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Faculty of Tropical AgriSciences

Adoption of Climate Change Adaptation Strategies by Pastoralist: A Case in Northern Ghana

MASTER'S THESIS

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Declaration

I hereby declare that I have done this thesis entitled "Adoption of Climate Change Adaptation Strategies by Pastoralist: A Case in Northern Ghana" independently, all texts in this thesis are original, and all the sources have been quoted and acknowledged by means of complete references and according to citation rules of the FTA.

In Prague 25th April 2024

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Oliver Kofi Tulasi

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Abstract

In Ghana, pastoralists are among the most important suppliers of meat and milk. Meanwhile, pastoralists in Northern Ghana, who are the main producers of ruminant livestock in the country, are facing challenges related to climate change (CC). This study investigated: i) farmers' experience of CC impacts on pastoralism; ii) the CC adaptation strategies used by pastoralists to mitigate CC impacts; and iii) the factors influencing the adoption of CC adaptation practices, i.e. periodic sale of animals, construction of ponds and reservoirs, and provision of supplementary feeding by pastoralists in Northern Ghana. Primary data were collected from 218 pastoralists in northern Ghana using a multistage sampling technique that included purposive and convenience sampling. We analyzed our first and second objectives using descriptive statistics. Multivariate logit regression was used to examine the factors influencing farmers' adoption of periodic sale of animals, construction of ponds and reservoirs, and supplemental feeding.

The results showed that pastoralists have experienced the selected CC impacts i.e., insufficient water supply, feed shortage or insufficient feed, increased livestock diseases, emergence of new livestock diseases, low milk production and low proliferation. In addition, age, financial constraints, and water availability had positive significant effects on farmers' choice of period for selling livestock and construction of ponds and reservoirs. On the contrary, level of education, rearing large ruminants (livestock species), access to weather information, , and access to credit reduce farmers' chances of adopting periodic livestock sale, construction of ponds and reservoirs, and supplemental feeding. Our results also show that rainwater harvesting reduces the likelihood of farmers selling animals regularly and practicing supplemental feeding. Participation in publicly funded water programs (e.g., One Village One Dam - 1V1D) reduces the likelihood that farmers build ponds and reservoirs, but has no effect on periodic animal sales and supplemental feeding.

Finally, farmers who experienced feed shortages during the intensive drought period in northern Ghana (January to March) are less likely to build ponds, but more likely to regularly sell their animals for income and invest in supplemental feeding. Climate policies and programs by the government and other development agencies should aim to provide year-round water availability through the construction of more ponds and dams in northern Ghana. Livestock extension programs should focus on educating pastoralists in northern Ghana on fodder preparation and storage during the rainy season. This can reduce fodder and water scarcity and herd mobility in search of fodder and water during the intensive harmattan periods.

Keywords: Climate change, climate change adaptation strategies, pastoralists, livestock, multivariate logit regression, Northern Ghana.

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List of Acronyms Used in The Thesis

Acronyms	Meaning
CC	Climate Change
GHGs	Green House Gases
IPCC	Intergovernmental Panel on Climate Change
CO2	Carbon Dioxide
FAO	Food and Agriculture Organization
IKS	Indigenous Knowledge System
OECD	Organization for Economic Cooperation and Development
SSA	Sub-Saharan Africa
UNFCCC	United Nation Framework Convention on Climate Change
INOCAS	Innovation Oil and Carbon Solutions

1. INTRODUCTION AND LITERATURE REVIEW

1.1 Introduction

Climate change (CC) is described as the long-term change in average weather patterns that has come to redefine the local, regional, and global climate of the earth. The impact of CC has become a prevalent global issue (Oppenheimer et al. 2014), mainly in drylands, where its effect is highly experienced in areas of rainfall variability (Kgosikoma & Batisane 2014) changes in temperature rise in weather conditions, decreases in agricultural production conjoining with extreme heat are all some of the major challenges facing pastoralists and farmers (Nelson 2009), pest of new crops and livestock, shortage of irrigation water for livestock and worsening of soil erosion (Kgosikoma et al. 2018).

Livestock production plays a vital role in the livelihood of several rural communities in Africa, especially in arid and semi-arid areas where milk and meat are very important dietary components due to the lower availability of food from crops. Animal productivity can be adversely or positively impacted by CC. It can help push/induce adaptive measures like changing management, area, or quantities of animals. Furthermore, also, the livestock sector shows an estimated 14.5% of total global anthropogenic greenhouse gases (GHGs) (Rojas-Downing et al. 2017). Therefore, livestock management changes have had a significant impact on the potential for cushion atmospheric GHGs and reducing future CC (Steinfeld & Wassenaar 2007). Livestock emission reduction and mitigation opportunities include managing grazing land resources, changing feeding practices, improving treatment offered to animals or use of animal manure, and changing the processing, mode of transportation, products of the animals' species, and types of breeds in the animal production area (Burnett, 2013), Looming over our daily lives, climate change disrupts routines and alters weather patterns. This disruption throws crop growing seasons into chaos, leading to declining agricultural yields. Consequently, biomass production suffers, raising the specter of global food insecurity (Destaw & Mekuyie 2021).

Farmers in rural communities, especially in developing countries that are found in the low-income bracket, tend to be adversely affected by climate change. Farmers have come to understand the major environmental risk it imposes and how CC is a threat to all living things and their livelihoods around the world. African countries are experiencing changes in the rainfall pattern, extreme climatic weather conditions, and extreme drought also being experienced in rural areas due to the CC (Hassan & Nhemachena 2008; Gbetibouo 2009). Farmers with formal education, training experiences, and access to reliable flowing water (Hassan & Nhemachena 2008) extension services such as veterinarians tend to be more agricultural resilient to adapt to new strategies that can combat the CC (Sampei & Aoyagi-Usui 2009). Farmers in Africa would need a lot to thrive in the agricultural sector, but some of the major things that should be taken into consideration are the size of the farm the farmers operate on, tenure status, good transportation system for goods to be transported from the farm to the market, and credit that the bank offers either by government or cooperative union that they belong to are other major determinants of adoption in Africa (Maddison 2006).

Using data collected from 218 pastoralists in the Nanumba North and South Districts of Ghana, this paper seeks to answer the following questions: i) Are pastoralists in northern Ghana aware of the impacts of climate change on their livestock? ii) What are the most practiced CC adaptation strategies among pastoralists? What are the drivers of pastoralists' decision to adopt an adaptation strategy? The thesis will inform future policies on CC in pastoralism in Northern Ghana by the government and livestock sector development agencies. It will also inform pastoralists on their choice of adaptation strategies. Finally, the thesis adds to the literature on the factors influencing farmers' adoption of CC adaptation strategies.

1.2 LITERATURE REVIEW

1.2.1 Climate Change and its Causes

Climate Change (CC) pertains to any significant alterations in meteorological phenomena that last for a long period, which usually last for a decade or more (Mondal 2021) including changes in average climatic conditions, unpredictable rainfall events, frequency and magnitude of extreme weather and sea levels, whether due to natural fluctuations or because of human activity. It is a process of global warming, which is generally attributed to the greenhouse gases generated from the burning of fossil fuels like coal, oil, natural gases, etc., caused by human activity (Mondal, 2021; Brett, 2009). Across the globe, the agricultural sector is grappling with climate change, a recognized threat of immense complexity and challenge (IPCC 2014; Tesfahunegn et al. 2016). Compared to other socioeconomic sectors in Africa, agricultural production is particularly susceptible to the disruptions caused by climate change. (Elum et al. 2017; IPCC 2014) The impacts of climate change on agriculture vary by time and location, but the threat to rain-fed systems is considered the most widespread. This is because future projections point toward worsening conditions due to changes in rainfall patterns and temperature (Kurukulasuriya and Mendelsohn, 2008). Climate change can create new and suitable conditions for weeds, insects and pathogens to proliferate, leading to a decrease in agricultural productivity (Destaw & Fenta, 2021) One of the major crop losses globally is attributed to the space competition between the weed and crops on farmland for water, which leads to the deprivation of nutrient is estimated around 34%(Destaw & Fenta, 2021; Oerke, 2006), and it is expected to worsen due to the current CC, which also goes to the productivity of livestock sector as a result of heat stress, poor nutrition (Kgosikoma et al., 2018b; Muntifering et al., 2006) and a scarcity of potable water, both of which are consequences of climate change (Kgosikoma et al., 2018).

Human activities on the planet have shown great concern, and its implications have been shown to be one of the major reasons why the climate has changed, with significant evidence to support it. There are changes in the high and low of the sea level. The Royal Society and the US National Academy of Sciences have written an article with the recent update on the climate issue, which stipulates the activities done by humans that directly constitute to climate change issues, but not all evidence can be clear or certain in human science. Through respiration, photosynthesis, and deterioration, plants, animals, and the atmosphere all constantly exchange carbon dioxide. This gas exchange occurs in both the ocean and the atmosphere. An amount of CO2 is released during volcanic eruptions due to the chemical weathering of rocks; approximately 1% of the CO2 released during the combustion of fossil fuels (National Academies Press, 2023).

In the mid-1800s, mid-1800s, there is known knowledge by scientists that the advantage of the Earth's energy balance was significantly influenced by the balance of the greenhouse. Coordinate estimations of CO2 within the environment which is discussed caught in ice appear that barometrical carbon dioxide has expanded by more than forty percent in between 1800 and 2019. Measuring isotopes has also shown that these are caused by human activities. Activities that have also been known to be one of the causes of CC are methane and nitrogen.

Human activities have also been linked to the cause of the cooling in the stratosphere and the warming of the troposphere, which was predicted by mathematical and physical models of the climate framework that increased in the 1960s (Mondal, 2021). The weather balloon and satellites have also provided a projection in line with the early prediction about the warming and cooling of the troposphere and the stratosphere, respectively (Mondal, 2021). The data that were derived from the computer simulation both point to human activities being the main causes of the changes. (Mondal, 2021).

1.2.2. Climate Change and Agriculture

Agriculture is known to be one of the sources of greenhouse gases that is directly linked to CC (Future Learn, 2022). Agriculture production is known to be heavily affected by climate change. In Ghana, the prices of products have increased due to the shortage of farm products and its decline in production, all due to CC, there are major food crises around the world due to food scarcity. Global food security always relies on both sufficient food production and access to nutritious food that would meet the human body's need for a healthy and sound life. (FAO, 1996).

Food is produced globally to meet human need, yet more than 10% are undernourished and do not receive the right amount of nutrients that is required in every diet (World Bank Group, 2023). In recent times we can pin-point to the fact that prices of farm products across the globe have increased, which is the prices at which the goods are sold, and a decrease in the food production system due to CC has become a concerning issue across the globe (World Bank Group, 2023). The water required for food production has become scarce and there is intense drought in the northern part of some African countries.

