UNIVERSITY FOR DEVELOPMENT STUDIES, TAMALE

IMPACT OF ADAPTATION TO CLIMATE VARIABILITY ON LAYER PRODUCTION AMONG POULTRY FARMERS IN THE NORTHERN REGION OF GHANA

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BY

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2025

DECLARATION

STUDENT'S DECLARATION

I hereby declare that this thesis, **"Impact of Adaptation to Climate Variability on Layer Production among Poultry Farmers in the Northern Region of Ghana,"** is the product of my original research and that no portion of it has been submitted for another degree in this University or elsewhere.

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SUPERVISORS' DECLARATION

We hereby declare that the thesis was prepared and presented under supervision in accordance with the guidelines on supervision of the thesis established by the University for Development Studies.

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ABSTRACT

Climate variability in developing countries hinders agricultural productivity, especially poultry layer production. Adopting climate adaptation measures could improve layer health and performance in poultry production. This study assesses the impact of climate adaptation strategies on layer production among poultry farmers in Ghana, filling a knowledge gap. The study made use of cross-sectional data from poultry farmers in the Northern region as well as secondary data from the National Aeronautic Space and Administration (NASA) power platform. Specifically, the study employed the copula switching regression model to determine how climate variability affects egg production and poultry farmers' net revenue; identified poultry farmers' adaptation strategies and their perceived effectiveness using descriptive statistics and Kendall's Concordance coefficient; analysed factors influencing the adoption of adaptation strategies using a multivariate probit model. Finally, the Marginal Treatment Effect (MTE) model was used to assess the impact of adopting poultry adaptation strategies on egg production while accounting for heterogeneity in treatment effects of farm and farmer observed and unobserved characteristics on their egg production. The Results show that the adoption of short-term related strategies (STRAS) and medium-term related strategies (MTRAS) increased egg output by 617%, and 307% respectively, whilst long-term related strategies (LTRAS) adoption alone decreased egg output by 30% folds when farms experience extreme temperature variability. This study calls for a proactive extension service system for information dissemination, educating and training poultry farmers on adaptation strategies to ensure widespread adoption for increased egg production in Northern Ghana.

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DEDICATION

The dissertation is dedicated to my parents Alhaj Umar Alhassan and Hajia Amama Abdulai, my dear wife Rahama Iddrisu, may Allah bless you all.

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LIST OF ACRONYMS

ACI- Artificial Cattle Insemination

DFID - Department for International Development

FAO- Food and Agriculture Organisation

FBO- Farmer-Based Organisations

GHG- Greenhouse Gas

GPP- Ghana Poultry Project

IPCC- Intergovernmental Panel on Climate Change

MoFA- Ministry of Food and Agriculture

NASA- National Aeronautics and Space Administration

NGOs- Non-Governmental Organaisations

PSM- Propensity Score Matching

SDGs- Sustainable Development Goals

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CHAPTER ONE

INTRODUCTION

1.1 Background

Poultry production is a significant source of income for many households in both developed and developing countries. It is believed that the consumption of meat and eggs from a well-organized poultry production system is safe, due to the standard practices maintained in dressing the birds ready for consumption (Saweda et al., 2018). Eggs are a good source of essential dietary proteins and minerals for healthy human growth and development, especially for the vulnerable in society such as children, expectant and nursing mothers, and the elderly.

Studies have shown that the world's egg and meat production is projected to increase by more than 650% by the year 2050, thereby tripling the consumption of poultry and poultry products (Nwobodo et al.2023). This explains the poultry subsector's importance in Ghana’s efforts to achieve the sustainable development goals (SDGs), particularly SDG 1 (End hunger) and SDG 2 (end poverty).

Adepoju and Osunbor (2018), stressed that climatic risks hurt layer production. These risks include drought, temperature swings, windstorms, increased pest infestations and diseases, decline in biodiversity, and shifting livelihood systems. Heat stress can lead to a drastic decline in egg production, quality, size, and bird health (Ranjan et al., 2019). This may even be very dangerous if not curtailed in the sense that, the high temperature reduces the rate at which layers convert feed into eggs and increases their vulnerability to climate variability. In times of high ambient temperatures, chickens and for that matter layers have higher energy (feed) requirements than when in normal environmental conditions. Major losses occur from a least effective conversion of feed to egg production, which detrimentally results in poor poultry health and egg productivity (Ezihe et al., 2020).

Until recently, inadequate literature existed on how livestock including poultry contributed to greenhouse gas emissions in the atmosphere. As indicated by Alade and Ademola (2013), agricultural production is accountable for about 14 percent of the world's Greenhouse Gas (GHG) emissions, and livestock and poultry production contribute significantly to overall GHG emissions, which greatly affects climate variability. Studies have also shown that layers have a higher rate of manure methane (CH_4) emissions relative to broilers (Abioja & Abiona, 2021). Due to the greater percentage of animal manure being treated in an anaerobic state results in increased CH_4 emissions levels.

Considering the impact of climate variability on the African continent, it is the most vulnerable compared to the rest of the continents despite it being the least emitter of greenhouse gases (Abioja and Abiona, 2021). In addition, Abioja and Adekunle, (2020) stated that in the year 2017, Africa was the third warmest since 1950 behind 2010 and 2016 which were the two warmest years. In comparison to the mean average from 1961 to 1990, the average mean temperature throughout Africa in 2017 was +1.20 degrees Celsius higher. The average temperature increased by 1.41 and 1.26 degrees Celsius between 2010 and 2016, respectively (Abioja and Adekunle, 2020).

The climate variability situation in Ghana continues to threaten the poultry subsector, especially layer production with direct and indirect impacts. Directly, laying hens experiencing a temperature of about 30°C persistently will respond by reducing feed intake leading to a decrease in egg production. Also, extreme temperatures ranging from 30°C to 38°C, lead hens to produce eggs with thin eggshells due to a reduction in oyster shells which contain calcium and bicarbonate for the chicken (Kulkarni, 2010). Indirectly, the poultry sector is impacted mostly by feed which is composed of grains or cereals used in production. Production of those items is affected by climate elements such as precipitation, temperature, and humidity among others. To add to this, Tiyumtaba (2016), asserts that climate variability affects livestock which includes poultry birds by exposing them to life-threatening factors such as prolonged periods of drought spells, floods leading to disease epidemics, insect and pest infestation and death due to heat stress.

Climate variability affects poultry feed utilization and mortality. The rearing of heat-and disease-tolerant breeds is gaining attention to sustain the poultry industry in Ghana (MoFA, 2020). To explain further, Gbedemah et al., (2018), stated that it is obvious that climate variability in the Ghanaian economy has intensified, with varying impacts being experienced everywhere across the country. This implies that efficient and location-specific adaptation strategies are key to providing conditions that promote healthy bird life and sustained egg production throughout the lifecycle of layers, especially commercial birds.

Various research has indicated that the climate is much hotter, with heat stress predicted to be far above normal temperature for successful habitation of living organisms, including poultry production. Cheng et al., (2022), suggested breeding techniques and breed selection type as an adaptation technique to lessen the impact of variation in the climate on layer production. This implied that genetic variation in heat stress response in livestock species makes some more resistant than others. Breeds that are smaller, naked neck, light-feathered, or light-coloured have proven to be heat resistant than thick-feathered and heavy-coloured breeds (Abiona and Abioja, 2021)

Mostly, poultry farmers have information regarding the deleterious effects of climate fluctuations on egg production. However, the knowledge gap, the scale of operation, effectiveness regarding the strategy's benefits, as well as the probability of a risk associated with a farmer's failure to adapt and his capacity to pay for it are some of the factors affecting farmers' options to subscribe to an adaptation strategy (Liverpool-tasie, 2019).

The impact of climate variability on the poultry industry, particularly, layer production should be considered a national security threat, and a threat to the survival of the poultry industry. Stakeholders and international organizations have made conscious efforts to advocate and promote climate change adaptation strategies as formidable policies to address extreme poverty, hunger, food insecurity, heat stress, and other impacts associated with climate variability (Fagariba et al., 2018). It is as a result of this reason that the current study seeks to address the impact of adaptation to climate variability on layer production among poultry farmers in the northern region of Ghana.

1.2 Problem Statement

As climate uncertainties become more pronounced, the livelihood of poultry farmers who depend on eggs as their primary income source becomes threatened. There is a need for adaptation measures to maintain production levels while improving birds' health. With poultry production accounting for 14% of Ghana's entire GDP, the industry is critical to the nation's economy (Boschloo, 2020). Chicken and eggs continue to be the most popular source of protein in Ghana and other West African nations. This can be attributed to the fact that they are cheap and easily accessible. Studies by Gbedemah et al. (2018), indicated that egg production projection in the year 2020 was shown to be around 122, 461 metric tonnes, indicating a significant increase over the 2018 estimation of 119,205 metric tonnes. The growth in the layer sector of the poultry industry in Ghana over the past decades can be argued that eggs are cheap relative to other livestock products, always available, and have received limited or no importation compared to broiler production.

In Ghana, there is more demand for poultry and poultry products than local producers can supply. Asante-Addo and Weible, (2020) reiterated that domestic poultry production has increased throughout the years in response to the expanding demand but has mostly fallen short of demand growth. As a result, Ghana currently is a leading importer and more importantly

Sub-Saharan Africa's third-largest importer of poultry products in the continent, with imports largely covering the shortfall. Zamani et al. (2022), added that in 2019 Ghana imported 261 million tons of poultry products, while domestic production rates fell from 54% in 2020 to 17% within the same year. The inability of poultry farmers to meet the total egg demand by consumers could be partly due to production challenges which are characterized by threats of climate variability.

According to a study by Adesiji et al. (2014), during dry and hot seasons, the prices of feed grains for poultry birds are usually higher than those of egg production. This is partially caused by the effects of climate variability, which also has an impact on the total number of birds that must be raised on the farm to produce eggs and the cost of production.

Nevertheless, the poultry sector is not left out of the harmful effects of climate variability. Fatoki, (2020) indicated that high temperatures put layers under a lot of stress, especially when combined with high humidity, which lowers performance. Temperature, relative humidity, light, and the amount of sunshine at a certain time are some of the environmental factors influencing the functionality, well-being, and productivity of layers. High temperatures and humidity hurt a bird's body temperature, which lowers the bird's live weight, increases mortality, reduces productivity, and produces eggs with poor quality.

According to the World Bank,(2021), there has been a consistent increase in Ghana's temperature of about 1°C, or 0.21°C on average every decade since the 1960s. Hot days (Tmax > 35°C) and hot nights (Tmin > 26°C) have both increased annually by over 13% and 20%, respectively, with September and November showing the most pronounced increases in both. In general, the north of the country has experienced faster growth rates than the south. This means that the poultry sector, especially layer production is therefore at risk due to climate variability in that the availability of grains as feed will be limited by inconsistent variations of weather impact, especially in the Northern region which is part of the arid and semi-arid regions of the country. Therefore, Ghana’s aim of achieving zero hunger and ensuring that all persons have access to safe, nutritious, and sufficient food all year round by 2030 in the Sustainable Development Goal 2 will not be achieved if the agricultural sector, and for that matter layer production continues to be threatened by climate variability impacts. To counteract the effects of climate variability on layer birds, adaptation measures must be adequately created and addressed comprehensively within the framework of comprehensive planning and policy for economic development (Trisos et al. 2022).

Although there are some studies on indigenous strategies farmers use to adapt to climate variability, much of the research is focused on crop production (Issahaku and Abdulai, 2019 and Belay et al., 2023). The research that has been conducted on how climate variability affects animals often concentrates on large animals like sheep, goats, and beef cattle (Tiyumtaba., 2016). Also, few studies have evaluated the adoption and impacts of adaptation strategies on egg production. Much of the research tends to concentrate on climate variability effects on egg production and adaptation strategies, rather than the effects of adopting the adaptation strategies (Nyoni et al., 2022; Soumya, 2022; Fatoki, 2020)

Despite layers' sensitivity to climate variability particularly, heat-stress, and high humidity, and the contribution of the poultry sector to livelihood in Ghana, there exist limited published studies on poultry farmers’ adaptation and adoption impacts to climate variability in Africa, and for that matter Ghana. Therefore, this study fills this research gap by assessing the impact of adaptation to climate variability on layer production among poultry farmers in the Northern region of Ghana. As a result, the following questions are the focus of this research.

1. What are the effects of climate variability on egg production?

2. What adaptation strategies are adopted by poultry farmers?

3. What factors influence the adoption of adaptation strategies among poultry farmers?

4. What are the effects of adopting climate variability adaptation strategies on egg production?

1.3 Objectives of the Study

The main objective of the research is to assess the impact of adaptation strategies to climate variability on layer production among poultry farmers in the Northern region of Ghana. The specific objectives are:

1. To estimate the effects of climate variability on egg production.

2. To identify climate adaptation strategies and their effectiveness among poultry farmers.

3. To examine the factors influencing the adoption of adaptation strategies among poultry farmers.

4. To estimate the effects of adopting climate variability adaptation strategies on egg production.

1.4 Significance of the Research

The findings from this study will meet the demands of key stakeholders, including researchers, NGOs, policymakers, and donors, as well as individuals within the poultry value chain:

Firstly, estimating the effects of climate variability on layer production in Northern Ghana could serve as a guide to decision-making on the effectiveness of the adaptation measures such as tree planting, chilled water, diet reformulation among others to cope with climate variations experienced in the region, especially among stakeholders like poultry farmers, agricultural extension officers and even the local hatcheries.

Also, findings from the study will identify adaptation strategies that are accessible for poultry farmers and fit their ecological and socioeconomic contexts, especially, ecosystem-based adaptation measures, such as tree planting to buffer the impacts of extreme climatic events.

This will contribute as a working document to industry players in adaptation strategy that is effective and efficient.

The study will also be a useful resource to guide future research on the impact of adaptation strategies to climate variability on the poultry industry sub-sector. This is because there exists limited literature on the adoption effect of poultry adaptation strategies on layer production.

1.5 Organization of the Research

The thesis is structured into five chapters. Chapter one deals with the introduction of the research topic, research questions and objectives, as well as the significance of the study. Chapter Two reviews related literature which includes definitions of concepts and terms, climate variability effects on egg production, poultry farmers' strategies used to adapt to climate variability, drivers of farmers' adoption decision of adaptation strategies to climate variability, and the effects of adopting adaptation strategies on egg production. Chapter Three talks about methodology which comprises of the study area, data collection methods, conceptual and theoretical frameworks as well as methods of data analysis. Key findings and discussions of the study are discussed in Chapter Four. Finally, Chapter Five presents a summary of major findings, conclusions, and recommendations.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

The relevant literature for this topic is presented in this chapter. It covers some terminologies and concepts, the vulnerability of the poultry industry to climate variability and its impacts on layer production, different types of adaptation strategies used by farmers to mitigate the effects of climate variability and the effects of adopting those strategies, theories of technology adoption, a review of factors influencing farmers' adoption of adaptation strategies.

2.2 Definition of Terminologies

2.2.1 Climate Variability: This includes conditions brought on by recurrent El Nino and La Nina occurrences, prolonged droughts, flooding, and changes in the average state of the climate on all temporal and spatial scales outside of specific weather events (Muller, 2007). Climate variability can be termed as the sustained changes that occur in the average weather parameters, including temperature, rainfall, humidity, and soil moisture, brought on by changes in the composition of atmospheric gases. Climate variability affects every country and economic activity. According to the IPCC Report (2022), climate variability affects nations' economic activities, including loss of lives and livelihoods. This suggests that climate variability is a global canker that impacts virtually everything regardless of the location.

That is, it is the variations in the average state of the climate elements over a short period. The causes of this fluctuation can either be internal (arising from the climate system's natural internal processes) or external (coming from changes in the external forces of nature or human activity).

2.2.2 Vulnerability to Climate Variability: The term 'vulnerability' has been used differently by various study disciplines to convey particular areas of interest to the targeted audience. IPCC, (2007), defines vulnerability as the inability and incapacity of a system to handle harmful effects of climate fluctuations, especially climate unpredictability and extremes. According to Alhassan (2016), vulnerability is the potential for harm to agricultural households and communities' inability to adjust appropriately and to adapt to climate shocks like prolonged drought, flood, and bushfires.

As a result, it follows that agricultural vulnerability to climate variability can be, for instance, described in terms of exposure to high temperatures, the sensitivity of livestock to high temperatures, and the ability of farmers to adapt to the effects of this exposure and sensitivity by, for example, keeping birds that are cross breed and are more heat-resistant to another type of birds. The IPCC (2007), identifies three main components of vulnerability: Exposure, sensitivity, and adaptive capacity which are mostly discussed within the realm of climate fluctuations. Sreymom et al., (2015), explains exposure as an organism's inability to adapt due to low capacity while at the same time being extremely sensitive to the negative repercussions of climate variability. Yu et al. (2021), assert that the degree to which the system is impacted by risk exposure is known as sensitivity. That is, a sensitive system is highly climate responsive and is susceptible to even slight climate changes. Climate adaptive capacity is the ability of an organism or system to reasonably accommodate and adjust appropriately to deal with the negative effects of climate shocks or stresses. (IPCC, 2007; Tsopmo et al., 2022; Fellmann, 2012). Tsopmo et al. (2022), argue that individuals, households, and organizations may experience relatively different adaptive capacities based on the information available to them, their ownership and access to resources, and their ability to make value judgments on issues related to climate issues.

2.4 Effects of Climate Variability on Egg Production

In recent times, the poultry sub-sector continues to be a significant contributor to the agricultural sector and the Ghanaian economy as a whole. Poultry products (meat and eggs) are the most widely accessible source of protein, especially for children, pregnant women, and the elderly in society. However, due to the negative effects of climate variabilities, especially on egg production, this importance is gradually being faded away. (Kumar et al., 2021), observed that the most notable sign of heat stress in layer birds is reduced feed intake, accompanied by increased panting and then a decrease in daily egg lay. Fatoki, (2020), also notes that high temperatures cause decreased productivity, high mortality, decreased live weight, and poor egg quality in chickens. Climate variability affects poultry productivity by lowering chicken output and feed quality, promoting disease and disease-spreading pests, reducing water accessibility, and making it difficult and exhausting for poultry birds to live (Aroyehun, 2022).

Soumya, (2022) opined that climate variability manifests as a result of an increase in temperature which causes a decrease in relative humidity and offers a favourable environment for the growth of bacteria and fungi. Disease epidemics become unavoidable; as a result, poultry illnesses including coccidiosis, fowl typhoid, hemorrhagic syndrome, chronic respiratory disease, fowl pox, and bronchitis will spread and become more common. According to Ayanlade et al., (2017), climate fluctuations in terms of changes in temperature and rainfall, especially long periods of dry spells, hikes in temperature, and feed unavailability have consequential effects on layer birds' performance in terms of disease resistance and laying output.

Henry, (2022) added that climate variability has a significant impact on how disease vectors are distributed, how they spread, and how they change over time. It can also have an impact on how poultry diseases first appear and how birds react to their environment. Individual birds' periods of laying either within or between the groups can also be greatly impacted by the variations in climate patterns (Andreasson et al., 2023 and Gikunju, 2019).

Studies like (Abioja and Abiona, 2021and Sirajuddin et al., 2017) have affirmed that the effects of climate variability on livestock can be both direct and indirect. For instance, reduced feed intake decreases the quantity and quality of eggs, and deaths are examples that are related to the direct effects of climate events on laying birds. Feed and water shortages and animals' attempts to adjust to their thermal environments are some examples of indirect effects. To add to this, farming operations provide ingredients for poultry feed such as maize, wheat offal, soya, and rice bran. So semi-arid areas with little rainfall and erratic patterns do not receive much harvests. This might increase the cost of poultry feed and intensify the struggle between animals and humans for feed resources.

2.5 Adaptation to Climate Variability Strategies

The IPCC, (2007) defines adaptation to climate variability as Changing human or natural systems in response to current or anticipated climatic stimuli or their effects to mitigate harm or take advantage of advantageous opportunities. This explains why adaptation is key to combating the effects of extreme climate events as well as providing an efficient way of reducing poverty and hunger and hence, achieving the Sustainable Development Goals (SDGs). This study focuses on how five adaptation strategies (housing, feeding, ventilation, breeding, and other strategies) affect poultry farmers' egg output and risk exposure. Below, these strategies are briefly discussed.

