2017.04.020

Ministry of Ghana (MOFA). (2011). *Birim North*. https://mofa.gov.gh/site/sports/district-directorates/eastern-region/223-birim-north

Muro, M., & Jeffrey, P. (2008). A critical review of the theory and application of social learning in participatory natural resource management processes. *Journal of Environmental Planning and Management*, *51*(3). https://doi.org/10.1080/09640560801977190

Musafiri CM, Kiboi M, Macharia J, Ng'etich OK, Kosgei DK, Mulianga B, Okoti M, & Ngetich FK. (2021). Adoption of climate-smart agricultural practices among smallholder farmers in Western Kenya: do socioeconomic, institutional, and biophysical factors matter? *Heliyon,* 8(1). Doi:10.1016/j.heliyon.2021.e08677.

Ngwira, A., Johnsen, F. H., Aune, J. B., Mekuria, M., & Thierfelder, C. (2014). Adoption and extent of conservation agriculture practices among smallholder farmers in Malawi. *Journal of Soil and Water Conservation*, *69*(2). https://doi.org/10.2489/jswc.69.2.107

Peprah, K. (2015). Sustainability of cocoa farmers' livelihoods: A case study of asunafo district, ghana. *Sustainable Production and Consumption*, *4*. https://doi.org/10.1016/j.spc.2015.09.001

Porter, J. R., Xie, L., Challinor, A. J., Cochrane, K., Howden, S. M., Iqbal, M. M., Lobell, D. B., Travasso, M. I., Aggarwal, P., Hakala, K., & Jordan, J. (2015). Food security and food production systems. In *Climate Change 2014 Impacts, Adaptation and Vulnerability: Part A: Global and Sectoral Aspects*. https://doi.org/10.1017/CBO9781107415379.012

Olorunfemi, T. O., Olorunfemi, O. D., & Oladele, O. I. (2020). Determinants of the involvement of extension agents in disseminating climate smart agricultural initiatives: Implication for scaling up. *Journal of the Saudi Society of Agricultural Sciences*, *19*(4). https://doi.org/10.1016/j.jssas.2019.03.003

Oppong, D. (2014). *Rationally motivated? cocoa production in ghana: motivations and de-motivations of small-scale producers in fawohyeden, ghana. Agricultural and Food Sciences, Business*. Master's Thesis.

Onumah, J. A., Al-Hassan, R. M., & Onumah, E. E. (2013). Productivity and technical efficiency of cocoa production in Eastern Ghana. *Journal of Economics and Sustainable Development*, *4*(4), 106-117.

Ouédraogo, M., Houessionon, P., Zougmoré, R. B., & Partey, S. T. (2019). Uptake of climate-smart agricultural technologies and practices: Actual and potential adoption rates in the climate-smart village site of Mali. *Sustainability (Switzerland)*, *11*(17). https://doi.org/10.3390/su11174710

Rogers, E.M. (2003). *Diffusion of innovations*, (5th edition), The Free Press, London.

Samoura, D. A., Wahab, B., Taiwo, O. J., & Bishoge, O. K. (2023). Small-scale farmers' coping strategies to extreme weather events in Upper Guinea. *Journal of Agriculture and Rural Development in the Tropics and Subtropics (JARTS), 124*(1), 13-21.

Scherr, S. J., & McNeely, J. A. (2008). Biodiversity conservation and agricultural sustainability: towards a new paradigm of ecoagriculture landscapes. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *363*(1491). https://doi.org/10.1098/rstb.2007.2165

Setshedi, K. L., & Modirwa, S. (2020). Socio-economic characteristics influence small-scale farmers' level of knowledge on climate-smart agriculture in mahikeng local municipality, north west province, south africa. *South African Journal of Agricultural Extension*, *48*(2). https://doi.org/10.17159/2413-3221/2020/v48n2a544

Schusler, T. M., Decker, D. J., & Pfeffer, M. J. (2003). Social learning for collaborative natural resource management. *Society and Natural Resources*, *16*(4). https://doi.org/10.1080/08941920390178874

Stone, G. D. (2016). Towards a general theory of agricultural knowledge production: environmental, social, and didactic learning. *Culture, Agriculture, Food and Environment*, *38*(1). https://doi.org/10.1111/cuag.12061

Teal, F., Zeitlin, A., & Maama, H. (2006). *Ghana cocoa farmers survey 2004: Report to ghana cocoa board*. Center for the Study of African Economies. University of Oxford, Oxford, United Kingdom.

The World Bank Group. (2019, December 4). *Climate Smart Agriculture Investment Plans: Bringing CSA to Life*

Vigneri, Marcella & Kolavalli, Shashi. (2018). *Growth through pricing policy: The case of cocoa in Ghana.* Background paper to the UNCTAD-FAO Commodities and Development Report

2017 Commodity markets, economic growth and development Growth through pricing policy: The case of cocoa in Ghana. FAO, Rome, Italy.

Voora, V., Bermúdez, S., & Larrea, C. (2019). *Global Market Report: Cocoa*. Sustainable Commodities Marketplace Series. International Institute for Sustainable development. Winnipeg, Manitoba, Cananda.

Wheeler, T., & Von Braun, J. (2013). Climate change impacts on global food security. *Science 341* (6145). https://doi.org/10.1126/science.1239402

Dissertation Paper Three

Advisory Services Supporting Drip Irrigation Adoption: An Example of Climate-Smart Technology

Introduction

As the population grows, food and water demand have increased enormously. According to the United Nations report, the global population is estimated to increase by about 2 billion in the next 30 years. Supplying food to the growing population has become difficult. At the same time, industrialization and urbanization have caused a decline in agricultural arable land. The World Bank (2018) reported a decrease in arable land for farming in Haiti since the 1960s, from 0.36 hectares per capita to 0.10 hectares per capita in 2018. Water is also becoming scarce due to drought, climate change consequences and natural disasters. Agriculture, including fruit and vegetable cultivation is one of the industries that primarily use water resources globally, and a decrease in water supply will hurt the agricultural industry. Extending irrigation to cropland watered only by rainfall will impact food production positively and reduce rural hunger and poverty. The growth in demand for food and water and the decrease in arable land and resources has opened the way for technological innovations such as drip irrigation. In Haiti, rural communities will be able to deal with high-risk crop losses and climate variability with the adoption of drip irrigation.

Conceptual Framework

Drip irrigation technology began in Israel during the 1950s through the 1970s. In the United States, drip irrigation expanded during the 1970s, and its utilization continues to spread. According to the US Geological Survey, 63,500 thousand acres of land were irrigated in 2015, out of which 5490 thousand accounted for drip irrigation systems. Drip irrigation involves the application of water through point or line sources under low pressure (Dasberg, 1999). Drip irrigation conserves water, improves crop quality, and boosts production compared to traditional methods. Additionally, it enhances efficiency by minimizing soil surface evaporation, run-off, and deep-water infiltration. Drip irrigation eliminates the necessity to over-irrigate field sections to counterbalance uneven water application (Skaggs, 2001). Megersa & Abdulahi's (2015) review on drip irrigation in Israel identified that crop timing might be enhanced through drip irrigation as the technology does not require removal during harvesting or reinstallation before the second planting. The authors also included that operating pressures are often less, reducing the energy cost associated with some irrigation systems.

Drawbacks to Drip Irrigation Equipment

Megersa & Abdulahi (2015) discussed some drawbacks to drip irrigations. The authors reported that system mismanagement may occur and can result in insufficient irrigation, diminished crop quality, or excessive irrigation. Over-irrigation can lead to aeration and percolation issues. Excessive emitters discharge relative to soil infiltration can result in soil overpressure around the emitter outlet, leading to surface runoff and undesirable wet spots in the field. Soil salinity may rise beyond the dripline, posing a hazard for emerging seedlings or small transplants. Clogging of emitters may occur, diminishing the service life of drip irrigation systems. Despite advancements like filtration, periodic acidification, chlorination treatments, and optimized emitter design, clogging remains a potential issue (Li et al., 2008; Avnimelech, 1993). A study in France revealed that drip irrigation is sensitive to clogging, which may be caused by small particles aggregating into bigger particles (Bounoua et al., 2016). The authors added that even though infiltration is used in drip irrigation to prevent clogging, it is usually ineffective.

Profitability of Drip Irrigation

The outlook for drip irrigation expansion is optimistic, supported by diverse systems for various income levels and farm sizes. Field trials show that low-cost drip systems rapidly recoup expenses in one season, prompting small farmers to adopt more intensive agricultural practices. (Postel et al., 2001).

The discourse around drip irrigation is the need for efficient use of agricultural water to contribute to sustainable development goals and shape a better future. In the past 50 years, research on drip irrigation has predominantly resulted in high-tech and costly systems tailored for farmers in developed economies. The shift occurred in the late 1990s/early 2000s, emphasizing the design and dissemination of irrigation technologies tailored to the requirements of smallholder farmers in developing nations. Low-cost drip systems made drip irrigation a vital agricultural technology for smallholder farmers, catalyzing a second green revolution for impoverished farmers globally (Postel, et.al., 2001). The majority of smallholders cultivate plots under two hectares, with canal irrigation benefiting only a small subset. Because subsidized surface schemes are often impractical or costly for most farmers in these locations. Therefore, introducing drip irrigation specifically to smallholder farmers has been very important and necessary.

