UNIVERSITY FOR DEVELOPMENT STUDIES

KNOWLEDGE AND PERCEPTIONS OF FARMERS ON SOIL, CLIMATE AND WEATHER IN TWO DISTRICTS OF NORTHERN REGION OF GHANA

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KNOWLEDGE AND PERCEPTIONS OF FARMERS ON SOIL, CLIMATE AND WEATHER IN TWO DISTRICTS OF NORTHERN REGION OF GHANA

BY

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DECLARATION

I, Baba Mohammadu Jamaldeen, hereby declare that this research paper titled "Knowledge and perceptions of farmers on soil, climate and weather in two districts of the Northern Region of Ghana", is an independent study and a part of the collaborated research between University for Development Studies, UDS – WACWISA and Wageningen University and Research (WUR) called WAGRINNOVA project. Due acknowledgements have been made to the work of others.

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ABSTRACT

The growth of vegetation is influenced by soil moisture. The principal supply of water for plants between periods of rainfall is water stored in the soil, which has an impact on crop output. From planting to harvesting, weed control and on-farm water management decisions are influenced by soil moisture levels. This necessitates a research into farmers' perceptions and knowledge of soil moisture, as well as their use of associated climate and weather data in their agricultural activities and decision-making. This study was conducted in 2021 at two communities in Savelugu Municipality and one community in Kumbungu District of Northern Region of Ghana. The data were collected through personal observations, reconnaissance field visits, key informant and focus group discussions and semi-structured individual interviews administered to a total of 48 smallholder rice farmers. The research questions were related to soil moisture knowledge and perceptions of farmers in the selected communities. Investigations revealed that the farmers used adaptation measures to reduce perceived effects of climate change (CC), particularly flood and drought. Two flood and four drought adaptation measures were identified during the study. Farmers possessed an intimate knowledge about the soil and its management. They placed lots of emphasis on getting the information about rainfall, temperature and soil moisture. Moreover, various techniques such as cutlass & hand feel method, footprint, plant uproot, color & smell is used by farmers to measure the soil moisture. Indicators are also used by farmers to determine moisture status before sowing. Farmers classified the soils in terms of texture (i.e. *Bihigu*, *Chichali*, *Gbingbili* and *Yagiri*), organic matter content (i.e. dark, brown and red soil) and also based on suitability for particular crops (i.e. *Kukogu*, *Baa* and *Bakukogu*). Further studies should be done to investigate and map the soils in each community and determine their suitability for particular crops cultivation.

TABLE OF CONTENTS

List of Tables

List of Figures

List of Plates

List of Abbreviations

UDS - University for Development Studies

WUR - Wageningen University and Research

CC - Climate Change

SSM - Surface Soil Moisture

FSC - Farmers' Soil Classifications

FGDs - Focus Group Discussions

IPCC - Intergovernmental Panel on Climate Change

GDP - Gross Domestic Product

FAO - Food and Agriculture Organization

CIA - Central Intelligence Agency

IKS - Indigenous Knowledge System

SM - Soil Moisture

SSA - Sub-Saharan Africas

LGP - Length of Growing Period

NSSO - National Sample Survey Organization

SF - Scientific Forecasts

IF - Indigenous Forecasts

IEIs - Indigenous Ecological Indicators

IKF - Indigenous Knowledge Forecasting

AMSR-E - Advanced Microwave Scanning Radiometer - Earth Observing System

SMOS - Soil Moisture and Ocean Salinity

SMAP - Soil Moisture Active Passive

ET - Evapotranspiration

WRB - World Reference Base

SPSS - Statistical Package for Social Sciences

IFRC - International Federation of Red Cross and Red Crescent Societies

KIDs - Key Informant Discussions

GPS - Global Positioning System

MOFA - Ministry of Food and Agriculture

SDGs – Sustainable Development Goals

CHAPTER ONE

1 INTRODUCTION

1.1 Background

Agriculture is a key to attaining the UN Sustainable Development Goals (SDGs) of securing food to end hunger for an increasing world population of 9-10 billion by 2050, which may need a boost in world food production (Foley *et al*. 2005; IAASTD 2009; Tilman *et al*. 2011; Pardey *et al*. 2014). Agriculture is also the primary livelihood of 2.5 billion smallholder farmers (FAO 2013a) of over 600 million individuals located in rural communities in Sub-Saharan Africa (SSA) (Rockström et al., 2014). These livelihoods resilience to escalating shocks and stressors received less attention (FAO 2013b).

The agricultural sector is consequently of special importance for the economy of Ghana, because it absorbs up to 44 % of labor and accounts for approximately one quarter of the Gross Domestic Product, GDP (CIA, 2012). The severity of crop failure and community vulnerability is highest in the northern areas of Ghana, notably Upper East, Upper West, Savanna, North East and the Northern areas. There are various uncertainties that challenged farmers located in these regions, mostly caused by water and climatic fluctuation (Gbetibouo *et al*., 2017).

Rain-fed agricultural production is highly susceptible to climatic shifts because crops and farming practices are suited to local conditions: minor changes such as temperature fluctuations at crucial stages in the development of crops can have considerable impacts on productivity (Hatfield *et al*., 2011). Climate change (CC) also threatens the future potential for food production through decreasing soil fertility and increasing soil erosion (Lal *et al*., 2011). Both seasonal and inter-annual rainfall fluctuations create an obstacle for farming decision-making in Ghana. Surface water and soil supplies are becoming less predictable, due to challenges related to climate change (IPCC, 2014). A lot of farmers are unable to manage these hard environments, which result in increased food insecurity (Di Falco *et al*., 2011). Future climate estimates show that, along with other impacts, there could be a decline in food security from a global perspective to the local level, particularly in developing nations (FAO, 2019).