2.5.1 Housing-Related Adaptation Strategies

This is defined in this research to include low side walls, use of fenced wire, housing design/alignment, and ceiling of the pen house. To improve airflow in laying hens' pens, housed in wire cages in open sheds or sheds with wire sides seems appropriate for places experiencing the effects of climate variability. A study by Abadula et al., (2022) has shown that improved layer housing lowers bird mortality and ensures steady airflow in the pen. This reduces the risk of climate shocks expected to be experienced on the farm. In hot climates, the floor of layer houses should be built of a material that drains, is elevated, and is simple to clean, such as wood, bamboo, or bricks to allow for adequate airflow and easy cleaning (Saeed et al., 2019).

2.5.2 Feeding-related Strategies

This adaptation strategy is defined in terms of the use of feeding birds with chilled water, diet reformulation, provision of vitamins, and changing feed times. These days to increase energy levels, fat is now added to chicken diets, particularly layer feeds in hot climates like Ghana (Gbedemah et al., 2018). This is achieved by adjusting the protein, amino acid and fat levels in the birds' diets to ensure that they get the needed nutrients required, especially during panting. It has also been demonstrated that altering poultry feeding regimes, such as supplementing their diets with minerals and vitamins and feeding them in the morning and evening when the heat load is at its lowest, can lessen the harmful effects of temperature increase (Kennedy et al., 2022; Gbedemah et al., 2018). Also Goel, (2021) stressed that Ammonium and Potassium chloride supplements for poultry birds are very vital because they restore the acid-base balance that is upset when birds suffer heat stress. Anti-stress properties of vitamins A, C, and E can be added to the layer feed to lessen the deleterious effects of heat stress. Poultry's ability to tolerate heat is improved by restricting feeding before or during heat exposure. According to Bhadauria (2017), restricting the feed consumed by birds during the peak of heat stress and moving their feeding time from mid-day to the evening, ensures that poultry intake of essential nutrients is boosted.

2.5.3: Controlled Ventilation or Cooling Device-Related Strategies

This adaptation strategy incorporates modern-day devices such as energy-efficient bulbs and fans to minimize heat and keep the layer house temperature ideal for habitation and production. Liverpool-Tasie et al., (2019), relate that the employment of modern technologies such as fans, air conditioners, or desert coolers as air ventilators in layer pens apart from controlling the temperature in poultry farms, also aid in removing odours caused by animal excrement.

2.5.4: Breeding Related Strategies

This adaptation strategy captures keeping local birds, crossbreeds, and exotic (foreign) breeds only, keeping birds with light feathers and rearing other animals. Nyoni et al., (2022), reported that local or indigenous breeds may be a valuable genetic resource and may be more tolerant of intense heat stress than commercial varieties. Research works like (Mutugi, 2019 and FAO, 2013) have argued that local poultry birds are more adaptive and resistant to diseases and climate variabilities. However, the foreign breed of birds contributes more in terms of eggs than the local birds. Regardless of the breed's ability to tolerate heat, commercial layers need proper management and nutrition to reach their genetic potential for egg production. Kennedy et al., (2022), demonstrate that the selection of a thermo-tolerance breed makes this type of strategy a potent method to ameliorate the effects of heat stress in layer birds. However, breeds should have a variety of beneficial features when transferred to new geographic locations, as introductions of breeds that only take into account one trait have not proven effective (FAO, 2015).

2.6: Factors Influencing the Adoption of Poultry Farmers' Adaptation Strategies

The suggested mitigation plan to address the negative repercussions of climate variability on layer bird production has been adaptations. Most of the time, location-specific factors determine which adaptation strategies farmers use. Therefore different strategies may be observed in different poultry farms based on distinct influencing factors.

Liverpool-Tasie et al.,(2019), researched the significant variables influencing Nigerian poultry farmers' decisions about how to adopt and adapt to climate change and variability. According to their findings, farmers who had access to extension and also belonged to farmer-based organisations significantly affected their adoption decisions of climate adaptation strategies. The sex variable though significant, had a negative influence on poultry farmers' adoption options. However, perception of rainfall changes, farmers' educational level, and their access to climate information had no significant effect on the adoption of climate adaptation strategies that farmers used.

Belay et al. (2023) conducted a study in Wadla district, northeast Ethiopia and indicated that farming households resorted to drought and disease-resistant, intercropping, improved livestock breeding and rainwater harvest as adaptation strategies in the study area and that sex, education, access to extension training, credit access, and farm size are important factors influencing the household choice of adaptation strategies.

The adoption of mixed cropping, crop diversification, changing planting dates, engaging in non-farm activities, irrigation, and water and soil conservation strategies were the different adaptation measures utilized by farmers in Ghana, South Africa, and Ethiopia to adapt to climate variability and thereby reduce their vulnerability, according to empirical studies (e.g Issaaku et al., 2021; Myeni & Moeletsi, 2020; Belay et al., 2023). A study by Nyoni, (2022), in Limpopo, found no explicit association between layer birds' performance and climate events. However, Nigerian farmers who experience the negative effects of climate variability use a variety of wide and intensive methods to counter the effects of climate variability.

According to Ogundeji, (2022), farmers' age has a considerable negative effect on poultry farmers' ability to perceive climate variability and implement climate-related adaptation techniques, which makes them more susceptible to climate shocks. This could be the case because, as they get older and have more responsibilities to their families, farmers may learn from their failures and become less inclined to invest in new adaptation strategies.

2.7: The Effect of Adopting Adaptation Strategies on Egg Production

Farmers expect that they derive the desired benefits to mitigate against the impact of risk, once an adaptation strategy is chosen. However, research such as Abu-Nashiru, (2018) has shown that depending on the geophysical and the weather patterns experienced, the adaptation methods employed can vary greatly according to locations. For instance, some studies (Issahaku et al., 2021; Mpala and Simatele, 2023), revealed that Climate-smart agriculture or adaptation increases the adaptability of agricultural systems and livelihoods and lessens the risk of future food and nutrition insecurity.

Also, Liverpool-Tasie et al., (2019) and Gbedemah et al., (2018) indicated that low temperatures during the laying time helped chicken producers who used traditional strategies including lower stocking, the provision of cooled water, and frequent litter changes increase the number of eggs birds lay each day. However, the adoption of breed type for production can make birds more susceptible to heat stress, which in turn makes them more susceptible to mitochondrial dysfunction and oxidative stress (Akbarian et al., 2016; Kumar et al., 2021).

2.8: Review of Methods of Analysis

The following methods of analysis are reviewed in line with the objectives of this research. The qualitative response regression analysis and tests of agreements among rankers are the main analytical methods used and justified as follows:

2.8.1: Non-Parametric Test of Rankings by Respondents and Descriptive Statistics.

The ranking of items by rankers has been put to the test using a variety of techniques. These methods include Friedman's two-way variance, Kendall's concordance coefficient, and Garrett's rank-scoring approach.

The Garrett rank scoring system turns the ranks into percentage positions once respondents have ranked the items. Next, these percentage ranks are converted into scores using Garrett's table. The total of the scores from each ranker is summed to get an estimated average score, which is the overall score for each item that has been examined. Following that, the results are shown in either increasing or decreasing order (Hanumantha ., 2019).

Among the drawbacks of the Garrett rank scoring technique are its cumbersome procedure and its inability to determine the level of ranker agreement. Furthermore, it does not explicitly test any one hypothesis (Etwire et al., 2013).

Friedman's two-way variance analysis and Kendall's concordance coefficient are used to measure the degree of agreement between rankers' rankings of different items. Legendre (2005), states that the two techniques utilize the same chi-square statistic to test their hypothesis against the same set of data. They merely differ in how they phrase their respective null hypotheses. The rankers themselves are the focus of Kendall's test, whereas Friedman's null hypothesis test focuses on the items or factors being ranked. This study employs Kendall's coefficient of concordance to test the degree of agreement among poultry farmers because the rankers themselves are the focus of the study on a Likert scale of 5 (most effective to least effective) on the perceived effectiveness of the adaptation strategies employed by farmers to mitigate against climate variability in egg production.

2.8.2: Qualitative Response Regression Models

The dependent variable in qualitative response regression models is qualitative. It might be polychotomous or binary (dichotomous). A binary variable is one in which the dependent variable can have only two possible values, such as whether a farmer subscribes to an adaptation strategy or programme or not. But, where the dependent variable assumes more than two values, it is a polychotomous variable such as farmers' choice of adaptation strategies (Gujarati, 2003).

Many academics have employed qualitative models in their empirical studies, particularly about the adoption of adaptation techniques. To better understand the factors driving the adoption of adaptation strategies in the Upper West area of Ghana, Tiyumtaba (2016), researched the adoption levels of these strategies among livestock producers in response to the effects of climate change. Using the multinomial logit regression model, they concluded that education, Farmer Based Organisation (FBO), credit availability, and access to weather information were the important independent variables that significantly and positively influenced the adoption of adaptation techniques.

Using the multinomial regression method, Etwire et al, (2013) investigated how smallholder farmers in Northern Ghana adopted technologies for climate change adaptation. Their empirical findings showed that agroecology (being in a Sudan or Guinea savannah) is becoming aware of fluctuating temperatures and factors that have an impact on the choice of using soil and plant health methods favourably. Additionally, having agricultural extension services enhances the likelihood that improved varieties and breeds will be adopted; nevertheless, agroecology was found to decrease the likelihood that these varieties and breeds will be adopted.

However, the multinomial logit/probit cannot be used when the technologies or adaptation strategies being studied are not mutually exclusive, necessitating the need for the multivariate probit model which is a superior econometric model and also allows for complementarities and substitutabilities of the adaptation strategies, which is what this study seeks to employ.

Liverpool-Tasie et al., (2019) employed the multivariate probit analysis to examine the drivers of poultry farmers' adoption decisions to climate change in Nigeria. Their findings demonstrated that different adaptation methods to climate events were employed by farmers to mitigate climate variation effects based on the size of the farm. The stocking of local breeds is a common traditional strategy used by small farms, whereas controlled methods such as air and water ventilation and the use of lightbulbs that produce less heat are modern practices used by medium and big farms. According to their research, farmers who have suffered losses due to heat are more inclined to embrace modern methods and several adaptation strategies at once.

Additionally, Azumah (2019), estimated the drivers of the adoption of better agricultural technology in Northern Ghana using the zero-inflated Poisson and multivariate probit regression models. According to the study, farmers' likelihood to adopt new technologies like bundling, among other things, the construction of nurseries, irrigation, line planting, briquetting, spacing, and harrowing increased, if they had access to radio, television, and training as well as demonstration field days. Conversely, larger-farming farmers in the northern region who received knowledge through the household extension strategy were less likely to adopt new rice-growing techniques.

In assessing the impact or effect of adopting adaptation strategies, several strategies can be used to account for sample biases that are both observable and unobservable. These methods, for instance, include the Propensity Score Matching (PSM) for observable biases. However, in the case of unobserved biases, a correction measure and impact on treatment are needed.

Eshetu et al.(2023), examined the effects of adopting artificial cattle insemination technology by smallholder farmers on their well-being in Ethiopia, using artificial cow insemination technology (ACI). Cross-sectional data were gathered from household heads, including adopters and non-adopters of ACI, using three-stage sampling approaches. The effect of implementing ACI on household welfare was estimated using the propensity score matching technique. The results demonstrated the positive impact of ACI adoption strategies on household well-being. The results also showed that, in comparison to households who do not utilise the technology, those who used it saw an increase in yearly gains in milk, livestock, and overall consumption income of 62.742, 31.215, and 11,325.694 Birrs, respectively. The sensitivity analysis showed that the estimated impact was not susceptible to unobserved selection bias.

Also, Rahman et al., (2021) used the probit regression model and Propensity score matching (PSM) to determine the factors influencing the fishers' adaptation and evaluate the impact of the adaptation strategies on income and food security in Indonesia. The results showed that membership in the fishermen's club, as well as having access to finance and climatic data, had a substantial impact on adaptation tactics. Additionally, PSM demonstrated that the adaptation techniques had a favourable and significant effect on the income and food security of fishermen. The income of individuals who used the adaptation strategies was higher than those who did not. This result suggests that the adaptation measures used by the fishing sector may result in significant expansion and decrease vulnerability to climate change threats.

The current study uses the copula functions method to capture the differential influence of temperature and rainfall variability on egg production and net revenue, as well as to take into consideration the selection bias that arises from the employment of this method. While a large body of prior research concentrated on impact analysis with bivariate techniques, such as propensity score matching or the Endogenous Switching Regression (ESR), standard selectivity correction models often rely on the normality assumption, which is easily broken, especially when the data involved does not follow a normal distribution. In these circumstances, the copula function approach is more effective than most classical selectivity correction techniques based on the strong normality assumption. This is because the copula approach can be used to both relax the assumption of normality and fit the model using the maximum likelihood method to achieve efficiency for the estimator. Also, the dependence parameter of the copula is an additional feature that allows for direct comparison with other copulas.

Mohammed and Abdulai, (2022), examined the effects of farmers' adoption of new agricultural technology on farm outcomes using the copula function approach. Their findings demonstrated that farmers who participated in the new agricultural technology obtained higher farm outcomes in terms of yields and net revenue returns as compared to those who participated in traditional technologies.

Grotkowska et al., (2018) also estimated the public-private pay differential in a post-transition economy in Poland using the copula endogenous switching regression model. Their study's conclusions suggested that employees in the public and private sectors choose to work in the fields where their income is higher than it would be in a counterfactual scenario. The results showed employees who chose to work in the public sector received higher wages than they would have earned if they were to be employed in the private sector.

In evaluating the impact of adopting poultry adaptation strategies on egg production, treatment effects regression models such as endogenous switching regression (ESR) or propensity score matching (PSM) (e.g Cao et al., 2021 and Issahaku et al., 2021) can be used. Nevertheless, a large portion of earlier research on assessing the benefits of adopting agricultural technologies has assumed that these methods will result in uniform treatment effects. However, the advantages that agents (poultry farmers) derive from embracing new technologies vary (Heckman et al., 2018). Estimating the effects of adoption may become attenuated if this variation is not taken into consideration. Also, climate parameters like temperature, rainfall, and socioeconomic variables must not be assumed to be insignificant in impact analyses. In this study, treatment effect heterogeneity in both observed and unobserved characteristics is accounted for using the marginal treatment effect (MTE) technique. Furthermore, policy-relevant treatment effect, average treatment effect, treatment impact on the treated, and treatment effect on the untreated are among the economically significant treatment effect characteristics that may be estimated using this method.

Heckman et al., (2016) analyzed the consequences of Germany's universal childcare programme using the marginal treatment approach. According to their findings, kids from underprivileged families are less likely than those from wealthy families to attend nursery, but they also experience greater treatment effects because of the worse outcomes they experience when they are not enrolled in nursery. Abdul Mumin and Abdulai, (2020), also employed the ordered selection approach to jointly estimate the impact of households' preferences on market orientation as well as their consumption of food and nutrients, taking into account the risks of selection bias and issues with omitted variables. Their empirical findings demonstrate that households' consumption of food and nutrients increases dramatically when they move from one market orientation to another.

CHAPTER THREE

METHODOLOGY

3.1 Introduction

This chapter presents the methodology employed to achieve the study's results. The areas to discuss in this section include the poultry sub-sector, study area, sampling procedure, data collection approach, conceptual frameworks, and data analysis methods.

3.2 The Poultry Sub-Sector

Poultry can be classified to include birds (e.g., chicken, turkey, duck) that are reared either for their meat, eggs, or feathers. As a result of differences in climate, environmental, and or cultural aspects of society, poultry production varies significantly from one geographical location to another. The GPP Report, (2016) in Ghana classifies commercial poultry into three classes: birds less than 10,000 are grouped as small-scale, birds ranging from 10,000 – 50,000 are grouped as medium-scale enterprises, and 50,000 birds and above are described as large-scale producers. Per the report, 13 out of the total of 29 large-scale poultry farms were located in the Ashanti region, the Bono and Ahafo regions combined had 12 while the remaining 4 were located in the Greater Accra region of Ghana. Nti, (2018) asserts that the main sector of Ghana's chicken industry is layer production with, just 38.8% of chicken farms producing broilers compared to approximately 74.3% who produced eggs in 2015. The commercial production system is an intense production technique that includes, on average, more birds that are housed indoors under conditions of medium to high biosecurity. This system is heavily dependent on imported exotic breeds, which require extremely high standards for health, housing, nutrition, and management techniques.

The Northern Region has been a major production and market centre for local poultry over the past years (Bonsu and Rich, 2010). However, with Covid and recent macroeconomic instabilities, the recent few years have seen a downward growth in the region's poultry sector.

This may be attributed to production challenges such as high cost of feeding and poor import control. Boschloo, (2020) indicates that Nearly 30% of Ghana's total maize production is used by the poultry sector. The growing cost of maize is the main factor driving up feed prices in Ghana. The Government of Ghana's centrepiece initiative, "Planting for Food and Jobs," (introduced in 2017) which was supposed to lower maize prices, has had little to no impact (Ghana Risk Review, 2021). Although Ghana has a larger potential for the poultry subsector to expand and significantly contribute to the achievement of sustainable development goal 2, the domestic output is still low, making it challenging to meet local consumption demand. Research by Baagyere et al., (2023) revealed that about 400,000 metric tonnes of poultry products were demanded in 2021 which is far more than what domestic producers can supply. Asante-Addo and Weible, (2020) reiterate that the demand gap is filled through importation. As a result, Ghana is now a net importer and the third-largest importer of poultry products in Sub-Saharan Africa

3.3 The Study Area

This research was undertaken in five districts (Tamale Metro, Sagnarigu, Nanton, Kumbungu, and Savelugu) in the Northern Region of Ghana. Due to its proximity to the Sahara Desert and the Sahel, the Northern Region of Ghana is one of the driest regions in the country. With only one wet season, the climate is hot and dry. The main source of income is agriculture. The minimum and maximum temperatures experienced in the region during the day and night are around 18°C at night and 42°C during the day. The area experiences two seasons which span from November to April for the dry season and May to October for the rainy season (GSS, 2014).

The Region's entire land area is roughly 25,459 square kilometres. It is part of Ghana's savannah belt and is situated between latitudes 8° and 10° N. Internationally, it shares borders with Togo to the East. The region shares borders with the Savannah Region farther south and the North-East Region to the north. In the southeast, it also shares borders with the Oti region. 2,310,939 people are living in the region, of which 1,141,705 (49.4%) are men and 1,169,234 (50.6%) are women (GLSS 7). The shea, baobab, dawadawa, and neem trees, together with other sporadic drought-tolerant species, make up the majority of the vegetation in the savannah zones. Many home needs for firewood and charcoal are met by the diverse collection of trees.

Poverty is present to a considerable extent. The Ghana Living Standards Survey's seventh phase and the 2021 Population and Housing Census (PHC) both reported high rates of poverty in the country's northern regions. For instance, the average annual income reported in the region by the Ghana Statistical Service for 2021 is GH¢5,748 which is far below the national average of GH¢44,042 (GLSS 7). Thus, communities in the region, particularly those whose households depend on the production of rain-fed crops, which is also the region's primary source of income, tend to experience worsening poverty levels as a result of the harsh climate conditions brought on by climate variability. This calls for a more thorough approach, including the identification of location-specific adaptation strategies that are consistent with projected climatic trends as well as a practical planning process for poultry adaptation to help choose and incorporate suggestions into already-existing policies and programmes for the production of eggs as a way to supplement households' income sources from raising poultry.