Features and Consideration of Drip Irrigation

Equipment utilized in drip irrigation systems is critical. Various equipment, including plastic hoses, emitters, pressure regulators, gauges, valves, fertilizer tanks, filter screens, time clocks, tensiometers, evaporative pans, meters, and fertilizer injectors, is utilized in drip irrigation systems (Dripworks blog, 2021). The filter is a crucial component in drip irrigation systems as the small diameters of emitters can easily clog with improper filtration. Therefore, conducting a water test before designing a drip irrigation system is essential, as the results guide the selection of the appropriate filtration type (Storlie,1995). Filtration is essential, and the additional investment in proper filtration ensures optimal performance from emitters. There are different types of drip irrigation systems used across the world. Efficiently designed and properly installed drip irrigation systems have the potential to conserve up to 80% of water compared to alternative irrigation methods (Howell, 2000). Howell (2000) also examined farm-specific factors influencing the use of drip irrigation, including farm size, water quality, land slope, and crop value. The authors highlighted the importance of aligning cultural practices such as bed width, crop rotation, and field access with the drip irrigation system.

While irrigated agriculture plays a crucial role in ensuring food security, various studies highlight insufficient investment in maintaining irrigation water systems, leading to water waste and leaks (Farmani et al., 2007; Ward, 2010). Losses of up to 25% for delivery systems and 20% from on-farm pipelines have been estimated, along with an additional 10–15% from inefficient water application technologies, potentially reducing the required water for sustaining food production. With growing pressure on irrigated agriculture to allocate water to alternative uses (Connor et al., 2008), securing funding for the maintenance of irrigated infrastructure becomes crucial in sustaining essential water sources for the food system. Beyond engineering, technology design, and financing, social entrepreneurship is the second most important pillar to consider for the success of drip irrigation. Venot (2016) contends that fulfilling technological promises requires adopting a market-based approach, suggesting the substitution of a technological fix with an institutional solution. In the drip irrigation sector, social entrepreneurship begins with the product's legitimacy in addressing global challenges and recognizing the potential of small-scale farmers to overcome difficulties in their current practices. Heierli & Polak (2000) asserted that in the development and dissemination of drip irrigation, smallholders should be regarded as consumers within a broader market-based approach. There exists a time lag between the introduction of technology and its adoption. Additionally, irrigation significantly impacts the marketing behavior of smallholders. Mwangi & Crewett (2019) found that, on average, a larger proportion of irrigators (96%) engage in selling indigenous vegetables as compared to 86% of non-irrigators. Additionally, the choice of irrigation technology influences participation in indigenous vegetable marketing, with 99% of modern irrigators and 90% of manual irrigators being involved in sales.

Diffusion refers to the gradual adoption of technology over time. The process of diffusion involves the transfer of technology to different locations, where it can be either rejected or adopted, leading to consequential impacts. Rogers (1962) conceptualized diffusion as an imitation process and calculated the diffusion curve as an S-shaped function unfolding over time. The diffusion paradigm explores questions related to the channels and rates of adoption, the influence of costs and benefits on adoption, the role of early adopters, their networks and promotion, and the nature of barriers. Griliches (1957) initiated the economic literature on adoption, highlighting that economic factor, such as profit, influence the shape parameter of the diffusion curve. In Shrestha's (1993) study on drip irrigation adoption, economic considerations such as water use, yield, and locational characteristics play a crucial role. The analysis emphasizes the need to incorporate physical and irrigation-specific features, including efficiency, costs, and environmental factors, in economic assessments of technology adoption and diffusion.

Theoretical Issues: Adoption and Diffusion Theory

Rogers (1995) outlined the adoption process and highlighted key innovation factors influencing a potential adopter's decision to embrace new technology. The author explored the perceived characteristics of the innovation, including its relative advantage, compatibility, perceived risk, divisibility, complexity, and observability (Rogers, 1995). Rogers (2010) defines relative advantage as the extent to which an innovation is perceived as superior to the idea it supersedes.

Compatibility denotes the extent to which an innovation aligns with sociocultural values, experiences, and perceived needs. Farmers are more likely to embrace a technological innovation if it is compatible with their specific farm conditions (Warner, Lamm, & Silvert, 2020). Complexity, according to Rogers (2010), refers to the degree of difficulty in using and understanding an innovation. Trialability pertains to the ease with which an innovation can be experimented with within a limited time, while observability relates to the ability to observe the innovation and its outcomes (McCann et al., 2015). When the perceived characteristics are not conclusive, other compelling factors can still foster a positive attitude toward change in the new technology. On the other hand, Morris et al. (2000) argued that external factors linked to political and institutional change could also play a crucial role in the adoption process.

The adoption process involves stages such as awareness, persuasion, evaluation and decision, implementation, and assessment. Prospective adopters gather formal and informal information before evaluation (Thaler, 1985; Weersink & Fulton, 2020). Kulecho & Weatherhead's (2006) study on adopting low-cost drip irrigation in Kenya revealed a high awareness of knowledge of low-cost drip irrigation among government representatives but low among farmers who do not use drip irrigation. The authors further stated that a lack of awareness could hinder farmers' adoption of drip irrigation. Promoting awareness about a new technology among farmers will involve education and training, involving change agents, and through the media and demonstrations. The authors also identified communication channels as media, friends, technical staff and in-person interactions. During the persuasive stage, the significance of agricultural extension staff as change agents should not be underestimated. Agricultural extension personnel facilitate learning processes and dissemination of knowledge among various stakeholders, including small-scale farmers, to support innovation adoption. They facilitate communication among farmers through field demonstrations, farm visits, face-to-face interactions, and training. Extension agents enhance their expertise by assimilating insights from farmers, understanding their practices, learning from their networks, and staying updated to better serve farmers.

In the decision stage, individuals assess the innovation's feasibility, considering its benefits and alignment with their needs. The implementation stage involves acquiring, installing, and using the technology, often posing challenges for potential adopters (Rogers, 2003). The assessment stage where adopters maximize objectives considering economic, budgetary, and informational constraints. Assessment guides decision-making, leading to either an immediate purchase or a dynamic decision strategy, incorporating learning from experience and trials (Ghadim & Pannell, 1999). A farmer may slowly introduce a new crop, and periodically reassess and readopting the technology. Consideration of the differences between early and late adopters, along with the impact of dynamic variables over time, is crucial (D'Emden, Llewellyn, & Burton, 2006). Farmers, equipment manufacturers, and policymakers must grasp the conditions favoring the benefits and adoption of drip irrigation, as well as factors influencing its diffusion.

Factors Influencing the Adoption of Drip Irrigation

Past research on agricultural technology adoption has categorized influencing factors into five groups: farmer characteristics, economic factors, farm attributes, technology characteristics, and institutional factors. Notably, educational level has been identified as a positive influence on adoption (Foltz, 2003). Yazdanpanah et al. (2022) corroborated this finding, indicating that farmers embracing the new irrigation system exhibit higher education levels and an awareness of the benefits associated with adopting innovative irrigation methods. The relationship between farmers' age and adoption patterns is inconsistent across studies, with some showing no correlation, a few suggesting earlier adopters are younger, and others indicating they are older. Yazdanpanah et al. (2022) discovered that improved irrigation adoption was more prevalent among older farmers than younger ones. A study in Ethiopia revealed that out of 13 explanatory variables, four (education, labor availability, technical knowledge of drip irrigation, and extension services) significantly influenced farmers' decision to adopt drip irrigation (Gebremeskel et al., 2017). Inclusion of farmer associations enhances water conservation technology adoption by providing valuable services that contribute to farmers' business and education (Sidibé, 2005). Economic factors influencing the adoption process include business size and credit availability. Typically, farmers with larger businesses tend to be more innovative, given their capacity to bear investment costs and secure credit promptly.

Kebede (1992) noted that farmers' access to non-farm income sources can impact technology adoption, either positively by enhancing income security or negatively by reducing the need for income enhancement. Research indicates that changes in input and output prices influence the adoption of agricultural innovations (Schaible et al., 1991). Caswell et al. (1990) found that the adoption of irrigation technologies is influenced by the price of water, with higher prices encouraging adoption. The role of gender can play in role in adopting drip irrigation technology. Nigussie et al. (2017) found that women, having lower access to resources, especially information, may be impacted in their adoption of innovations.

Barriers to Adopting Drip Irrigation

Several barriers to adopting drip irrigation technology have been discussed in literature. Sandberg and Aarikka-Stenroos (2014) categorized adoption barriers as external and internal. External barriers include market, economic and environmental factors—for example, a lack of government investment and general support for improved irrigation technologies or innovations. Access to resources was one barrier among Australian farmers (Senyolo et al., 2017). A reluctance to depart from traditional farming practices due to perceived risks and a lack of familiarity and knowledge of the innovation are internal barriers to drip irrigation adoption (Senyolo et al., 2017). Internal barriers to innovation adoption, such as organizational structure, were identified in Long et al.'s (2016) study. Farmers face barriers to adopting drip irrigation, including insufficient technical skills, high initial and maintenance costs, and variations in water availability (Kaarthikeyan & Suresh, 2019).