Soil moisture is viewed as a critical link between bio-geochemical and hydrological processes that synthesize the relationship between soil, vegetation and climate; consequently, it is an indispensable water balance component for the production of food (Rodríguez-Iturbe *et al*., 2007). When there is a deficit of soil moisture during droughts (Griffin *et al*., 2014), various management practices may alter the quantity of soil moisture that can be stored in the system. Therefore, the effectiveness of rain fed farming depends substantially on the way the farmers are able to adapt their decisions concerning farm methods to the existing weather. Accessibility of hydro-climatic data sources is vital for defensible agricultural operations and therefore boosting farmers' adaptability which will results to improved yields, and least crop failure risk (Nyadzi *et al*., 2018). Farmer's capacity to make climate-smart choices for maximum yield requires assistance from the accessibility of precise and current climate information.

In Ghana, farmers rely largely on rainfall that changes yearly and seasonally. This greatly influences the availability of soil water and the possibility for low yields of crops and failure increases (Kunstmann and Jung, 2005; Asante and Amuakwa-Mensah, 2014).

Research have revealed that before scientific forecast technologies were formed, individuals produced regular projections on bases of their previous experience(s) i.e., indigenous knowledge and linked them with present observations (Olsson *et al*., 2004; Orlove *et al*., 2010). Indigenous knowledge system (IKS), additionally referred to as native, local, folk, ethno-science, and traditional knowledge can be described relative to agriculture in the most basic sense, as a built-up knowledge, technology and skill of indigenous individuals acquired through interaction with the nature. Though based on experience(s) transferred, indigenous knowledge however develops, evolves and absorbs new thoughts (Becker and Ghimire, 2003; Rist and Dahdouh-Guebas, 2006). It can be exact to region and may be different amongst people from various backgrounds according to characteristics such as occupation, age, wealth, gender and ethnicity (Pawluk *et al*., 1992; Dawoe *et al*., 2012). Knowing why and how farmers have reacted to climate change is a key step to guiding how to facilitate both current and future adaptation (Ravi Shankara, *et al*., 2013). A research conducted by Gbangou *et al*. (2020), found that smallholder farmers lean mostly on local knowledge for farming activities caused by inadequate specific information and weak grasp of scientific projections. The local farmers involvement in generation of forecast data can assist create trust and boost the application and comprehension of scientific forecasting knowledge. Also, accumulation and incorporation of local or native skills with scientific data can help raise reliability as well as enhance on the acceptance of modern forecast within native farmers (Nyadzi *et al*., 2020; Gbangou *et al*., 2020).

1.2 Problem Statement and Justification

Sustainable agriculture is ingrained in how people and the environment interact, particularly in how people feel about climate change, how quickly it is happening, and how it affects the entire agroecosystem, including the soils, plants, and animals. Farmers' propensity to recognize and respond favorably to environmental changes is crucial for the effective implementation and adoption of new technologies, husbandry techniques, and farming methods as well as for their adaptation to changes in their ecosystems. In most developing nations, including Ghana, poor understanding of changes and their effects on agriculture is a barrier to long-term sustainable agriculture (Kotei *et al*., 2007). The body of research on farming acknowledges that small-scale traditional farmers in the tropics conserve a thorough understanding of the environment and their understanding of soils and management is crucial in the development of environmentally friendly farming systems (Rist and Dahdouh-Guebas, 2006; Sutanto *et al*., 2022). Farmers' knowledge of the local soils has been evaluated in several research (Ali, 2003; Birmingham, 2003; Dawoe *et al*., 2012; Barbero-Sierra *et al*., 2016). Research in this domain has mostly concentrated on the understanding of crops, insecticides, and fertilizers in the local area. Less focus has been placed on farmers' understanding of and perspectives on the significance and establishment of soil moisture.

The majority of people's perceptions of the fundamental problems and factors causing change generally vary greatly, with some adopting a more religious perspective and others a more scientific one. Many subsistence farmers, who are by definition usually uneducated, utilize superstition to explain how nature works because it is their only source of "information," which leads to some of the views being unscientific (Kemausuor *et al*., 2011). Farmers in the Sahel (Mertz *et al*., 2009) and the Northern area (Limantol *et al*., 2016) are mindful of climate variability and have developed coping mechanisms to deal with the impacts yet they still need assistance. Households and groups instead cite economic, political, and social issues as the primary causes of change when questions on land use and livelihood change are not specifically asked in a climate context (Mertz *et al*., 2009). According to a study by Kemausuor *et al*. (2011) in the Ejura-Sekyedumase district on farmers' perceptions of climate change, farmers noticed that the district's temperature had increased and that the timing of the district's rainfall had changed, increasing the frequency of droughts. These conclusions are consistent with those of a study by Limantol *et al*. (2016). A different study by Alhassan *et al*. (2018) that looked at smallholder women rice farmers' research-based and indigenous adaptation strategies to climate variability found that farmers believed crop-related practices (indigenous varieties and mixed cropping) to be the best indigenous adaptation practices while improved variety approaches (early maturity, resistant to drought and high yielding varieties) are perceived as the most effective research-based methods of adaptation.