Most of the land in some regions has become unsuitable for agricultural production and those that are suitable have become naturally competitive since the demand has increased. Extreme weather conditions and extremely intense drought are also known to be the result of CC. The scarcity of water can lead to less production of farm products (Edwige, 2021).

a) Effects of climate change on the soil

There is a direct link between the impact of CC and soil functionality. The consequences of climate change are anticipated primarily through the increase in temperature and the general increase in CO2. Soil forms and properties that can reestablish the richness and efficiency of soil are anticipated to be influenced by climate generally through increments in temperature and carbon dioxide levels. Climate change is altering the distribution of plants and animals and simultaneously impacting interactions in living organisms (van der Putten, 2012). Natural communities are complex and composed of life forms with exceptionally distinctive life history characteristics, warm resistances, and dispersal capacity. Additionally, interactions between community members can be beneficial, pathogenic, or have little or no functional impact and these interactions can change with environmental stress (Vandenkoomhuyse et al., 2015). Numerous studies have shown that shifts in species interaction in response to climate change cascade to alter biodiversity and the function of terrestrial ecosystems (Gottfried et al., 2012). Living organisms found in soil organisms interrelate with each other in a multitude of ways to shape and maintain ecosystem properties. In fact, soil microbial interaction with each other, as well as with plants, can shape landscape patterns of plant and animal abundances, diversity, and composition (van der Putten et al., 2013). Plant microbial interactions are considered negative when the net effect of all soil organisms, including pathogens, symbiotic mutualists, and decomposers decreases plant performance, while interactions are considered positive when the benefits brought about by the soil community upgrade plant performance such as biomass production and survival. Plant development is directly linked to the accessibility of water, and critical soil forms are decided by a few soil properties counting porosity (Mondal,2021), field capacity, lower limit of plant available water, plant available water capacity, macropore flow (Jarvis, 2007). The dispersion and accessibility of soil water has a great direct impact on CC, when it comes to intense and variable rain or drought. Infiltration rate is a key factor in determining both soil water availability and its ability to retain its nutrients, which in turn impacts the ecosystem's ability to work properly (Mondal, 2021).

b) Impacts of climate change on livestock

The issue of global food security is a significant topic of discussion around the world. Livestock products play a crucial role in this, providing 17% of the world's kilocalories and 33% of protein intake (Rosegrant et al., 2009). The livestock industry supports the livelihoods of 1 billion of the poorest people in the world and employs approximately 1.1 billion people (Hurst et al., 2005). The demand for livestock products is on the rise and its rapid expansion in developing nations has been termed the 'livestock revolution' (Wright et al., 2012). Milk production is expected to increase in 2006 by 664 tonnes and an additional 413 by 2050, and we would have prices of meat production increasing from 258 to 455 million during the stipulated period of time (Alexandratos and Bruinsma, 2012).

Climate change is expected to affect both the volume and quality of animal feed, intensify heat and water stress, accelerate the spread of livestock diseases and vectors, and accelerate the loss of biodiversity and livelihoods (Thornton et al., 2009). Changes in the composition of legumes and grasses affect the quality and quantity of feed. The quality of pasture is influenced by alterations in the concentrations of water-soluble carbohydrates in given dry matter yields (Hopkins and Del Prado, 2007). Rising average temperatures lead to significant changes in rangeland species, composition, patterns, and biome distribution (Hanson et al., 1993). These changes alter the dynamics of competition between species and the compositions of mixed grasslands, resulting in changes in livestock productivity. However, Thornton et al. (2007) suggest that increased temperatures often favor the growth of forbs and legumes over grasses. They argue that higher temperatures often lead to lignification of plant tissues, reducing plant digestibility. The formation of lignin in plant cell walls can ultimately reduce the availability of nutrients for animals. Without addressing the adverse impacts of climate change on livestock production, food insecurity will persist and become more severe in the future. Previous research has identified heat stress and humid conditions as the main deterrents in livestock production. Heat stress is often associated with mortality, reduced growth, and reproduction (SCA, 1990). Sirohi and Michaelowa (2007) assert that increased heat leads to reduced feed intake, and behavioral and metabolic changes in livestock.

The need to improve livestock breeding to increase resistance to high temperatures and diseases is emphasized by Mader and Davis (2004), who affirm that locally adapted livestock may be tolerant to disease and excessive heat. King et al. (2006) suggested that changing climate can result in reduced livestock feed intake, leading to a decrease in animal fertility, general fitness, and longevity, aspects supported by Aydinalp and Cresser (2008). Marcoux (1998) highlights the importance of gender mainstreaming and how poverty and gender determine adaptive response options to the changing climate among livestock. A gender-based approach to understanding the impact of climate change is not new in development and climate research (Meinzen-Dick et al., 2014). Increased temperatures may also necessitate the spread of pathogens or parasites that are harmful to livestock, including animal herders (Harvell et al., 2002). WHO (1996) supports this claim and points out that parasites and pathogens are sensitive to temperature, moist or dry conditions, resulting in pathogens multiplying or decreasing in numbers. Reilly et al. (1996) maintain that there is limited documentation on appropriate intervention measures in dealing with the impact of climate change in the livestock sector. Appropriate intervention measures such as diversification of livestock and the use of indigenous knowledge are among adaptation measures that can be used for sustainable livestock production. Romanini et al. (2008) emphasized the need for studies focusing on adaptation to climate change in livestock production to formulate effective policies. Gbetibouo's (2009) research on small-scale farmers and adaptation to climate change in the Limpopo River Basin in South Africa highlighted the use of indigenous knowledge as an adaptation measure. In Africa, livestock often rely on their Indigenous Knowledge Systems (IKS) to adapt to climate change (Nyong et al., 2007). Indigenous or traditional knowledge is wisdom accumulated over generations (Agrawal, 2003). IKS have demonstrated potential to improve livestock production through the use of appropriate local adaptation measures (Joshua et al., 2012). Liu et al. (2008) underscored the need for appropriate adaptation strategies, such as improved irrigation, livestock breeding, and access to extension services and markets, to ensure sustainable livestock production. As mentioned above, changes in rainfall and temperature could increase vectors of livestock diseases (midges, flies, ticks, mosquitoes and tsetse). Romanini et al. (2008) warned that climate change could lead to ecosystem alterations, biodiversity loss, and exposure of species to pathogens and vectors that can harm livestock and humans.

Thornton et al. (2006) identified rangeland-based arid-semi-arid and mixed rain-fed arid-semi-arid systems as the most vulnerable to climate change in Africa. They found that existing adaptation practices might not be sufficient to mitigate the adverse effects of future climate on livestock. Patz et al. (2005) suggested livestock diversification and intensification and integrated pasture management as effective adaptation measures. They concluded that investing in research for improved livestock breeding could be beneficial for adapting to future climates. To maintain sustainable livestock production, it is crucial to implement appropriate intervention measures that ensure ongoing genetic breeding and improvement to produce efficient livestock under climate change. For example, locally adapted livestock can be resistant to drought, disease, heat, and can produce high milk yields and high reproduction rates. To achieve this, it is essential to correlate breeds and genes of livestock with the surrounding environment to identify animal species that can adapt to changing climatic conditions (Seré et al., 2008).

c) Effect of Climate Change on forage biomass

The climate is changing around the world, mainly due to anthropogenic activities (Hatfield et al., 2011). Due to changes in the quantity and quality of forage, livestock are affected by climate change both directly and indirectly (Giridhar & Anandan, 2015). Fundamental indicators of climate change, such as increased mean temperatures, changes in precipitation patterns, and floods that occur more often, are activated by land use changes (Hopkins and Del Prado, 2007). Climate change affects grasslands by varying the composition of pastures (e.g., changes in the ratio of grasses to legumes), changing grass growth and quality, and modifying precipitation occurrence (Giridhar and Samireddypalle, 2015). At extreme temperatures, plant species lose a lot of moisture affecting forage quality and quantity. Furthermore, as a result of changes in crop production during drought, it has become a problem for animals that depend on different grains and their by-products. Increases in atmospheric carbon dioxide may increase pasture productivity; however, they decrease their quality. Intense CO2 has led to a reduction in the quality of forage found in pasturelands, livestock also need quality forage in other areas to grow well (Giridhar and Samireddypalle, 2015). Moist conditions may increase the prevalence of parasites and diseases that severely affect livestock production. Effect of climate change has shown in particular in primary feed production, especially in developing countries. In the coming decades, fodder production is expected to face warmer temperatures, a higher concentration of atmospheric carbon dioxide, and a shortage of safe water availability (Giridhar and Samireddypalle, 2015). An increase in global temperatures by 1.8 to 2.3 degrees Celsius may be beneficial for overall food production, but in dry and hot areas it has a negative effect on production, due to increased evapotranspiration. Physiological and productivity responses to elevated atmospheric carbon dioxide concentration, temperature stress, and aridity can differ markedly between plant species, particularly between C3 and C4 species. Giridhar and Samireddypalle (2015) postulated that elevated atmospheric carbon dioxide could promote the accumulation of dry matter in C3 and C4 species. The assertion has been confirmed by authors, including Ward et al. (1999) and Liu et al. (2014), who observed enhanced photosynthesis and growth in the mesic Abutilon Theophrastus (C3) and Amaranthus retroflexes (C4) under elevated carbon dioxide concentrations, but without water stress.

d) Effects of climate change on water for livestock

Water is a critical element that illustrates the effects of climate change on the ecosystem, livelihoods, and various other productive aspects of the planet. Climate change affects water demand, availability, and quality. Alterations in temperature and weather patterns can influence the quality, quantity, and distribution of rainfall, snowmelt, river flow, and groundwater (IPCC, 2007). Currently, many developing countries are grappling with water stress. If water management is not adequate, it could jeopardize poverty alleviation programs and sustainable development in economic, social, and environmental aspects. According to Thornton et al. (2008), water scarcity is also known to be one of the major crises facing humanity and it is estimated that over a billion people would be affected in the coming future. This will affect the number of pastures that would be harvested for the animals and the feeding system.

Animal physiological processes are greatly impacted by water scarcity, leading to weight loss, reduced reproductive rates, and decreased resistance to diseases (Barbour et al., 2005). Trypan tolerance, an adaptive trait that has evolved over millennia in the subhumid zones of West Africa, could be lost, thereby leading to a higher risk of disease in the future. Water scarcity and irregular rainfall are common characteristics in arid and semi-arid environments. Along with limited access to water, the availability of feed and feed is also reduced in these regions.

1.2.3. Climate Change and Water Scarcity

Water scarcity poses a significant challenge in livestock production, as all living organisms require water to survive. As climate change reduces precipitation, surface water bodies become insufficient to meet the required water needs, leading people to resort to groundwater sources. The over pumping and depletion of groundwater contribute to the problem of water scarcity. During severe droughts, most of the water bodies dry up, forcing pastoralists in such areas to migrate long distances in search of water. Some of these water bodies become polluted due to the large number of animals that depend on them. Outbreaks and the spread of infectious diseases are common during such periods.

Among the environmental factors that affect animals, heat stress is a major factor that makes animal production challenging in many parts of the world (Giridhar & Anandan, 2015; Sejian et al., 2018). While animals can adapt to climatic stressors, response mechanisms that ensure survival can also be detrimental to their performance. The susceptibility of livestock to heat stress varies according to species, genetic potential, life stage, management or production system, and nutritional status (Giridhar & Anandan, 2015; Das et al., 2016). Furthermore, under challenging environmental conditions, animal productivity is affected, resulting in economic losses for the livestock industries. Therefore, it is crucial to make efforts to understand the adaptive responses of domestic livestock (Giridhar & Anandan, 2015).