3.4 Sampling Procedure and Data Collection Approach

3.4.1 Sample Size

Yamane's formula (1967) for sample size determination was used to determine the sample size for the research. A sample size of three hundred (300) poultry farmers was selected out of a population of one thousand, two hundred and four (obtained from the vet clinic, Tamale). This is computed with the Yamane's formulation (1967) below:

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

Where:

N denotes population size = 1204 poultry farmers (veterinary clinic, Tamale)

e denotes Margin of error = 0.05

n denotes sample size = 300

3.4.2 Sampling Procedure

The study employed a multi-stage sampling procedure to obtain the sample size. In the first stage, the Northern Region of Ghana was purposively selected for this study because it is one of the regions that are most severely impacted by the effects of climate variability since it is in a guinea savanna agro-ecological zone and is situated in a semi-arid climate region and their involvement in poultry production activities. Next, a key informant interview with the veterinary officer in charge of the veterinary clinic in Tamale provided the list of poultry farmers in the area to constitute the sampling frame for the study. The veterinary clinic is a government-based organisation that provides essential services to animal producers, especially cattle, sheep, poultry, and even dogs. Based on the list of total poultry farmers and production densities, five districts were purposely selected (Tamale Metro, Sagnarigu, Nanton, Savelugu, and Kumbungu) and clustered into urban and peri-urban based on the density of poultry farmers in each district using the cluster sampling. Grouping of the sampling into urban and peri-urban was necessary, to the extent that there exist differences in the housing, access to inputs such as feed millers, already formulated feed and other poultry inputs and facilities. Proportionate and random sampling were used to finally select the three hundred (300) poultry farmers from the five districts to ensure fair distribution of the sampled population. The survey also made use of a detailed questionnaire to solicit information on poultry farmers and household characteristics, such as age, education, access to credit, and extension services, as well as farm-level characteristics such as egg production in the number of crates per week, flock size, breed type of bird, housing and feed. We then visited each sampled poultry farmer at their farm location to explain the rationale behind the study, seek their consent, administer a questionnaire with them and take the location coordinates of the farm which was used to obtain the temperature and rainfall data at the farm level from the National Aeronautic Space and Administration (NASA) platform. Sagnarigu Municipal was seen to have more poultry farmers compared to other districts, especially Tamale Metro. This was in particular noticed from the key informant registry of poultry farmers obtained from the veterinary clinic and other poultry farmers association leadership.

The sample size according to districts and respondents is presented in Table 3.1 below:

Table 3.1: Sample Size Distribution by Respondents and Districts

District	Number of Respondents
Tamale Metro	66
Sagnarigu	142
Nanton	45
Savelugu	23
Kumbungu	24
Total Sample Size	300

3.4.3. Data Collection Approach

The study made use of a structured questionnaire to solicit primary data from 300 poultry farmers across communities in the five districts in the Northern region. Key informant interviews were also conducted especially, with the Tamale veterinary clinic in charge to ascertain the total number of poultry farmers in their register in the region. The information taken to register farmers included their names, farm location, district, flock size, source of day-old chick as well as their contact details. The chairman of the Poultry Farmers Association in the Northern region was also contacted to solicit information on poultry adaptations, their effectiveness and poultry challenges. The National Aeronautics and Space Administration (NASA) provided secondary data on temperature and rainfall distribution for each farmer's location to help determine their variabilities by districts, while the Veterinary clinic provided a farmer list for sample size determination.

3.5 Conceptual Framework

The conceptual framework is developed from the Department for International Development (DFID, 2000) Sustainable Livelihood Approach. The researcher developed a framework that links the various aspects of the work which included climate variability, climate adaptations, egg production, and net revenue. According to Filho, (2015), those who are unable to cope with climate variability are often vulnerable and unable to achieve sustainable livelihoods. This includes people who cannot adapt temporarily or permanently. In light of this, poultry layer producers implement strategies for adapting to climate variability to maintain or enhance the resilience of their livelihood outcomes, including increased layer health, annual income, and egg production.

Scoones (1998), added that the concept of adaptation to climatic variability originated from low advancement, inefficiency, or failure of international policy to guarantee a decrease of the greenhouse gas emissions that cause the change in the global climate. Therefore, rather than making an effort to prevent it (commonly referred to as mitigation), adaptation in this sense tries to directly address the effects of climate variability produced by an increase in greenhouse gas concentration in both proactive and reactive ways.

Changes in volcanic activity, solar output, the earth's orbit around the sun, ocean currents, atmospheric circulation, and other natural and human factors all contribute to climate variability (emission of greenhouse gases). Hence, it has recently been discovered that the layer bird droppings and other livestock waste are contributing to an increase in greenhouse gases, which is creating climate variability. The Northern Region experiences irregular rainfall, shifting temperatures, and varying humidity, which can result in climatic shocks like temperature hikes, floods, and droughts. Figure 3.1 presents the conceptual framework linking the various aspects of the study below:

CONCEPTUAL FRAMEWORK

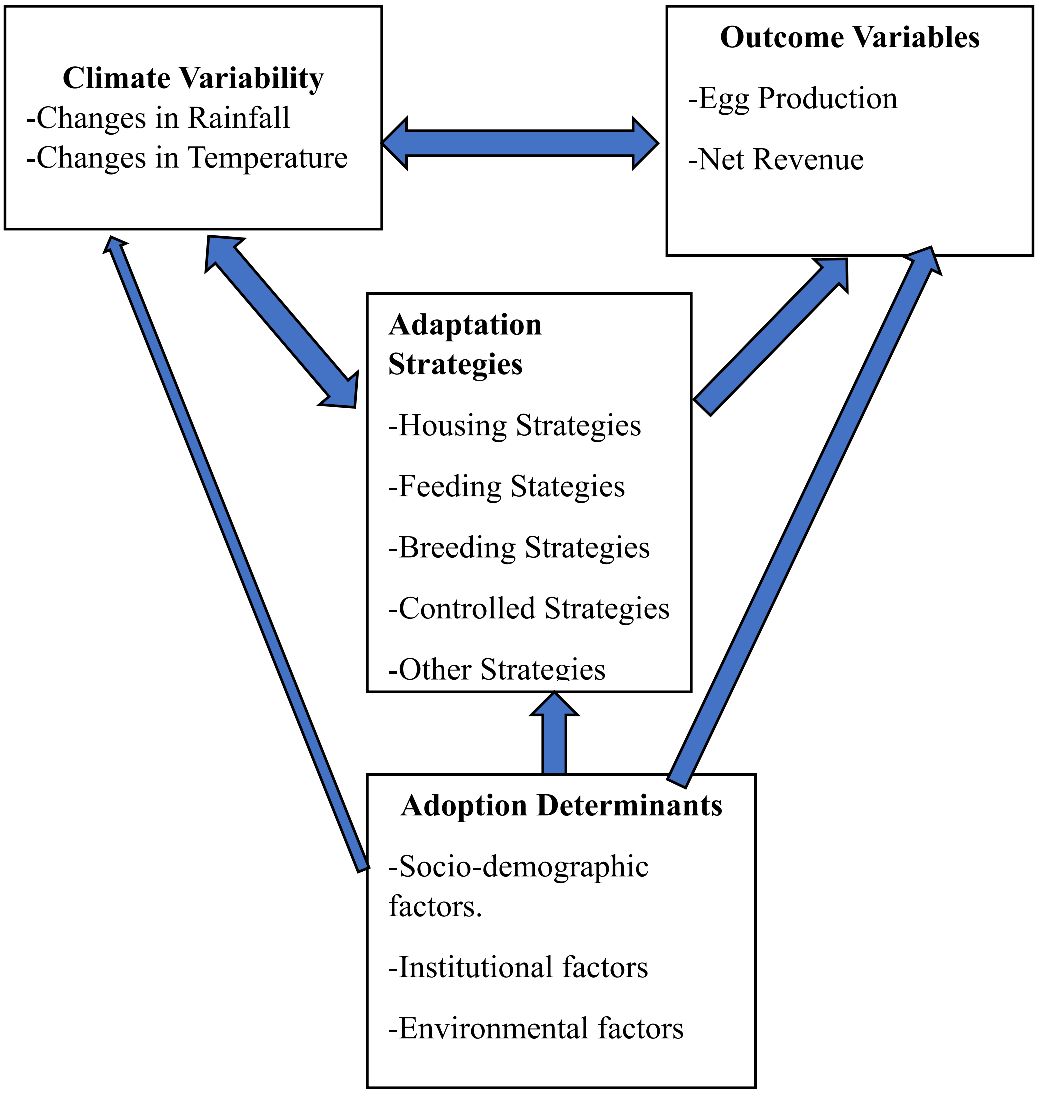


Figure 3.1: Conceptual Framework linking climate variability, Adaptation and Egg Production

(Source: Author's Construction, 2023)

The conceptual framework of the study is shown in Figure 3.1. The foundation of the framework is climate variability, which is a real problem that directly affects egg production at the local level. It demonstrates how layer producers' livelihoods and egg production are negatively impacted by climate variability. Climate variability in the form of erratic rainfall and fluctuation in temperatures affects the health, feeding and egg production of layers. Most poultry often contract diseases or die when there is excessive heat or when the weather is too cold. Besides, studies have shown that layer feeding reduces drastically during high temperatures, a situation which reduces egg production (Nyoni et al., 2022). Climate variability also affects the cost of poultry feed especially when there is a low yield of cereals, which is the main feed for poultry. As shown in Figure 3.1, the layer bird and other animals' waste or droppings can also lead to climate variability. This is argued that the methane gas contained in the layer droppings affects the ozone layer, which also turns out to increase the greenhouse gas in the atmosphere The first objective of the study examine the effects of climate variability on layers' egg production.

Based on the effects of climate variability on egg production, poultry farmers adopt climate variability adaptation strategies to maintain or boost egg output and enhance the health of the laying birds. To lessen the effects of climatic shocks, poultry farmers can often choose between or combine different adaptation strategies. These strategies include housing-related strategies, feeding, ventilation, breeding and other related adaptation strategies. The second objective of the study identify poultry farmers' adaptation strategies and their effectiveness as a measure of climate shocks in the poultry pen.

The framework also shows that farmers' decisions about adaptation techniques (housing, feeding, ventilation, breeding, and so on) are influenced by several powerful factors that drive adaptation options and implementation as well as the net benefits (egg output and net revenue). That is, socio-demographic characteristics of the farmer, institutional and environmental factors. A poultry farmer's level of adoption of the adaptation strategies is heavily influenced by these three sets of variables and the third objective of this study analysed the factors influencing farmers' adoption of climate variability adaptation strategies.

Climate adaptations to weather events are expected to provide layer birds with the conditions that increase their resilience to extreme climate events, like temperature hikes to enhance their health and performance. For example, adopting breeding strategies will ensure that poultry are resistant to climate-induced diseases. Also, feeding strategies will stimulate feeding and conversion rates for egg production while housing strategies will ensure that poultry birds are always kept in appropriate temperatures to avoid stress emanating from heat and/or cold weather. The fourth objective determines the effects of farmers' adoption of adaptation strategies on egg production and net revenue.

3.6 Methods of Data Analysis

3.6.1. Effects of Climate Variability on Egg Production.

This is analyzed using the copula function approach. It is impossible for climatic data, such as temperature and rainfall to follow a normal distribution using multiple years' worth of data, because some years may record extremely high or low values. This approach is justified by the fact that a large number of prior research studies that concentrated on impact analysis using bivariate approaches—such as propensity score matching (PSM) or Endogenous Switching Regression (ESR) tend to employ standard selectivity correction approaches that invoke the normality assumption, which in most cases is easily broken, especially when the data involves different distributions. In these situations, the copula endogenous switching regression approach is more effective than traditional selectivity correction techniques based on the strong normality assumption. This is because the copula endogenous switching approach can be used to both relax this assumption and also fit the model using the maximum likelihood method to achieve efficiency for the estimator. It also allows to switch between and within copulas (like the Joe, Frank, Clayton, Plackett etc.) to find a copula combination that offers the best model fit using the maximum likelihood to attain efficiency.

The Copula Model Specification and Identification Strategy

The conditional mean outcome for each farmer as specified by the researcher Y, (positive variability), due to their farm location is expressed as follows:

$$Y_i = a_0 + X_i\beta + K_C\gamma + \varepsilon_i \qquad (2)$$

where a_0 is a constant, β and γ are parameters of interest to be estimated, ε is the error term, and X is a vector containing the observed characteristics of farmers. K_C indicates how climate parameters (temperature and rainfall) affect the farmer's farm (positive variability in our case).

However, estimating equation (2) following the ordinary least squares (OLS) approach using observational data, some econometric problems will emanate; specifically, the climate variability options (negative or positive variability of temperature and rainfall) based on the farmer's location, K_C. For instance, due to differences in the locational temperature and rainfall distribution levels, farmers' egg output and net revenue levels may tend to differ. Farmers may self-select into locations they believe will have the most favourable climate variability as a result, leading to selectivity bias and estimates that are inconsistent (Heckman, 1979).

Strategy for Identification

The strategy accounted for possible selection bias and endogeneity in the farmers' choice of farm location decision is presented in this section. Two climate parameters are considered, which include average temperature and annual rainfall. The climate variability indicator, denoted by j, is used to determine an individual farmer's conditional egg output for a particular climatic condition. For example, Y_{tem} and Y_{rain} represent a farmer's conditional egg output and net revenue for choosing a farm location that is likely to experience positive temperature and rainfall variability, respectively. As a result, the preceding conditional outcome equation is re-specified using the selected climatic parameters as follows:

$$Y_{ij} = a_0 + X_i\beta + D_j\gamma + \varepsilon_{ij} \qquad (3)$$

where D_j is a binary variable indicator that equals 1 if the farm is located at a place that experiences negative climate variability (i.e., temperature or rainfall variability) and 0 otherwise, a_0 is a constant, β and ɣ are parameters of interest to be estimated, and ε_j is the error term. X is a vector of poultry farmers' characteristics that can be observed.

However, experiences with climatic variability parameters (temperature and rainfall) could be endogenous due to unobserved factors (innate abilities) that determine a farmer's experience of high climate variability may correlate with that of the conditional egg output which is based on the location of receiving positive climate variability. Intuitively, a farmer will locate his farm at a place given that the conditional egg output for experiencing positive climate variability at a given location is greater.

Consider D_j^* as a latent indicator of the net conditional egg output depending on the location of positive climate variability as reported by the researcher. D_j is a binary variable indicator that equals 0, indicating that the farmer will locate if $D_j \leq 0$, and 1 otherwise.

$$D_j = Z_i\delta + \varepsilon_j \qquad (4)$$

Z is a vector of observed characteristics that directly affects D_j but not Y_j (variables excluded from the model of Y_j, i.e. the instrument for identification, δ is a vector of parameters and ε_j is the error term. Consequently, there are two regimes of conditional outcomes that are associated with any climate variability parameter experienced, which can be observed and stated as follows:

Temperature Variability:

$$\text{Regime1: } Y_{tem1} = X_i\beta + \mu_1 \text{ ; if } D_j = 1 \left[D_j^* > 0\right] \qquad (5)$$

$$\text{Regime0: } Y_{tem0} = X_i\beta + \mu_0 \text{ ; if } D_j = 0 \left[D_j^* \leq 0\right] \qquad (6)$$

Rainfall Variability:

Regime1: $Y_{rain1} = X_i\beta + \mu_1$; if $D_j = 1 \left[D_j^* > 0\right]$ (7)

Regime0: $Y_{rain0} = X_i\beta + \mu_0$; if $D_j = 0 \left[D_j^* \leq 0\right]$ (8)

where Y_{tem1} and Y_{rain1} are the conditional egg output for locating farms in areas experiencing negative temperature variability and negative rainfall variability, respectively. The conditional egg output cases for experiencing positive temperature and rainfall variabilities are denoted as Y_{tem0} and Y_{rain0}, respectively. The error term is represented by μ, while the rest of the terms remain the same as described before.

Estimating the Average Treatment Effects of Experiencing Climate Variability

After accounting for observed and unobserved factors, various treatment effects parameters of climate variability on farm outcomes such as farmers' weekly egg output and net revenue from egg production are then estimated. By comparing farm expected net benefits (e.g., weekly egg output and net revenue) of farmers located in areas experiencing positive climate (i.e., temperature and rainfall) variability to that of farmers located in areas with negative climate variability, the counterfactual, the average treatment effects on the treated (ATT) can be computed. Specifically, the ATT in the copula switching model as computed in Hasebe (2013) is specified separately below:

ATT = $E(Y_{r1} - Y_{r0} | X, D_r = 1) = X'\beta_{r1} - X'\beta_{r0} + E(\mu_{r1} - \mu_{r0} | r > Z'\delta)$ = ATE +

$E(\mu_{r1} | r > Z'\delta) - E(\mu_{r0} | r > Z'\delta)$ (9)

The ATE, which is the average treatment effect, can be specified as below;

ATE = $(Y_{r1} - Y_{r0} | X'\beta_{r1}, X'\beta_{r0}) = (X'\beta_{r1} - X'\beta_{r0})$ (10)

3.6.2 Climate Variability Adaptation Strategies and their Effectiveness.

The effectiveness of the adaptation strategies was ranked by poultry producers using Kendall's Coefficient of Concordance (W), and descriptive statistics, such as frequencies and percentages, were employed in the analysis and presentation of the data in the form of tables. Farmers were given a 5-point Likert scale (most efficient, more efficient, efficient, least efficient and uncertain) to indicate how effective they thought the selected adaptation strategies were. This was done using Kendall's Coefficient of Concordance (W). The positive value of the coefficient of concordance (W) falls between zero (0) and one (1). A Kendall's concordance coefficient of one indicates the highest level of agreement among rankers, whereas a coefficient of zero indicates the highest level of disagreement. Following Alhassan, (2016) the Kendall (W) is specified as follows:

$$W = \frac{12[\sum_T 2-(\sum_T 2)/n]}{mn^2\ (n^2-1)} \qquad (11)$$

Where T = sum of ranks for factors being ranked; m = number of factors being ranked; n = number of respondents; and, W = Kendall's Coefficient of Concordance. The probability Chi-square statistic was used to assess the degree of agreement among the respondents on their rankings.

Hypothesis

H_0 : There is no agreement among farmers on the perceived effectiveness of the adaptation strategies used by poultry farmers.

H_1: There is agreement among farmers on the perceived effectiveness of the adaptation strategies used by poultry farmers.

3.6.3 Factors Influencing the Adoption of Adaptation Strategies Among Poultry Farmers.

The Multivariate probit (MVP) model was used to examine the factors influencing poultry farmers' adoption of adaptation strategies. The choice of MVP model for this analysis is because farmers can choose more than one strategy at a time, hence, the choice of adaptation strategies are not mutually exclusive. Literature was reviewed to identify specific adaptation strategies. These strategies were further categorised into feeding, housing, controlled/ ventilation, breeding and other strategies used by poultry farmers to adapt to the effect of climate variability on layer production. The multivariate probit model is such that, the adoption decision of farmers can be made jointly with other adaptation practices. When several technologies, such as poultry adaptation strategies, are estimated without considering the potential trade-offs and combined effect of the adoption choices, the resulting estimates of the factors influencing adoption decisions are skewed and inefficient (Greene, 2003). It also allows us to assess if specific adaptation techniques are complementary or substitutes

The multivariate probit model is derived under the assumption of the utility-maximizing behaviour of the decision maker. A farmer's utility is latent, thus an adaptation strategy that yields the highest utility to the farmer is the one that is chosen. As a result, if $U_i^a > U_i^b$ the observed variable indicator equals one (1); otherwise, it equals zero (0). Following Liverpool Tasie et al. (2019), the multivariate probit model is expressed as follows:

$y_m^* = X_m\beta_m + \varepsilon_m$, where $y_m = 1$ *if* $y^*m > 0$, 0 *otherwise*, $m = 1 \ldots\ldots, M$ (12)

$$E\left(e_{,m|\,x_1\ldots x_m}\right) = 0, \qquad Var\left(e_{,m|\,x_1\ldots x_m}\right) = 1 \tag{13}$$

The equations for farmers facing *m* adaptation choices (strategies) can be written as:

$y_{1=}^* \; X_1\beta_1 + \varepsilon_1 \quad y_1 = 1 \; if \; y_1^* > 0, 0 \; otherwise$

$$y_{2=}^{*} X_2\beta_2 + \varepsilon_2 \quad y_2 = 1 \; if \; y_2^{*} > 0, 0 \; otherwise \tag{14}$$

: : :

$$y_m^{*} = X_m\beta_m + \varepsilon_m \quad y_m = 1 \; if \; y_m^{*} > 0, 0 \; otherwise$$

All the unobservable elements that could affect the marginal probability of choosing a strategy *m* are accounted for by the random variable (εm). Each m is chosen from an M-variate normal distribution with a zero conditional mean and variance normalised to one, and the covariance matrix is provided.