To develop policies and programs that will successfully support the agricultural sector's adaptation, it is necessary to have a greater understanding of how farmers view climate change, current adaptation measures, and the variables influencing the choice to adjust farming techniques (Bryan *et al*., 2009). Farmers must have accurate views of the situation and probable future patterns in order to adjust to change efficiently. Farmers make judgments in their own environment in real life, and there may be disparities between their perceived and actual environments (Mather, 1992). Further research should be done on farmers' awareness of soil moisture in order to apply conservation measures and sustain output, according to the study of Kemausuor *et al*. (2011). Farmers need at the very least should be aware of the phenomena and their effects and causes if they are to participate in developing mitigation and adaptation methods. Studies on climate change of farmer adaptations have only known gender studies on climate change, farmers' adaptation strategies, farmers' perceptions of the efficacy of identified strategies related to climate variability, and challenges of farmers faced in adoption of adaptation strategies based on the literature mentioned above. Not like former studies, this study will add to literature by assessing the level of smallholder farmers' knowledge and perceptions on soil, climate, and weather information used in farm practices and decision-making in two districts of Ghana's Northern region.

The findings of this study could be used as a foundation for further moisture analysis and vulnerability assessments, add more to knowledge and therefore, help stakeholders to formulate adaptation policies for farmers in the region. The use of participating and collective approaches will be necessary to smooth the incorporation and insertion of farmer perspectives in the development and policy formulation processes of agriculture, particularly to utilize the farmers' rich knowledge base on soils and soil moisture indicators.

1.3 Study Objectives

The main objective of the study was to assess the level of smallholder farmers' knowledge and perceptions on soil, climate, and weather information used in farm practices and decision-making.

4.3.1 Specific Objectives

The specific objectives of this study were:

1. To ascertain the importance of weather information for smallholder farmers.
2. To assess methods used by farmers in soil moisture measurement and soil classification.
3. To analyze farmers' perceptions on the effects of climate change on farming systems and adaptation practices.

4.3.2 Research Questions

The following research questions were constructed to achieve the main objective. The research questions answered in this study were;

1. What is the importance of weather information for smallholder farmers?
2. What are the farmers' moisture measurements and soil classifications practices?
3. What is the farmers' perception of climate change effects and what adaptation practices are used in the study communities?

1.4 Organization of Thesis

There are five chapters in this work. The first chapter is the introduction, which provides background information on the study, including a synopsis of Africa and Ghana agriculture, climate change (CC) impacts for agriculture in Ghana, importance of soil moisture (SM) and weather information for rain fed agriculture, and plant growth, and indigenous knowledge required to monitor the soil moisture (SM) and weather information.

The review of literature on subjects related to the study is covered in the second chapter, including impacts of climate change on dry spell, growing season, and rainfall onset and cessation, perception of climate change, the relationship between adaptation to climate change and perception, climate information services in Ghana and in the Northern region, indigenous soil and water conservation practices to combat change in climate, role of information in agriculture, agricultural information sources for farmers, farmers information needs, indigenous knowledge systems, moisture of the soil, precipitation and soil moisture, factors influencing surface soil moisture (SSM), and knowledge of local soil classification.

The study materials and methods are presented in the third chapter. The description of the study area, methodology, and techniques for gathering and analyzing data have been covered.

The findings and discussions from the study on the socio-economic characteristics of lowland rice farmers, importance of weather information for smallholder farmers, farmers' soil classification methods, moisture importance for farm practices and measurement, and farmers' perception of climate change impacts on their farming systems and the adaptation strategies they have adopted are presented in the fourth chapter. Finally, the firth chapter presents conclusions and recommendations.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Dry Spells, Growing Season Length, Rainfall Onset and Cessation and Other Climate Variability Effects on Small Scale Agriculture in Sub-Saharan Africa

The variations in weather parameters like rainfall, temperature, and atmospheric pressure are caused, in part, by global atmospheric and oceanic circulations (Endris *et al*., 2018). The signs of climate variability and change in climate include increases in the hydrological cycle, unpredictability in rainfall distribution and amount, and the occurrence of extreme events in various parts of the globe (Merabtene *et al*., 2016). In particular for the people of Sub-Saharan Africa (SSA), climate variability and change pose serious dangers to emerging nations (Barana, 2017). Climate change and variability set back the nations' development by lowering crop productivity and escalating food insecurity (Gemeda and Sima, 2015; Mirza, 2003). While its amount is predicted to decline, rainfall anomaly is projected to grow in the SSA (IPCC, 2014).

The same paper notes that the clear link between rising global temperatures and greenhouse gas emissions also has an impact on rainfall anomalies. Higher temperatures across SSA are having a direct and indirect impact on agriculture, such as shorter growing seasons, increased pest and disease pressure, soil drying, increased evapotranspiration, unstable suitable areas for raising of livestock and crops, and other effects (Lobell et al., 2008; Cline, 2007). In addition, climate change increases the frequency and amount of life-threatening events like storms, droughts/dry spells, and floods as well as the variability of rainfall across most of SSA. Although change in climate is a global occurrence, its effects vary depending on the geographical area and location (Elsanabary and Gan, 2015; Ramli *et al*., 2019). As a result, current climate studies have tended to focus on small scales that offer more detailed data for planning and better management of local resources.