Conclusion

Addressing global food security and poverty amid escalating water scarcity demands innovative agricultural and economic development strategies. Many impoverished farming households in developing nations lack both access to irrigation water and the necessary technologies for efficient and productive water use. The widespread adoption of new, affordable drip irrigation systems tailored to diverse farm sizes and income levels holds the potential to extend irrigation benefits to millions of small-scale farmers. Drip irrigation's water-conserving and yield-boosting capabilities offer a promising avenue for enhancing productivity and incomes within some of the most economically challenged segments of the rural population. The adoption of new and innovative technologies, practices, and products is critical to reducing food insecurity (Lindner et al., 2016).

References

Alcon, F., Miguel, M.D.D., & Burton, M. (2011). Duration analysis of adoption of drip irrigation technology in southeastern spain economics. *Technological Forecasting and Social Change*, *78*, (6), 991-1001.

Avnimelech, Y. (1993). Irrigation with effluents: The Israeli experience. *Environmental Science and Technology*, *27*(7), 1278–1281.

Bounoua, S., Tomas, S., Labille, J., Molle, B., Granier, J., Haldenwang, P., & Izzati, S.N. (2016). Understanding physical clogging in drip irrigation: in situ, in-lab and numerical approaches. *Irrigation Science*, *34* (4), 327-331.

Caswell, M., Lichtenberg, E., & Zilberman, D. (1990). The effects of pricing policies on water conservation and drainage. *American Journal of Agricultural Economics*, *72* (4), 883-90.

Connor, K., Schwabe, K., & King, D. (2008). Irrigation to meet growing food demand with climate change, salinity and water trade sustain. *Irrigation Management Technology Policies*, *112*, 43-52.

Dasberg, S. (1999). *Drip Irrigation*, Springer,

Berlin.D'Emden, F.H., Llewellyn, R.S., & Burton, M.P. (2006). Adoption of conservation tillage in australian cropping regions: An application of duration analysis Technology.*Forecast Social Change*, *73* (6), 630-647. DOI: 10.1016/j.techfore.2005.07.003

Farmani, R., Abadia, R., & Savic, D. (2007). Optimum design and management of pressurized branched irrigation networks. *Journal of Irrigation and Drainage Engineering*, *133* (*6*), 528-537.

Foltz, J. D. (2003). The economics of water-conserving technology adoption in tunisia: An empirical estimation of farmer technology choice. *Economic Development and Cultural Change*, *51* (2), 359-373.

Gebremeskel, G., Gebremicael1, T. G., Hagos, H., Gebremedhin, T., & Kifle, G. (2017). Farmers' perception towards the challenges and determinant factors in the adoption of drip irrigation in the semi-arid areas of tigray, ethiopia. *Sustainable Water Resource Management, 4,* 527–537.

Griliches, Z. (1957). Hybrid Corn: An exploration in the economics of technological change. *Econometrica*, *25*, 501-522.

Ghadim, A.K.A., & Pannell, D.J. (1999). A conceptual framework of adoption of an agricultural innovation. *Agricultural Economics*, *21*(2), 145-154.

Heierli, U., & Polak, P. (2000). *Poverty alleviation as a business*. *The market creation approach to development*. Swiss Agency for Development and Cooperation, Freiburgstrasse 130, CH-3003 Berne Switzerland.

Howell, J. (2000). Drops of life in the history of irrigation. *Irrigation Journal*, 50 (1), 8-11.

Kaarthikeyan, G.M., & Suresh, A. (2019). A study on understanding the adoption of water saving technology: A case study of drip irrigation. *International Journal of Recent Technology and Engineering*, *7* (6), 1123-1130.

Kulecho, K., & Weatherhead, E.K. (2006). Adoption and experience of low-cost drip irrigation in Kenya. *Irrigation and drain*, *55*(3), 435–444.

Kebede, Y. (1992). Risk behavior and new agricultural technologies: the case of producers in the central highlands of Ethiopia quarterly. *Journal of International Agriculture*, *31*, 269-284.

Li Y.K, Yang, P. L., Xu T.W., Ren S.M., Lin X. C., Wei, R.J., & Xu, H.B. (2008). CFD and digital particle tracking to assess flow characteristics in the labyrinth flow path of a drip irrigation emitter. *Irrigation* Science, *26*, 427–438.

Lindner, J. R., Rodriguez, M. T., Strong, R., Jones, D., & Layfield, D. (2016). New technologies, practices, and products adoption decisions. *American Association for Agricultural Education National Research Agenda*, *2020*, 19-27. https://www.researchgate.net/profile/Grady-Roberts/publication/371610015_American_Association_for_Agricultural_Education_National_Research_Agenda_2016-2020/links/648c4c6cb9ed6874a5b336d5/American-Association-for-Agricultural-Education-National-Research-Agenda-2016-2020.pdf

Long, T.B., Blok, V. & Coninx, I. (2016). Barriers to the adoption and diffusion of technological innovations for climate-smart agriculture in europe: evidence from the netherlands, france, switzerland, and italy. *Journal of Cleaner Production*, *112*(1), 9-21.

McCann, L., Gedikoglu, H., Broz, B., Lory, J. & Massey, R. (2015). Effects of observability and complexity on farmers' adoption of environmental practices. *Journal of Environmental Planning Management*, *58*, 1346–1362.

Megersa, G., & Abdulahi, J. (2015). Irrigation system in Israel: A review. *International Journal of Water Resources and Environmental Engineering*, *7*(3), 29-37. DOI: 10.5897/IJWREE2014.0556

Morris, C.J., Mills, J., & Crawford., I. M. (2000). Promoting farmer uptake of agri-environment schemes: The countryside stewardship arable options scheme. *Land Use Policy*, *17*, 241-254.

Munir, A, Muhammad, I., & Farooq. U. (2016). *Food security and its constraining factors in South Asia: challenges and opportunities*. PIDE Working Paper 10, Pakistan Institute of Developmental Economics. https:// www.researchgate.net/publication/30392211

Mwangi, J.K., & Crewett, W. (2019). The impact of irrigation on small-scale African indigenous vegetable growers' market access in peri-urban kenya. *Agricultural Water Management*, *9*(2), 295-305.

Nigussie, L., Lefore, N., Schmitter, P. & Nicol, A. (2017). *Gender and water technologies: Water lifting for irrigation and multiple purposes in ethiopia*. Nairobi, Kenya: ILRI

Postel, S., Polak, P., Gonzales, F., & Keller, J. (2001). Drip irrigation for small farmers. *Water International*, *26* (1),3-13.http://dx.doi.org/10.1080/02508060108686882Published

Rogers E. M. (1995). *Diffusion of Innovations*, 4th edn. Free Press: New York.

Rogers, E.M. (1962). *Diffusion of innovations*. New York: The Free Press

Rogers, E.M. (2010). *Diffusion of Innovations*; Simon and Schuster: New York, NY, USA.

Rogers, E. (2003). *Diffusion of Innovations*. Fifth edition. Free Press: New York.

Shrestha, R.B, & Gopalakrishnan, C. (1993) Adoption and diffusion of drip irrigation technology: an econometric analysis. *Economic Development & Cultural Change*, *41*(2),407-418.

Somers. N. (2000). *Learning about sustainable agriculture: the case of Dutch arable farmers*. N. Röling, M.A.E. Wagemakers (Eds.), Facilitating Sustainable Agriculture: Participatory Learning and Adaptive Management in Times of Environmental Uncertainty, Cambridge University Press, Cambridge, United Kingdom, 125-131.

Sidibé, A. (2005). Farm-level adoption of soil and water conservation techniques in northern Burkina Faso. *Water Management*, *71*, 211-224.

Schaible, G., Kim, C.S., & Whittlese, N. (1991). Water conservation potential from irrigation technology transitions in the Pacific-Northwest. *Journal Agricultural Economics*, *16* (2), 194-206.

Sandberg, B., & Aarikka-Stenroos, L. (2014). What makes it so difficult? a systematic review on barriers to radical innovation. *Industrial Marketing Management*, *43*, 1293-1305.

Senyolo, M.P., Long, T.B., Blok, V. & Omta, O. (2017). How the characteristics of innovations impact their adoption: an exploration of climate-smart agricultural innovations in South Africa. *Journal of Clean. Prod*.

Skaggs, R.K. (2001). Predicting drip irrigation use and adoption in a desert region. *Agricultural Water Management*, *51*(2), 125-142.

The World Bank data (2018). https://data.worldbank.org/indicator/AG.LND.ARBL.ZS

Thaler, R. (1985). Mental accounting and consumer choice. *Marketing Science 4*(3), 199-214.

Venot, J. (2016). A success of some sort: Social enterprises and drip irrigation in the developing world. *World Development, 79*, 69-81.

Ward, F.A. (2010). Financing irrigation water management and infrastructure: A review.*International Journal of Water Resource Development*, *26*(3), 321-349.

Warner,L.A.; Lamm, A.J. & Silvert, C. (2020). Diffusion of water-saving irrigation innovations in florida's urban residential landscapes. *Urban Green*, *47*, 126-540.