3.6.4 Effects of Adopting Adaptation Strategies on Eggs Production.

The study adopts the framework employed by Cornelissen et al (2018) to examine treatment effect heterogeneity in both observed and unobserved farmer and farm characteristics using the marginal treatment effect (MTE) technique.

Model Set-Up

Following Cornelissen et al (2018), the study assume the adoption decision of the farmer to binary, C_i with associated potential outcomes for farmers *i* as Y_{1i} and Y_{0i}. Where C_i= 1 if the farmer adopts and C_i= 0 in non-adoption state. Therefore, modelling the potential outcomes gives the following equations stated below:

$$Y_{1i} = \beta_1(X_i) + U_1 \tag{15}$$

$$Y_{0i} = \beta_0(X_i) + U_0 \tag{16}$$

Equations (15) and (16) show the difference in treatment effect received by farmer i who adopts the adaptation strategies and farmer who does not with U_1 and U_0 been the error terms of the equations. The observed farmer characteristics and their associated conditional mean are represented by Xi and Y_i respectively.

$$Y_{1i} - \; Y_{0i} = (X_i) - (X_i) + \; U_1 - U_0 \tag{17}$$

Equation (17) highlights the fact that farmers with varying observed ($X's$) and unobserved (U_{1i}, U_0) traits can still profit from adoption, and this is a key finding of our study that highlights the heterogeneity in the effects of adopting an adaptation strategy.

We represent farmers' net benefit resulting from adopting or not adopting the adaptation strategies as Ci^*. Considering the latent of farmers adoption decisions and the fact that farmers are risk-averse, farmer *i* will adopt if the net benefit (Ci^*) is greater than or equal to zero. Since we cannot observe Ci^* because it is latent, we model it as a function of the observed and unobserved factors represented as *Z* and *V* respectively below in the following model.

$$C_1^* = \beta_c(Z_i) - V_i, \text{ But } C_i = 1 \text{ if } C_1^* \geq 0 \; and \; 0 \; otherwise \quad (18)$$

Z comprises the model identification tool (instrument) as well as the covariates Xi that are present in the outcomes of equations (15) and (16). To put it another way, *Z* has a variable that shows up in the selection equation (18) but is absent from the outcome or result equations.

The identifying instruments in this study are the shock threshold and the ratio of the farm to the extension. In selection equation (18), the error term V_i has a negative sign, implying that the unobserved characteristics reduce the likelihood of poultry farmers' adoption of the adaptation strategies. According to (Cornelissen, 2018), *Vi* is often commonly defined in the literature as Unobserved "resistance" or "distaste" to treatment.

This suggests that compared to poultry farmers with low values of V_i (high adoption rates), individuals with higher values of V_i (low adoption rates) are less likely to implement poultry adaptation strategies. By applying a cumulative density function to equation (18) it is transformed into $\mathrm{F}(\beta_c(Z_i)) \geq F(V_i)$. The likelihood that farmer i with an observed trait Z will choose to adopt an adaptation technique is the propensity score. This means that a farmer with a low "distate" to adoption (high propensity score to adoption) has an increased probability to adoption as compared to those with a high "distaste" or resistance to adoption (low propensity score to adopt) $(P(Z_i)) \geq F(V_i)$.

We describe mathematically the additive nature of the marginal treatment effect following the assumptions put forward by (Cornelissen, 2018) in the form of observed and unobserved components below:

$$\text{MTE } ((x, \mu_D) = \text{E}(\ Y_{1i} - \ Y_{0i} | X_i = x, U_{Di} = \ u_D = \qquad (19)$$

$$x(\beta_1 - \beta_0) + \text{E}(\varepsilon_{1i} - \ \varepsilon_{0i} | X_i = x, U_{Di} = \ u_D)$$

Observed part **unobserved part**

With this, $(\beta_1 - \beta_0)$ represent the treatment effect differences between those who have adopted and those who have not. This implies that the MTE's assumption can be found over the propensity score's unconditional support, which is produced by the instrument and the observed variables, X_i, as opposed to the propensity score's support conditional on X_i.

The first stage in which the instrument Z_i in Equation (18) produces variation in the probability of adoption, conditional on the observable features is necessary for the estimation of the treatment effects. This implies that given the observed controls, the instrument must therefore be independent of the error factor in Equation (18). The variables, ratio of distance from farm to extension and farm shock are used as instruments for adopting the adaptation strategies. The ratio of distance from farm to extension measures the distance in kilomtres of 6km from farm to extension access and farm shock threshold was measured as a dummy to indicate if a farm location had experienced a temperature range of 1.01-3+ beyond degrees Celsius (high) or +0.5-1 degree Celcius (low) temperature shock in the previous production schedule. The study is contend that the degree to which farmers' adoption decisions are affected by the distance to extension determines the ratio of distance from farm to extension. When the distance is near, farmers will be more likely to access extension with ease and the vice versa. This enhances their adoption decisions and access to climate variability information. These instruments, however, are not expected to affect our outcome variable, egg production directly.

Estimation Procedures

The study used the selection correction model which involve the application of local instrumental Variable approach to estimate the marginal treatment effects (Cornelissen et al., 2018). Equation (15) and equation (16) produce the following result, which is dependent on the propensity score P(Z) and the observed covariates X:

$$\mathrm{E(Y|X, P)} = X_i\beta_0 + X_i(\beta_1 - \beta_0)P + K(P) \quad (20)$$

where $K(P)$ is a nonlinear function of the propensity scores (P). Thus, the MTE equals the derivative of Equation (20) with respect to the propensity scores

$$\mathrm{MTE}(X_i = x, U_{Di} = P) = \frac{\partial E(Y|X,P)}{\partial P} = X_i(\beta_1 - \beta_0) + \frac{\partial K(P)}{\partial P} \quad (21)$$

The study applies the exclusion restriction-based methodology by first estimating a first-stage probit of Equation (5) and then modelling K(P) as a degree-k polynomial in P. Thus, we use the following outcome equation to quantify the influence of adoption in the second stage.

$$Y_i = X_i\beta_0 + X_i(\beta_1 - \beta_0)P + \sum_{k=1}^{k} a_k P^k + \varepsilon_i \quad (22)$$

The marginal treatment effect is obtained after taking the derivative of equation (21) with respect to P. we then use the second-order polynomial (K=2) in the scores of the propensities to estimate the baseline model.

3.7 Definition of variables

Table 3.2: variable definitions, measurement and apriori expectations for the study

Variable	Description	Measurement	Expected Sign
Eggs output	log of the number of eggs	Crates per week	+
Net revenue	log of Egg gross revenue less variable cost	GHS	+
Sex	gender of farmer	dummy: 1=Male, 0=Female	+
Age	Age of farmer in years	Years	+
Hhh	Household head of respondents	dummy: 1=Male, 0=Female	+
Education	Years of education	Years	+
Labour force	Household members working on Extensions	Man-day hours	+/-
Years in poultry production	poultry experience of the farmer	Years	+
Extension services	Farmers' access to Extension	Number	+/-
Org channels	Extension services medium	Number of contacts	+
Poultry association	Member of a poultry-based organization or group	Dummy: 1=Yes, 0= No	+
Farm location	The geographical location of the farm	Dummy: 1 = urban, 0= peri-urban	+/-
Climate info pr	Access to climate information	Dummy: 1=Yes, 0= No	+
Rainfall pattern	Farmers' perception of rainfall	Dummy:1=decrease,0=otherwise	+/-
Temperature	Farmers' perception of temperature	Dummy:1=increase,0=otherwise	+/-
Flock size	Total number of layer birds a farmer has	Number of birds	+
Chick cost	Total cost of layer birds	Ghana cedis (GHS)	+
Spent layer	Total revenue received for the sale of spent layers	Ghana cedis (GHS)	+/-
Credit constraint	Farmer access to credit	1 if farmer is credit constrained, 0 otherwise	+
Farm Shock	Farm experience to climate shock	1 if farm experience any shock such as mortality, low egg production due to weather in the past production cycle, 0 otherwise	+

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1 Introduction

This chapter presents empirical findings from the study. It provides in-depth analyses of the respondents' socioeconomic characteristics, the effects of climate variability on egg production, and the variables that affect poultry farmers' adoption of adaptation strategies. The final section covers the effects of adopting climate variability adaptation techniques on egg production.

4.2 Socio-Economic Characteristics of the Respondents

The respondents' socioeconomic characteristics included in this part comprise sex, age distribution, years of experience in raising poultry, educational attainment, and marital status. Other variables include respondents' flock size, household size, main occupation, extension visits, and involvement in farmer-based organizations. The interviewed respondents ranged in age from 19 to 58 years (see Table 4.1), with the average age of a farmer being 41.44. Most of the sampled respondents (99%) have formal education. The levels of formal education range from the basic to the tertiary level. For instance, one hundred and ninety-three (193) respondents, 64.3%, had tertiary education. The high level of educated individuals working in the poultry industry may have been explained by the technical aspects of the industry, such as feed formulation, medication, assessing the health of poultry birds, and determining the quality of the eggs produced. The average flock size (number of birds) of sampled farmers is 832.44. This implies most farmers’ flock sizes in the study area were far below 5,000 and fell into the very small-scale category according to the Ghana Poultry Project (GPP, 2016) classification of commercial poultry producers.

At least every poultry farmer has a year of experience in poultry farming with an average farming experience of 6.63 years for the sampled farmers. Experience matters in poultry farming because farmers can respond to climatic changes like temperature increases and biosecurity concerns by understanding and using the right management practices. Almost all the farmers in the five districts are married (90%) and engage in salary work as their primary occupation (66.33%). This is expected since most of the respondents were household heads with ages ranging from 19-58, it was pervasive to find most of them being married. The mean average temperature and annual rainfall experienced by respondents in the region is 27.04℃ and 1004.32mm respectively. The poor outcomes in terms of egg output in the study area can be one of the many factors attributed to rising temperatures and dwindling rainfall intensity. For instance, the average temperature is far above the operational mean temperature of 22℃ favoured for egg production. The average distance of a farm from home is about 2.34km. This is normal because most of the farms were located in the homes or near the home. However, the distance from the farm to the agricultural extension (veterinary clinic) office seems very far with a mean distance in kilometres averaging about 10.65km. This is informative because only 28.67% of the respondents had access to extension services. Also, the mean weekly egg output and farm net returns from egg sales in the study area are about 94.37 crates and GHS 3892.77, respectively.

Table 4.1: Descriptive Statistics of Continuous Variables

Variable	**Mean**	**Std. Dev**	**Minimum**	**Maximum**
Egg output (crates)	94.37	106.08	17	606
Farm net returns (GHS)	3892.77	10433.87	-5920	69960
Age (years)	41.44	6.87	19	58
Education (years)	15.68	2.26	8	23
Experience (years)	6.63	4.08	2	36

Flock Size (no. of birds)	832.44	882.99	170	5000
Annual rainfall (mm)	1004.32	174.25	580.08	1328.56
Average temperature (degree Celsius)	27.04	0.943	25.46	29.28
Average feed per bird (kg)	37.53	14.85	11.67	73.33
Average feed cost (GHS)	5773.82	2277.39	3100	13000
Farm distance from homestead (km)	2.34	3.63	0	15
Distance to Agric. Extension office (km)	10.65	4.85	3	22

Source: Field Survey, 2023

Some of the categorical variables or factors considered by this study include extension access, access to formal credit (credit constraint), farm location (urban or peri-urban) and membership in a farmer group.

Table 4.2: Some Descriptive Statistics of Categorical Variables

Categorical variables

Variable	No. of respondents	Percentage (%)
Gender		
Male	251	83.67
Female	49	16.33
Marital Status		
Never married/single	31	10.33
Married	269	89.67
FBO Membership		
Yes	184	61.33
No	116	38.67
Credit constraint		

Yes	201	67
No	99	33
Noticed change in the climate pattern for the past 10 years		
Yes	257	85.67
No	43	14.33
Major Occupation		
Poultry farming	68	22.67
Salary work	200	66.67
Business	18	6
Others	14	4.67
Extension Access		
Yes	86	28.67
No	214	71.33
Urban		
Yes	208	69.33
No	92	30.67

Source: Author's computation from field survey, 2023.

About 29 percent of sampled farmers have access to formal extension services (veterinary services) with the remaining 71 percent either using a farmer-to-farmer extension or private extension agents. The formal agricultural extension services and private extension agents mostly provide services on vaccination like fowlpox, Newcastle and sometimes debeaking for a fee. In line with Mohammed and Abdulai (2022), receiving extension visits helps build the capacity of farmers in their productive activities. Also, about 61.33 percent of sampled respondents belonged to at least a farmer-based organization where they share farming experiences and receive education on best management biosecurity practices from experts with in-depth knowledge of poultry activities to enable them to receive the full benefits of technologies.

Also, 67 percent of poultry farmers interviewed indicated being credit constraint. This they explained had untold effects on input purchases such as feed and routine vaccination, especially when the birds have not reached the laying point. In terms of farm location, there were more poultry farms located in the urban areas (Tamale Metro and Sagnarigu), 69.33% compared to areas classified as rural and peri-urban (Savelugu, Nanton and Kumbungu), which constitute about 30.67%

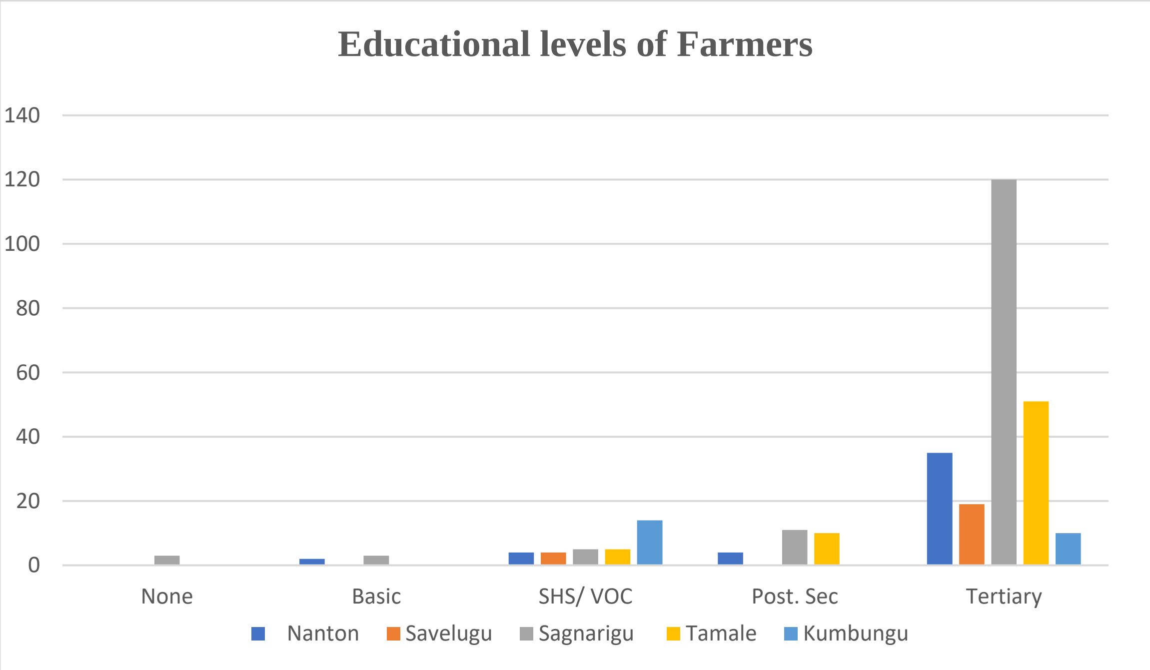


Figure 4.1: Educational Levels of Farmers

Source: Author's computation from field survey, 2023

4.2.1 Environmental Factors

The two main environmental factors considered in this study are qualitative measurements of respondents' perceptions of changing rainfall and temperature patterns over the past ten years. Throughout the time under review, all interviewees acknowledged some environmental change, but their perceptions of such changes varied. Unpredicted rainfall patterns and decreased intensity, reported by 47% of farmers, were identified as a significant challenge for crop production, which indirectly affected layer birds' growth and production vis-à-vis the cost of production. Farmers (73.33%) recognized that rising temperatures will probably hinder layer output in the future, as they could affect both the quality and number of eggs laid, which would ultimately affect commercial poultry producers. This conforms with the findings of some past studies (Fatoki, 2020; Nyoni et al., 2022 and Saweda et al., 2018).

To know the effects of rainfall and temperature variability on egg output, farmers were asked how the variability in the climatic conditions affects their birds' performance. There was a unanimous agreement among farmers that the common problems birds face included decreased feed intake, heat stroke, delay point of lay and mortality.

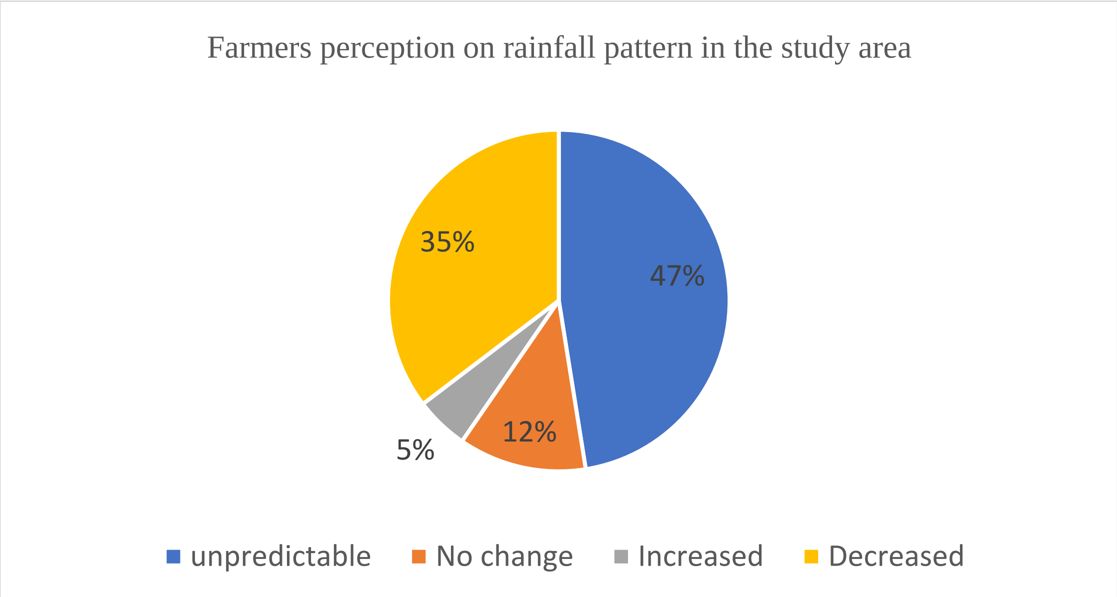


Figure 4.2: Farmers perception on rainfall pattern in the study area

Source: Author's computation from field survey, 2023

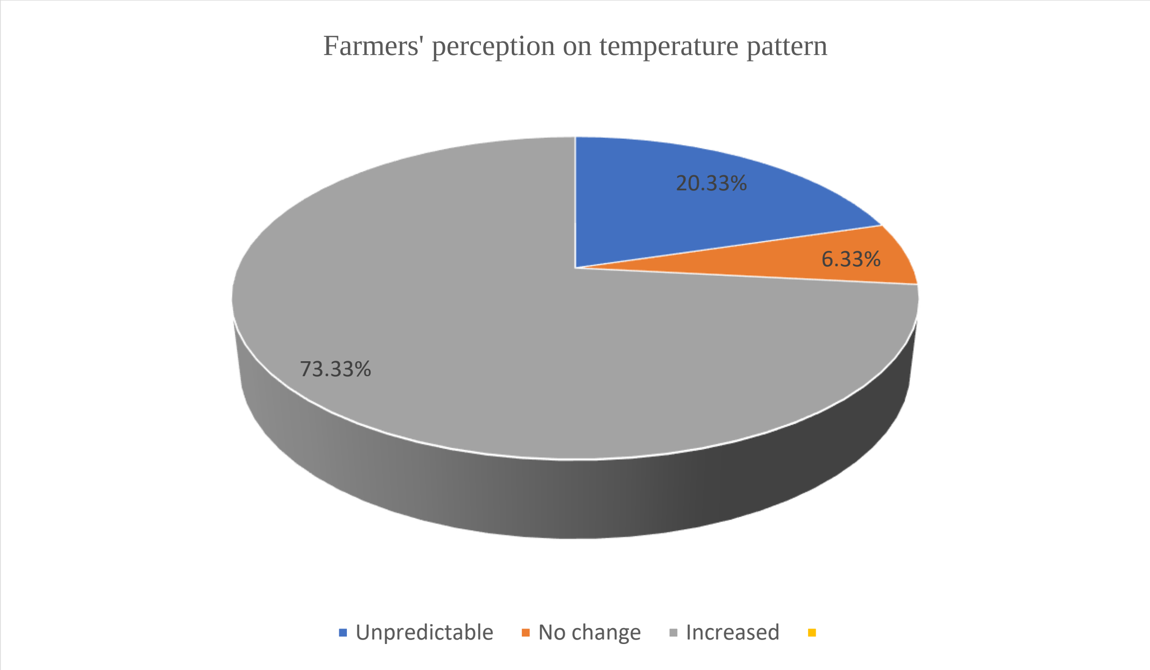


Figure 4.3: Farmers' perception of temperature patterns in the study area

Source: Author's computation from field survey, 2023

4.3 Effects of Climate Variability on Egg Production

The effects of climate variability on egg production are discussed in this section. Clayton, Gumbel and Plackett copulas are chosen for the temperature and rainfall experiment (temperature and rainfall variability), because in this estimation, a probit link function with Bernoulli distribution is employed since the temperature and rainfall variables are dichotomous, and the expected outcomes of interest (egg output and net revenue) are continuous. The type of copula(s) used in the estimation are reported in the top row of the results Tables (i.e. Tables 4.3, 4.4, 4.5 and 4.6) below. The estimates show the conditional probability of encountering negative or positive temperature and rainfall variabilities based on the farmer's location. The variable chosen as an instrument (altitude) for the selection equation proved highly significant in explaining the probability of experiencing temperature and rainfall variabilities in all the models. It is expected that the altitude at which a poultry farm is located can influence the farmer's temperature or rainfall it receives or experiences on the farm, but it should not have any correlation with his egg output or net revenue. Intuitively, higher altitudes lead to cooler temperatures, because in basic geography atmospheric air becomes cool and expands due to a drop in atmospheric pressure while the reverse holds for lower altitudes. So, farms that are located at lower altitudes will experience heat rise which stresses poultry, reduces feed intake and poor egg production (altitude provides the pathway for temperature but not egg production). With the rainfall effect, higher altitude also means more rainfall because warm air from the earth's surface is pushed up higher to facilitate cooling and condensation, hence rain. This means the altitude at which a farm is located can determine the amount of rainfall at that place but not the egg output or net revenue of the farmer.