Agriculture is the primary economic activity in most African countries, with a high number of people who depend solely on the agricultural sector for their livelihood. (OECD, 2009). Crop farming is generally considered subsistence and rainfed. Due to CC, the rainfall pattern has changed, the amount of fall has reduced over the period of time, and this has impacted the quality and quality of farm crop products. climate change has actually made Africa countries vulnerable (Giridhar & Anandan, 2015). The vulnerability of the region is further exacerbated by the fact that the climate is already too hot, given its tropical nature (Akinnagbe and Irohibe, 2018).

1.2.3.1. Animal nutrition

The water bodies dry up because of climate change which leads to highly intense drought which has an adverse effect on the feed supplies required to feed the animals. Lignification of the grass occurs when there is a highly intense drought, which slows down digestion in the animals. The average amount of food the animals would take during this period would be less as a result of the high intensity of the drought. The water the animals take during this period has also increased. The various physiological functions of the animals have changed, as have the reproductive and productive efficiency altered as a result of CC (Nardone et al., 2010). Livestock requires different types of nutrients to grow properly, which changes depending on the geographical location (Thornton et al., 2009). If the nutritional needs of the animals are not met during the heat stress, it affects how their digestive and metabolism work, which is considered to be an adverse effect (Mader, 2003). Sodium and potassium insufficiency during warm stretch can cause metabolic alkalosis in dairy cattle, and also lead to increased respiration rates. (chase,2012).

1.2.3.2. Animal health

Water is required in every living thing, including livestock, by maintaining body fluids and adequate ion balance, digest, absorb, and metabolize nutrients, it also helps to eliminate waste material and excess heat from the body. livestock, such as cattle, consume water in larger quantities. Thus, the availability and quality of water to livestock is critical for animal health and productivity. Animals physiologically are greatly impacted by water dehydration, leading to weight loss of the animals, low reproductive rate, and low resistance to diseases (Barbour et al., 2005). Animals who do not have enough drinking water may suffer from stress from dehydration, which can result in weight loss, skin tightness, dryness of the mucous membranes and eyes. When livestock are exposed to high temperatures, it has an adverse effect on protein and fat metabolism. Some pathogens and disease-causing organisms thrive in harsh climatic conditions, leading mainly to an increase in diseases, and contagious diseases spread faster in hot climatic conditions.

1.2.3.3. Animals' productivity and reproduction

Heat stress is known to be one of the repercussion effects of extremely hot climatic weather conditions on livestock that impede their reproduction. It is known to be one of the major reasons for the low productivity in the dairy and cattle industry (Nardone et al., 2010), with considerable economic consequences. The US livestock industry has a loss of between 1.69 and 2.36 billion dollars per year due to heat stress, with the dairy industry accounting for half of the total of stipulated amount (St-Pierre et al., 2003).

High-producing dairy cows produce more metabolic heat than low-producing dairy cows. As a result, high-producing dairy are more abrasively affected by heat stress. When metabolic heat output increases alongside heat stress, milk production falls (Berman 2005). Heat stress also adversely impacts sheep, goat and buffalo milk production (Finocchiaro et al.2005). Heat stress also affects the quantity and composition of goat milk. In warm seasons, the nursing goat is intrinsically triggered to reduce water loss. During seasons where there are limited water supplies, this mechanism reduces water loss in urine in the other way to favor of milk production of the goat (Olsson and Dahlborn, 1989). An increase in temperature alters the heart, respiration rate, and also its rectal temperature, and it also has an adverse effect on the buffalo's ability to produce milk (Rojas-Downing et al., 2017; Seerapu et al., 2015). However, due to this ability of the llivestock to tolerate heat and the decreased demand for their milk, these livestock have received less attention in recent times (Nardone et al., 2010). In the context of meat production, heavier, darker, and thicker coated beef cattle are more vulnerable to heat (Nardone et al., 2010). Ruminant body size, carcass weight, and fat thickness can all decrease because of global warming (Mitloehner et al., 2001). heat stress has a negative impact on animal reproduction efficiency in both sexes. According to Barati et al. (2008), oocyte development and quality are affected by heat stress. Additionally, it inhibits the rate of reproduction and embryo development (Hansen, 2007). Research has indicated that heat stress in bulls can result in a decrease in the quantity and quality of sperm.

1.2.4. Perception of Climate Change

Farmers and pastoralists depend heavily on rainfall for agriculture growth and cattle rearing. agriculture is known to be the backbone of Ghana's economy. (Fosu-Mensah et al., 2012). Farmers have perceived that there is a significant change in the CC (Limantol et al., 2016). In the district of Sekyedumase over 92% of the farmers perceive that there has been a CC after an interview was conducted, they also stated that over 80% of the farmers perceive a decline in the precipitation (Fosu-Mensah et al., 2012). There have been changes in rainfall patterns, duration and intensity of the rainfall have also changed which poses a great impact on agricultural production (Limantol et al., 2016).

Research shows that there is a strong correlation between the observed climate trends and the perceptions of pastoralists. Since the 1970s, they've reported significant changes in their local environment, including a substantial decline in yearly rainfall and a rise in both temperature and the frequency of droughts and strong winds (Snaibi et al., 2021). It was also shown that pastoralists who have amassed wealth will tend to employ more strategic adaptation practices while low-income pastoralists employ a weaker strategy. CC adaptation practices are mostly tagged/influenced by the level of education, household size, herd size, level of training, and agroecological setting among others (Snaibi et al., 2021). A community's understanding of its environment (perceptions), the adjustments it makes in response (adaptations), and its social and economic background (socioeconomics) are all intricately linked (Snaibi et al., 2021).

These changes in the rainfall pattern have made most of the farmers adopt another source of feeding their animals, by providing supplementary feed. A farmer's understanding of climate change shapes their adaptation choices, ultimately affecting their support for mitigation efforts through financial contributions (Acquah et al., 2015). Gbetibouo (2009) observed that fertile soil and access to water for irrigation decrease the likelihood that farmers will perceive climate change. Adaptation and CC perception can be influenced by a couple of other things such as age, level of education, access to credit, access to extension services, and grants from government and NGOs' this would influence the farmers/pastoralists' ability to how early they perceive the changes and how they plan to adopt (Acquah et al., 2015).

In Burkina Faso which is very close to the Northern Region of Ghana, studies show that the farmers were not that aware of the CC especially of the temperature changes, and rainfall patterns (Zampaligré et al., 2013). The most mentioned adaptation strategies provided by the farmers were diversifying crops, integrating farming and livestock practices, and employing water conservation techniques like rainwater harvesting (Zampaligré et al., 2013).

1.2.5. Climate Change Adaptation

Climate change is currently affecting everything in the ecosystems and species are greatly impacted by it (Mawdsley et al., 2009; Gitay et al., 2002). There are many activities being done to mitigate its impact but, as of now, its adverse effect is felt more than it good around the world , despite all the efforts to predict the effect of CC (Mawdsley et al., 2009; Hanner et al., 2002). These methods are called "adaptation strategies" in the rapidly developing conversation on CC research and policy (Rojas-Downing et al., 2017). For more than two centuries, biologists have referred to the term 'adaption' as the evolutionary process that a population organism undergoes over time in response to other organisms and their physical surroundings (Mawdsley et al., 2009).

Extreme weather conditions and farmers using the same plot of land over a period have made the quality of the soil deplete over a period, which is linked to food security in Africa. Recent research indicated that an alarming concern of CC poses a high alert of the world not being able to produce more food to feed the population (Fagariba et al., 2018; Mabe et al., 2014). As disruptions to weather patterns and extreme weather events threaten agricultural yields, jeopardizing global food security. When farmers face a combination of harsh weather, depleted soil nutrients, and outdated agricultural methods, their ability to produce crops effectively suffers greatly. This, in turn, makes both farmers and their families more susceptible to hardship. Developed countries tend to invest largely in researching areas to combat climate change, but most African countries are still lacking in that area which has become a hindrance to agricultural growth and development in bridging the barrier to tackle climate change (Fagariba et al., 2018; Antwi-Agyei et al., 2012).

a) Climate change adaptation around the world

Climate change adaptation is increasingly being discussed in policy discussions. Adaptation is covered in a variety of UNFCCC and Kyoto Protocol articles. Considering the alarming risks linked to CC, there must be a process that must be taken to identify and adopt this CC. Intervention is therefore needed to adapt to the full capacity or the ability to adapt to new or changing conditions without becoming more exposed. Adaptation analogies in the former are accompanied by policy and social science research on the present adaptable capacities of governments, civic society, and markets to deal with climate agitations. The economic costs of future modifications are computed by comparing the monetary losses linked to different scenarios of technological application and distribution. A significant difficulty for these methodologies is the identification of workable modifications in poor countries where physical vulnerability persists. Therefore, even in successful projects such as large-scale irrigation and infrastructure projects or local resource management strategies, there will always be winners and losers. Prioritizing the distinction between the adaptation being tried and the interests of the various stakeholders involved is crucial. People have clearly adapted to shifting climatic circumstances throughout human history and will undoubtedly continue to do so because these conditions are only one facet of the greater environmental context in which humans exist. As a result, communities and individuals are vulnerable to the consequences of climate change, as well as to other factors, and this vulnerability can spur the management of adaptable resources. Adaptation occurs on multiple geographical scales and social agents. People adapt to climate hazards in various ways and these adaptations are sometimes triggered by individual extreme events (Ribot et al., 1996). On behalf of society, governments carry out supplementary adjustments; these are typically carried out in reaction to events, although they are occasionally carried out in advance of change. Scenarios from climate model experiments are compared with historical climate change analogies to gain insight into adaptation. By applying the analog technique, one can look at detailed case studies of past reactions to extremes in climate or variability, or contemporary patterns of behavior in regions with climate conditions like those that might arise in the area of interest. The goal is to determine how people and institutions respond and prepare for the risks associated with climate variability, as well as how policy has affected these reactions. To investigate the implications and responses to future climate change and identify the critical components that determine successful adaptation in the future, it is imperative to have a thorough understanding of the current impact and response to climate variability at all levels of social organization. The high levels of variability of interannual rainfall in Africa and its effects on water resources are examples of how climate, environment, and society interact. One widely acknowledged limitation of the analog approach to assessing climate change is the expectation of significant differences between past and future climate variability, especially with regard to the rate and magnitude of changes. However, in many places in Africa, the observed fluctuations in rainfall exceed the changes that climate models project to occur over the next 50 to 100 years (Hulme, 1998).

Adaptation techniques in confined livestock systems that can reduce heat stress caused by climate change are used in areas where animals are mostly kept in what are known as industrial systems (Gerber et al., 2013). These systems include things like well-insulated buildings, high livestock densities, and mechanical ventilation systems. Improved mechanical ventilation/regimes, additional cooling/heating systems, changes in stocking density, heat tolerant lines / strains (using genetic selection/genomic approaches), and feeding strategies are a few examples of these adaptation measures.