Weersink, A., & Fulton, M. (2020). Limits to profit maximization as a guide to behavior change. *Applied Economic Perspectives and Policy*, *42*(1), 67–79. https://doi.org/10.1002/aepp.13004

Yazdanpanah, M., Zobeidi, T., Sieber, S., Löhr, K. & Homayoon, S. B. (2022). Replacing rice with lower water consumption crops: green policy implications for Iran. *Climate Resource, 88,* 101-114.

Conclusion to Dissertation: Implications and Directions

According to Antwi-Agyei et al., (2021), farmers’ perceptions about climate patterns effectively influence their actions and decisions and determine the type of adaptation measures. The insurgence of climate-smart agriculture suggests a potential route for adapting to and mitigating climate change effects on cocoa production, potentially curbing deforestation-driven expansion of forest lands and environmental impacts of climate change while influencing farmer yield and livelihoods.

Climate change perception is a multifaceted process encompassing psychological factors like knowledge, beliefs, attitudes, and concerns regarding climate change (Whitmarsh & Capstick, 2008). Some researchers in Africa have measured farmers’ perception based on changes in weather related variables including rainfall changes, temperature, and precipitation. The study on cocoa farmers' climate change perceptions in Birim North, Ghana, highlights the vital importance of their awareness regarding climate change impacts on their farms and livelihoods. The study further highlights factors that affect farmers’ climate change perception and their willingness to adopt adaptation practices to climate change.

Climate-smart agriculture (CSA) is an approach introduced in 2010 by the Food and Agriculture Organization to enhance agricultural output and ensure food security while preserving the environment (Lipper et al., 2014). Practices and technologies related to CSA offer the potential for triple-win by concurrently advancing food security, income generation, climate change adaptation, and greenhouse gas mitigation (Campbell et al., 2014). Ajibade & Eche (2017) revealed that profitable and environmentally- friendly agricultural practices like climate-smart agriculture if integrated into farm production will improve smallholder production.

Asare (2014) also highlighted the benefits of climate-smart agriculture practices on cocoa production. The authors mentioned that adopting mulching using cleared weeds during land preparation would enhance soil organic carbon, and planting hybrid seedlings would improve yield and disease resistance. Further, the authors identified adhering to recommended fertilizer regimes to enhance cocoa growth and soil carbon stocks, and recommended pesticide application for control of black pods, fungal diseases, and pests affecting cocoa as CSA practices in cocoa production. The author elaborated that permitting natural regeneration and planting shade trees results in moderate carbon sequestration and the mitigation of greenhouse gas emissions. Bunn et al. (2019) added that diversifying cocoa production by intercropping with food crops like palm oil, peanuts, yam, etc. can reduce climate shock risk to household income. Therefore, examining farmers perceptions of climate-smart agriculture in cocoa production is key to addressing environmental impacts to climate change and the improvement of farmer livelihoods in rural Ghana.

Farmer Perception of Climate Change

The findings indicated that most farmers observed variations in rainfall, temperature, and the duration of wet and dry seasons. Farmers' perceived changes in climate corresponded with weather data from the study district. Farming experience and education demonstrated a notable correlation with farmers' climate change perceptions. Farmers strongly agreed to be interested in learning about farm-level adaptation practices to climate change. Farmers also strongly agreed to take risks by changing their current farming practices to adopt climate change adaptive practices.

Farmer Perception of Climate Smart Agriculture

Paper two builds on paper one. Paper two assesses cocoa farmers' perceptions of climate-smart agricultural practices as an adaptation and mitigation strategy to climate change.

The findings indicated that most farmers had heard the term climate smart, but the majority did not understand what it means. When it comes to local specific climate-smart practices, majority of the farmers cleared their lands without burning, planted hybrid seedlings, practice agroforestry and intercropping with food crops, use of integrated pest management, application of fertilizer, manure, and pruning. Many farmers indicated increase in yield as their main motivation factor to adopting CSA on their farm. All cocoa farmers have access to extension services in the communities because of the presence of Cocoa board's extension division. Most farmers reported an increased frequency of farm visits by extension agents in the past six months. Overall, farmers were satisfied with the support they receive but indicated a need for more training on climate smart agriculture practices. Many farmers have attended a training course on climate smart agriculture and those who have not attended a training indicated an interest in attending future training. The results further revealed that gender, education, and training significantly and positively influence the adoption of climate-smart agriculture practices among smallholder farmers.

Advisory Services on Drip Irrigation in Haiti-A Climate Smart Technology

The Paper 3 discusses an advisory paper focusing on the adoption of drip irrigation in Haiti, as a climate-smart technology. Paper three is intricately connected to paper one and two in its examination of how technology is adopted and disseminated within a given system. Paper three also utilizes the adoption and diffusion theory to elucidate the process by which drip irrigation can be embraced in Haiti over time.

Limits and Unique Contributions

The study encountered several limitations during data collection, such as limited time, difficulty reaching farmers during the rainy seasons, and challenging road conditions. To mitigate these challenges, collaboration with extension agents in the Birim North District facilitated advance contact with farmers and early morning farm visits. Additionally, daily monitoring of weather reports ensured awareness of prevailing weather conditions.

The study contributes to the importance of indigenous knowledge of farmers in training and policy decisions. The study highlights the importance of socioeconomic and institutional factors in the adoption and diffusion of climate-smart agricultural practices among smallholder farmers. The study also points out training opportunities should target both males and females and should be broadcasted by extension agents and farmer groups to create awareness and increase participation.

Theoretical Implications

Drawing on Rogers (2003) adoption and diffusion of innovation, the study anticipates farmers' perception and adoption of climate-smart agriculture practices. Rogers (2003) innovation-decision process comprises of five stages: knowledge, persuasion, decision, implementation, and confirmation. In the Knowledge stage, the farmer becomes aware of the innovation and gradually becomes interested in adopting it based on interactions like farm visits and training. Rogers (2003) emphasized that farmers will adopt technology or practices such as climate-smart agriculture when they know or are aware of such practices and their benefits.

The research contributes valuable insights to the existing literature on smallholder cocoa farmers’ knowledge on climate-smart agriculture practices in Ghana and encourage the scaling of CSA practices in Ghana. Promoting and scaling locally tailored climate-smart agriculture practices is essential for mitigating the adverse effects on cocoa farms, enhance farmer resilience to climate change and improve farmer livelihood. The research also draws on the Theory of Planned Behavior (TPB) (Ajzen, 1991) to anticipate how farmers make decisions about using technologies such as climate-smart agriculture. The study identifies socioeconomic factors such as gender, education, and training to have an influence on the adoption of climate-smart agriculture practices among smallholder farmers. Farmers in the study indicated a need for more CSA training and indicated their wiliness to participate in future CSA training and programs. The study implies that extension agents should incorporate training programs and demonstrations that are farmer centered and focus on the concept and benefits of adopting CSA practices to promote the adoption of CSA practices.

Empirical Implications (Future Research)

Future research is needed to continue to build knowledge on CSA adoption, including barriers to adopting CSA among smallholder cocoa farms, and b) identifying specific governmental and external support to promoting, sustaining, and scaling CSA among smallholder cocoa farmers. Research in this area offers vital insights into the sustainability of CSA practices amid climate change, and environmental degradation.

Practical and Policy Information

Climate smart agriculture promises a triple win approach to farmers by building resilience, increasing income and productivity while preserving the environment. With surge in prices of cocoa bean on the export market and shortage of cocoa beans from Ghana and other African countries due to climate change impacts, smuggling and intricacies of future markets, it is critical for Ghana Cocoa Board (COCOBOD) to look at ways to address impacts from climate change on cocoa. This study highlights the importance of training, yield as a motivation to adopt CSA and socioeconomic and institutional factors that impact CSA adoption in Ghana. The Ghana COCOBOD for years have supported smallholder farmers in various capacities. For example, supplying farm inputs such as hybrid seedlings, and fertilizers to aid cocoa farmer production. The Ghana COCOBOD have also worked with international organizations like the World bank, CARE, Cargill, and Rainforest Alliance to scale up CSA in cocoa production in Ghana. However more awareness about CSA and its benefit on cocoa and the environment should be promoted among smallholder farmers. Financial resources as well as technical support through training of extension agents and smallholder farmers on the benefits and impact of CSA to farmers, the environment and cocoa production in general.

The study also highlights the need for farmer groups and cooperatives as a way to build trust among farmers and promote the adoption of agricultural practices such as CSA. Farmer cooperatives should be encouraged among smallholder farmers which will serve as a medium where farmers can voice their concerns and learn from other farmers.

The large presence of extension agents in the study area highlights the importance of extension services in rural areas and among smallholder farmers. Extension service in Ghana should continue to create awareness of CSA among smallholder farmers to encourage adoption and scaling of CSA. Extension agents can harness farmers' interest in CSA through field demonstrations that demonstrate the positive impact CSA has on cocoa yields. Extension agents should incorporate training programs and resources that are farmer centered and demonstrate the benefits of adopting CSA practices. Extension agents should also engage farmers in the design of climate-smart agriculture training to help improve their capacity to understand the concept and the benefit to their cocoa production and the environment. Also, training opportunities should target both males and females and should be broadcasted by extension agents and farmer groups to create awareness and increase participation. Extension agents can promote and encourage weather information among smallholder farmers to help farmers take the right production decisions regarding their farms.