Table 4.3: Results From Copula Regression Estimates of Temperature on Egg Production

Model: Clayton-Gumbel			
Variables	**Selection**	**Farms Location with Negative temperature Variability**	**Farms Location with Positive temperature Variability**
	1	**2**	**3**
Constant	Coefficient	Coefficient	Coefficient
	-4.823*	1.053***	2.377***
	(2.732)	(0.403)	(0.174)
Gender	0.5154	-0.385***	0.135***
	(0.499)	(0.058)	(0.047)
Farmer age	0.054*	0.020***	0.004*
	(0.029)	(0.004)	(0.002)
Feed per bird (Kg)	-0.004	0.016***	0.002**
	(0.325)	(0.004)	(0.001)
Keep exotic breeds	1.375***	0.139*	0.141***
	(0.465)	(0.084)	(0.032)
Urban	1.416***	0.192***	0.028
	(0.199)	(0.065)	(0.021)
Flock size	8.45e-06	0.001***	0.001***
	(0.002)	(3.22e-05)	(4.33e-05)
Ext. Access	0.826**	0.035	0.015
	(0.354)	(0.042)	(0.027)
Yrs. in Poultry Prod.	-0.009	0.076***	0.011***
	(0.782)	(0.009)	(0.003)
Farmer Yrs. of Edu.	0.115	0.011	0.029***
	(0.095)	(0.010)	(0.006)
Altitude	-0.022*** (0.007)		
$\ln\sigma1/\ln\sigma0$		0.125***(0.021)	0.150***(0.012)
$\rho1/\rho0$		3.484 (1.682)	0.609 (0.315)
$\tau1/\tau0$		-0.713 (0.139)	-0.234(0.092)
Log-likelihood		-129.64	
Wald chi2(12)		75.35***	
LR test of independence Eqns.		5.542**	
Number of observations		300	

*Note: The mean difference comparison of the traits between farmers who received negative-temperature variability in their egg yield and farmers who experienced positive-temperature variability is shown in Table 4.3 above. ***, ** and * are 1%, 5% and 10% significance levels, respectively, and values in brackets are standard errors, τ is Kendall's coefficient of concordance parameter.*

Table 4.4: Copula Regression Estimates of Temperature on Net Revenue

	Model: Clayton- Plackett		
Variables	1 Selection	2 Farms Location with Negative temperature Variability	3 Farms Locations with positive temperature Variability
	Coefficient	Coefficient	Coefficient
Constant	-0.656	8.757***	3.828***
	(1.339)	(2.887)	(1.373)
Gender	-0.283	-0.356	-0.007
	(0.331)	(0.096)	(0.344)
Farmer age	0.053***	-0.018	0.028
	(0.016)	(0.042)	(0.019)
Feed per bird (Kg)	-0.006	-0.023	-0.006
	(0.007)	(0.029)	(0.007)
Keep exotic breeds	0.595**	-0.199	0.667 ***
	(0.235)	(0.718)	(0.252)
Urban	0.514***	-0.441	0.334***
	(0.106)	(0.559)	(0.113)
Flock size	1.086e-04	0.001**	0.001***
	(1.193e-04)	(2.562e-04)	(1.368e-04)
Ext. Access	0.287	-0.132	0.389*,
	(0.224)	(0.356)	(0.225)
Yrs. in Poultry Prod.	-0.146**	0.207*	0.026
	(0.069)	(0.116)	(0.026)
Farmer Yrs. of Edu.	-0.077	0.062	0.076
	(0.059)	(0.108)	(0.051)
Altitude	-0.008***		
	(0.002)		
lnσ1/lnσ0		1.542	1.224***
		(0.162)	(0.286)
ρ1/ρ0		2.63e-06**	128.7***
		(1.03e-05)	(217.3)
τ1/τ0		-1.32e-06	
		(5.16e-06)	
Log likelihood		-846.3	
Wald chi2(12)		59.82***	
LR test of independence Eqns.		57.59***	
Number of observations		300	

The estimates in Table 4.3 show that the coefficient of the age variable is positive and statistically significant at 1% and 10% for farms experiencing negative temperature variability and positive temperature variability respectively. This implies that a year increase in the age of a poultry farmer, with a farm located at a place experiencing negative temperature variability increases egg output (number of crates per week) by 2% while the same year increase in the age of a poultry farmer, with farm experiencing positive variability, increases in the number of weekly crates obtained by 0.4%. The differential impact in weekly crates of eggs obtained by the farmers in both regimes could be explained by the fact that the older poultry farmers that obtained higher egg gains in the face of negative temperature variability may have better knowledge and experience in adapting to the shocks of negative temperature variability.

Closely linked with the age variable is years in poultry production which is also significant statistically at a 1% confidence level in both outcomes for farms experiencing negative temperature variability and farms with locations experiencing positive temperature variability. This means that an additional increase in the year a poultry farmer spent in poultry production is associated with a 7.6% increase in weekly crates of egg output obtained if a farm is located in an area experiencing negative temperature variability while egg output obtained weekly by poultry farmers marginally increase by 1.1% for an additional year spent in poultry production by farmers whose farms are located at places with positive temperature variability. The economic reasoning for these variations could be that farmers that experienced negative temperature variability at their farm locations adopted effective and efficient adaptation options, such as canopy tree planting, lowside walls and vitamins which enabled them to minimise heat effect on their layer birds as well as manage disease outbreak in a better way than those farmers whose farms experienced positive temperature variability.

Rather intriguing is the variable showing the quantity of feed ingested by each bird during the laying schedule or cycle has a coefficient that is both statistically significant and positive (Table

4.3) in the outcome equations, which is an indication that irrespective of the type of temperature variability a farmer experiences, poultry farmers are more likely to increase in egg output as feed consumed per bird increases. The economic rationale behind this is that eggs laid per day holding other factors constant is also preconditioned on the feed consumption and conversion rates of birds.

Additionally, Table 4.3 and 4.4 estimates reveal that the variable's coefficients relating to keeping exotic breeds are significant statistically and positive in both outcomes, suggesting that poultry farmers who keep exotic breeds, with farms located at places with positive temperatures obtained 14.1% and 66.7% more in egg output in the number of crates per week and net revenue respectively than those farms locations experiencing negative temperature variability and not keeping exotic breeds.

In all the outcome equations, the results reveal a positive and statistically significant coefficient for flock size (Table 4.3 and 4.4), indicating that poultry farmers with larger flock sizes obtained increased egg output and net revenue returns of about 0.1% as their flock size increases with farms located at areas with temperature variabilities. Also, the coefficient of the variable representing urban in the outcomes representing farmers with positive temperature variability (Table 4.4) is significant statistically and positive in the net revenue model, indicating that poultry farms located in urban areas experiencing negative temperature variability received lesser in net revenue of 44.1% compared to farms located in peri-urban areas. In Table 4.3 the variable coefficient of years of farmer's education is positive and highly significant at 1% for farms located in areas with positive temperature variability. This implies that farms located at positive temperature variability areas obtain higher egg output in crates per week as years spent in education increases. Intuitively, highly educated farmers can obtain relevant information on temperatures favourable for layers, adopt methods that mitigate against heat stress or identify areas with low temperature variability to set their farms, hence obtaining higher egg output.

With rainfall variability, the discussion is focused on Tables 4.5 and 4.6. The estimate of the coefficient of the variable representing flock size in both outcomes of Table 4.5 and 4.6 are positive and statistically significant (at 1% level), suggesting that egg output in number of crates and net revenue received by poultry farmers increase marginally by about 0.1% as flock sizes increases, and have farms located in areas experiencing rainfall variabilities. This may be attributed to the fact that, though rainfall variability still has negative effects on layer performance, its effects are not far-reaching as compared to temperature variabilities which lead to reduced feed intake and mortalities. Also, in Table 4.5 the estimates reveal that the coefficients of the variables representing farmer years of poultry production are positive and statistically significant in both outcomes of farms experiencing negative and positive rainfall variabilities. This suggests that poultry farmers' egg output in the number of crates per week increases by 0.9% and 2.5% as the years spent in poultry production increases, and farms located at places receiving negative and positive rainfall variabilities respectively. Similarly, in the same Table 4.5 farmers' years of education coefficient is positive and statistically significant in the outcomes of farms located at places with negative and positive rainfall variabilities. This implies that, as poultry farmers years of education increase by a year, and farms located at places experiencing negative and positive rainfall variabilities obtain an increase in their egg output in weekly crates produced by 2.2% and 2.6% respectively. This is quite informative because higher education provides farmers with enough knowledge to control dumpy litter which is mostly associated with high rainfall variabilities and its negative effects on providing breeding grounds for disease infestations.

Table 4.5: Copula Regression Estimates of Rainfall Variability on Egg Production

Model: Clayton-Clayton

Variables	Selection	Farms Location with Negative rainfall Variability	Farms Location with Positive rainfall Variability
	Coefficient	**Coefficient**	**Coefficient**
Constant	-2.533 (1.835)	2.627*** (0.174)	2.767*** (0.326)
Gender	0.549 (0.395)	0.119** (0.056)	-0.073 (0.068)
Farmer age	-0.016 (0.022)	0.004 (0.003)	0.003 (0.004)

Feed per bird (kg)	0.007 (0.008)	3.476e-04 (0.001)	0.004*** (0.001)
Keep exotic breeds	-0.468* (0.268)	0.139*** (0.038)	-0.047 (0.046)
Urban	0.243*(0.135)	-0.007 (0.019)	0.011 (0.022)
Flock size	4.113e-0 (2.836e-04)	0.001*** (4.95e-05)	0.001*** (9.95e-05)
Ext. Access	0.039 (0.232)	0.003 (0.032)	0.001 (0.036)
Yrs. In poultry prod.	0.017 (0.045)	0.009* (0.004)	0.025** (0.010)
Farmer yrs. Of edu.	0.033 (0.061)	0.022*** (0.006)	0.026** (0.011)
Altitude	0.008** (0.004)		
lnσ1/lnσ0		0.157*** (0.015)	0.175***(0.022)
ρ1/ρ0		7.65e-08*** (6.57e-08)	7.259*** (2.429)
τ1/τ0		-3.82e-08 (3.29e-08)	-0.784 (0.057)
Log Likelihood		-238.955	
Wald Chi2(12)		19.63**	
LR Test of Independence Eqns.		28.649***	
Number of Observations	300		

****, ** and * are 1%, 5% and 10% significance levels, respectively, and values in brackets are standard errors. Table 4.5 above contains the mean difference comparison of the characteristics between farmers who receive negative rainfall variability with egg output as their outcome and farmers with positive rainfall variability.*

4. 6: Copula Regression Estimates of Rainfall Variability on Net Revenue

Model: Plackett-Plackett			
Variables	**Selection**	**Farms Location with Negative rainfall Variability**	**Farms Location with Positive rainfall Variability**
	Coefficient	**Coefficient**	**Coefficient**
Constant	-0.702 (1.102)	7.427*** (1.466)	7.076*** (1.402)
Gender	0.357 (0.273)	-0.099 (0.382)	0.227 (0.321)
Farmer age	-0.023 (0.016)	0.005 (0.022)	0.010 (0.024)
Feed per bird (Kg)	0.003 (0.007)	-0.005 (0.009)	0.014 (0.011)

Keep exotic breeds	-0.318	0.513*	-0.044
	(0.205)	(0.281)	(0.251)
Urban	0.215**	-0.265**	0.014
	(0.089)	(0.126)	(0.114)
Flock size	8.13e-05	8.402e-04***	9.486e-04***
	(1.274e-04)	(1.564e-04)	(1.83e-04)
Ext. Access	0.048	0.391	0.012
	(0.204)	(0.272)	(0.255)
Yrs. in Poultry Prod.	0.021	0.001	0.003
	(0.027)	(0.034)	(0.039)
Farmer Yrs. of Edu.	0.027	0.034	-0.010
	(0.040)	(0.054)	(0.049)
Altitude	0.002***		
	(0.001)		
lnσ1/lnσ0		1.906***	1.644***
		(0.208)	(0.211)
ρ1/ρ0		4.0e-04***	0.999***
		(7.0e-04)	(0.004)
Log-likelihood		-849.702	
Wald chi2(12)		23.20**	
LR test of independence Eqns. 229.9***			
Number of observations		300	

****, ** and * are 1%, 5% and 10% significance levels, respectively, and values in brackets are standard errors. Table 4.6 contains the mean difference comparison of the characteristics between farmers who experienced negative rainfall variability and farmers with positive rainfall variability.*

4.3.1 Temperature and Rainfall Variability Effect on Egg Output and Net Revenue

This section of the study presents the treatment effects, which measure the impact of poultry farms located in areas experiencing temperature and rainfall variabilities on egg output and farm net revenue. The average treatment effects (ATE) which relate to the average egg output in crates per week and net revenue for farms experiencing temperature and rainfall variabilities, average treatment effects on the treated (ATT) relates to egg output in the number of crates per week and net revenue for those farms that are located at places experiencing negative temperature and rainfall variabilities and the average treatment effects on the untreated (ATUT) represent egg output in number of crates and net revenue of farms that are located at places experiencing positive temperature and rainfall variabilities. The estimates are presented in Table 4.7.

Table 4.7: Effects of Temperature and Rainfall Variabilities on Farm Outcomes

Panel A	Temperature Variability	
	Outcomes	Parameter
Eggs Output	**Net Revenue**	
-0.429***	0.029*	ATE
(0.032)	(0.072)	
-0.733***	-8.64e-06***	ATT
(0.066)	(1.50E-07)	
0.157***	5.241***	ATUT
(0.005)	(0.195)	

Panel B	Rainfall Variability	
	Outcomes	Parameter
Eggs Output	**Net Revenue**	
-0.195***	-0.363***	ATE
(0.007)	(0.032)	
-5.25e-08***	5.252***	ATT
(7.86E-09)	(0.195)	
0.484***	4.524***	ATUT
(0.008)	(0.161)	

*Note: The estimations of the various treatment effects parameters of rainfall and temperature variabilities on farmers' net revenue and egg output are shown in Table 4.7. ATT (treatment effect on the treated), ATUT (treatment effect on the untreated), and ATE (average treatment effect). The values in brackets represent standard errors, and the ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.*

Panel A in Table 4.7 shows that the average poultry farmer selected randomly from the pool of poultry farmers, with farms located in areas experiencing negative temperature variability significantly decrease in egg output in the number of crates obtained weekly by 43% and a slight increase of 2.9% of net revenue received. This may be quite intuitive because the slight increase in net revenue in the face of decreasing egg output due to rising temperature may be accounted for by price hikes as a result of shortages created in the market due to low egg production. However, in the case of poultry farmers that are in areas exposed to negative temperature variability (ATT) is associated with 73.3% and 0.001% lower number of crates of eggs per week and net revenue, respectively than those not living in such areas. The intuition behind this is that layers are more sensitive to high temperature variabilities. This causes reduced feed intake among birds, paralyses them and in severe cases death of birds. In effect, once birds are not able to lay the right quantity of eggs due to the absence of favourable temperatures, surely revenue from egg sales will negatively be affected. In the same panel also, an average poultry farmer experiencing positive temperature variability (ATUT) as a result of their farm location would obtain a significant increase in egg quantity in the number of crates per week and net revenue from egg sales by 15.7% and 524.1% points respectively. This suggests that farmers would be far better off in terms of egg output and net revenue if they were to locate their farms at places that experienced positive temperature variabilities.

Panel B in Table 4.7, the estimated ATEs are -0.19 and -0.36 for egg output and net revenue, respectively, implying that for a poultry farmer picked at random from the population of poultry farmers, experiencing negative rainfall variability decreases in egg output by 19% and net revenues by 36% points. In the case of the ATT, which relate to farmers that experienced negative rainfall variability due to their farm location, imply that the average poultry farmer's egg output marginally decreases by less than 1% points, but, significantly results in an increased net revenue by about 525% points. In the same panel for the ATUT, the results means that the average poultry farmer's farm that experienced positive rainfall variability, substantially increased the number of crates of eggs per week and net revenue by about 48% and 525% points respectively.

4.4 Identification of Poultry Farmers' Adaptation Strategies and Their Effectiveness

Thirteen (13) poultry adaptation strategies have been identified as widely used by poultry farmers in the Northern Region of Ghana to adapt to climatic stresses or shocks. These adaptation strategies have been categorized into five major categories, namely, housing-related strategies, feeding-related adaptation strategies, ventilation/regulated-related strategies, breeding-related adaptation strategies and other related strategies.

Table 4.8 shows the percentage of farmers adopting and utilising each of the main and specific adaptation techniques for each of the main categories.

Table 4.8: Category of Adaptation Strategies and Their Specific Strategies

Specific Adaptation Strategy	Number of Respondents	% of Respondents
	Housing Strategies	
Low side walls	255	85
Fence wiring	255	85
Housing alignment/ design	168	56.3
	Feeding Strategies	
Provision of chilled water	231	77
Provision of vitamin	300	100
Diet reformulation	57	19.7
Change feed times	159	53.7
Wet feeding	57	19
	Ventilation Strategies	
Energy efficient bulb	255	85
Fans	27	9
	Breeding Strategies	
Keeping local breeds	201	67
	Other Strategies	
Litter change	231	77
Tree planting	216	72

Source: Author's computations from field survey, 2023

Low-side walls, fence wiring and housing alignment are the specific housing-related adaptation strategies used by poultry farmers in the Northern Region. Fence wiring and low side walls were the most widely used housing-related adaptation strategy among poultry farmers in the Northern Region with 85 percent each for both of the sampled farmers reporting using it as a strategy for adapting to climate-related events compared to 56.33 percent of sample farmers who use housing alignment adaptation strategy. Housing-related adaptation strategy reduces the likelihood of heat presence in the poultry house or pen as a result of the negative effects of rising temperatures as layer birds need minimal temperature for laying.