The average capacity of an agricultural system to adapt to climate change increases with diversification. Instead of focusing the farm on a single form of production, integrated systems combine crops, livestock, and forest into one of four combinations. The Brazilian Agricultural Research Corporation opted that the combined farming system would be able to produce fiber, timber, non-timber, and food in the same area if it was placed in crop rotation. This practice system would help improve the resilience of the farm, i.e., farm, i.e. by providing more water, lowering the local temperature and increasing it. increasing it. The harsh climatic weather conditions against animals and farm crops tend to be reduced, which would decrease soil erosion, help improve productivity, and positively impact farmers in being able to produce more, sell more, and increase family income and livelihood. In Brazil, to improve soil quality, farmers plant native pals in pastures which would serve as a source of shade for grazing animals, according to INOCAS. This type of system ends up creating more revenue in the long run, the soil quality also improves cattle during the extreme temperature. Others have restored degraded pasturelands as a means of adapting to changing climate. Because degraded land is more likely to be eroded, it retains less moisture and has less nutrient-rich feed for animals. One of the ways for farmers to restore degraded pasture is by applying fertilizer, but they are not the most sustained practice because the farmers would have to reapply them again after a maximum of 5 years. The installation of trees is known to be one of the best ways to restore degraded land. One of the ways that can help create more environmentally friendly methods of animal husbandry is known to be rehabilitating pastures. Planting trees is known to be one of the best ways to restore degraded pastures, which also has positive effects on climate adaptation; it would help increase air humidity and decrease heatwaves and droughts.

b) Factors Influencing Climate Change Adaptations

Climate change affect farmers all over the world and farmers from sub-Saharan African (SSA) are no exception. (Trenberth et al. (2015) posited that climate change is a new normal, and they would have to cope with it. In the face of an ever-increasing population, anthropogenic activities contribute to climate change (Mwinkom et al., 2021). Research shows that agricultural policies in Africa are inadequate to mitigate climate change largely due to poor agricultural policies, inadequate technologies, and corruption (Mwinkom et al., 2021). In addition to CC extreme African countries are more known to face limitations in education, access to financing and not investing much in research and development programs (UNFCCC, 2007). Climate projections from existing data have shown that prolonged and more intense droughts are likely to cause intense dryness in SSA by 2040 (Boyd et al., 2013). Other studies have revealed that choosing the appropriate adaptation strategies for the unpredictability of CC in SSA is challenging due to the various biophysical barriers related to geographical location. (Thomas et al., 2007). Climate change has an extreme heat effect and extreme drought, with pests supposedly being handled by the known adaptation strategies (Mwinkom et al., 2021). knowing that there is no complete or valid certainty on CC but out of that uncertainty can bring about the solution (Mwinkom et al., 2021). Furthermore, studies have revealed a significant change in temperature in West Africa between 0.5 degrees Celsius and 0.9 degrees Celsius between 1990 and 2010 and predicted an increase in this magnitude by 2050 (Sissoko et al., 2011). In Ghana, a related study by the World Bank (2010) based on a downscaled climate scenario revealed projected temperature trends spanning 2010 to 2050 showed warming entirely in Ghana with specifically peaking temperatures for the Northern, Upper West, and Upper East regions, and further projected the temperature rise ranging 2.1 to 2.4 degrees Celsius by 2050. Studies conducted in northern Ghana have shown the severity of CC in that region from December to March, pastoralists encounter many changes in how to feed their animals because during that season grasses become completely dry (Mwinkom et al., 2021), This decline in climate suitability has severely impacted agricultural production in northern Ghana. The area is known to be responsible for nearly half of the nation's legume and grain production over the past two decades; this region now contributes less than a quarter (Mwinkom et al., 2021). The application of fertilizers to reduce the detrimental effects of climate change in the region has not shown satisfactory results.

1.3. Conceptual Framework

Climate change and its effects are obvious challenges for northern Ghana. Pastoralists are struggling with different ways to adapt and manage their livestock during periods of harsh weather conditions brought about by climate change. This research focuses on identifying the adaptation strategies used by pastoralists during harsh or unfavorable weather conditions. Our study also analyzes pastoralists' knowledge about climate. The knowledge of climate change, considering the causes, recent impacts and perceived or expected damages in the future, coherently determines the response to climate change (CC). Finally, we examine the drivers of farmers' adoption of CC adaptation strategies using multivariate logit regression. We assume that a farmer's decision to adopt an adaptation strategy is influenced by farmer and farm specific factors as well as institutional drivers (see Figure 1).

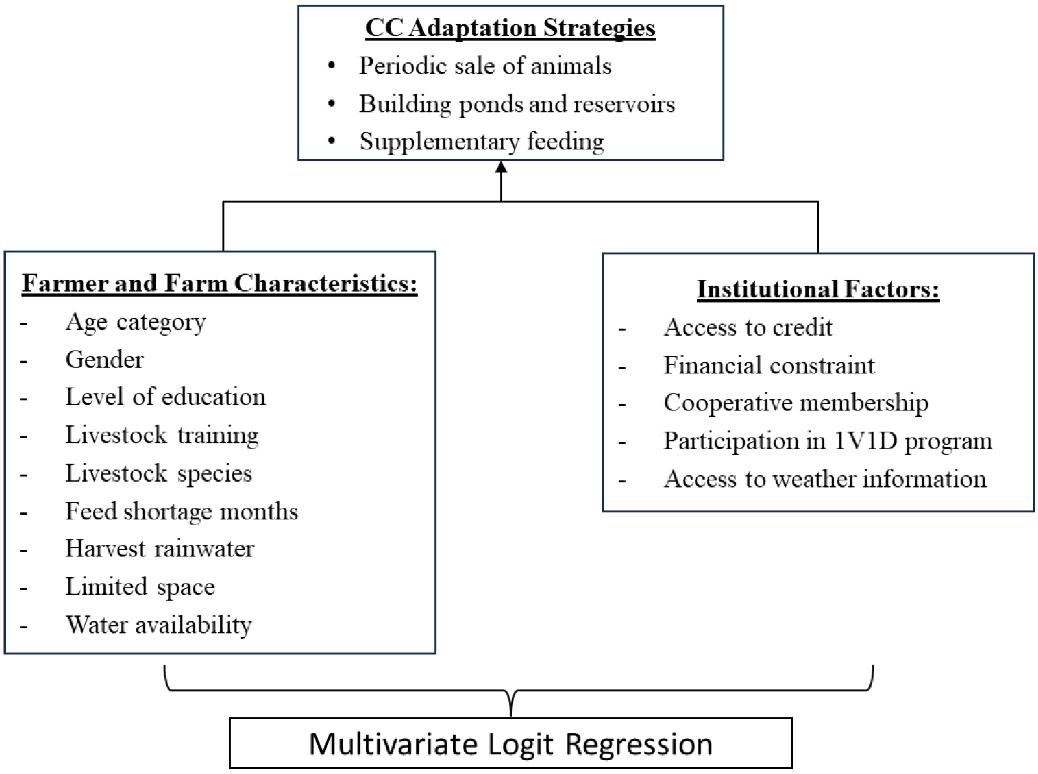

Figure 1: Conceptual framework on the drivers of farmers' adoption of CC adaptation strategies

We captured specific local factors in our model, such as access to the One Village One Dam (1V1D) program and data on months of fodder shortage due to severe CC impacts. This helps to capture the impact of access to free water provided by the government (1V1D) and feed shortages on a herder's decision to adopt specific strategies.

2. AIMS OF THE STUDY

The overall objective of the study is to determine pastoralists' knowledge of CC, the adaptation strategies they practice, and the drivers of CC adaptation strategies among pastoralists in northern Ghana. The specific objectives are to:

1. Determine farmers’ perception about climate change’s impact on pastoral farming.
2. Determine the climate change adaptation strategies of farmers in area.
3. Determine the factors that affect the adaptation practices (periodic sale of animals, building of ponds, and supplementary feeding).

2.1. Study Hypothesis

H1: Harvest of rainwater has a significant effect on pastoralist decision to adopt CC adaptation strategies.

H2: Participation in a public water program, i.e., 1 village and 1 dam, will have statistically significant effect on farmers’ choice of adaptation strategy (building of ponds and reservoirs).

H3: Scarcity of feed will have statistically significant effect on farmers’ adoption of CC adaptation strategy (periodic sale of animals).

3. METHODOLOGY

3.1. Data Collection

3.1.1. Primary data

The primary data was collected using a semi-structured questionnaire. The questionnaire was carefully developed based on literature and the study objectives. To allow a profound insight into the characteristics, impacts and practice of CC adaptation strategies, the questionnaire was divided into four categories with a total of 52 questions of various nature (Likert scale, dichotomous, continuous, etc.). They were categorized into farmers, farms, institutional, behavioral/perceptual characteristics, and water access.

A. ***Characteristics of farmers:*** age, experience, education and training, animal species (type).

B. ***Characteristics of farm:*** land ownership, animal production system, status of rangeland forage during drought.

C. ***Institutional Characteristics:*** access to one village one dam program, access to weather information, access to extension services, access to credit facilities, cooperative membership.

D. ***Behavior perception of CC and water access:*** temperature changes, rainfall patterns, livestock pests and diseases, livestock response to treatment, livestock productivity, and adaptation practices.

The questionnaire was developed in English but administered in the local dialect of the study area. It was also piloted and revised before the start of data collection through personal contact with some executive members of the farmer association in the study area to ensure clarity of the tool. We had key informant interviews with four experienced farmers to improve our knowledge of the target population. The feedback from the interview with the farmers further informed us of the changes we made in the questionnaire. The enumerators were trained considering the knowledge of the target population and the intended results.

Kobo toolbox was mainly used in data collection. The questionnaires were therefore deployed in the Kobo collect software for the respondents to offer their responses. The hard copies of the survey questionnaire were used at some points of data collection when soft copies were not accessible due to technical challenges.

3.1.2. Sample Selection

A multi-stage sampling technique was used for the study where cattle farmers who are members of the association were sampled and interviewed. First, the study area was selected purposively as an area where pastoralist are based. Second, settlements and farmers were selected purposively and using a snowball sampling. The study was conducted in Northern region of Ghana, specifically in the Nanumba North and South Districts, from November 2023 to January 2024. Nanumba North Municipal District can be found in the eastern part of the Northern region of Ghana. Both cattle farmers who belong and do not belong to the cooperative organization were selected for interview based on convenience. Small ruminants' farmers (sheep and goats) were also sampled and interviewed based on convenience. Snowball sampling technique was also where some executive members of the cattle farmers association referred us to a nearby village which had several pastoralists (cattle, sheep and goats) farmers. A total of 218 respondents were interviewed for this research.

The study could not adopt the random sampling for the entire sample because of the absence of a complete list of all pastoral farmers in the targeted study area as well as their inaccessibility.