References

Ajibade, L. T., & Eche, J. O. (2017). Indigenous knowledge for climate change adaptation in Nigeria. In *Indigenous knowledge systems and climate change management in Africa.*

Ajzen, I. (1991). The theory of planned behavior. *Organizational Behavior and Human Decision Processes, 50*(2). https://doi.org/10.1016/0749-5978(91)90020-T

Antwi-Agyei, P., Dougill, A. J., and Abaidoo, R. C. (2021). Opportunities and barriers for using climate information for building resilient agricultural systems in Sudan savannah agro-ecological zone of north-eastern Ghana. *Clim. Serv*. 22:100226. doi: 10.1016/j.cliser.2021.100226

Asare, R.A. (2014). *Understanding and Defining Climate-Smart Cocoa: Extensions, Inputs, Yields and Farming Practices*; Natural Conservation Research Center-Forest Trends: Accra, Ghana.

Bunn, C., Läderach, P., Quaye, A., Muilerman, S., Noponen, M. R. A., & Lundy, M. (2019). Recommendation domains to scale out climate change adaptation in cocoa production in ghana. *Climate Services*, *16*. https://doi.org/10.1016/j.cliser.2019.100123

Campbell, B. M., Thornton, P., Zougmoré, R., van Asten, P., & Lipper, L. (2014). Sustainable intensification: What is its role in climate smart agriculture? In *Current Opinion in Environmental Sustainability*, 8. https://doi.org/10.1016/j.cosust.2014.07.002

Lipper, L., Thornton, P., Campbell, B. M., Baedeker, T., Braimoh, A., Bwalya, M., Caron, P., Cattaneo, A., Garrity, D., Henry, K., Hottle, R., Jackson, L., Jarvis, A., Kossam, F., Mann, W., McCarthy, N., Meybeck, A., Neufeldt, H., Remington, T., … Torquebiau, E. F. (2014). Climate-smart agriculture for food security. *Nature Climate Change*, *4*(12). https://doi.org/10.1038/nclimate2437

Rogers, E.M. (2003). *Diffusion of innovations*, (5th edition), The Free Press, London

Whitmarsh, L.; Capstick, S. (2018). Perceptions of Climate Change. In *Psychology and Climate Change: Human Perceptions, Impacts, and Responses*; Clayton, S., Manning, C., Eds.; Academic Press: Cambridge, MA, USA, 13-33.

Appendix A

Auburn University Human Research Protection Program

EXEMPTION REVIEW APPLICATION

For information or help completing this form, contact: **THE OFFICE OF RESEARCH COMPLIANCE**
Phone: 334-844-5966 **Email:**IRBAdmin@auburn.edu

Submit completed application and supporting material as one attachment to IRBsubmit@auburn.edu.

1. PROJECT IDENTIFICATION **Today'sDate** ______

a. Project Title Climate Smart Agriculture: The Perception of Smallholder Cocoa Farmers in Ghana

b. Principal Investigator Akua Adu-Gyamfi Degree(s) MS
Rank/Title Graduate student Department/School Curriculum and Teaching
Phone Number 334-444-9624 AU Email aza0043@auburn.edu

Faculty Principal Investigator (required if PI isa student) James Lindner
Title Professor Department/School Curriculum and Teaching
Phone Number 334-844-6768 AU Email jrl0039@auburn.edu

Dept Head Marilyn Strutchens Department/School Curriculum and Teaching
Phone Number 334-844-6838 AU Email strutme@auburn.edu

c. Project Personnel (other PI) – Identify all individuals who will be involved with the conduct of the research and include their role on the project. Role may include design, recruitment, consent process, data collection, data analysis, and reporting. Attach a table if needed for additional personnel.

Personnel Name Akua Adu-Gyamfi Degree (s) MS
Rank/Title Graduate student Department/School Curriculum and Teaching
Role study design, instrument development, data collection (recruitment,conducting interviews, consent participants) data analysis and data representation
AU affiliated? ☒ YES ☐ NO If no, name ofhome institution ______
Plan for IRB approval for non-AU affiliated personnel? ______

Personnel Name James Lindner Degree (s) PhD
Rank/Title Professor Department/School Curriculum and Teaching
Role advisor; will advise study design, instrument development and data analysis
AU affiliated? ☒ YES ☐ NO If no, name ofhome institution ______
Plan for IRB approval for non-AU affiliated personnel? ______

Personnel Name ______ Degree (s) ______
Rank/Title ______ Department/School ______
Role ______
AU affiliated? ☐ YES ☐ NO If no, name ofhome institution ______
Plan for IRB approval for non-AU affiliated personnel? ______

d. Training – Have all Key Personnel completed CITI human subjects training (including elective modules related to this research) within the last 3 years? YES ☑ NO ☐

The Auburn University Institutional Review Board has approved this Document for use from 10/06/2021 to --------- Protocol # 21-470 EX 2110

AU Exemption Form Version 07.14.2020 Version Date (date document created): 12/9/2021 page 1 of 8

e. Funding source – Is this project funded by the investigator(s)? ☑ YES ☐ NO
Is this project funded by AU? ☐ YES ☑ NO If YES, identify source ____________________
Is this project funded by an external sponsor? ☐ YES ■ No If YES, provide the name of the sponsor, type of sponsor (governmental, non-profit, corporate, other), and an identification number for theaward.
Name____________________Type____________________Grant # ____________________

f. List other AU IRB-approved research studies and/or IRB approvals from other institutions that are associated with this project.

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2. Mark the category or categories below that describe the proposedresearch:

☐ 1. Research conducted in established or commonly accepted educational settings, involving normal educational practices. The research is not likely to adversely impact students' opportunity to learn or assessment of educators providing instruction. 104(d)(1)

■ 2. Research only includes interactions involving educational tests, surveys, interviews, public observation if at least ONE of the following criteria. (The research includes data collection only; may include visual or auditory recording; may NOT include intervention and only includes interactions). **Mark the applicable sub-category below (i, ii, or iii).** 104(d)(2)

■ (i) Recorded information cannot readily identify the participant (directlyorindirectly/linked);
OR
- surveys and interviews: no children;
- educational tests or observation of public behavior: can only include childrenwhen investigators do not participate in activities beingobserved.

☐ (ii) Any disclosures of responses outside would not reasonably place participant at risk; **OR**

☐ (iii) Information is recorded with identifiers or code linked to identifiers and IRB conducts limited review; no children. **Requires limited review bythe IRB.***

☐ 3. Research involving Benign Behavioral Interventions (BBI)** through verbal, written responses (including data entry or audiovisual recording) from adult subjects who prospectively agree and ONE of the following criteria is met. (This research does not include children and does not include medical interventions. Research cannot have deception unless the participant prospectively agrees that they will be unaware of or misled regarding the nature and purpose of the research)
Mark the applicable sub-category below (A, B, or C). 104(d)(3)(i)

☐ **(A)** Recorded information cannot readily identify the subject (directly or indirectly/linked); **OR**

☐ **(B)** Any disclosure of responses outside of the research would not reasonably placesubject at risk; **OR**

☐ **(C)** Information is recorded with identifiers and cannot have deception unless participant prospectively agrees. **Requires limited review bythe IRB.***

☐ 4. Secondary research for which consent is not required: use of identifiable information or identifiable bio-specimen that have been or will be collected for some other 'primary' or 'initial' activity, if one ofthe following criteria is met. Allows retrospective and prospective secondary use. **Mark the applicable sub-category below (I, ii, iii, or iv).** 104(d)(4)

☐ (i) Biospecimens or information are publically available;

☐ (ii) Information recorded so subject cannot readily be identified, directlyorindirectly/linked; investigator does not contact subjects and will not re-identify thesubjects;OR

☐ (iii) Collection and analysis involving investigators use of identifiable health information when use is regulated by HIPAA "health care operations" or "research or "public health activities and purposes" (does not include biospecimens (only PHI and requires federal guidance on how to apply); OR

☐ (iv) Research information collected by or on behalf of federal government using government generated or collected information obtained for non-research activities.