Under feeding-related adaptation strategies, five specific adaptation practices have been identified to be used by poultry farmers to adapt to climate-related stresses. These include feeding birds with chilled water, provision of vitamins, diet reformulation, changing feed times and wet feeding. With 100% of the sampled farmers reporting using this specific strategy, vitamin provision is not only the most popular feed-related technique but also the most generally employed adaptation method by Northern Region poultry producers. The provision of vitamins ensures the layer bird has enough energy in the body to cope with heat stress behavioural activities like panting and reduced feed conversion and mortality resulting from heat stroke. About 77 percent of farmers interviewed reported feeding their birds with chilled water in their farms to lower the temperature of their birds in periods of temperature exceeding ambient levels. About 19.67 percent of sampled farmers also reported reformulating their diet as a way of adapting their birds against climate variability, especially heat stress. This strategy involves increasing the energy-giving food like fats and oil and carbohydrates content in the feed while decreasing the growth-giving food like protein. Too much protein content in the feed builds up heat in the body of the layer bird during metabolic activities. The low adoption rate of this technology among the farmers in the region was noted that it was new to the farmers and more time and education are required for it to be diffused among the farmers. Also, 53.67 percent and 19 percent of farmers reported adopting change feed times and wet feeding respectively to mitigate against changing climate variability in the Northern region.

Ventilation or regulated/ automated adaptation strategies had four specific strategies which included the use of air conditioners, mist blowers, the use of energy-efficient bulbs and the use of fans. However, the use of energy-efficient bulbs and fans are the two specific ventilation or regulated adaptation practices with 85 percent and 9 percent of respondents using them respectively. Key informant interviews with poultry farmers' leadership indicated that the non-adoption of air conditioners and mist blowers was because they were costly compared to the other ventilation strategies, and that adaptation strategies like air conditioners needed an enclosed pen to function well. However, more than ninety percent of the poultry farmers in the Northern region operated with the deep litter system with low side walls and fence wiring.

Breeding strategy is the fourth main category of adaptation strategies. This strategy only kept local breeds as the only specific adaptation strategies to climate-related shocks. About 67 percent of sampled farmers reported keeping local birds such as Akate black and brown birds as an adaptative measure to heat stress. The intuition behind this strategy is that local birds are more resistant to climate stresses than exotic breeds. This study is in line with the findings of Saweda et al., (2018) investigation of Nigerian poultry farmers' adaptations to climate change.

The final adaptation strategy under the main category is other related adaptation strategies. This has two specific adaptation strategies which include frequent change of litter and tree planting. Seventy-seven (77) percent of farmers interviewed reported changing their litter (material spread to absorb birds' droppings) frequently. Regular litter changes and pen cleaning during the heat wave contribute to lowering farm temperatures and preventing the unneeded build-up of bird faeces, which releases methane gas. The fact is that methane build-up exposes layers to in-house temperature increase which is not favourable for normal egg production. Also, seventy-two (72) percent of the farmers responded to planting trees around their poultry pens. This is recommended because it creates a colder atmosphere that improves feed conversion ratios (and growth) and boosts egg production as well.

4.4.1 Ranking of the perceived effectiveness of the Adaptation Strategies by Farmers

The main adaptation strategies namely housing-related adaptation strategies, feeding-related adaptation strategies, controlled/ regulated adaptations, breeding-related strategies and other related strategies were presented to poultry farmers to rank from the most effective (1) to the least effective (5) as to which strategy provides a better measure of adapting to climatic stressors or climatic shocks. After calculating and obtaining the total rank scores and mean rank scores for each of the five adaptation categories, the strategy with the lowest mean rank score (or lowest total score) was found to be the most effective one. Housing and feeding-related adaptation strategies were perceived by respondents to be the most effective with mean ranks of 1.8 and 2.05 respectively. Thus, low-side walls, fence wiring and housing alignment or design are perceived by poultry farmers to be the most effective adaptation strategies. This is shown in the Table 4.9 below:

Table 4.9: Ranking of the Perceived Effectiveness of Main Categories of Adaptation Strategies Used by Farmers

Adaptation Strategy	Mean Rank	Rank
Housing strategy	1.8	1st
Feeding strategy	2.05	2nd
Other Strategies	2.69	3rd
Breeding strategy	3.45	4th
Automated strategy	4	5th
Kendall's Test Statistics:		
N	255	
Kendall's W^a	0.557	
Chi-Square	291.299	
df	4	
Asymptotic. Significance	0.000	

Source: Author's computations from field survey, 2023

The Kendall's Concordance Coefficient was used to test the level of agreements of the rankings by poultry farmers. Results of Kendall's Test showed that the Chi-Square was significant at 1 percent with Kendall's concordance coefficient of 0.557 as seen in Table 4.9. This means that there is a significant of 55.7 percent agreement among poultry farmers on the ranking of the perceived effectiveness of the poultry adaptation options to climate stress. The null hypothesis is thus rejected.

4.5 Factors influencing the adoption of the adaptation strategies

Table 4.10 presents the multivariate probit regression (MVP) estimates which explains the factors influencing the adoption of layer poultry adaptation strategies. The Wald Chi-Square of 105.41 is statistically significant at a 1%, confidence level according to the regression results, which confirms the MVP fitness of the model for the data. As a result, the null hypothesis—which states that each equation's regression coefficients are all collectively equal to zero is rejected. This shows that the explanatory factors influencing farmers' adoption decisions differ significantly amongst the adaptation strategies, as demonstrated by the MVP model. This is presented in the Table 4.10 below:

Table 4.10: MVP regression estimates of the factors influencing adoption of the adaptation strategies.

Covariates	Housing strategies. Coefficient	Feeding strategies. Coefficient	Controlled strategies Coefficient	Breeding strategies. Coefficient	Other strategies. Coefficient
Age	0.009	-0.005	0.016	0.019	-0.004
	(0.014)	(0.012)	(0.012)	(0.013)	(0.014)
Sex	-0.180	-0.182	-0.332	**0.831*** **	-0.023
	(0.257)	(0.215)	(0.224)	(0.238)	(0.238)
Yrs. of Educ.	**0.076***	**-0.069*** **	0.033	-0.038	0.019
	(0.040)	(0.036)	(0.035)	(0.034)	(0.041)
Ext. Access	**-0.509*** **	**-0.349*** **	-0.048	0.226	-0.074
	(0.194)	(0.162)	(0.159)	(0.159)	(0.183)
FBO	**0.349*** **	-0.103	-0.171	-0.258	0.025
membership	(0.183)	(0.163)	(0.162)	(0.159)	(0.184)
Climate info.	**0.297***	0.078	**-0.686*** **	0.222	**0.328***
Access	(0.179)	(0.163)	(0.166)	(0.164)	(0.178)
Flock size	3.9e-05	**1.6e-04***	**2.2e-04*** **	1.5e-04	9.2e-05
	(1.0e-04)	(9.2e-05)	(1.0e-04)	(9.9e-05)	(1.1e-04)

Credit Access	0.129 (0.189)	0.055 (0.165)	0.084 (0.166)	-0.180 (0.164)	**0.343**** (0.179)
Perceived change in clim. pattern	0.122 (0.178)	0.032 (0.155)	**0.328**** (0.155)	-0.142 (0.154)	0.157 (0.173)
Constant	-0.703 (0.891)	**2.223***** (0.789)	-0.485 (0.801)	-0.992 (0.804)	0.236 (0.868)
Number of Observations		300			
Wald chi2(45)			105.41		
Prob > chi2			0.0000		
Log-likelihood			-811.96		

*Note: The 1%, 5%, and 10% levels of significance, respectively, are indicated by the asterisks ***, **, and *.Housing strategies are comprised of low-side walls, fence wiring and structure design/ alignment. Feeding strategies include provision of chilled water, diet reformulation, change feed times and wet feeding. Controlled/regulated strategy is made up of only the use of energy-efficient bulbs. Under breeding strategies, we have the keeping of local birds. Finally, other adaptation strategy is made up of tree planting and frequent litter change*

The MVP regression estimate of the variable coefficient relating to the gender of farmers shows a positive and statistically significant effect on the adoption of breeding strategies, meaning that male poultry farmers have a higher probability of adopting breeding strategies than their female poultry farmers' colleagues to minimise climate variability on layer production. This could be explained by the fact that commercial poultry farming in the study area is male-dominated. The few female farmers may not be aware of keeping local breeds of birds as an adaptation strategy, hence have less knowledge of this strategy thereby affecting their adoption of this strategy. A study by Azumah, (2019) on agricultural technology adoption also had the gender of a farmer to have a positive and statistically significant effect on adoption decisions by farmers. Years of education had significant positive and negative effects on housing and feeding strategies, respectively. This implies that poultry farmers' probability of adopting housing strategies to adjust to the negative effects of climate variability on layer production increases with a year increase in education. However, farmers' probability of adopting feeding strategies decreases with a year increase in education attained. This plausibly could be explained that the adoption of feeding strategies such as the provision of chilled water, and diet reformulation comes with the extra cost of adopting this category of strategies.

Also, the MVP estimate of the coefficient which relates to the access to public extension variable had a negative and statistically significant effect on the adoption of housing (low-side walls, fence wiring, and housing design) and feeding strategies (diet reformulation, change feed times, provision of chilled water), which suggest that poultry farmers who received public extension services tend to have a decreased probability of adopting housing and feeding-related strategies. The research results revealed that private extension services were the most common means through which farmers received services such as debeaking, fowlpox, and Newcastle injections, given that none of these private extension agents in the study area provided education on adaptation-related issues. This might plausibly explain the inverse relationship between extension services and the adoption choice of housing and feeding strategies. This confirms current studies by Ankrah et al., (2023) who also found the extension variable to impact negatively on agricultural technology innovation practices on sustainable livelihood by farmers in the Bono and Ahafo regions in Ghana. Contrary to earlier research,(e.g Issahaku et al., 2021 and Alhassan, 2016) rather found a positive influence between farmers' adoption decisions and extension service access. This means farmers who receive extension tend to adjust favourably to climate events compared to colleagues without extension access.

Additionally, the results showed that farmers' adoption of low-side walls, fence wiring, and housing design or alignment was significantly and positively impacted by their active participation in farmer-based organisations. This implies that farmers who are members of these associations have a higher likelihood of adopting housing strategies. This finding emphasizes the critical role that farmer groups play in distributing knowledge about agricultural innovations.

The results also demonstrated that farmers' adoption of housing-related and other related strategies, such as planting trees and changing their litter frequently, was significantly increased by receiving climate information, but their adoption of controlled or regulated strategies, such as energy-efficient bulbs, was significantly reduced. This suggests that the likelihood of a farmer implementing regulated measures reduces, as the poultry farmer's access to climate information increases. However, on the contrary, the likelihood of adopting housing and other strategies to lessen the effects of climate variability events on layer production increased as their access to climate information increased.

Also, the MVP estimate of flock size coefficient tends to be significant and had a positive association with controlled or regulated strategies such as the use of energy-efficient bulbs but had a negative significant relationship with feeding strategies like diet reformulation, changing feed times, and provision of chilled water. This means that poultry farmers with larger numbers of birds were more inclined to adopt regulated strategies compared to feeding strategies. This may be explained by the fact that adopting feeding adaptation strategies comes with extra costs aside from time being inefficient to manage.

The estimate of the variable indicating farmers' access to credit had a significant positive effect on the use of frequent litter change and planting of trees. This implies that farmers' likelihood of implementing frequent litter change and tree planting increases significantly as the farmer's access to credit increases. The reason could be that changing the litter is considered labour-intensive and costly though effective in regulating temperature in the pen and this might reflect on the willingness of farmers with sufficient credit to adopt this strategy. The study also captures farmers' perceptions about how climate variability influences their adoption of adaptation strategies. Although all the coefficients except breeding showed a positive direction, only a controlled or regulated strategy (the use of energy-efficient bulbs) was found to have a positively significant effect on poultry farmers' perception of climate variability events. This implies that as farmers' perception of climate variability increases, the probability of adopting a regulated or controlled adaptation strategy increases. This result is inconsistent with (Saweda et al., 2018).

4.5.1 The relationships among the poultry adaptation strategies – pairwise correlations

Results of the pair-wise correlation from the multivariate probit model of the poultry adaptation strategies (Table 4.11) showed that pairs of adaptation strategies had both positive and negative coefficients. The poultry adaptation strategies estimate from the multivariate probit model indicated positive and negative coefficients for pairs of adaptation strategies. In contrast, a negative correlation coefficient between the adaptation pairs shows that one adaptation approach is more preferred in adapting to climate events (temperature and rainfall stresses) than another. On the other hand, a positive correlation shows that the possibilities for adaptation are complementary. Out of the ten (10) correlation pairs of the adaptation strategies, the results revealed that five (5) adaptation correlation pairs were statistically significant and six (6) were positively associated, which is an indication that poultry farmers considered the five adaptation strategies to be complementary rather than substitutional. The error terms were neither correlated directly among the adaptation alternatives nor across equations. All likelihood ratio tests at the 1% level (chi2(10) =26.7863 (Prob > Chi2=0.0000) are statistically significant, indicating the equations are independent and the MVP data fit the model.

The use of housing and automated strategies, housing, and other strategies, and then automated and other strategies are found to be positively and statistically significantly correlated, indicating that these adaptation technologies complement one another. However, the employment of breeding strategies was significant and inversely correlated with the employment of housing strategies, automated and other adaptation-related strategies, indicating possible trade-offs between these adaptation practices. Quietly intuitive, breeding strategies which also feature the keeping of local breeds are noted to traditionally show more resistant to climate stress compared to other breeds of poultry birds. Ideally, poultry farmers might be able to optimize the benefits of these adaptation strategies to full effects for higher egg output when they adopt the complete package. Presented below is Table 4.11 which shows the pair-wise correlation errors and also explains the complementarity and substitutability among adaptation strategies:

Table 4.11: Pair-wise correlation errors and likelihood ratio test

Correlation pairs	**Coefficient**	**Standard Error**	***p*-value**
Housing strategy * feeding strategy (rho21)	0.098	0.111	0.380
Automated strategy* housing strategy (rho31)	0.309***	0.104	0.000
Breeding strategy* housing strategy (rho41)	-0.163	0.112	0.144
Other strategy* housing strategy (rho51)	0.313***	0..111	0.005
Automated strategy * feeding strategy (rho32)	0.007	0.099	0.940
Breeding strategy* feeding strategy (rho42)	0.076	0.099	0.448
Other strategy * feeding strategy (rho52)	-0.068	0.113	0.546
Breeding strategy* automated strategy (rho43)	-0.166*	0.095	0.083
Other strategy* feeding strategy (rho53)	0.213**	0.105	0.043
Other strategy*breeding strategy (rho54)	-0.226**	0.108	0.036

Likelihood ratio test of rho21 = rho31 = rho41 = rho51 = rho32 = rho42 = rho52 = rho43 = rho53 = rho54 = 0

Chi^2 (10) = 26.7863

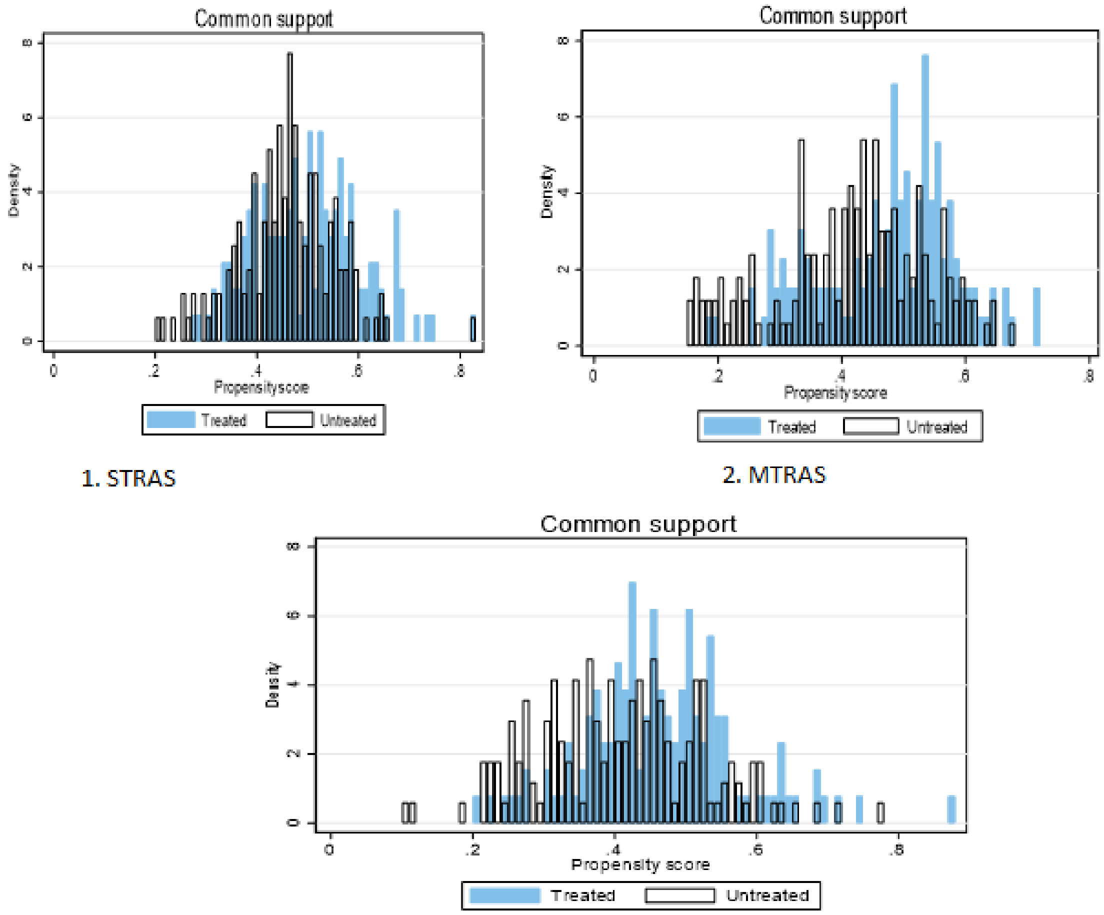
Prob > Chi^2 = 0.0000

The asterisks***, **, and * are significant at 1%, 5%, and 10%, respectively.

4.6 The Impact of Adopting Poultry Adaptation Strategies on Egg Production

To ease presentation, the adaptation strategies used in the multivariate probit model were further categorised into three strategies based on their relative duration of adoption effect to minimise climate events on egg production. These are short term regulated adaptation strategies (STRAS), which comprises the use of frequent litter changes, provision of chilled water, and the use of energy-efficient light bulb. Next is medium-term regulated adaptation strategies (MTRAS), which is made up of diet reformulation, changing feed time and keeping of local birds. Lastly, are long-term regulated adaptation strategies (LTRAS) primarily composed of housing improvements such as planting of canopy trees, low side walls and housing design or alignment.

The MTE first and second probit estimates on adaptation impacts on egg production are provided in this section. The drivers of adopting the adaptation strategies and their effects on egg output are based on the estimates from farm and farmer-level observed and unobserved factors. On the other hand, the marginal treatment effect estimates in the last section demonstrate whether farmers who have a higher likelihood to adopt poultry adaptations tend to benefit or not from their adoption of the strategies (LTRAS, MTRAS & STRAS) due to their observed and unobservable traits. Along with the MTE curve, the average treatment effect, treatment effect on the treated, and average treatment effect on the non-treated parameter estimations are also provided. The common support likelihood score which needs a considerable intersection in the characteristics of individuals who have adopted and those who have not, identifies the marginal treatment impact. The common support values of 0.1 and 0.8 in Figure 4.4, demonstrate a significant overlap between these two groups (adopters and non-adopters). Hence, making them comparable.