Rain-fed agriculture accounts for the majority of agricultural production in SSA. Due to widespread poverty, a rising population, and a lack of technical advancement, the SSA is also extremely exposed to change in climate and variability (Antwi-Agyei *et al*., 2012). Length of growing season (LGP), dry spells and the rainfall onset and cessation dates are all impacted by this climate change. The delicate ecosystem is threatened by the rising seasonality and variability of rainfall, which also concerns food security and human livelihoods. Although changes in rainfall seasonality (onset and cessation) affect when cropping calendar activities take place, they have received less attention than trends in rainfall volume (Muthoni, 2020; Atiah *et al*., 2020). In rain-fed farming systems, the timing of the cropping calendar is crucially determined by the temporal rainfall variability, which is measured by three indices: rainfall start dates, end dates, and the LGP. Days of the year when rainfall begins and finishes are known as the start and end dates. The LGP is the discrepancy between the dates of beginning and cessation. Diverse agro-ecological zones and planned uses can be accommodated by a number of approaches for predicting the beginning and ending dates of rainfall (Liebmann *et al*., 2012; Akinseye *et al*., 2016; Dunning *et al*., 2016; Liebmann & Marengo, 2001).

2.2 Climate Variability in Northern Ghana

In contrast to seasonal distribution, rainfall variability amounts in northern Ghana has received greater attention (Baidu *et al*., 2017; Atiah *et al*., 2020; Muthoni, 2020) and other meteorological indices. Furthermore, despite the fact that these three indices - the beginning, ending, and LGP in northern Ghana - are significant predictors of cropping season activities, there is little agreement in the research on them. Due to irregular rainfall onset and cessation dates, LGP in northern Ghana is highly variable (Boansi *et al*., 2019; Amekudzi *et al*., 2015). For instance, between Tamale and Wa in northern Ghana, between 1986 and 2010, Gbangou *et al*. (2019) recorded rain season early onset dates between - 0.3 and - 0.5 days per year (earlier onset of 7.5 - 12.5 days). Nevertheless, Laux *et al*. (2008) discovered a considerable delay of up to 0.88 days per year in the Volta basin, which equates to a late onset by 35 days over 40 years, in northern Ghana. Amekudzi *et al*. (2015) showed similar considerable variation in the timing of rainfall's onset and cessation during a range of 2 to 8 years spanning several agro-ecological areas in Ghana. Recent research employing gauge recordings has shown that crop yields in northern Ghana significantly fall due to late start or early stop of rains, as well as a high rate of recurrence of dry spells during the production season (Owusu *et al*., 2020; Chemura *et al*., 2020). The agricultural calendar is unpredictable due to the variability of rain's start and mid-season breaks, which also makes decisions about when to sow, which crops to choose, and which varieties to choose more difficult (Mkonda & He, 2018; Boansi *et al*., 2019). Food production and food security are severely hampered by unpredictable and delayed rainfall start (Amekudzi *et al*., 2015). One of the primary causes of low maize yield in Northern Ghana is insufficient collaboration between rainfall starts and agronomic decisions such as planting dates (Owusu *et al*., 2020). In northern Ghana, false rains starts (Ocen *et al*., 2021) have increased in frequency and cause farmers to sow and cultivate without enough subsequent wet days to support crop growth (Van de Giesen *et al*., 2010). For the synchronized timing of cropping calendar operations, precise forecast of the start, end, and length of rainy days dates is crucial. The dangers and expenses associated with re-sowing seeds due to the season's false start can be reduced with precise knowledge of when seasonal rain starts and stops (Sarku *et al*., 2020). A dependable early signal of food insecurity can be found many months before harvesting when rains start to arrive later than expected (Shukla *et al*., 2021). Drought conditions are more likely if the rainy season arrives ten days later. Early drought detection and warning can help with planning for interventions to save lives and livelihoods.

Instead of providing a thorough study of the scope of the problems associated with such variability and the potential mitigation solutions, studies already undertaken are limited to analyzing change in climate and variability on a large scale (Tesfaye *et al*., 2022). In order to help policymakers and decision-makers as well as farmers to formulate and carry out their plans, rainfall data analysis, such as variability and trends, can be used to give information. It also helps researchers concentrate their research on more effective adaption technologies to achieve productivity in sustainable agriculture in the actual conditions.

2.3 Climate Change Perception

According to Whitmarsh and Capstick (2018), the perception of change in climate is a complicated process that includes a variety of psychological categories about whether and how the climate is changing, including information, concerns, beliefs, and attitudes. The features of the individual, their experiences, the data they get, and the cultural and geographic setting in which they reside all affect and shape perception (Whitmarsh and Capstick, 2018; van der Linden, 2015). As a result, it is hard to measure perceptions of change in climate and attempt to identify their causes.

One of the numerous difficulties that a person encounters when attempting to differentiate between climate change manifestations and typical short-run changes is that the local weather variability can have from one day to the next, one season to the next, and across years (Hansen *et al*., 2012). In reality, local short-term fluctuations frequently stand out more than long-term trends, and as a result, they can significantly influence how people perceive climate change (Lehner and Stocker, 2015). Farmers, for example, who directly rely on the weather for at least a portion of their income, tend to have perceptions that are more accurate than those of their counterparts. However, they may still struggle to accurately interpret changes in the weather based on their prior experience (Whitmarsh and Capstick, 2018; Weber, 2010).

People's perceptions are influenced by their life experiences, and those who have personally experienced extreme climatic occurrences tend to believe that they are likely to occur again (De Matos Carlos *et al*., 2020; Patt and Schröter, 2008). Additionally, the information that a person receives can affect or change the view that person has regarding climate change (Weber, 2010). Finally, it should be remembered that perception is partially a subjective process, therefore even while persons in the same location may experience the same weather patterns, they may have different views of climate change (Simelton *et al*., 2013).