☐ 5. Research and demonstration projects which are supported by a federal agency/department AND designed to study and which are designed to study, evaluate, or otherwise examine: (i) public benefit or service programs; (ii) procedures for obtaining benefits or services under those programs; (iii) possible changes in or alternatives to those programs or procedures; or (iv) possible changes in methods or levels of payment for benefits or services under those programs. (must be posted on a federal web site). 104(d)(5) (must be posted on a federal web site)

☐ 6. Taste and food quality evaluation and consumer acceptance studies, (i) if wholesome foods without additives are consumed or (ii) if a food is consumed that contains a food ingredient at or below the level and for a use found to be safe, or agricultural chemical or environmental contaminant at or below the level found to be safe, by the Food and Drug Administration or approved by the Environmental Protection Agency or the Food Safety and Inspection Service of the U.S. Department of Agriculture. The research does not involve prisoners as participants. 104(d)(6)

New exemption categories 7 and 8: Both categories 7 and 8 require Broad Consent. (Broad consent is a new type of informed consent provided under the Revised Common Rule pertaining to storage, maintenance, and secondary research with identifiable private information or identifiable biospecimens. Secondary research refers to research use of materials that are collected for either research studies distinct from the current secondary research proposal, or for materials that are collected for non-research purposes, such as materials that are left over from routine clinical diagnosis or treatments. Broad consent does not apply to research that collects information or biospecimens from individuals through direct interaction or intervention specifically for the purpose of the research.) **The Auburn University IRB has determined that as currently interpreted, Broad Consent is not feasible at Auburn and these 2 categories WILL NOT BE IMPLEMENTED at this time.**

***Limited IRB review* – the IRB Chairs or designated IRB reviewer reviews the protocol to ensure adequate provisions are in place to protect privacy and confidentiality.**

*****Category 3 – Benign Behavioral Interventions (BBI)* must be brief in duration, painless/harmless, not physically invasive, not likely to have a significant adverse lasting impact on participants, and it is unlikely participants will find the interventions offensive or embarrassing.**

3. PROJECT SUMMARY

a. Does the study target any special populations? (Mark applicable)

Minors (under 18 years of age)	☐ YES ☑ NO
Pregnant women, fetuses, or any products of conception	☐ YES ☑ NO
Prisoners or wards (unless incidental, not allowed for Exempt research)	☐ YES ☑ NO
Temporarily or permanently impaired	☐ YES ☑ NO

b. Does the research pose more than minimal risk to participants? ☐ YES ☑ NO

Minimal risk means that the probability and magnitude of harm or discomfort anticipated in the research are not greater in and of themselves than those ordinarily encountered in daily life or during the performance of routine physical or psychological examinations or test. 42 CFR 46.102(i)

c. Does the study involve any of the following?

Procedures subject to FDA regulations (drugs, devices, etc.)	☐ YES ☑ NO
Use of school records of identifiable students or information from instructors about specific students.	☐ YES ☑ NO
Protected health or medical information when there is a direct or Indirect link which could identify the participant.	☐ YES ☑ NO
Collection of sensitive aspects of the participant's own behavior, such as illegal conduct, drug use, sexual behavior or alcohol use.	☐ YES ☑ NO
Deception of participants	☐ YES ☑ NO

4. Briefly describe the proposed research, including purpose, participant population, recruitment process, consent process, research procedures and methodology.

The purpose of the evaluation is to assess cocoa farmers' perception of climate-smart agriculture practices in Ghana. The population of this evaluation are cocoa farmers from the eastern region of Ghana. Data will be collected using standard survey methods through orally administered questionnaires (in-person distribution of questionnaires). Ghana Cocoa Health and Extension Division will share a list of cocoa farmers (see attached letter). Participants will be randomly selected, and in-person interviews (on the farm site) conducted. The interview should take approximately 10 minutes.
Data collection will be conducted in an open area where each participant and the PI will be positioned 6 feet or more apart while wearing masks and gloves at all times according to Ghana policy on covid-19. On occasions where gloves are not used, PI will sanitize hands periodically.

5. Waivers

Check any waivers that apply and describe how the project meets the criteria for the waiver. Provide the rationale for the waiver request.

- ☐ **Waiver of Consent (Including existing de-identified data)**
- ☑ **Waiver of Documentation of Consent (Use of Information Letter)**
- ☐ **Waiver of Parental Permission**

All retrospective information will be de-identified.

No personal information will be collected that can identify participants. Those in the study will have no greater risk due to participating in the study.

6. **Describe how participants/data/specimens will be selected. If applicable, include gender, race, and ethnicity of the participant population.**

Farmers will be selected from a list of farmers provided by the Ghana Cocoa Health and Extension Division.The participants are male and female that are at least 18 years old. Participants' contact information will be secured through the Ghana Cocoa Health and Extension Division.

7. **Does the research involve deception? ☐ YES ☒ NO If YES, please provide the rationale for deception and describe the debriefing process.**

8. Describe why none of the research procedures would cause a participant either physical or psychological discomfort or be perceived as discomfort above and beyond what the person would experience in daily life.

The risks associated with participating in this study include possible exposure to COVID-19. Data collection will be conducted in an open area where each participant and the PI will be positioned 6 feet or more apart while wearing masks, and gloves at all times according to Ghana policy on covid-19 to minimize risk. PI will sanitize and wash hands periodically on occasions where gloves are not used.

9. Describe the provisions to maintain confidentiality of data, including collection, transmission, and storage.

Data will be collected via an orally administered instrument (in-person distribution of questionnaires and interviews). Agreement to participate in the interview will serve as consent. No identifiable information will be collected.

10. Describe the provisions included in the research to project the privacy interests of participants (e.g., others will not overhear conversations with potential participants, individuals will not be publicly identified or embarrassed).

Individual participants will not be identified. Data collected will not identify participants. There will be no audio or video collected.

11. Will the research involve interacting (communication or direct involvement) with participants?
☒ YES ☐ NO If YES, describe the consent process and information to be presented to subjects. This includes identifying that the activities involve research; that participation is voluntary; describing the procedures to be performed; and the PI name and contact information.

While the PI may not interact directly with the participants, however the research does in the form of the recruitment email, information letter, and survey.
The research will be conducted through a process of information letters, orally administered instrument, voluntary participation where participants consent through agreeing to be interviewed. The PI for this study is Akua Adu-Gyamfi: aza0043@auburn.edu.

12. Additional Information and/or attachments.

In the space below, provide any additional information you believe may help the IRB review of the proposed research. If attachments are included, list the attachments below. Attachments may include recruitment materials, consent documents, site permissions, IRB approvals from other institutions, etc.

The attachments include: CITI training certificates, information letter and sample questionnaires for interviews.

Principal Investigator's Signature__________ **Date** 12/9/2021

If PI is a student,
Faculty Principal Investigator's Signature__________ **Date** 12/9/2021

Department Head's Signature__________ **Date** 12/09/2021

Version Date (date document created): 12/9/2021

AUBURN UNIVERSITY

COLLEGE OF EDUCATION

CURRICULUM & TEACHING

(NOTE: DO NOT AGREE TO PARTICIPATE UNLESS AN IRB APPROVAL STAMP WITH CURRENT DATES HAS BEEN APPLIED TO THIS DOCUMENT.)

INFORMATION LETTER

for a Research Study entitled

Climate-smart Agriculture: Perception of smallholder cocoa farmers in Ghana

You are invited to participate in a research study on cocoa farmers' perception of climate- smart agriculture in Ghana. The study is being conducted by Akua Adu-Gyamfi under the direction of Professor James Lindner of the Auburn University Department of Curriculum and Teaching's Agriscience Education Program. Participants contacts information will be shared by the Ghana Cocoa Health and Extension Division. You are invited to participate because you are a Ghanaian cocoa farmer. You must be at least 18 years old to participate in this study.

What will be involved if you participate? Your participation is completely voluntary. If you decide to participate in this research study, you will be asked to complete a questionnaire via an orally administered questionnaire. Your total time commitment will be approximately ten minutes.

Are there any risks or discomforts? The risks associated with participating in this study include possible exposure to COVID-19. Data collection will be conducted in an open area where each participant and the PI will be positioned 6 feet or more apart while wearing masks and gloves at all times according to Ghana policy on covid-19 to minimize risk. PI will sanitize and wash hands periodically on occasions where gloves are not used.

Are there any benefits to yourself or others? There are no direct benefits to your participation in this study. Benefits to others may include a better understanding of climate-smart practices among smallholder farmers in Ghana.

Will you receive compensation for participating? You will not receive any compensation for your participation.

Are there any costs? Other than your time there are no costs associated with your participation.

If you change your mind about participating, you can withdraw at any time by choosing to discontinue the electronic questionnaire. Your decision about whether or not to participate or to stop participating will not jeopardize your future relations with Auburn University, the College of Education, the department of Curriculum and Teaching, and the Agriscience Education program.

Any data obtained in connection with this study will remain anonymous. We will protect your privacy and the data you provide by maintaining your anonymous responses and insuring there are no connections between your responses and you. At the conclusion of this study all data collected will be destroyed. Information collected through your participation may be used for presentations at academic conferences,

5040 HALEY CENTER

AUBURN, AL 36849-5212

TELEPHONE:

334-844-4434

FAX:

334-844-6789

WWW.AUBURN.EDU

If you have questions about this study, please contact Akua Adu-Gyamfi at aza0043@auburn.edu or Professor James Lindner at jrl0039@auburn.edu.

If you have questions about your rights as a research participant, you may contact the Auburn University Office of Research Compliance or the Institutional Review Board by phone (334)-844-5966 or e-mail at IRBadmin@auburn.edu.

HAVING READ THE INFORMATION PROVIDED, YOU MUST DECIDE IF YOU WANT TO PARTICIPATE IN THIS RESEARCH PROJECT. IF YOU DECIDE TO PARTICIPATE, THE DATA YOU PROVIDE WILL SERVE AS YOUR AGREEMENT TO DO SO. YOU CAN SAVE OR PRINT A COPY OF THE INFORMATION LETTER FOR YOUR RECORDS.