1. STRAS

2. MTRAS

3. LTRAS

Figure 4.4: Common support for the three Adaptation Strategies

4.6.1 Determinants of Adoption of Poultry Adaptation Strategies

The factors affecting the adoption of poultry adaptation measures are presented in Table 4.12. Column (1) shows the probit selection estimates from the first stage of farmers' adoption decision. The results show that variables such as age, education, extension contacts, flock size and average feed per bird are the factors significantly driving the adoption of adaptation strategies among poultry farmers. In particular, the age of a poultry farmers is negative and significant driver of short term related adaptation strategies (STRAS) – frequent litter changes, provision of chilled water, and the use of energy-efficient light bulbs – suggesting that an increase in a poultry farmer's age by a year decreases the farmer's likelihood of adopting STRAS to reduce the negative effects of climate events on layer birds. Thus, older farmers are less likely to adopt this strategy. This finding is in line with the intuition that STRAS adoption can be laborious and intensive for older farmers.

The education variable shows a positive coefficient in all three groups of adaptation practices but exhibits significant influence on the adoption of medium-term regulated adaptation strategies (MTRAS) – diet reformulation, change feed time and keeping of local birds – implying that poultry farmers with higher levels of education are more likely to adopt MTRAS. A plausible explanation for this finding is that the composition of MTRAS requires a given level of knowledge (education) to implement. For instance, in diet reformulation, a farmer must know the various feed components (carbohydrates, protein, fats and oil and other minerals) that need to be readjusted and by what percentage before its efficacy can be well achieved. Similar findings have been revealed by past studies on the influence of education on agricultural technology adoption in Africa (e.g., Adam and Abdulai, 2021; Mohammed and Abdulai, 2022).

Extension contacts positively and significantly drive the adoption of LTRAS at the 5% level of confidence, Extension access positively and significantly drive the adoption of LTRAS at the 5% level of confidence, implying that poultry farmers who accessed agricultural extension in their poultry production have a higher probability of adopting LTRAS compared to poultry farmers without extension access. This result is consistent with previous findings (e.g., Mohammed and Abdulai, 2022; Alhassan, 2016 and Adam and Abdulai, 2021). This is expected because poultry farmers can be provided with additional information through extension agents on new adaptation techniques, their proper implementation and probably how to improve upon bird health for optimal lay if climate uncertainties affect their performance.

Moreover, the variable denoting flock size shows a negative association with the LTRAS adaptation practices, implying that poultry farmers with smaller farms are more likely to embrace long-term regulated strategies as a measure to climate threat on the layer bird as their flock size decreases

Additionally, in the column showing short-term regulated adaptation strategies (STRAS in Table 4.12), the variable coefficient reflecting average feed per bird has a positive and statistically significant effect on its adoption. This suggests that as the average feed consumed by birds increases, the probability of adopting short-term regulated adaptation options to mitigate against climate variability stresses increases.

Table 4.11: Coefficient Estimates of the Probit Selection Model Adoption Decision

	STRAS	MTRAS	LTRAS
Selection (Variables)	**Coefficient**	**Coefficient**	**Coefficient**
Constant	-0.285	1.241	0.643
	(2.546)	(2.542)	(2.576)

Gender	0.104	0.112	0.108
	(0.172)	(0.173)	(0.173)
Age of farmer	-0.024*	-0.013	-0.013
	(0.013)	(0.013)	(0.014)
Farmer Yrs. of Educ.	0.019	0.067*	0.018
	(0.035)	(0.036)	(0.036)
Yrs. in poultry prod.	0.036	0.018	0.031
	(0.022)	(0.022)	(0.022)
Access to Extension	-0.069(0.182)	0.102(0.185)	0.400**(0.185)
Active FBO member	-0.177	-0.125	-0.221
	(0.156)	(0.158)	(0.158)
Credit constraints	0.118(0.216)	-0.033(0.217)	-0.135(0.216)
Annual rainfall	1.30E-04	6.14E-04	2.60E-05
	(4.50E-04)	(4.58E-04)	(4.69E-04)
Average temperature	0.022 (0.083)	-0.043(0.084)	-0.027(0.084)
Flock size	-5.00E-05	3.71E-05	2.1e-04**
	(9.90E-05)	(1.06E-04)	(1.08E-04)
Urban	-0.051(0.191)	0.125(0.191)	0.269(0.189)
Feed per bird	0.009*(0.005)	-0.003(0.005)	0.002(0.005)
Ratio of distance from farm to extension	-0.392** (0.169)	-0.498***(0.171)	
Shock threshold			-0.225** (0.098)
Number of observations	300	300	300
Log-likelihood	-197	-195.4	-194.4
Test of unobservable heterogeneity, p-value	0.0354	0.0344	0.0308

*Note: The adoption decision's coefficient estimates from the probit selection model are shown in Table 4.12. Where those in brackets are standard errors and *p < 0.1, **p < 0.05, and ***p < 0.01 is the significance level.; MTRAS (medium-term regulated adaptation strategy is composed of diet reformulation, change feed time and keeping of local birds; LTRAS (long-term regulated adaptation strategies) include housing design, low side walls and canopy tree planting. STRAS (short-term regulated adaptation strategies) are composed of frequent litter change, provision of chilled water and the use of energy-efficient bulbs.*

4.6.2 Treatment Effect Heterogeneity in Observed Characteristics (Eggs Production)

Columns (1, 3 & 5) and (2, 4 & 6) in Table 4.13 show MTE estimates for the effects of adopting an adaptation strategy on egg production in the non-adoption (untreated) $\boldsymbol{\beta_0}$ and adoption (treated) $\boldsymbol{\beta_1}$-$\boldsymbol{\beta_0}$ states, respectively.

Table 4.12: Heterogeneity in Treatment Effects in Observed Characteristics

Variable	**STRAS**		**MTRAS**		**LTRAS**	
	1	2	3	4	5	6
	$\boldsymbol{\beta_0}$	$\boldsymbol{\beta_1}$-$\boldsymbol{\beta_0}$	$\boldsymbol{\beta_0}$	$\boldsymbol{\beta_1}$-$\boldsymbol{\beta_0}$	$\boldsymbol{\beta_0}$	$\boldsymbol{\beta_1}$-$\boldsymbol{\beta_0}$
	Coeff.	**Coeff.**	**Coefficient**	**Coeff.**	**Coefficient**	**Coeff.**
Constant	-2.719	2.452	-2.576	4.353	2.773	3.103
	(3.266)	(6.224)	(3.579)	(6.529)	(2.511)	(5.621)
Gender	-0.02	-0.068	-0.144	0.299	0.088	-0.247
	(0.296)	(0.609)	(0.218)	(0.469)	(0.196)	(0.411)
Age of farmer	0.124***	0.242***	0.036**	-0.072*	-0.014	0.026
	(0.037)	(0.082)	(0.018)	(0.04)	(0.014)	(0.032)
Farmer Yrs. of	0.03	-0.02	0.092*	0.265**	0.033	-0.009
Educ.	(0.066)	(0.137)	(0.053)	(0.115)	(0.038)	(0.081)
Yrs. in poultry	-0.063	0.153**	0.043	-0.027	0.0534**	-0.079*
prod.	(0.05)	(0.062)	(0.036)	(0.073)	(0.025)	(0.047)
Access to	0.385	0.899*	-0.139	0.275	0.421	-0.839
Extension	(0.315)	(0.534)	(0.238)	(0.507)	(0.362)	(0.749)
Active FBO	0.989***	1.171**	-0.309	0.435	-0.162	0.207
member	(0.334)	(0.515)	(0.207)	(0.455)	(0.216)	(0.441)
Credit constraints	-0.518	0.968	-0.179	0.064	-0.306	0.6
	(0.327)	(0.744)	(0.27)	(0.55)	(0.218)	(0.459)
Annual rainfall	8.40E-05	-4.40E-05	1.7e-04	-0.001	2.50E-04	6.70E-04
	(6.10E-04)	(0.001)	(0.001)	(0.002)	(0.001)	(0.001)
Average	-0.094	0.21	0.104	-0.209	0.096	-0.195
temperature	(0.119)	(0.241)	(0.099)	(0.209)	(0.08)	(0.193)
Flock size	0.001***	2.40E-04	0.001***	3.10E-04	2.50E-04	0.003***
	(2.00E-04)	(4.40E-04)	(1.1e-04)	(2.60E-04)	(5.30E-04)	(3.20E-04)
Urban	0.058	-0.088 (0.431)	-0.130	0.359 (0.510)	-0.051	0.258 (0.594)
	(0.207)		(0.225)		(0.285)	
Feed per bird	-0.015(0.014)	0.034(0.029)	0.011*	-0.011(0.014)	0.012**(0.005)	-0.022**(0.012)
			(0.001)			
Number of observations	300		300		300	
P-Value observable heterogeneity	0.0004	0.0002	0.02		0.0000	
P-Value essential heterogeneity	0.035	0.0008	0.052		0.0492	

Note: The coefficients β_1-β_0 in the adaptations panel show changes in treatment effects across covariate values, and coefficients β_0 in the non-adopters panel represent average differences in outcomes across covariates.

According to the MTE estimate, the age variable is positive and statistically significant in the treated state for STRAS and negative for MTRAS. This implies that, STRAS adoption is more beneficial for poultry farmers who are advanced in age whiles the negative treatment effect in the case of MTRAS means that the adoption of this category of strategy favours younger farmers. Also, in the column of MTRAS adoption (Table 4.13), the MTE estimate of the variable denoting education has a positive and statistically significant coefficient in the treated and the untreated states in terms of egg output. This suggests that, after adopting MTRAS (diet reformulation, adjusting feeding times, and keeping local birds), poultry farmers who have higher levels of education typically tend to gain more in their egg production (26.5% points).

The results also show that in the adoption state for STRAS and LTRAS, the years spent in poultry production coefficient is positive in STRAS and negative in LTRAS. This tends to suggest that STRAS adoption significantly increases egg output for farmers with more experience in poultry production whiles the negative interpretation of LTRAS suggest that poultry farmers with less years of poultry experience suffer loss in their egg output per week by 7.9 percentage points.

Furthermore, in the non-adoption state, the estimates showing extension access increases average poultry farmers' egg output by just 39 percentage points. However, when poultry farmers who access agricultural extention adopt STRAS, their output in egg production increases by about 90 percentage points more than their non-adoption state. This result emphasises even more the essential role extension plays in providing knowledge diffusion and assimilation of agricultural technologies.

Moreover, the estimate of the FBO (farmer-based organization) variable (Table 4.13 of STRAS) has shown positive and statistically significant coefficients in both the non-adoption and adoption states, indicating that farmers who do not belong to farmer based associations typically increase their egg output by 98 percent in non-adoption phase. However, the adoption phase is even more interesting because farmers who participate in more FBOs even see higher returns of about 117 percentage points in egg gains after adopting STRAS. This result emphasises the importance of FBOs in farm knowledge and skill acquisition

In Table 4.13, the flock size coefficients showed a positive and significant effect for non-adoptors of both MTRAS (diet reformulation, change feed times, and keeping local birds) and STRAS (frequent litter changes, chilled water provision, and energy-efficient bulb use). This suggests that farmers with a larger flock size increase the number of egg in crates per week for not adopting these strategies. On the contrary, the flock size variable under LTRAS (low side walls, house design or alignment and planting canopy trees) in the treated state is positive and significant at 1%, suggesting that LTRAS adoption increase the number of crates of egg per week for poultry farmers with larger number of birds.

4.6.3 MTE Marginal Treatment Effects Parameter Estimates

An essential aspect of this thesis is examining how farmers' adoption of poultry adaptation techniques to reduce climate uncertainty affects layer output or egg yield, and how this effect varies substantially with their unobserved traits. The marginal distribution of treatment returns over various degrees of unobserved resistance to treatment U_D (in this case, resistance to adopting adaptation techniques) among the farmers is represented by the marginal treatment curve, which is shown in Figure 4.5 below.

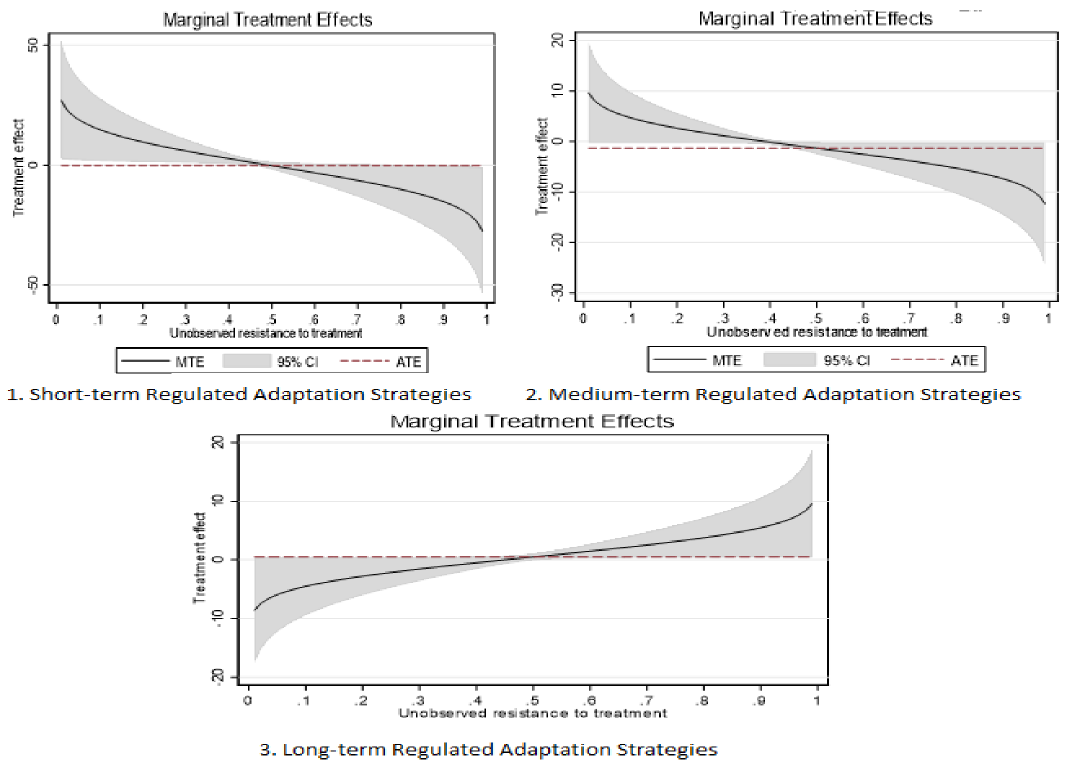


Figure 4.5: MTE curves for the Adaptation Strategies

Figure 4.5 illustrates an upward-sloping trend for long-term regulated adaptation strategies (LTRAS), with low treatment effects at the initial stage of the U_D distribution and a steady rise to positive outcomes toward the distribution's far-right end. This indicates that the impact of LTRAS adoption on egg output varies across farmers' unobserved characteristics. Adopting long-term regulated adaptation techniques improves egg output by about 50% for a poultry farmer selected randomly from a pool of poultry farmers, as indicated by the MTE estimated ATE of 0.5 for egg output (weekly crates) (see columns 3 of the treatment impact Table 4.14). More specifically, as in the case of the treated (ATT) parameter, the coefficient has a negative and statistical significance at 10% suggesting that poultry farmers who have a higher tendency to adopt LTRAS are those who obtain a lower quantity of eggs, thus,30 percentage points less given their unobserved characteristics. Additionally, in the treatment effect on the untreated (TUT) case, for an average non-adopting poultry farmer, substantially increase egg gain in weekly crates by the poultry farmer by 307% points. The marginal treatment curve in Figure 4.14 for LTRAS illustrates an inverse selection on egg gains, as confirmed by the treatment effects parameters, which reveal the following pattern: ATT (-2.91) < ATE (0.49) > TUT (3.09). The reverse selection as in the case of LTRAS can be explained that there are certain unobserved factors among poultry farmers which is limiting their adoption of this strategy.

With regards to the MTE estimates for egg output in MTRAS and STRAS in Figure 4.14, the marginal treatment effect pattern shows a declining marginal treatment effect pattern for egg production in MTRAS and STRAS. This suggests that poultry farmers who have the tendency to use STRAS practices (like giving birds chilled water, changing litter frequently, and using energy-efficient bulbs) and MTRAS practices (like reformulating diets, changing feed times, and keeping local bird breeds) tend to gain more from adopting these practices. This implies that there is positive selection among farmers unobservable returns on gains.

According to the estimates, for the average poultry farmers (ATE) selected at random from the pool of poultry farmers producing eggs, adopting STRAS and MTRAS significantly decreased in their egg output per week by about 149 and 133 percentage points respectively

Also, the results of the average treatment effects on the treated (ATT), which is of interest reveal that poultry farmers with low resistance to treatment (high propensity score values for adoption), tend to significantly increase more in their egg output obtained when they adopt STRAS and MTRAS. Thus, their adoption of MTRAS and STRAS increased their egg output by 307 percentage and 617 percentage points respectively. For the average treatment effect on the untreated farmers (ATUT), both strategies show negative significance to treatment on egg output. This implies that farmers with high unobserved resistant to adoption of MTRAS and STRAS tend to decrease more in their egg output by 508 and 851 percentage points respectively, and this is a typical MTE pattern of positive selection on gains: ATT (3.07) >

ATE (-1.49) > TUT (-5.08) for MTRAS and ATT (6.17) > ATE (-1.33) > TUT (-5.08) for STRAS

Table 4.13: Parameter Estimates on Treatment Effects

	EGG PRODUCTION		
PARAMETER	**STRAS**	**MTRAS**	**LTRAS**
ATE	-1.489***	-1.325**	0.493*
	(0.449)	(0.593)	(0.295)
ATT	6.167***	3.071**	-2.907*
	(1.941)	(1.611)	(1.631)
TUT	-8.505***	-5.077**	3.096**
	(2.405)	(2.291)	(1.348)
Test of essential heterogeneity, p-value	0.0354	0.0344	0.0492
Number of observations	300	300	300

Note: Table 4.14 presents the estimates of different treatment effects parameters; ATE (average treatment effect), ATT (effect of treatment on the treated), and TUT (effect of treatment on the untreated). The reported test of observed heterogeneity is a test of whether the treatment effect (β_1-β_0) varies across the observed covariates. The p –value for the test of essential heterogeneity, which is a test for a non-zero slope of the MTE curve is presented. The ***, **, and * are significant at 1%, 5%, and 10% levels, respectively.

CHAPTER FIVE

SUMMARIES, CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This chapter reports a summary of the findings of the study, from which relevant conclusions are drawn. Based on the findings, the chapter also contains some relevant policy recommendations. The chapter also presents some suggested research gap(s) for future studies.

5.2 Summary of Major Findings

The study seeks to assess the impact of climate variability adaptation strategies on layer production among poultry farmers in the Northern region of Ghana. The objectives of the study were to: determine the effects of climate variability on egg production; identify the adaptation strategies used by poultry farmers and their effectiveness; determine the factors influencing the adoption of the adaptation strategies and examine the impact of adopting climate variability adaptation strategies on egg production.

The study made use of relevant tools and econometric models like the copula endogenous switching regression to determine the effects of climate variability on egg production; descriptive statistics such as percentages, tables, frequencies and Kendall's coefficient of concordance were used to identify poultry adaptation strategies and rank the effectiveness of the adaptation strategies used by farmers; factors that influence the adoption of the adaptation strategies was achieved with use of the multivariate probit regression model and finally the marginal treatment effects model was employed to examine the impact of adopting climate variability adaptation strategies on layer production. Primary data was solicited from 300 poultry farmers using a questionnaire. The study also made use of secondary data on rainfall and temperature from the National Aeronautics Space and Administration (NASA) platform.

The findings of the research on the socioeconomic characteristics of the farmers included gender, age, educational status, farming experience, household size, and main activities among others. The results show that 83.67% and 16.33% of the respondents were males and females respectively. The average age of poultry farmers interviewed was about 41 years with 21 and 58 years being the minimum and maximum age of farmers' respectively. The educational status of the respondents shows that about 97% had formal education with 78.33% receiving tertiary education. A respondent had an average of about 7 years of poultry experience.

In objective one, the empirical results show that farms that are located in low-temperature variability areas performed better, in terms of egg output and net revenue gains of 16% and 525% respectively, compared to farms located in areas exposed to extreme temperature variability with decreased in egg output, especially of about 73.3%. However, in terms of rainfall variability, the study could not establish a significant difference between farms located in high rainfall variability areas and those located in low rainfall variability areas as seen in Table 4.7, particularly their net revenue returns are the same for ATT and ATUT. This observation may be due to the reason that, unlike crop production, rainfall has no direct impact on poultry production as compared to temperature. Rainfall is only one of the means through which we can have a low or high temperature.