3.2 Study Area

Northern Ghana made up the Northern, Upper East, Upper West regions as well as the Savanna, and North East regions, are considered the livestock hub for the country (Dei et al. 2007). The area is well known for producing sheep (30%), goats (35%), and cattle (70%). Therefore, pastoralism is a very common practice in the northern regions of Ghana. The study was conducted in Northern region of Ghana, specifically in the Nanumba North and South Districts. Nanumba North Municipal District can be found in the eastern part of the Northern region of Ghana. Geographically, the district is located between the latitude 8.5 and 9.25 N and longitude 0.57 E and 0.5 W and spans an area of 1,986 square kilometers. The district lies in the tropical climatic zone which is characterized by high temperatures almost throughout the year. Recently, rainfall patterns have altered and become unpredictable and the average temperature has increased tremendously. Temperatures range from 29 degree Celsius to 41 degrees Celsius with average annual rainfall of about 1,268 millimeters. The district experiences a long period of drought between November and March (Ministry of Food and Agriculture Ghana, 2021). The area experiences water scarcity during drought period. Natural dams and ponds become completely dry. These fluctuations in climate change coupled with the high livestock production, makes northern Ghana an ideal area for the study.

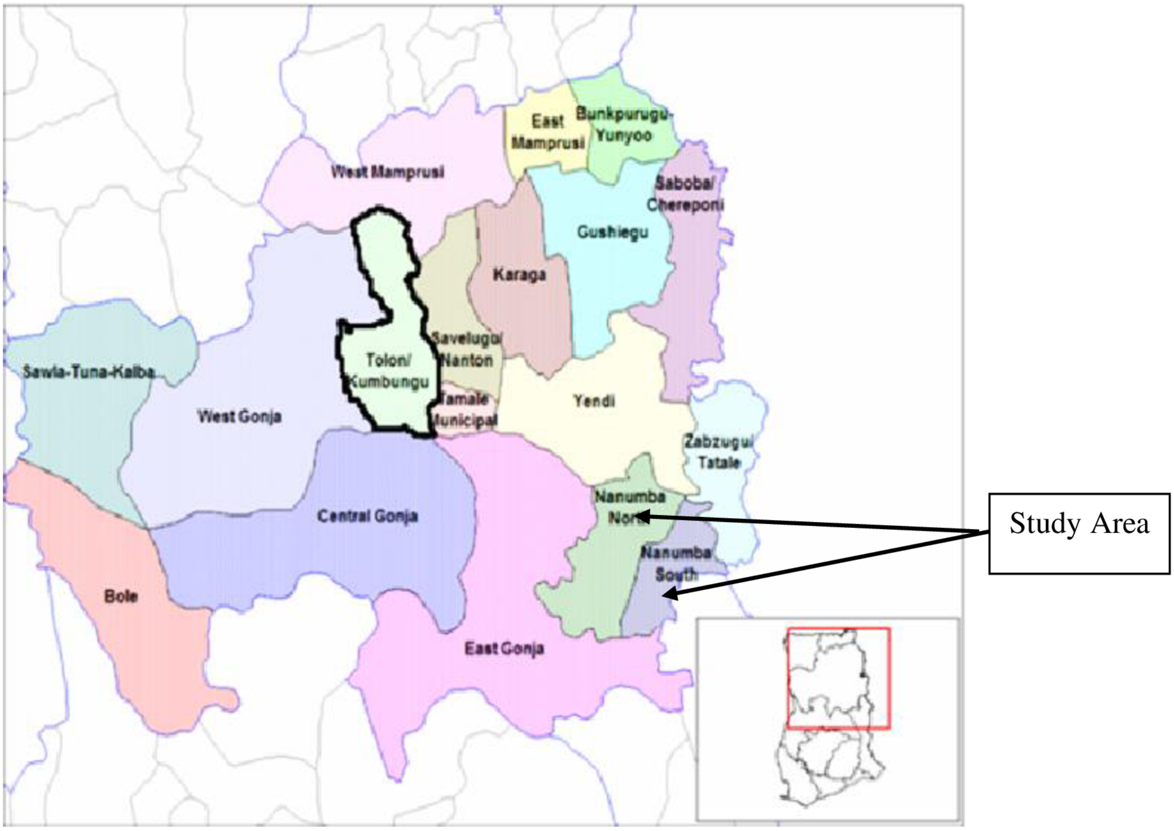

Figure 2: Map of the research area

Source: Quaye et al. (2009)

3.3. Data Analysis

3.3.1. Descriptive statistics

Sample characteristics and the used information sources were analyzed on a descriptive base. In addition, the impact of climate change on pastoralism and the factors affecting the adaptation practices were revealed by using descriptive statistics.

3.3.2. Multivariate logit regression model

We used the multivariate logit model to analyse our third objective. This analytical method helps us to use multiple CC adaptation strategies which may be correlated as dependent variables and carefully derived factors, backed by literature, as covariates to estimate any possible effects. A simple logistic regression model has a binary outcome and one predictor, a multiple or multivariable logistic regression model finds the equation that best predicts the success value of the π(x)=P (Y=1, X=x) binary response variable Y for the values of several X variables (predictors). As shown in equation 1, the β coefficient represents the amount of change in the logit (log-odds) per one-unit change in X (predictor) for a simple logistic regression model. A multivariate logit therefore has the form:

which gives the probabilities of outcome events given the covariate values $X_1, X_2, \ldots\ldots, X_n$, and

$$Logit[\pi(x)] = \log(\pi(x)/ 1 - \pi(x)) = \beta_0 + \beta_1 x \quad (1)$$

Instead, a multivariable or multiple logistic regression model would take the form:

$$\text{Log}(\pi_i /1 - \pi_i) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \text{I} + \beta_n X_n \quad (2)$$

where π(x) =P (Y=1, X=x) is a binary independent variable Y with two categories, X is a single predictor in the simple regression model, and $X_1, X_2, \ldots\ldots, X_n$ are the predictors in the multivariable model. However, there are situations when the categorical outcome variable has more than two levels (i.e., polytomous variable with more than two categories that may either be ordinal or nominal). Each of these model structures has a single outcome variable and one or more independent or predictor variables.

A multivariate logit regression model would have the form:

$$\text{Log}\left(\pi_{ij}/1- \pi_{ij}\right) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 \text{I} \ldots + \beta_n X_n + \alpha_i$$

where the relationships between multiple dependent variables measures of multiple repeated observations j within cluster i and a set of predictor variables (ie, Xs) are examined. For this equation, a random effect, α_i, is often assumed to follow a normal distribution with mean zero and constant variance (ie, αi ~ N (0, σ2 α).

The multivariate logit for this thesis takes the form:

$$\text{Log}\left(\pi_{ij}/1-\ \pi_{ij}\right) = \beta_0 + \beta_1 S_i + \beta_2 C_i + \beta_3 I_i + \alpha_i$$

where S_i is a vector of farmer factors; C_i represents a vector of farm characteristics; I_i is a vector of institutional variables. Our dependent variable is CC adaptation strategies which has three repeated observations, i.e., periodic sale of animals, building of ponds/reservoirs, supplementary feeding. The multiple dependent variables were measured as binary with a farmer having the option to choose more than 1 adaptation strategy.

3.4. Selection of variables

Table 1 presents the independent variables which had a significant influence on the adaptive practices of pastoral famers in northern Ghana. In addition, the three dependent variables used for the multivariate analyses have been presented in Table 1.

3.4.1. Description of independent variables

a) Farmer and farm variables

Variables with possible influence on CC adaptation strategies, such as gender, age, education, farm size, and farming experience, were included in our model to capture the farmer and farm characteristics on their choice of adaptation strategy. There is growing evidence that farmers and farm characteristics of farmers such as gender, age, education level and years of experience influence their decisions to adopt adaptation strategies (Trinh et al., 2018). In this study, we suggest that each of these factors plays a role in farmers' choice of adaptation strategies.

b) Institutional variables

This study examines the impact of three key variables on farmers' choice of adaptation strategy: access to credit, participation in the One Village One Dam (1V1D) program, and membership in farmer cooperatives. The literature clearly shows that farmers with access to publicly funded ponds/reservoirs such as the 1V1D, access to formal and informal credit, and membership in cooperatives are more likely to adopt CC adaptation practices (Vaughan et al., 2019).

c) Information source variables

The sources of information play a key role in the farmers' behavior towards adopting an adaptation practice, hence the need to include these variables in the analysis. Specifically, sources of information and receiving livestock production training) were included in our analysis. Both variables were measured dichotomously.

3.4.2. Description of Dependent Variables

The dependent variable for our multivariate logit regression is the adoption of adaptation strategies. Specifically, we selected 3 adaptation strategies from the list provided by the farmers - periodic sale of animals, building ponds and reservoirs, and supplementary feeding - to capture farmers' strategies for dealing with fodder and water scarcity. The dependent variables were measured dichotomously, taking 1 if a farmer practices the adaptation strategy and 0 if the farmer does not practice or adopts the strategy (see Table 1).

4. RESULTS

4.1. Sample Description

Table 1 presents the means and standard deviations of our variables. From the results, most of the respondents had up to basic education as shown by the mean level of education (2.21) – a little over 50% of the respondents had some form of formal education. Furthermore, Table 1 indicates that males tend to be the highest among the gender distribution that are into pastoralism – about 95% of the pastoralists were male. The results reveal a variation in age distribution, where just a single respondent falls into the age group 1- 20 years which means that almost all the respondents in the sample were above 20 years. The results again show that 84.5% of the pastoralists had some level of training in livestock production.

Additionally, 38.4% of the respondents indicated that they experience feed shortage yearly between January and March (severe harmattan period) compared to November and December when the rains have just subsided. A few of the pastoralists harvested rainwater (10.6%) during the rainy season. In addition, 43.6% of the farmers responded they have limited spaces for livestock farming whereas 67.9% had available water for farming. Regarding the institution factors, 22.9% of the respondents were members of farmer cooperatives. Moreover, 78.90% of the respondents had access to weather information. Only 0.9% of the respondents had access to credit facilities for farm improvement.