Akua Adu-Gyamfi December 9, 2021

Graduate Student

James Lindner, Ph.D. December 9, 2021

Professor

Consent form

Greetings,

My name is Akua Adu-Gyamfi, a current graduate student in the Agriscience Education program at Auburn University. We invite you to participate in our research study to assess cocoa farmers perception of climate-smart agriculture in Ghana. As a cocoa farmer, you are the primary source of information on this topic, and we value your opinions and perspectives.

Please review the information letter which is attached to this consent form.

Your participation is voluntary and anonymous. There will be no compensation for participating. Participation involves minimal risk, no more than encountered in everyday life. All responses will be aggregated.

The Ghana Cocoa Health and Extension Division will share your contact information. Data will be collected face to face by PI. Data collection will be conducted in a secluded area where each participant and the PI will be positioned 6 feet or more apart while wearing masks, and gloves at all times according to Ghana policy on covid-19. On occassions where gloves are not used, PI will santize hands periodically. Before data collection occurs, the participants will have a consent form and information letter.

If you have any questions, please contact my advisor or me using the information below.

Thank you, and we look forward to your response.

Akua Adu-Gyamfi
Graduate student
Auburn University
aza0043@auburn.edu

James Lindner
Professor ,Program Lead
Auburn University
jrl0039@auburn.edu

▢ I AGREE to participate (I have read the information letter and agree to participate)

▢ I DO NOT wish to participate

Information on COVID-19 For Research Participants (updated 05/27/2021)

Auburn University recognizes the essential role of research participants in the advancement of science and innovation for our university, community, state, nation, and beyond. Therefore, protection of those who volunteer to participate in Auburn University research is of utmost importance to our institution.

As you are likely aware, COVID-19 references the Coronavirus that is being spread around the world including in our country, state, and community. It is important that we provide you with basic information about COVID-19 and the risks associated with the virus so that you can determine if you wish to participate or continue your participation in human research.

How is COVID-19 spread? COVID-19 is a respiratory virus that is spread by respiratory droplets, mainly from person-to person. This can happen between people who are in close contact with one another. COVID-19 may also be spread by exposure to the virus in small droplets that can linger in the air. This kind of spread is referred to as airborne transmission. It is also possible that a person can get COVID-19 by touching a surface or object (such as a doorknob or counter surface) that has the virus on it, then touching their mouth, nose, or eyes.

Please visit the CDC's web page for more information on how COVID-19 spreads.

Can COVID-19 be prevented? Although there is no guarantee that infection from COVID-19 can be prevented, there are ways to minimize the risk of exposure to the virus. For instance, stay 6 feet apart from others who don't live with you; get a COVID-19 vaccine when it is available to you; avoid crowds and poorly ventilated indoor spaces; use effective barriers between persons; wear personal protective equipment like masks, gloves, etc.; wash hands with soap and water or use hand sanitizer after touching objects; disinfect objects touched by multiple individuals.

What are the risks of COVID-19? For most people, COVID-19 causes only mild or moderate symptoms, such as fever and cough. For some, especially older adults and people with existing health problems, it can cause more severe illness. While everyone is still learning about this virus, current information suggests that about 1-3% of people who are infected with COVID-19 might die as a result.

Who is most at risk? Individuals over age 65 and those with chronic conditions such as cancer, diabetes, heart or lung or liver disease, severe obesity, and conditions that cause a person to be immunocompromised have the highest rates of severe disease and serious complications from infection.

What precautions should be taken? Based on the proposed research, precautions for the risk of COVID-19 will be addressed on a project by project basis. You will be provided with information about precautions for the project in which you may participate. Any site where research activities will occur that are not a part of Auburn University (offsite location) are expected to have standard procedures for addressing the risk of COVID-19. It is important for participants to follow any precautions or procedures outlined by Auburn University and, when applicable, offsite locations. Further, participants will need to determine how best to address the risk of COVID-19 when traveling to and from research locations. The US Center for Disease Control and Prevention has issued recommendations on types of prevention measures you can use to reduce your risk of exposure and the spread of COVID-19.

Auburn University is continuing to monitor the latest information on COVID-19 to protect our students, employees, visitors, and community. Our research study teams will update participants as appropriate. *If you have specific questions or concerns about COVID-19 or your participation in research, please talk with your study team.* The name and contact information for the study team leader, along with contact information for the Auburn University Institutional Review Board for Protection of Human Research Participants, can be found in the consent document provided to you by the study team.

COCOA HEALTH & EXTENSION DIVISION

(SUBSIDIARY OF GHANA COCOA BOARD)

P. O. BOX 25
NEW ABIREM
EASTERN REGION

Ref. No. CHED/ER/NA/FARM/128

5th November, 2021
Auburn University Institutional Review Board
c/o Office of Research Compliance
115 Ramsay Hall
Auburn, AL 36849

Please note that Ms. Akua Adu-Gyamfi, AU Graduate Student, has the permission of the Cocoa Health and Extension Division to conduct research at the Birim North District in the Eastern Region of Ghana for her study, "Climate-smart Agriculture: Perception of Cocoa Farmers in Ghana".

Ms. Adu-Gyamfi has the permission to contact farmers with the assistance of our extension staff. Her plan is to conduct evaluations with our registered cocoa farmers. Our office will provide identified information and a list of cocoa farmers for her research. Ms. Adu-Gyamfi's onsite research activities will be finished by 30th July 2022.

Ms. Akua Adu-Gyamfi, has agreed to conduct an evaluation at an assigned space with farmers that agree in an orally administered instrument. She has also agreed to provide my office a copy of the Auburn University IRB-approved, stamped consent document before she recruits participants in the district, and she will also provide a copy of any aggregate results.

If there are any questions, please contact me on **agyemike4586@gmail.com** or **+233244467791**.

Regards.

DISTRICT COCOA OFFICER
COCOA HEALTH & EXT. DIV.
NEW ABIREM

MICHAEL OKOAMPA – AGYEMANG
DISTRICT COCOA OFFICER
NEW ABIREM

CITI PROGRAM

Completion Date 07-Jan-2019
Expiration Date 06-Jan-2024
Record ID 23890842

This is to certify that:

james lindner

Has completed the following CITI Program course:

Responsible Conduct of Research for Social and Behavioral	(Curriculum Group)
Social, Behavioral and Education Sciences RCR	(Course Learner Group)
1 - RCR	(Stage)

Under requirements set by:

Auburn University

CITI
Collaborative Institutional Training Initiative

Verify at www.citiprogram.org/verify/?w48234dc0-022c-4c7c-93c1-531e0357f2bf-23890842

Completion Date 10-Apr-2024
Expiration Date 10-Apr-2027
Record ID 52901515

This is to certify that:

Akua Adu-Gyamfi

Not valid for renewal of certification through CME.

Has completed the following CITI Program course:

IRB Additional Modules
(Curriculum Group)
Social, Behavioral and Education Sciences
(Course Learner Group)
1 - Basic Course
(Stage)

Under requirements set by:

Auburn University

CITI
Collaborative Institutional Training Initiative

101 NE 3rd Avenue, Suite 320
Fort Lauderdale, FL 33301 US
www.citiprogram.org

Generated on 10-Apr-2024. Verify at www.citiprogram.org/verify/?w627f0b91-ff6e-4bb2-b53b-e4151186f64a-52901515

CITI PROGRAM

Completion Date	14-Jun-2022
Expiration Date	13-Jun-2025
Record ID	49399845

This is to certify that:

Akua Adu-Gyamfi

Not valid for renewal of certification through CME.

Has completed the following CITI Program course:

IRB # 2 Social and Behavioral Emphasis - AU Personnel - Basic/Refresher
(Curriculum Group)
IRB # 2 Social and Behavioral Emphasis - AU Personnel
(Course Learner Group)
1 - Basic Course
(Stage)

Under requirements set by:

Auburn University

CITI
Collaborative Institutional Training Initiative

101 NE 3rd Avenue, Suite 320
Fort Lauderdale, FL 33301 US
www.citiprogram.org

Generated on 10-Apr-2024. Verify at www.citiprogram.org/verify/?w3b99f927-7d93-496d-aea6-fb7b518148df-49399845

Climate-smart Agriculture:

Name of field Officer

- ◯ Smith Kyei
- ◯ Eben Adebah
- ◯ Essien Emmanuel

Your participation and expertise is important and valued

My name is Akua Adu-Gyamfi and I am a Agriscience education doctoral candidate in the Department of Curriculum and Teaching at Auburn University. I am working under the supervision of James Lindner, Ph.D. I would like to invite you to participate in my research study to investigate the perception of climate-smart agriculture among smallholder cocoa farmers. You may participate if you are 18 years or older. You will be asked to complete a questionnaire requiring approximately twenty minutes of your time. To mitigate risk potential, your personal identifiable information will not be collected. No compensation will be provided , and no direct benefits exist. if you would like to know more about this study, an information letter will be provided for you.

Personal Data

Name of community

____

Enumerator Name

____

Respondent is head of household?

- ◯ Yes
- ◯ No

What is your relationship to the head of household?

- ◯ Spouse (husband/wife)
- ◯ Child
- ◯ Grandchild
- ◯ Sibling
- ◯ Visitor

How many people are in your household?