In objective two, the research revealed that thirteen (13) poultry adaptation strategies have been identified to be widely used by poultry farmers in the Northern Region of Ghana to adapt to climatic stresses or shocks. These adaptation strategies have been categorized into five major categories, namely, housing related strategies (Low-side walls, fence wiring and housing alignment), feeding related adaptation strategies (feeding birds with chilled water, provision of vitamins, diet reformulation, changing feed times and wet feeding), ventilation/regulated related strategies (use of energy efficient bulbs and fans), breeding related adaptation strategies (kept local breeds) and other related strategies (frequent change of litter and tree planting).

Kendall's coefficient of concordance was also employed to assess the perceived effectiveness of the main categories of the adaptation strategies used by poultry farmers in the region. Housing and feeding-related adaptation strategies were perceived by respondents to be the most effective adaptation strategies to climatic shocks with mean ranks of 1.8 and 2.05 respectively. Results of Kendall's Test showed that the Chi-Square was significant at 1 percent with Kendall's concordance coefficient of 0.557 as seen in Table 4.9. This means that there is a significant of 55.7 percent agreement among poultry farmers on the ranking of the perceived effectiveness of the choice of adaptation strategies to climate stress.

The study in objective three revealed that out of the ten (10) correlation pairs of the adaptation strategies, five (5) adaptation correlation pairs were statistically significant and six (6) were positively associated, which is an indication that poultry farmers considered the five adaptation strategies to be complementary rather than substitutional. The estimation results indicated that the variables affecting farmers' decisions to adopt an adaptation strategy with differing signs included sex, years of education, access to extension services, membership with farmer-based organisations, flock size, credit access, access to climate information and farmer perception about climate change.

Objective four's empirical findings indicated a significant degree of heterogeneity effect in the adaptation strategy adoption (STRAS, MTRAS, and LTRAS) impacts on egg yield, suggesting that farmers' adoption decisions depend on their competitive advantage. Additionally, it was found that farmers who were more likely to adopt STRAS and MTRAS and adopted them obtained more egg output than farmers who were less likely to adopt them. The study also indicated that age, years of education, flock size, extension access and average feed per bird significantly influenced the adoption of STRAS (frequent litter change, provision of chilled water and the use of energy efficient bulbs), MTRAS (diet reformulation, change feed time and keeping of local birds) and LTRAS (housing design, low side walls and canopy tree planting)

5.3 Conclusions

Based on the key findings, the study concludes that there is a heterogeneity effect of temperature and rainfall variabilities on egg output and net revenue based on the geographical location of the poultry farms. We observe that poultry farms that experienced extreme temperature variability in particular recorded a negative effect on their egg output and net revenue. Also, most of the adaptation strategies (housing, feeding, ventilation, breeding and others) examined in this study are complementary rather than substitutes. This means that policies implemented at the farm level that impact one adaptation technology for layer production may also impact other strategies of adaptation as well. The MTE estimates of STRAS and MTRAS, in particular, showed that farmers with a high propensity to adopt greatly increased their egg output up to 307 percent and 617 percentage points, respectively, following the adoption of the adaptation strategies. This is relevant a piece of information for the MTE regarding the impact of adopting the adaptation strategies.

5.4 Recommendations

This study assessed the impact of adaptation to climate variability on layer production among poultry farmers in the Northern region of Ghana. Several key issues emanate from the discussion of the study. Firstly, climate variability continues to pose a greater threat as to the number of crates birds can lay daily. Given this, there should be investment in research to understand the specific impacts of climate variability on egg production across different locations in the region. Also, the promotion of climate-resilient infrastructure and adaptation strategies for egg production facilities must be encouraged. This includes improved ventilation systems (housing design or alignment), temperature control mechanisms, and breeding strategies to mitigate heat stress and other climate-related shocks.

The study recommends that poultry farmers should be educated on the need to adopt climate adaptation strategies as a whole package rather than choosing individual strategies to adopt.

This could ensure the optimization of the benefits farmers derive from the adoption of these strategies. Also, poultry farmers should be educated on poultry adaptations to climate stresses by agricultural extension agents, through frequent training to raise their awareness of the benefits of existing strategies and how to apply new ones. The study further recommends that radio and television talk shows on layer production should be given the needed attention just like crop production by public extension officers to increase poultry farmers' awareness and knowledge of the availability and effectiveness of the adaptation strategies.

Integrating climate adaptations into national policies. For instance, mainstreaming poultry specific strategies (tree planting) into Ghana government flagship programme of planting for food and jobs and rearing for food and jobs initiatives This can also inform poultry farmers on adaptative measures that guarantee layer health and productivity.

Moreso, the Ministry of Food and Agriculture should support breeding programs to improve egg production of local breeds (e.g, Akate black/brown). The local breeds in recent times have proven to be more adaptive to our local climate and less costly.

Since the study was restricted to just one of Ghana's sixteen administrative regions, we suggest that future studies be expanded to cover the entire nation to offer more insight to guide policies in the poultry sector of the country. This could provide insight into areas or regions with climate conditions that favour egg production so that those regions can be well targeted and integrated into the government's flagship programme of "rearing for animals and jobs" for overall national benefits

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APPENDIX

Questionnaire

Introduction and consent

My name is........................., and I am M.Phil. student studying Agricultural Economics at the University for Development Studies (UDS). I am assessing socioeconomic drivers of adaptation methods to climate variability and how these adaptation methods affect egg output among commercial poultry producers in the northern region of Ghana. The information gathered for this project is only for academic purposes, and it will not be shared with any outside parties. Your identity will be kept private and will not be included in the resulting report. Policymakers will be assisted by the information in developing climate-smart poultry production techniques to improve poultry production and the entire poultry value chain business.

Do you agree to participate in this survey? 1. Yes [ ] 0. No [ ]

Background and Personal Information

Interviewer name ……………………………………………..

Date: ………………………………………………………….

District: Tamale [ ] Sagnarigu [ ]

Community name: ……………………………………………

Household Code: ……………………………………………..

Respondent name: …………………………………………….

Respondent phone number: …………………………………….

GPS ……………………………………………………….

SECTION A: Household level information

5. Sex of respondent. 1. Male [ ] 0. Female [ ]

6. What is your religion? 1. Islam [ ] 2. Christianity [ ] 3. African Traditional [ ]

7. Are you the household head? 1. Yes [ ] 0. No [ ]

8. Age of respondent in years ……………………….

9. Your Marital status: 1. Never married/single [ ] 2. Married [ ] 3. Widow/widower [ ] 4. Divorced [ ]

10. School [ ] JSS/JHS/Middle School [ ] SSSCE/WASSCE/Vocational [ ] Post Secondary (Teacher/Nursing training college/Diploma course[ ] Tertiary (Polytechnique/University) [ ] Post-graduate (Masters/PhD, Professional Cert) [ ] Others [ ]

11. Respondent's years of education [ ]

Age range	Males	Females	Total
0 – 14 (years)			
15 – 59 years			
60+ years			
Total			

12. How many people are living in your house under your care? [ ]

13. How many of the household's labour force (15 – 59 years) are working to earn income?[ ]

14. What is your major occupation? 1. Poultry farming [ ] 2. Salary work [ ] 3. Business (traders/petty trading) [ ] 4. Construction work [ ] other (specify) …………………….

15. If option one (poultry farming), which of the following livelihood activities do you

S/N	Activity	
1	Salary work	
2	Construction work;	
3	Seamstress	
4	Carpenter	
5	Business (traders/petty trading)	
6	Selling poultry inputs	

16. engage in?

17. How many years have you been into poultry production? ……………………….

18. Who own the poultry farm? Myself [ ] Family [ ] Friend [ ] Partnership [ ] Others [ ] Specify: …………

19. Who makes decision about the poultry production? Myself only [ ] Myself and my partner [ ] Myself and business partner [ ] Myself and farm manager [ ] Only farm manager [ ] Family/Friend [ ] Others [ ] Specify: ……..

20. Who manages the poultry farm? Myself only [ ] Myself and my partner [ ] Myself and business partner [ ] Myself and farm manager [ ] Only farm manager [ ] Family/Friend [ ] Others [ ] Specify: ……..

Section B: Access to services and social capital

21. Do you have access to extension/veterinary services in your poultry production? 1=yes [ ]

0 = No [ ]

22. If yes, which of the following organisation/channels do you access extension services

S/N	Organisation/channel	Response:1=Yes;0.= No	Number of visits per year
1	Public (MoFA)		
2	Private (individuals)		
3	NGO		
4	Farmer-to-farmer (meeting place)		
5	Television (TV)		
6	Radio		
7	news paper		
8	Poultry farmers association		
9	Social media/SMS		

Please indicate the distance in kilometres to the places in the questions (Q18-20) below:

23. Your home to extension services office ……………km

24. Distance from your home to poultry farm …………….km

25. Distance from your home to poultry inputs shop (where you mostly purchase inputs) ………...km

26. Have you visited any extension office or invite extension offer to seek service for yourself? 1=Yes [ ] 0 = No [ ]

27. If yes, did you pay for the service provided? 1 = Yes; [ ] 0. No = [ ]

28. If yes, how much did you pay? GHS ……………….

29. Do you have poultry association? 1. Yes; [ ] 0. No [ ]

30. If yes, are you an active member? 1=Yes [ ] 0 = No [ ]

31. If yes, do you hold meetings? 1= Yes [ ] 0 = No [ ]

32. If yes, how many times? 1. Weekly [ ] 2. Monthly [ ] 3. Quarterly [ ] 4. Once a year [ ]

33. Are you a leader in the association? 1.=Yes [ ] 0 = No [ ]

34. How many farmers do you know? ……………………..

35. What is the distance from your home to the association's meeting venue? ………(km)

36. How many people (farming and friends) are helping you in your poultry production? ………….

37. How did you acquire the land for the poultry production? 1. Own [ ] 2. Rented [ ] 3. Borrow [ ] 4. Gifted [ ] 5. Family land [ ] 6. Other (specify) …………………………..

38. Where is your poultry farm located? 1=.home [ ] 0=Another place [ ]

SECTION C: Access to Climate Information

39. Which of the following assets do you own? (Tick all applicable):

Functional TV set [ ] Functional Radio Set [ ] Functional Mobile phone [ ]

40. Did you receive climate information in the previous production season? 1=Yes [ ] 0= No [ ]

41. If yes to question (34), which of the following channels did you access climate information with ?

S/N	Channels	Response:1=Yes 0= No
1	Radio	
2	TV	
3	SMS/phone	
	Social media platforms (Facebook, WhatsApp Instagram, etc.)	
4	Extension agent (MoFA)	
5	Farmer-to-farmers	
6	Friends and family	

42. Which of the following climate information services did you received in your poultry production?

S/N	CIS type	Response: 1. Yes; 0. No
1	Temperature control in poultry house	
2	Humidity control	
3	Storage of eggs	
4	Hatching	
5	Regulation hatching machine temperature	
6	How to keep day-old chick against bad weather	
7	Other (specify) …………………………	

43. Do you use your mobile phone to access climate variability information? 1=Yes [ ]

0=No [ ]

44. To what extent did the climate variability information benefit you? 1=Very good [ ]

2= Good [ ]3=Moderately good [ ] 4= Bad [ ] 5=Very bad [ ]

45. Do you have adequate information on storage and handling of your eggs? 1=Yes [ ] 0=No [ ]

Section D: Awareness on Climate Variability and Perceived Effects on Egg Production

46. Do you notice any variability in the climate pattern within the last 10 years? 1=Yes[ ] 0=No[ ]

47. What is your perception about the rainfall pattern in the last 10 years?

1. Unpredictable [ ]2. No change [ ] 3. Increased [ ] 4. Decreased [ ]

48. What is your perception about the temperature patterns in the last 10 years?

1. Unpredictable [ ]2. No change [ ] 3. Increased [ ] 4. Decreased [ ]

49. What is your perception of the following climate variability indicators over the past 10 years? *Please explain*

Statement on eggs Production	**Noticed change** 1=Yes 0=No 2=Don't know	**Kind of change** 1=Increased 2=Decrease 3= Fluctuate	How likely can you attribute the change in egg production to climate variability? 1 (Very likely), 2 (Likely) 3 (Uncertain), 4 (Unlikely) and 5 (Very unlikely)
Point of lay (maturity)			
Number of Eggs produced			
Number of birds			
Poultry diseases			
Poultry parasites			

SECTION E: Adaptation Strategies to climate variability

50. Which of the following adaptation strategies have you used to respond to climate variability? (Tick all applicable by selecting yes). Also, indicate the number of bird farmer apply strategy on. Finally, using a Likert Scale of 1 (most effective) to 5 (least effective), rank the perceived effectiveness of adopted strategies in adapting to climate variability.

S/N	Adaptation Strategy	1. Yes; 0. No	Flock size (no. of birds)	Rank of effectiveness (1 – 5)
Housing related strategies				
a	Low side walls			
b	Fence wire			
c	Mud blocks building			
d	Others (specify …………………..)			
Feeding related Strategies				
a	Feeding birds with chilled water			
b	Diet reformulation			
c	Provision of vitamins			
d	Provision of honey			
e	Other supplements (specify………….)			
Controlled Ventilation/ (Heating & Cooling) Related Strategies				
a	Air condition			
b	Use of energy efficient bulbs			
c	Installation of mist blowers			
d	Use of fans			
e	Others (specify………….)			
Breeding Related Strategies				
a	Keeping local birds			
b	Keeping cross breeds			
c	Keeping exotic (foreign) breeds			
c	Heat resistant breeds			
d	Rearing of other animals			
e	Other supplements (specify………….)			

Other Related Strategies				
a	Frequent change of litter in the pen			
b	Reduce stock level per square meter			
	Others (Specify …………..)			

SECTION E: Production and Revenue

51. What type of poultry breeds are you rearing? 1. Local breeds only [ ] 2. Foreign breeds only [ ] 3. Both local and foreign breeds [ ]

52. Which of the poultry breeds are resistant to climate variability? 1. Local breeds only [ ] 2. Foreign breeds only [ ] 3. Other (specify) ……………………………………..

53. Which of the poultry breeds are resistant to diseases? 1. Local breeds only [ ] 2. Foreign breeds only [ ]3. Other (specify) …………………………………………………………..

54. Do you have access to Day- old chicks? 1. Yes [ ] 0. No [ ]

55. Where do you buy your day-old chicks for brooding? 1. Local hatcheries [ ] 2. Imported

[ ]

56. How much cost did you incur in buying a day-old chicks ? GHS…………………

57. Were you still producing eggs before Covid-19 ? 1 = yes [ ] 0 = No [ ]

58. Please indicate how the **pre-covid era** affected your poultry farm (***tick those that apply).***

1. Increased feed availability [ ] 2. Reduced feed availability [ ] 3. Increased in eggs demand [ ] 4. Decreased in eggs demand [ ] 5. Increased feed cost [ ] 6. Decreased feed cost [ ] 7. Easy access to day-old chicks [ ] 8. Difficulty accessing day-old chicks [ ]

2. Please indicate how your farm was affected **during** the covid era? (***tick those that apply)***.

1. Increased feed availability [ ] 2. Reduced feed availability [ ] 3. Increased in eggs demand [ ] 4. Decreased in eggs demand [ ] 5. Increased feed cost [ ] 6. Decreased feed cost [ ] 7. Easy access to day-old chicks [ ] 8. Difficulty accessing day-old chicks [ ]

54. Please indicate how your farm was affected **after** the covid era? (tick those that apply).

1. Increased feed availability [ ] 2. Reduced feed availability [ ] 3. Increased in eggs demand [ ] 4. Decreased in eggs demand [ ] 5. Increased feed cost [ ] 6. Decreased feed cost [ ] 7. Easy access to day-old chicks [ ] 8. Difficulty accessing day-old chicks [ ]

5

Age of bird (in weeks)	**Number of birds laying**	**Number of eggs produced per week (crates)**	**Egg size (1 – small, 2 – medium, & 3 – large)**		
< 20			**1**	**2**	**3**
21 – 30					
31 – 40					
41 – 50					
51 – 60					
61 – 70					
> 70					

5. please provide egg production cycle schedule for your birds.

3. Do you sort your eggs before selling? 1 = yes [ ] 0 = No [ ]

4. If yes, please indicate the unit price in GH ₵ for the sizes of crate of eggs below:

   Large GH ₵ ……………. ; medium GH ₵ ……….. small GH ₵ ……………

5. If no, indicate the price you sell crate of unsorted eggs GH ₵ ……………………..

6. What was the unit price of a spent layer after the egg production cycle? GH₵ ……………..

7. What did you use the proceeds from sale of spent layers for? 1. Invest in feed [ ] 2. Buy new day-old chicks [ ] 3. Others (specify) …………………………………..

SECTION F: Feeding, Nutrition and Cost

8. Which of the following feed do you give to your birds?

Feed type	Quantity (Bags, 100kg) per week	Unit cost (GHS)
Maize		
Soyabean		
Wheat brand		
Rice brand		
Millet		
Other (Specify)		

9. How frequent do you feed your birds? 1. Once a day [ ] 2. Twice a day [ ] 3. Thrice a day [ ] 4. Anytime [ ]

10. How does climate variability affect feed for your birds in the rainy season? Increases feed cost [ ] Decreases feed cost [ ] No effect [ ] increases feed availability [ ] Decreases feed availability [ ]

11. How does the hot season affect nutrition of your layers? 1. Increases feed conversion [ ] 2. Decreases feed conversion [ ] 3. No effect [ ]

12. What is the main source of water for your birds? 1. Dam [ ] 2. River [ ]

3. Tap water [ ] 4. Borehole [ ] 5. well [ ]

SECTION C: Housing

63. What material is your poultry pen build with? 1. Blocks [ ] 2. Bricks [ ] 3. Mud [ ] 4. Other (specify) ………………………….

64. What is your pen roofing type? 1. Zinc [ ] 2. Thatch [ ] 3. Palm raffia [ ] other (specify) ……………………………..

65. Is your layer pen ceiled? 1 Yes [ ] 2. No [ ]

66. Why did you decide to build such a structure? 1=Security [ ] 2= improve air flow [ ] 3= cost effectiveness [ ] 4=Other (Specify)………………………………………..

67. Is there another way you would have liked to build the layer pen? 1=Yes [ ] 0=No [ ]

68. If yes, why?

____

69. How would you like it to be built?

…………………………………………………………

____

70. What are the implications of your type of housing on layer productivity?

1=Increases [ ] 2=Decreases [ ] 3=No effect [ ] 4=Other/ Specify…………………………...

SECTION D: Poultry Health

71. Do you experience any health problems among your layers? 1=Yes [ ] 0=No |___|

72. If Yes, what are the various health problems? 1= [ ] Diseases 2= [ ] Parasites 3= [ ] Both diseases and parasites 4= [ ] Malnutrition 5= [ ] Wounds 6= [ ] Other? Specify…………………

73. How do you tell that your birds are infested with parasites? 1= [ ] Dullness 2= [ ] Scratching 3=[ ] Reduced Feed Intake 4 = [ ] inspection 5 = [ ] Other (Specify)

____

74. What are the impacts of the parasites on your layers? 1= [ ] Reduced growth 2= [ ] Reduced egg production 3= [ ] Both 4=[ ] Death 5=[ ] Other Specify ________________

75. How has climate variability changed layer bird health over the years?

1= improved [ ] 2= decreased [ ] 3= no effect [ ] 4= other (specify)………………………

Section F: marketing channels, revenue and Credit sourcing

Sale Point	**Response** **1.Yes** **0.No**	**Reason (s)**
Farm gate		

Home		
Market outlet		
Other: …………….		

76. Where do you sell the eggs and why do you sell at these points?

Buyer	**Response Yes=l No=0**	**Reason**
Wholesaler		
Retailer		
Consumer		
Gov't institutions (schools, prisons etc)		

77. Who buys your eggs and why do you sell to this person/ institution?

78. Do you source credit to finance your poultry farm activities ?.. 1. [ ] yes 0. [ ] no

79. If yes, please indicate name of the credit source ………………………………………………………………………………………………..

80. Do you still source credit from them and why?...

81. What is the average amount of money you can get from this source? GH₵-------------------------

82 . If no, please state the reasons for not sourcing credit? ....

End of Questions. THANK YOU