2.4 The Link between Perception and Adaptation to Climate Change

The agricultural industry must adapt to the negative consequences of change in climate in order to save the lives of the people that directly rely on it (Asfaw *et al*., 2016). The choice to accept or put into practice a certain adaptation measure would simply be a matter of evaluating the net benefits of said measure on an earth with accurate data, full markets, and suitable incentives. However, small and subsistence farmers in poor nations do not operate in that environment. Thus, the world/environment where there is accurate data, full market and suitable incentives (Castells-Quintana *et al*., 2018). As a result, adopting adaptation measures is not a simple or automated procedure; quite the opposite. According to the data, small and subsistence farmers face difficulties to adopting new technologies because of issues like poor access to insurance or credit, a lack of knowledge about adaption options, and imperfect property rights (Asfaw *et al*., 2016). Additionally, adopting a new technology or method of production frequently involves cognitive processes, such as mental accounting (Thaler, 1999), loss aversion (Kahneman and Tversky, 1979), and hyperbolic discounting (Laibson, 1997), which can result in suboptimal adoption levels (Zilberman *et al*., 2012). This is especially important for climate change adaptation because even farmers who have access to weather data and climate projections deal with high levels of doubt

(Silvestri *et al*., 2012). In these circumstances, understanding farmers' adaptation choices requires a comprehension of their perceptions of change in climate (Clarke *et al*., 2012).

In order to adapt, people must not only believe that something is changing or could change, but they must also give this belief enough credence that they are prepared to act on it (Eakin *et al*., 2014). As a result, it is possible to view awareness of climate change as a prerequisite for the adoption of agricultural adaptation strategies (Simelton *et al*., 2013; Makuvaro *et al*., 2018). Additionally, the involvement and participation of the intended beneficiaries are required, among many other things, for the successful implementation of public policies meant to promote adaptation. It is likely that the policy will not be implemented successfully if their understanding of the effects or urgency of change in climate differs from that of the policymakers (Patt and Schröter, 2008).

2.5 Climate Information Services in Ghana and in the Northern Region

According to several studies (Kankam-Yeboah *et al*., 2013; Water Resources Commission, 2010; Obuobie *et al*., 2012), Ghana's climate will become more unpredictable and varied in the future, making the agricultural industry more vulnerable. The capacity to anticipate rainfall has recently improved, going from a few days to seasonal projections (Njau, 2010). For farmers and other water users to make informed plans and decisions, it is essential to be able to forecast climate and weather, especially rainfall (Logah *et al*., 2013). According to empirical studies (Patt *et al*., 2005; Phillips *et al*., 2001; Roncoli *et al*., 2009), climate predictions can enable farmers to optimize opportunities when favorable conditions are projected while also reducing their exposure to drought and climatic extremes.

The majority of the rural population in Ghana's northern area engages in small-scale rain-fed agriculture and experiences a significant amount of dryness. The communities in this region are particularly susceptible to recurrent crop failures due to the region's extreme climate unpredictability and change (Gbetibouo *et al.*, 2017). In order to understand this region's climatic variability, personalized climate and weather information based on native weather conditions is becoming increasingly crucial (Gbangou *et al.*, 2019).

According to Etwire *et al*. (2017), Anoop *et al*. (2015), and Okello *et al*. (2011), the fundamental premise underlying the existing practices of hydro-climatic information services is that if we give the farmer access to better and more data, they would be able to enhance their agricultural methods.

Crops require water to sustain their metabolic activities and for evaporative cooling, which is particularly critical in hot climates (Crawford *et al*., 2012). As temperatures rise, it becomes more crucial to retain water within agricultural systems. Water holding capacity and soil water retention can both be significantly influenced by the physical characteristics of the soil, including its texture, density, and organic matter concentration (Dexter, 2004). Soil management choices made by individual farmers, such as the types of materials and amendments they employ, may have a significant impact on how well water is used in these systems. These management techniques have the potential to change the water balance of the system by either reducing or enhancing the broader climatic effects in the immediate environment (Szolnoki *et al*., 2013).

2.6 Indigenous Soil and Water Conservation Practices to Combat Climate Change

The encouragement of making the best use of a land possible in order to ensure its upkeep and enhancement is known as soil and water conservation (Dudal, 1981). The goal of soil conservation is often to prevent or stop erosion and other types of soil degradation. It entails taking action to repair deteriorated soils, guard against additional harm, and adopt solid soil management practices that result in continuous satisfactory output (Quansah, 2000). The various soil management technologies were described by Quansah (2000), who also provided recommendations for choosing them and explained the risks involved with each technique.

The majority of soil and water conservation strategies focus on agronomic practices, farming systems, and land use. Composting, compound farming, bunds and stone terraces, rotation of legume and cereal crops, contour earth bunding, tied-ridging, ridging, and farming close to a homestead using trash and manure are a few of these techniques.

Physical buildings for soil and water conservation are scarce, with the exception of earth bunding for water collection and, more recently, bunds and stone terraces in the Upper East region and the Bunkprugu-Yinyoo district of northern Ghana. In recent years, vegetative barriers have been utilized to slow runoff, spread it out, and give it time to absorb and filter through the particles of soil. Native American conservation efforts include:

Beds: When used, bed systems are often spaced out across a slope in various directions. It prevents runoff, which increases water infiltration and lowers soil loss.

Stone terraces and bunds: Stone bunds are constructed in stony locations, primarily in the Upper East Region of the nation, to hold water and soil for plant development. The stones are either arranged to form a terrace or are lined up along contours to construct a stone bund (Antwi *et al.*, 1998).