____

How many school age children are in your household?

____

Gender

- ◯ Male
- ◯ Female
- ◯ Prefer not to say

What is your average monthly income (Ghana cedi)?

- ◯ below 900
- ◯ 900-2000
- ◯ above 2000

What are the main sources of your household income?

check all that apply

- ☐ Cocoa farming
- ☐ Subsistence farming
- ☐ Petty trading
- ☐ Civil servant
- ☐ Teaching

What is your most important source of household income?

Select one

1st

- ◯ Cocoa farming
- ◯ Subsistence farming
- ◯ Petty trading
- ◯ civil servant
- ◯ Teaching

Knowledge on Climate change

Do you have access to weather information?

- ◯ Yes
- ◯ No

Sources of weather information

Check all that apply

- [ ] Media (Tv/ radio)
- [ ] Personal observation
- [ ] Extension agents
- [ ] Farmer coorporatives
- [ ] Family and Friends

Over the past 10 cropping seasons (2016-2022), how much did the following environmental parameters change?

Temperature

- ◯ Increased
- ◯ Stayed about the same
- ◯ Decreased

Rainfall

- ◯ Increased
- ◯ Stayed about the same
- ◯ Decreased

Length of wet season

Rain

- ◯ Increased
- ◯ Stayed about the same
- ◯ Decreased

Length of dry season

Harmattan

- ◯ Increased
- ◯ Stayed about the same
- ◯ Decreased

How worried are you about the change in weather patterns on your cocoa farm?

- ◯ Not at all worried
- ◯ Not very worried
- ◯ Somewhat worried
- ◯ Very worried

I am worried because of the following reasons

check one or more that apply

- [ ] Low yield from cocoa
- [ ] Low income from low yield
- [ ] Food crop loss due to drought
- [ ] High Mortality rates of cocoa trees
- [ ] High incidence of pest and diseases

Changes in weather patterns are caused by

check one or all that apply

- [ ] Slash and burn agriculture
- [ ] Deforestation through illegal logging and expansion of land
- [ ] Use of wood fuels
- [ ] Caused by a curse
- [ ] full-sun cocoa plantation

what are some of the adaptation strategies you do to protect your cocoa from the changes in weather impacts?

Please indicate your level of agreements with the following statements

---

I am interested in learning about farm level agricultural practices that will help me cope with the changing weather

- ○ strongly agree
- ○ Somewhat agree
- ○ Neither agree nor disagree
- ○ Somewhat disagree
- ○ Strongly disagree

I am willing to change my current practices to cope with the changes in weather

- ○ strongly agree
- ○ Somewhat agree
- ○ Neither agree nor disagree
- ○ Somewhat disagree
- ○ Strongly disagree

I am willing to try new agricultural technologies and management practices if other farmers are using it

- strongly agree
- Somewhat agree
- Neither agree nor disagree
- Somewhat disagree
- Strongly disagree

I intent to adopt climate management practices if the government grant subsidies

- strongly agree
- Somewhat agree
- Neither agree nor disagree
- Somewhat disagree
- Strongly disagree

knowledge on climate smart agriculture

Have you heard the term climate smart agriculture/ cocoa before?

- Yes
- No

Do you understand what the term climate-smart agriculture/ cocoa means?

- Yes
- No

What does it mean to you?

Have you adopted these good agricultural practices (CSA) on my farm?

Manual clearing without burning

- Yes
- No

High yielding hybrid seedlings or drought or disease/pest resistant seedlings

- Yes
- No

Compost tea/ Manure

- ◯ Yes
- ◯ No

Agroforestry with Timber trees

- ◯ Yes
- ◯ No

Intercropping with food and leguminous crops

- ◯ Yes
- ◯ No

Use of integrated pest management (recommended pesticide doses, target application, correct spraying practice

- ◯ Yes
- ◯ No

How often do you spray pesticides on your farm?

___

Use of inorganic fertilizers

- ◯ Yes
- ◯ No

Good post-harvest practices (eg.6-7 days fermentation, dry and aerated storage)

- ◯ Yes
- ◯ No

Pruning

- ◯ Yes
- ◯ No

How often do you prune your cocoa farm?

___

Do you understand the benefit of using any of the agricultural practices above on the climate?

- ◯ Yes
- ◯ No

Adopting the good practices above (CSA) will

check one and all that apply

- [ ] Increase farm income and yield
- [ ] Reduce pest and diseases on my farm
- [ ] Protect my farm from future impact to the changing weather
- [ ] Increase household security

Barriers to adopting climate smart agricultural practices

____

I have the financial capacity to adopt the good agricultural practices (csa) above

- ○ Strongly agree
- ○ Somewhat agree
- ○ Neither agree nor disagree
- ○ Somewhat disagree
- ○ Strongly disagree

I have access to credit facilities to adopt the agricultural practices (CSA) above

- ○ Strongly agree
- ○ Somewhat agree
- ○ Neither agree nor disagree
- ○ Somewhat disagree
- ○ Strongly disagree

I have the knowledge to adopt the agricultural practices (CSA) above

- ○ Strongly agree
- ○ Somewhat agree
- ○ Neither agree nor disagree
- ○ Somewhat disagree
- ○ Strongly disagree

I have the technical skills to adopt CSA

- ○ Strongly agree
- ○ Somewhat agree
- ○ Neither agree nor disagree
- ○ Somewhat disagree
- ○ Strongly disagree

The cost of farm inputs is high

- Strongly agree
- Somewhat agree
- Neither agree nor disagree
- Somewhat disagree
- Strongly disagree

I have access to extension support to adopt CSA

- Strongly agree
- Somewhat agree
- Neither agree nor disagree
- Somewhat disagree
- Strongly disagree

I have access to labor support to adopt CSA

- Strongly agree
- Somewhat agree
- Neither agree nor disagree
- Somewhat disagree
- Strongly disagree

I have access to climate information to inform decision to adopt CSA

- Strongly agree
- Somewhat agree
- Neither agree nor disagree
- Somewhat disagree
- Strongly disagree

I have access to ready market to adopt the agricultural practices (CSA) above

- Strongly agree
- Somewhat agree
- Neither agree nor disagree
- Somewhat disagree
- Strongly disagree

I have access to government support to adopt the agricultural practices (CSA) above

- Strongly agree
- Somewhat agree
- Neither agree nor disagree
- Somewhat disagree
- Strongly disagree

I have access to land to adopt CSA

- Strongly agree
- Somewhat agree
- Neither agree nor disagree
- Somewhat disagree
- Strongly disagree

Roles of extension advisory services to adopting CSA practices

---

Do you have access to extension advisory service support for your farm?

- Yes
- No

How many times in the last 6 months have you interacted with an extension agent?

- Never
- Once
- Two or Three times
- More often

Overall, rate your satisfaction with extension advisory services on your cocoa farming in your community

- Very satisfied
- Satisfied
- Neither
- Dissatisfied
- Very dissatisfied

What are your reason(s) to the above question?

Have you been to any training on good agricultural practices that help increase cocoa production while protecting the environment?

- ◯ Yes
- ◯ No

Training was offered by ?

check all that apply

- ◯ Extension agents/COCOBOD
- ◯ International NGO's
- ◯ Farmer cooperatives
- ◯ Local institutions

Would you like to attend any training on good agricultural practices that will help increase cocoa production while protecting the environments (CSA)?

- ◯ Definitely yes
- ◯ Probably yes
- ◯ Might or might not
- ◯ Probably not
- ◯ Definitely not

I need extension agents to

check all that apply

- ☐ Visit my farm often
- ☐ Provide more information on the risk of changing weather on my farm
- ☐ Provide more training on good agricultural practices that will help my farm production while protecting the environment
- ☐ Provide more farming incentives

Are you a member of any farmer cooperative?

- ◯ Yes
- ◯ No

Why did you decide to join a farmer cooperative?

____

Do you receive any support for inputs from COCOBOD?

- ◯ Yes
- ◯ No

What are some of the inputs you get?

____

Age

- ◯ 18-29
- ◯ 30-44
- ◯ 45-59
- ◯ over 60 years

Education

- ◯ Basic (6 years or less)
- ◯ Secondary (7 to 12 years)
- ◯ Tertiary (attended university or more
- ◯ No formal education

Marital Status

- ◯ Single
- ◯ Married
- ◯ Divorced
- ◯ Widowed

Farming experience

- ◯ 1-5 years
- ◯ 6-10 years
- ◯ 11-15 years
- ◯ Over 16 years

What is the size of your farm?

- ◯ less or equal to 1 acre
- ◯ Greater than 1 acre but less than 3 acres
- ◯ Greater than 3 acres but less than 5 acres
- ◯ Greater than 5 acres

What is the title status of the land you are currently farming on?

- ◯ Owner/outright purchase
- ◯ Joint Ownership
- ◯ Rent/lease
- ◯ Inheritance

Interview date

yyyy-mm-dd

hh:mm

Record your current location

latitude (x.y °)

longitude (x.y °)

altitude (m)

accuracy (m)

Point and shoot! Use the camera to take a photo

Click here to upload file. (< 5MB)

Thanks for your time and cooperation