Table 1: Dependent and independent variables used for statistical analysis

Variables	Type	Mean	Std. Dev.
Dependent Variables			
Periodic sale of animals	Dichotomous: 1 = yes; 0 = no	0.908	0.289
Building of ponds/reservoirs	Dichotomous: 1 = yes; 0 = no	0.083	0.276
Supplementary feeding	Dichotomous: 1 = yes; 0 = no	0.720	0.450
Independent Variables			
Farmer/Farm variables			
Age category	Categorical: 1 = 1-20yrs, 2 = 21-30yrs, 3= 31-40yrs, 4 = 41-50yrs, 5=51-60yrs, 6= Above 60yrs	4.525	1.114
Gender	Dichotomous: 1 = male; 0 = female	0.951	0.191
Level of education	Ordinal/ 1= basic, 2= secondary, 3= vocational, 4= tertiary	2.210	1.197
Livestock training	Dichotomous: 1 = yes; 0 = no.	0.845	0.363
Livestock species	Dichotomous: 1 = large ruminants (cattle); 0 = Small ruminants (sheep and goats)	0.457	0.499
Feed shortage months	Dichotomous: 0 = Nov - Dec (less dry season period); 1 = Jan - Mar (dryer period)	0.384	0.487
Harvest of rainwater	Dichotomous: 1 = yes; 0 = no	0.106	0.308
Limited space	Dichotomous: 1 = yes; 0 = no	0.436	0.497
Water availability	Dichotomous: 1 = yes; 0 = no	0.679	0.468
Institutional variables			
Access to credit	Dichotomous: 1 = yes; 0 = no	0.009	0.096
Financial constraint	Dichotomous: 1 = yes; 0 = no	0.271	0.445
Cooperative membership	Dichotomous: 1 = yes; 0 = no	0.229	0.421
1V1D program	Dichotomous: 1 = yes; 0 = no	0.803	0.399
Weather information	Dichotomous: 1 = yes; 0 = no	0.789	0.409

In addition, less than 1% of the respondents have access to credit facilities for farm improvement and over 99% of the respondents' report that they do not have access to credit facilities. In addition, 22.9% of the respondents were members of farmer cooperatives while 78.90% responded that they had access to weather information. Only 0.9% of the respondents had access to credit facilities for farm improvement while 99% of the respondents claim to have no access to credit facilities. Our results again show that 80.3% of the pastoralists benefited from the One Village One Dam (1V1D) project - free dams provided by the government to rural communities in Northern Ghana. In terms of the three CC adaptation practices used as our dependent variables for the multivariate logit, over 90.8% of the farmers practiced periodic sale of animals as an adaptation strategy, 8.2% practiced building ponds/reservoirs, and 72% of the respondents practiced supplementary feeding.

Table 2 presents summary statistics on the livestock species kept by the farmers. Our results show that the most reared livestock (among goats, sheep and cattle) is cattle. From the results, 3924 cattle representing 48.5% were reared by the respondents while 2558 goats representing 31.5% and 1621 sheep representing 20% were reared by the 218 sampled pastoralists. During the survey, we observed that the farmers mainly practice semi-intensive farming (i.e. leaving the animals to forage during the day and providing shelter at night). This choice depended on financial constraints, limited space, water availability and feeding constraints. Regarding the three CC adaptation practices used as our dependent variables for the multivariate logit, over 90.8% of the farmers practiced periodic sale of animals as an adaptation strategy, 8.2% practiced building ponds/reservoirs, and 72% of the respondents practiced supplemental feeding.

Table 2: Summary statistics of livestock reared by all the farmers

Livestock Species	Number of Livestock	Percentage (%)
Goat	2558	31.5
Sheep	1621	20
Cattle	3924	48.5

4.2. Farmers' Perception about CC at their farm

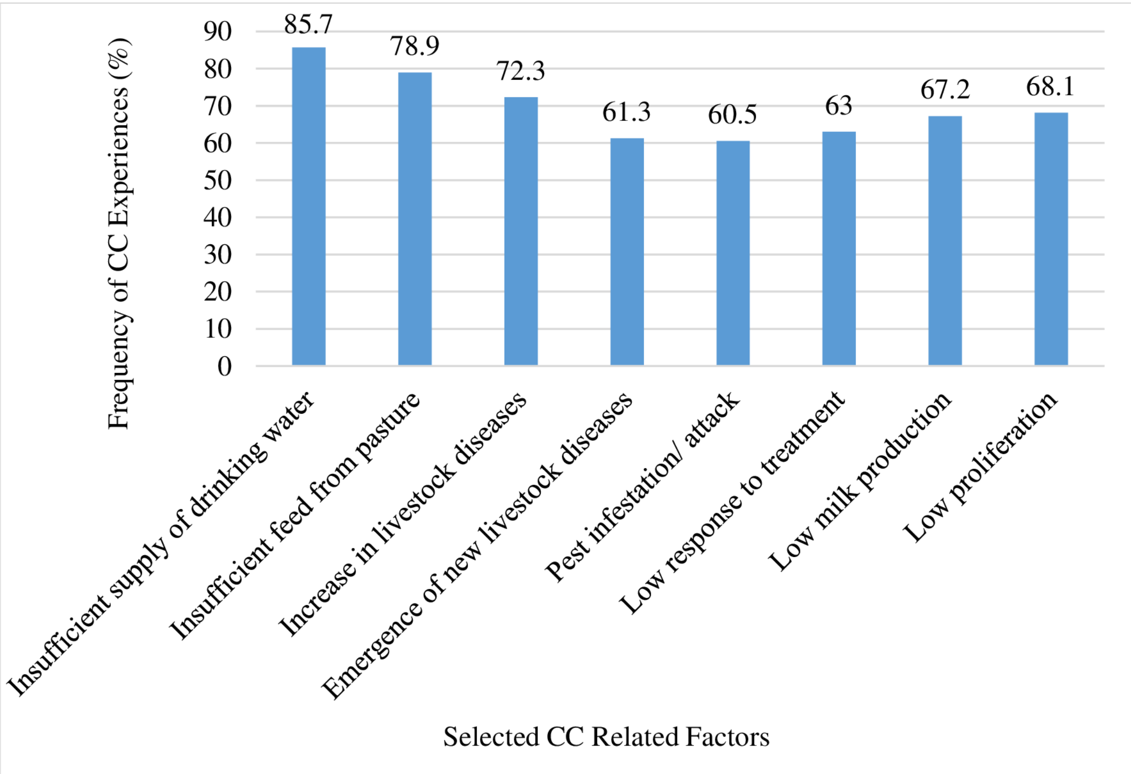

Figure 3: Farmers' experience/perception about features of CC at their farm

Source: Author's analysis

Pastoral farmers were asked to tell how frequently they experience the events in Figure 3 (i.e., features of climate change for pastoralists). From the results, 85.7% of the respondents agreed that they often experience insufficient supply of drinking water for their animals, especially during the harmattan season (November to mid-March). 78.9% of the respondents said that fodder from the pastures is insufficient for the animals during the harmattan period. Similarly, 72.3% of the respondents also noted that the climatic conditions during the harmattan period increase livestock diseases, while 61.3% of the respondents said that CC causes the emergence of new livestock diseases. Moreover, 60.5% of the respondents confirmed this statement. This result was corroborated by some farmers who verbally reported that CC causes pest infestation on both rangeland and livestock, especially during the harmattan season. In addition, 63% of the respondents claimed to have experienced low response of their livestock to treatment. In addition, 67.2% of the respondents had experienced low milk production because of CC while 68.1% of the respondents claimed to have experienced low reproduction. These results show that farmers have an above average level of knowledge summarizing the perception of farmers about the impact of CC on their livestock due to changes in climatic conditions.

4.3. Adaptation Strategies Practiced by Pastoralists

Figure 4 shows the adaptation strategies used by pastoralists. These strategies are well documented in the literature (Biggs et al. 2018; De Sousa et al. 2018). The results show that periodic sale of animals is a common adaptation strategy used by the pastoralists - 91.3% of the farmers from the sampled population (218) sell their livestock during periods of food and water scarcity (harmattan season). In addition, 72.1% of the farmers use supplementary feeding during the harmattan season when fodder is scarce. However, only 8.2% of the pastoralists practiced the building of ponds and reservoirs to complement water scarcity. The results further indicate that 20% of the farmers responded that they often switch to crop farming to raise capital to invest in their livestock farms. Similarly, 31.1% of the pastoralists move their livestock from the northern part of Ghana (study area) to the south in search of pasture. This is because the rains end earlier in the north (monomodal rainfall) compared to the southern and central zones (bimodal rainfall). In addition, 5.9% of pastoralists frequently change livestock species to adapt to disease outbreaks and feed and water shortages. In addition, 8.2% of the pastoralists indicated that they have changed to new breeds of cattle, sheep and goats recommended by the veterinary officers to be resistant to diseases and the hash climatic conditions. However, most pastoralists vaccinate their livestock (95%) to prevent diseases under the harsh climatic conditions.

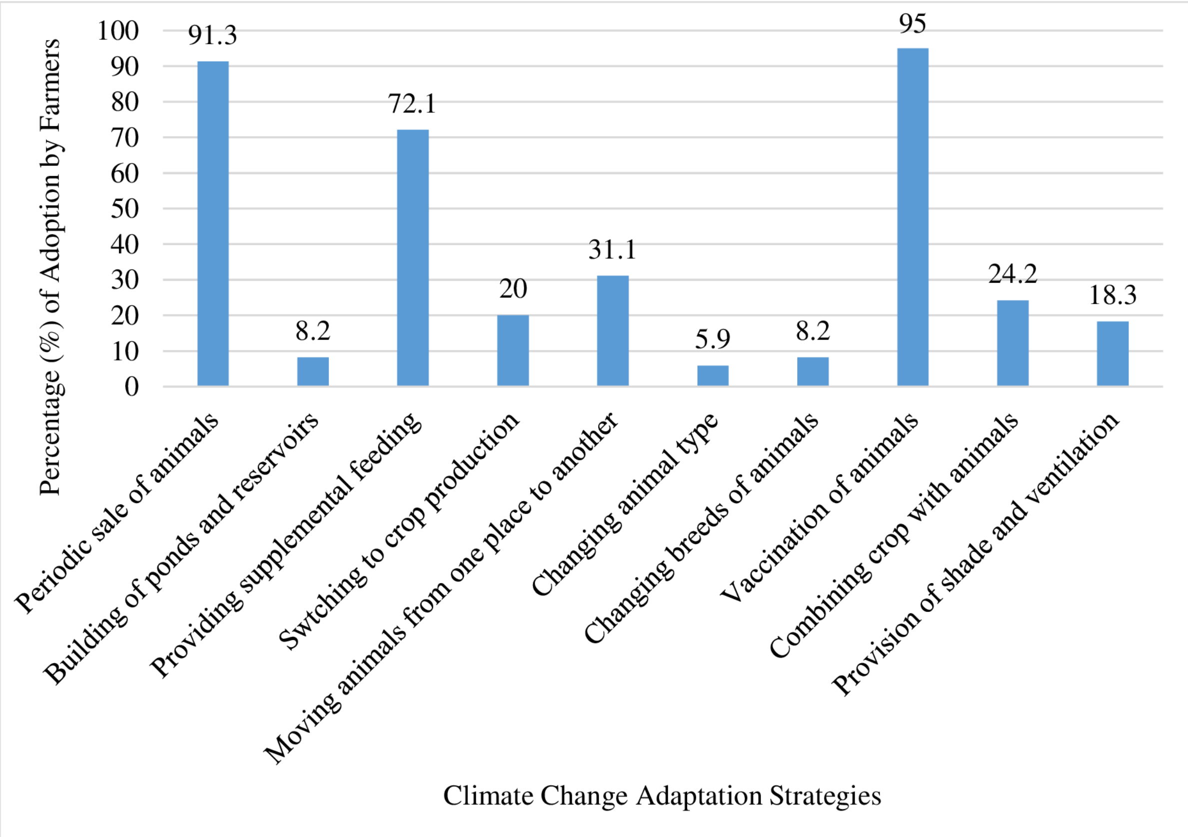

Figure 4: CC adaptation strategies practiced among pastoralists

4.4. Results from the Empirical Model

Tables 3a-c show the results of the multivariate logit used to examine the effect drivers of CC adaptation strategies. Three adaptation strategies - periodic sale of animals, construction of ponds and reservoirs, and provision of supplementary feeding - were selected for the analyses. The results show that our multivariate logit model is statistically significant based on the p-values presented in Tables 3a-c. The R-squares of the model indicate that up to 32.2%, 31.7%, and 23.4% (see Tables 3a-c) of the changes in periodic sale of animals, building ponds and reservoirs, and providing supplementary feeding, respectively, are explained by changes in the explanatory variables. The relatively low R-squares can be explained by the large number of binary variables in the model. In addition, 8, 5 and 3 of the 14 variables have a statistically significant impact on periodic sale of animals, building ponds and reservoirs and providing supplementary feeding, respectively.