Mounds: Mounds are built to increase the soil amount (i.e., depth) that may be used for farming. Dependent on the farm site, geography, and crop(s) being grown, the mounds are typically positioned in a straight line or staggered. In the Northern Region, the mounds are typically planted with cassava (*Manihot esculenta*) and yam (*Dioscorea sp*.) and in the Upper West and Upper East Regions, sorghum (*Sorghum bicolor*) or millet (*Panicum collonum*).

To stop soil erosion, bridging is frequently employed across slopes. Tied-ridging is employed in urgent circumstances. It better conserves soil and regulates runoff.

Agronomic practices include cover crops, shifting cultivation, contour ridges, crop rotation, mixed cropping, mulching, strip cropping, minimal tillage, re-vegetation, appropriate grazing land management and afforestation as well as agroforestry are all part of efficient soil conservation strategies.

2.7 Role of Information in Agriculture

The pattern of matter and energy organization is called information (Parker, 1974: 10). Bates (2005) defines it as an arrangement of matter and energy that has been imbued with meaning by a living entity while knowledge is defined as information that has been given meaning and combined with other understanding-related materials (Bates, 2005). Kochen, (1983) characterizes knowledge as meaning imparted to information. Organizational patterns extend beyond perceptions. But our own thought, emotion, and memory patterns are formed and stored in our brains' neurons, from which we later generate new ideas and take actions (Bates, 2005). All books have information, even if they are left unread during the holidays at a closed library. Information in these books becomes knowledge only when it is really read by an understanding human being. The act of reading gives its contents meaning (Bates, 2005).

Information continues to play a key role in the growth of human society and has long since influenced how we think and behave (Meyer, 2005). Increasing agricultural productivity and enhancing marketing and distribution techniques both depend on information (Oladele, 2006). Additionally, information creates doors to sharing insights, new markets, sources of financial support and best practices. In a same vein, information empowers farmers to take well-informed decisions about production and marketing as well as successfully managing their lives to deal with day-to-day issues and seize chances (Matovelo, 2008; Idiegbeyan-ose and Theresa, 2009). Information is essential for maintaining and enhancing agricultural production in any nation or country, as stated by Aina *et al*. (1995). Additionally, according to Ochieng (1999), having access to knowledge is a crucial instrument for giving people the power to decide for themselves or to take action for the advancement of their communities. Supporting the aforementioned points, Durutan (1999) claimed that agricultural producers already understand the importance and value of information, and all they require is timely access to it in order to increase agricultural output. Any growth process, including agriculture, has been negatively impacted by a lack of adequate and pertinent information, claim Camble (1994) and Sturges and Neill (1990). According to Ferris (2005), farmers who have access to reliable, timely, and relevant information are better equipped to decide when and what to produce, and where to sell it than farmers who do not. Similarly, Byamugisha *et al*. (2008) add that improving farming practices including knowing what to sow, when to apply fertilizer or manure, and how to cure disease, and are all potential benefits of employing current agricultural information.

2.8 Sources of Agricultural Information for Farmers

According to Statrasts (2004), an information source is a company, organization, or person who develops or disseminates a message. Constancy, exhaustiveness, precision, relevance, cost effectiveness, trustworthiness, applicability, and aggregation level are qualities of a good information source (Statrasts, 2004). The choice of an information source is influenced by a number of variables, such as income level, size of farm, farmer age, literacy, and where the farmer is located (Riesenberg and Gor, 1999). Adhiguru *et al*. (2009) discovered that small and marginal farmers accessed information less frequently and from few sources than medium and large-scale farmers using the Indian NSSO 2003 survey. Community leaders, farmer groups, bulletins, journals, and newspapers are just a few of the information sources mentioned by Buba (2003), Ogboma (2010), Mtega and Benard (2013), and Meitei and Devi (2009) as being utilized by farmers to receive their agricultural information. Farmers are said to use radio, televisions, agricultural extensions and posters as their information sources, according to a 2009 research by Daudu *et al*. Furthermore, according to a research by the FAO from 1997, farmers prefer to get their information from their farmers' cooperative organization, neighbors and their fellow farmers. Ogboma (2010) noted that local Government officers, personal experience, training, friends and neighbors, the Ministry of Agriculture, workshops and seminars, agricultural magazines, extension agents, posters, libraries of agriculture, and non-governmental organizations were some of the information sources used by rice farmers. Further research by Daudu *et al*. (2013) in Nigeria revealed that radio, friends, extension agents and libraries were the primary information sources used by farmers to access agricultural knowledge. Similar findings were made by Bozi and Ozcatalbas (2010), who found that Turkish farmers' primary sources of knowledge included extension agencies, family members, media, input suppliers and the nearby farms.

However, because each farmer favors particular information sources or channels over others, it is therefore, crucial to conduct careful research before choosing an information source to address farmer information needs.

2.9 Information Needs of Farmers

Information needs, according to Devadson and Lingam (1996), are gaps in the user's current knowledge. In daily employment, a loss of independence generates a demand for information. In order to fill in the gaps in their knowledge and information, rice farmers may be motivated by information requests. For daily agricultural activities, farmers need a variety of information. Furthermore, depending on a variety of variables, including ease of information use, age, level of awareness, education level, availability of information sources and socioeconomic status, an individual's or a group of individuals' level of information demands may vary (Kaniki, 2003). Rural farmers, according to Meitei and Devi (2009), are not receiving the appropriate information at the appropriate time, which is causing agricultural activities to progress slowly. Farmers' information demands must be categorized, according to Dulle and Aina (1999), in order to offer timely, appropriate, and relevant information to them. According to research by Meitei and Devi (2009), Benard (2011), Sabo (2007), Mtega and Benard (2013), farmers have a variety of information needs, including knowledge of where and how to buy agricultural equipment as well as knowledge of irrigation, improved seed varieties, soil fertility, access to loans or credit, marketing strategies and weather conditions.

An additional investigation by Babu *et al.* (2012) discovered that the application of pesticides and fertilizers, the management of pests and diseases, the optimal time to plant, seed treatment, storage, and the planting method were the most important information requirements for rice farmers. When Tologbonse *et al.* (2008) studied the information needs of rice farmers in Niger State, the results revealed that 89.9 % of the farmers had a need for knowledge on crop productivity. According to a study conducted in Tanzania by Lwoga (2009), 66.3 % of the small-scale farmers surveyed needed information on managing plant diseases and pests, 58.6 % needed it on loan options, 29.3 % needed it on irrigation techniques, 59.1 % needed it on marketing and 54.7 % needed it on managing animal diseases. Furthermore, Ozowa (1995) contends that given the constant exposure to brand-new, intricate challenges, farmers have different information needs.

2.10 Indigenous Knowledge Systems

Indigenous forecasts (IF) are still widely used in distant areas of the developing world, including Africa, where indigenous knowledge systems (IKS) are an integral part of communities, despite the rise in the dissemination of scientific forecasts (SF) via radio, television, and the internet (Hoegh-Guldberg *et al*., 2018). Studies have demonstrated that people regularly formed predictions and compared them to current observations based on past experiences before sophisticated scientific weather and climate forecast systems were created (Olsson *et al*., 2004; Orlove *et al*., 2010). The behavior of birds, insects, and mammals as well as the positions of the moon and sun and the shadows they cast, the position of the clouds, physiological changes in the vegetation and the speed and direction of the wind are used by the locals as sources to create forecasts (Chang'a *et al*., 2010). A growing body of knowledge, belief and practice about the relationships of living beings (including humans) with one another and with their environment has been described as an IKS by Berkes (1999, p. 8). This suggests that IKS has two dimensions: one concerned with the passage of time from one generation to another, and the other with events that take place in a specific location. Indigenous knowledge forecasting (IKF) is one of many components of IKS.

Better and more easily accessible meteorological and climate information services are desperately needed to aid decision-making, particularly for small-scale farmers. The climate varies greatly across most of Africa, and better climate information services may be able to assist farmers in coping with climate change and fluctuation. Food production makes a significant economic contribution to Ghana, where smallholder farmers account for 80 % of the nation's overall agricultural output (Barnett *et al*., 2017). Rainwater is mostly used by these farmers to produce their crops. Because of this reliance on rains, the area is defenseless to change in climate and variability, including changes in the timing of showers, seasonal rainfall levels, and the incidence of dry spells (Yaro, 2013; Gbangou *et al*., 2019; Owusu and Waylen, 2009). Local farmers thus struggle to ensure their own food and financial security. They can adjust and take better decisions to raise their agricultural yields with the aid of improved and personalized weather and climate forecast information (Gbangou *et al*., 2018, 2019; Derbile *et al*., 2016).

Although earlier research (Roudier *et al*., 2014; Codjoe *et al*., 2014; Orlove *et al*., 2010) demonstrated that African farmers employ both indigenous and modern forecasting knowledge on climate and weather across Africa, there are still a number of constraints. First, at high spatial resolutions (i.e., local scale), scientific forecast information frequently exhibits poor skills and accuracy (Fitzpatrick *et al*., 2015; Vellinga *et al*., 2013; Derbile *et al*., 2016). Additionally, the effectiveness and applicability of forecasts can occasionally be constrained by farmers' knowledge and acceptance of modern forecasts (Ingram *et al*., 2002). Moreover, this expertise is frequently poorly adapted to the requirements of end users. Second, there are accusations that local forecasting expertise is less trusted as a result of the loss of indicators, which is most likely brought on by shifting meteorological and climatic circumstances (Ziervogel and Downing 2004; Ziervogel 2001; Kalanda-Joshua *et al*., 2011). Due to problems with reproducibility that prevent scientific and practical knowledge from spreading, local knowledge is also suspect (Pierotti and Wildcat 2000; Gilchrist *et al*., 2005; Huntington 2000).

2.11 Soil Moisture

On Earth, soil is a vital natural resource. Although soil is a natural resource that can be replenished, over time it may run out. Due to the loss of the nutrient-rich top soil and the decreased ability of the eroded soils to retain water, soil loss and deterioration in soil quality are the primary on-site effects of soil erosion (Schoonover *et al*., 2015).

Soil moisture is one hydrological factor that has an impact on a variety of meteorological, vegetation growth and hydrological processes. The primary water source for plants between rainfall events is stored in the soil, which affects yield of crops, and moisture levels of soil have an impact on decisions about when to plant, when to use pesticides and herbicides, when to apply fertilizer, and when to schedule irrigation (Brocca *et al.*, 2017; Sarwar *et al.*, 2021; Zhang *et al.*, 2019). In the hydrological cycle, surface soil moisture (SSM) has a significant impact on runoff, evapotranspiration, and vegetation growth (Zhang *et al.*, 2019; Quan *et al.*, 2022). SSM is an important indication of agricultural dryness in the soil. According to Liu *et al.* (2020), soil-plant-atmosphere interactions, soil organisms, soil density, soil structure, soil texture, climatic and meteorological conditions all influence the amount of soil moisture that is available. The amount of water in the soil's pore space is gauged by its water content. Moisture, temperature, soil texture, soil organisms and soil organic matter all have an impact on the amount of water in the soil.