In respect to our research hypotheses, the results show that harvesting rainwater has a negative statistically significant effect on farmers' adoption of periodic sales of animals (-0.288) and supplementary feeding (-0.203) as CC adaptation strategies (H1). Farmers who harvest water before the harmattan season are less likely to sell their livestock and buy supplementary feed because the animals have drinking water during the harsh climatic period. Understandably, rainwater harvesting does not statistically affect farmers' decision to build ponds and reservoirs as a CC adaptation strategy. Second, access to the 1V1D program significantly reduces farmers' adoption of building ponds and reservoirs as an adaptation strategy (-0.077). Thus, farmers who have access to publicly funded 1V1D water programs will not spend money on building ponds and reservoirs (H2). However, access to 1V1D has no statistical significance on periodic sales of animals and use of supplementary feeding. Thirdly, feed or food shortage during the hash harmattan months (January to March) has a positive statistically significant effect on pastoralists' adoption of periodic sales of animals (0.093) and supplementary feeding (0.279) (H3). Conversely, months of feed or food shortages have a negative effect on the building of ponds and reservoirs by pastoralists (-0.107). The result implies that pastoralists are more likely to sell their livestock and use supplementary feed during feed shortage periods to reduce their losses. Furthermore, Table 3 also shows that age category (0.04) has a direct effect on the likelihood of a pastoralist selling animals periodically. Thus, older pastoralists are more willing to sell their livestock periodically as an adaptation strategy compared to younger pastoralists. Similarly, financial constraints (0.09) and water availability (0.102) have positive effects on the likelihood of adopting periodic livestock sales as an adaptation strategy. In contrast, livestock type (i.e., rearing cattle = -0.076), access to weather information (-0.203), and access to credit (-0.487) have a negative significant effect on the likelihood of farmers periodically selling their animals as an adaptation strategy (see Table 3a). Thus, pastoralists who are more resourceful are less likely to use period sales of livestock as an adaptation strategy. Table 3b shows that higher level of education (-0.032) and farmer cooperative membership (-0.245) have negative statistical significance on pastoralists' likelihood of building ponds and reservoirs as an adaptation strategy to climate change. However, financial constraint (0.222) has a positive significant effect on farmers' choice of building ponds and reservoirs as an adaptation strategy. Furthermore, the provision of supplementary feeding as an adaptation strategy is negatively influenced by access to cooperative membership (-0.245) and rainwater harvesting (-0.203). The remaining variables, i.e., gender, participation in livestock training, and limited farm space, have no statistical significance on the likelihood of farmers adopting any of the adaptation strategies (see Table 3a-c).

Table 3: Multivariate analyses of the drivers of selected CC adaptation practices

	Periodic Sales of Animals (a)			**Building Ponds and Reservoirs (b)**			**Supplementary Feeding (c)**		
	Coef.	Std. Err.	P>t	Coef.	Std. Err.	P>t	Coef.	Std. Err.	P>t
Gender	-0.014	0.095	0.885	0.061	0.091	0.504	0.166	0.157	0.291
Age category	**0.041**	0.016	0.012	0.024	0.015	0.115	-0.013	0.026	0.625
Level of education	-0.020	0.016	0.209	**-0.032**	0.015	0.037	0.001	0.026	0.979
Livestock training	-0.034	0.055	0.532	0.072	0.052	0.171	0.073	0.090	0.417
Livestock species	**-0.076**	0.037	0.044	0.052	0.036	0.146	0.017	0.062	0.779
Feed shortage months	**0.093**	0.037	0.012	**-0.107**	0.035	0.003	**0.279**	0.061	0.000
Weather information	**-0.203**	0.060	0.001	-0.052	0.058	0.373	0.069	0.100	0.492
Access to credit	**-0.487**	0.182	0.008	-0.047	0.174	0.786	0.433	0.300	0.151
Cooperative membership	-0.025	0.045	0.590	**-0.129**	0.043	0.003	**-0.245**	0.075	0.001
Harvest of rainwater	**-0.288**	0.059	0.000	0.028	0.056	0.624	**-0.203**	0.097	0.038
Financial constraint	0.092	0.041	0.028	**0.222**	0.040	0.000	0.045	0.069	0.509
Limited space	0.018	0.039	0.644	-0.006	0.037	0.865	0.032	0.064	0.617
Water availability	**0.102**	0.048	0.033	0.018	0.046	0.694	0.072	0.079	0.363
1V 1D program	-0.058	0.047	0.217	**-0.077**	0.045	0.089	0.077	0.077	0.322
_cons	0.772	0.153	0.000	-0.081	0.146	0.580	0.448	0.252	0.077
No. of Obs.	218			218			218		
P	0.000			0.000			0.000		
R-square	0.322			0.317			0.234		
F	6.387			6.241			4.109		

5. DISCUSSIONS

5.1. Farmers' Level of Knowledge about CC and the Commonly Practiced Adaptation Strategies

The thesis analyses the knowledge of pastoralists on climate change (CC), adaptation strategies adopted by farmers and the determinants of farmers' adoption of climate change adaptation strategies, i.e., period sales of livestock, building of ponds/reservoirs and use of supplementary feeding. Our results show that pastoralists have above average knowledge level or awareness about the selected characteristics of climate change (see Figure 3), i.e., insufficient water supply, feed short or insufficient feed, increased livestock diseases, emergence of new livestock diseases, low milk production and low proliferation. Our findings conform with Belay et al. (2022) found high perception and knowledge about changing local climate in Ethiopia. Madaki et al. (2023) similarly found that Nigerian farmers have high level knowledge about existing climate change issues affecting their farmers. Secondly, we determined the CC adaptation strategies commonly used by the sampled pastoralists. The results in Figure 4 show that pastoralist in northern Ghana resort to adaptation strategies such as periodic sales of their livestock, building ponds and reservoirs, supplementary feeding, switching to crop farming, moving their livestock to the middle and southern part of Ghana, changing the type and breed of animals, vaccination, mix farming (adding crop to the livestock), and providing shades. Thus, the pastoralists' experience with CC informs their use of different practices to cope with the impact of the changing climate on their farms. Similar studies have found practices such as livestock diversification, movement, herds and species diversification and search for off-farming income to supplement livestock production as adaptation strategies commonly use among pastoralists (Opiyo et al. 2015; Dirriba 2016).

5.2. Drivers of CC Adaptation Strategies Practiced by Pastoralists

In addition to analyzing pastoralists' knowledge of CC and commonly used adaptation strategies, we examined the determinants of their adoption of specific CC adaptation strategies (Table 3). The hypotheses are that rainwater harvesting (H1), participation in the government funded water scheme (1V1D) (H2) and periods of fodder scarcity/shortage (H3) will have statistical significance on farmers' choice of adaptation strategies. The results show that harvesting rainwater has statistically significant negative impact on adopting period sales of livestock and supplementary feeding (see Table 3a&c). This implies that farmers who harvest and store rainwater are less likely to sell their livestock because they would be able to meet the animals' water needs during drought. Farmers are therefore less likely to invest in supplementary feeding. Perhaps this is because they can use some of the harvested water to improve their pastures during the period of severe drought. This result confirms our first research hypothesis and is consistent with previous studies that have highlighted the importance of rainwater harvesting as a key adaptation strategy to CC (Brookes et al. 2010; Cain 2014). On the other hand, participation in the 1V1D program reduces investments in the construction of ponds and reservoirs. This is because the goal of the program is to provide free water for sustainable agriculture. Therefore, pond construction is unnecessary if a farmer benefits from the free water program (1V1D). The results confirm our second research hypothesis that access to free water affects farmers' choice of adaptation strategy. However, participation in 1V1D had no statistical significance on periodic livestock sales and supplementary feeding. Finally, our findings indicate that the period of feed shortage (January to March) has significant positive effects on periodic sale of livestock and provision of supplementary feeding. The study area experiences monomodal rainfall pattern with intense drought between January and March. It is therefore understandable that pastoralists are more likely to sell some of their livestock and provide supplementary feed for the reduced herd rather than adopt high investment strategies such as building ponds and reservoirs.

Regarding the institutional variables, cooperative membership had negative significant effects on the construction of ponds and reservoirs and the use of supplementary feeding as adaptation strategies to CC. Similarly, access to credit had a negative significant effect on the periodic sale of animals. This implies that, farmers who had access to credit would invest in alternative ways such as purchase of hay, water and vaccination to maintain the animals in the course of the dry season. This finding is consistent with a study by Tessema et al. (2018), which found that access to credit increases the likelihood of farmers adopting CC adaptation practices. In addition, our analyses show that financially constrained farmers periodically sell their livestock to adapt to harsh climatic conditions. The result implies that resource-constrained farmers adopt less costly adaptation strategies such as periodic livestock sales compared to supplementary feeding. Periodic livestock sales also help them to generate income to manage the reduced herd. Water availability had a positive impact on livestock sales. Farmers choose to sell healthy animals before the dry season and during festive seasons such as Christmas to avoid losing animals to drought. The rate of vulnerability increases during drought and therefore the likelihood of falling sick or becoming thin. Access to weather information had a negative significant effect on the practice of supplementary feeding, which is consistent with the findings of Tazeze (2012) and Dirriba (2016). One possible reason is that farmers who have access to weather information can plan in advance by storing some hay or other feeds, and thus would be able to get through the drought season without much difficulty.

In addition, the results on farmer and farm characteristics show that older farmers are more likely to engage in periodic sales of their livestock (see Table 3a) - older farmers may be willing to sell some of their livestock as drought intensifies due to CC compared to younger farmers. One possible explanation could be that older pastoralists are physically weak and cannot move their livestock several kilometers to southern Ghana to find pasture and water. Dirriba (2016) found that older pastoralists are less likely to adopt labor-intensive strategies, such as fodder storage and livestock mobility. In contrast, higher levels of education reduce farmers' adoption of pond and reservoir construction. Although the result was not expected a priori, it may be that highly educated pastoralists are socially connected and have access to public water sources such as the 1V1D. However, our result contradicts the finding of Tessema et al. (2018) that farmers with higher levels of education would have a better understanding of adaptation strategies and therefore would be expected to adopt adaptation strategies than less educated farmers. Livestock species had a negative effect on the practice of regular sale of animals. Farmers keeping large ruminants (cattle) are less likely to sell their animals. This is because cattle have a higher adaptive capacity to CC compared to small ruminants (sheep and goats). Cattle also have the capacity to travel longer distances in search of feed and water during intense drought compared to sheep and goats.

6. CONCLUSION

This paper analyzes pastoralists' experience with climate change (CC) challenges, commonly practiced adaptation strategies, and drivers of CC adaptation strategies among pastoralists in northern Ghana. The results show that pastoralists have experienced climate change challenges to pastoralism. The experience contributes to the use of several adaptation strategies by pastoralists to mitigate the effects of CC. In addition, age, financial constraints and water availability had positive significant effects on farmers' choice of period for selling livestock and constructing ponds and reservoirs. On the contrary, level of education, rearing of large ruminants (livestock species), access to weather information, access to credit, and access to credit reduce farmers' chances of adopting periodic sale of animals, construction of ponds and reservoirs, and supplemental feeding. Regarding the study hypotheses, our results show that farmers who harvest rainwater are less likely to adopt periodic sale of animals and supplemental feeding (see Table 3a&c) (H1). In addition, participation in publicly funded water programs (1V1D) influences farmers decision on building pond or reservoir, but has no effect on periodic animal sales and supplemental feeding (H2). Finally, farmers who experienced feed shortages during the intensive drought period of harmattan (January to March) are less likely to build pond and reservoirs, but more likely to periodically sell their animals for income and invest in supplemental feeding (H3).

Our findings have some implications and recommendations to be considered, especially by the Government of Ghana and other NGOs working on climate change among pastoralists in the Northern Region. First, extension education can be directed towards promoting important but less adopted adaptation strategies such as changing livestock breeds and switching to livestock resilient to diseases and the harsh climate in the study area. Extension services could also focus on promoting other disease prevention adaptation strategies among pastoralists in the face of increasing diseases and pest infestation due to CC. Vaccination is the only disease prevention adaptation strategy practiced among the farmers. Second, access to water (rainwater harvesting and water availability) is a critical determinant of farmers' decision to periodically sell their livestock during the harmattan season (drought period). Pastoralists often lose out in such ad-hoc sales because they are not in a good position to negotiate good prices, having to choose between selling and keeping all the animals, which they may not be able to feed well during the drought. Keeping the animals without food and water can lead to high weight loss, disease and mortality. The government and other livestock development agencies should work to improve access to water in the northern region during the drought. Programs such as One Village One Dam (1V1D) should be extended to all rural communities. New dams can be constructed to provide year-round water for agriculture and other domestic uses in the study area. Finally, the government and its allies should develop programs to educate pastoralists in the study area on fodder preparation and storage during the rainy season. Fodder was not a common adaptation strategy mentioned by the pastoralists. The government could consider expanding the scope and objective of the 1V1D program to include free communal grazing areas for pastoralists during dry periods. This can reduce fodder scarcity and herd mobility in search of fodder and water during the intensive harmattan period.

Despite the important findings, our study has some limitations that need to be considered for future studies. First, our sample size of 218 pastoralists is limited for more robust inferential analyses. However, we could not expand the sample due to limited resources and time. Future studies can therefore use larger sample sizes. Second, our analyses of farmers' knowledge of CC challenges and commonly practiced adaptation strategies were descriptive. We suggest the use of regression models, following a similar approach by Madaki et al. (2023), to test pastoralists' knowledge of CC impacts. Finally, our findings on farmers' knowledge of CC impacts may be limited because our data are cross-sectional, but behavior and knowledge change over time. Therefore, we recommend that future studies use panel data to capture changes in farmers' behavior and knowledge about CC over time.

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APPENDIX 1 - QUESTIONNAIRE

AGROPASTORALIST CLIMATE CHANGE ADAPTATION STRATEGIES: A CASE OF NORTHERN GHANA

I am a student at the Czech University of Life Science Prague, Czech Republic, and I am conducting this study to learn more about the "***Pastoralist climate change adaptation strategies in northern Ghana*** ". Kindly help me by filling out the questionnaire below. This exercise will only take few minutes. I would appreciate it very much if you would help in filling out this with utmost sincerity so as to obtain accurate results for the research. Thank You!

Identification

Name of respondent……………………………………………………………………………

Phone number…………………………………………………………………………………...

Local government area………………………………………………………………………….

Date of interview……………………………………………………………………………….

Section A: **Characteristics of farmers**

1. When did you start rearing livestock?	
2. How many members of your family are you living with?	
3. How many children of your family are you living with? (under age 15)	
4. How did you get the farm/animals?	Inhereted ☐ purchased ☐
5. How many older people of your family are you living with?(60yrs and over)	
6. Your gender please?	Male ☐ Female ☐
7. Have you had any form of education?	Yes ☐ No ☐
8. If yes, what kind of education is it?	Formal ☐ Non-formal ☐
9. What is your highest level of education?	Basic ☐ Secondary ☐ Tertiary ☐ Vocational ☐ Others……………………………………

10. Have you had any training in livestock production?	Yes ☐ No ☐
11. How long did you undergo such training?	
12. If yes, If yes how long did you undergo such training?	
13.	
14. In which month(s) did you experience feed shortage last year?	Nov ☐ Dec ☐ Jan ☐ Feb ☐ March ☐ April ☐
15. In which month(s) did you experience water scarcity last year	Nov ☐ Dec ☐ Jan ☐ Feb ☐ March ☐ Apr ☐
16. Do you own a land?	Yes ☐ No ☐
17. Do you possess any establish Pasture?	Yes ☐ No ☐
18. If Yes, what is the size of pasture (in Arces)	
19. What species of animal are you keeping?	Goat ☐ Sheep ☐ Cattle ☐
20. How many species do you have in your Farm? Each	Goat ☐ Sheep ☐ Cattle ☐
21. What is or are the main source of feed for your animals during the dry season?	Concentrate feed ☐ Hay ☐ Other(s)………………………………
22.	

Section B: **Characteristics of farm**

23. What is or are the main source of feed for your animals during the dry season?	Yes ☐ No ☐
24. If yes, what type of ownership	Customary ☐ Statutory ☐
25. Do you possess any established pasture?	
26. What is the size of your pasture?	………………………….Acre(s)
27. What species of animals are you keeping?	Goat ☐ Sheep ☐ Cattle ☐ Poultry ☐
28. How many animals do you have on your farm?	
29. What is or are the main source of feed for your animals during the dry season?	Rangeland ☐ Agroforestry ☐ Other(s) ☐ ………………………
30. What is or are the main source of feed for your animals during the rainy season?	Rangeland ☐ Pasture ☐ Others ☐
31. How large area of forages got extinct last year during the drought?	………………………………… Acres

32. What production system do you practice?	Extensive ☐ Semi intensive ☐ intensive ☐
33. What is the reason for your choice of animal production system? E.g. Extensive, semi-intensive or intensive. system?	

Section C: **Institutional Characteristics**

34. Do you know of the 1D1F program?	Yes ☐ No ☐
35. Have you ever profited from this program?	Yes ☐ No ☐
36. Do you still profit from the 1D1F program?	Yes ☐ No ☐
37. Do you have access to weather information?	Yes ☐ No ☐
38. Who provides the weather information?	Radio ☐ TV ☐ Internet ☐ Other……………………..
39. How frequent do you receive weather information?	Every day ☐ Several times a month ☐ Several times a year ☐
40. Do you receive extension services?	Yes ☐ No ☐
41. Who provides the extension services to you?	Ministry of Agriculture ☐ NGOs ☐ Other(s)………………
42. How often do you receive extension services?	……………time(s) a week ……………time(s) a month ……………time(s) a year
43. Do you have access to credit?	Yes ☐ No ☐
44. Are there any Grant(s)?	Yes ☐ No ☐
45. If yes, from which agency?	NGO ☐ Government ☐ (Specify) ……………..
46. Are you a member of farmers' cooperative society?	Yes ☐ No ☐

Section D: **Behaviour perception of climate change and access to water**

Climate perception

40. Do you agree with following (consider about the last 10 years)?					
Event[1]	**SD**	**D**	**UD**	**A**	**SA**
Temperature keeps increasing					

Delay in coming of rainfall					
Decrease in rainfall duration (days)					
Increase in frequency of drought					
Increase in frequency of flooding					
Increase in evaporation/drying of the soil					
Increase of livestock pest and disease outbreak					

[1] **SD= Strongly disagree, D=Disagree, UD=Undecided, A=Agree and SA=Strongly agree**

Perceived impact of climate change on livestock

41. Have you experienced the following events on your farm in the last 10 years?

Event[1]	**Very often (several times a year)**	**Often (few times a year)**	**Sometimes About once a year**	**Seldom Once in several years**	**Never**
Insufficient supply of drinking water for animal					
Insufficient feed from pasture					
Increase in livestock disease outbreak					
Emergence of new animal disease					
Pest infestation/attack					
Low response to treatment					
Low milk production					
Low proliferation					

SD= Strongly disagree, D=Disagree, UD=Undecided, A=Agree and SA=Strongly agree

Adaptation Strategies

42. What is the strategy /ies used in your livestock farming in the last three years to adapt on the changing weather (multiple choice is allowed)?	Periodic sales of animals ☐, Building of ponds and reservoirs ☐, Providing supplementary feeding ☐, Switching to crop production☐, Moving animals from one place to another ☐, Changing the type of animal (eg. from cattle to goat)☐, Changing breeds of animals of the same species ☐ Vaccination of animal ☐, Combining crop farming with animal☐ , Provision of shade and ventilation ☐. Others……………………………………..
43. Are these some of the illnesses your animals struggle with in the past years? Cowdriosis Botulism Tuberculosis Diarrhoea Anthrax PPR Bluetongue	Yes ☐ No ☐ Yes ☐ No ☐ Yes ☐ No ☐ Yes ☐ No ☐ Yes ☐ No ☐ Yes ☐ No ☐ Yes ☐ No ☐

	Other(s)………………….

44. Which of these months do you struggle with water scarcity?	November ☐ December ☐ January ☐ February ☐ March ☐

Which of these months do you struggle with water scarcity?	**Nov.**	**Dec.**	**Jan.**	**Feb.**	**Mar.**
Very serious					
Normal serious					
Non-serious					

45. Which water source(s) are available to you in times of extreme drought?	
47. Are there times when water is completely unavailable in your area?	
48. How do you provide water for your animals in these times?	
49. What does the veterinary or the extension agent suggest in these times?	
49. Do you harvest rain water in the rainy season?	Yes ☐ No ☐
50. If yes, how do you store it?	Plastic drums ☐ Plastic tanks ☐ Cement tanks ☐ Metal drum barrel ☐ Other(s) ……………………..
50. Which period do you often sell your animals?	Month 1,2,3,4,5,6,7,8,9,10,11,12
51. What are the reason for the sale of the animals?	Water shortage, feed shortage, income purpose, disease outbreak
51. What does the veterinary or the extension agent suggest in these times?	
52. Please how old are you?	

APPENDIX 2: PICTURES