Although it also significantly contributes to agricultural water security, moisture of the soil is a good indicator of crop output in the future (Tian *et al.*, 2019). The soil water storage depth is the most important factor affecting soil moisture. The main element regulating soil moisture is the root zone depth, which is the section where crops may absorb water. Quantity of water given to the soil, the precipitation amount, and the ground's drainage are used to determine the proper depth of the root zone. The SSM (depth of moisture up to 10 cm) is regarded as a more representative component of the soil for these types of studies of agricultural water management in the research studies addressing agricultural hydrologic features of soil moisture (Corti *et al.*, 2011; Tian *et al.*, 2019). It is alarming because soil moisture is currently trending downward. SSM is a stand-in for soil moisture related to yield. In order to forecast future yields and ultimately enhance crop output and food security, it is essential to comprehend the causes and effects of SSM (Tian *et al.*, 2021).

2.12 Soil Moisture and Precipitation

SSM is thought to make up about 0.001 % of the freshwater on Earth, yet it has a significant impact on the hydrologic cycle (McColl *et al.*, 2017). Quantity of water in the top soil affects major hydrologic processes like river discharge, precipitation, flood, and drought as well as how much heat is exchanged between the ground and the atmosphere. Because of its importance, moisture of the soil is used to predict weather, assess agricultural production, anticipate climate change, and provide early warning for flood and drought (Entekhabi *et al*., 2010).

The interaction between moisture of the soil and precipitation has a significant impact on the water and energy cycles on land. While certain facets of this relationship are clear-cut, others are debatable. The variability of runoff, precipitation, and evapotranspiration affects the geographical and temporal patterns of soil moisture (McCabe and Wolock, 2013; Famiglietti and Rodell, 2013). Although soil moisture is dependent on the aforementioned hydrologic components, there are additional questions about its function as a response mechanism for precipitation and other hydrologic components (James and Roulet, 2009; Liang *et al*., 2010; Koster *et al*., 2004).

The relationship between moisture of the soil and precipitation is intricate, with regional variations in the correlation's strength and direction (positive/negative). Some physical processes that contribute to the favorable associations between precipitation and moisture of the soil have been previously studied. (Eltahir, 1998; Zheng and Eltahir, 1998; Findell and Eltahir, 1997). These investigations offer validity to the idea that moister soil might supply an abundance of moisture to the air, raising humidity and, consequently, promoting precipitation. From the perspective of the energy balance, moister soil reduces surface albedo, allowing for an increase in net solar and terrestrial radiation as well as a rise in moisture convergence, all of which may eventually lead to an improvement in precipitation. Such a mechanism backs up the axiom that "wet regions get wetter, dry regions get drier," which postulates that flood risks are higher in wet regions and drought risks are higher in dry parts.

However, current research (Guillod *et al.*, 2015; Yang *et al.*, 2018; Cook *et al.*, 2006) suggests that precipitation and moisture of the soil are negatively associated in some locations. Because of the stronger convective system, for instance, greater precipitation is seen in areas with dry soil, such as Southern Africa, which increases the danger of flooding (Cook *et al.*, 2006). The well-known "wet regions get wetter, dry regions get drier" pattern is challenged by this opposing phenomena, which raises questions regarding the association between precipitation and moisture of the soil (Feng and Zhang, 2015; Greve *et al.*, 2014). The time series analysis carried out by Robin *et al.* (2019) identifies which of the two mechanisms is responsible for negative correlations: either a) moisture of the soil increases while precipitation does not increase (i.e., decreases or stays the same), or b) moisture of the soil decreases while precipitation does not decrease (i.e., increases or stays the same). In particular, the time series helped to explain why moisture of the soil occasionally increased when precipitation did not in the Amazon Rainforest and Central California. The relationship between moisture of the soil and precipitation appears to be inverse in major river basins, suggesting that the two variables are not always positively correlated. This is likely because of two physical processes, including hydraulic relocation by tropical trees (Yan and Dickinson, 2014; Harper *et al.*, 2010), as well as river transport and expansion brought on by upstream precipitation (Conway, 2000, 2005). Additionally, the local climate and environment have a significant impact on the interplay between soil moisture and precipitation (Ford *et al.*, 2015a; Ford *et al.*, 2015b; Boé, 2013). These bodies of research suggest that the interactions between soil moisture and precipitation may be significantly influenced by environmental factors including climate regimes and land cover.

The quality and availability of the data, in addition to climatic conditions, further complicate the research of soil moisture and precipitation. In recent years, measures of soil moisture have seen a significant advancement in technology. Through the use of remote sensing, they are no longer constrained to sparse networks of on-farm samplings and have almost complete worldwide coverage. The Soil Moisture Active Passive (SMAP) (O'Neill *et al*., 2016), Advanced Microwave Scanning Radiometer - Earth Observing System (AMSR-E) (Wentz *et al*., 2014), and Soil Moisture and Ocean Salinity (SMOS) (Kerr *et al*., 2013) are three datasets for soil moisture collected throughout the satellite era. Although these datasets denote significant technological advancements in the research of moisture of the soil, verification is still necessary to guarantee the accuracy of the data.

2.13 Factors influencing surface soil moisture (SSM)

Five important variables, including soil characteristics, climate, vegetation, topography and land-use patterns, affect the spatial and temporal variance of SSM. Climate factors, which are ongoing meteorological parameters, have an impact on SSM dispersion both directly and indirectly. For instance, while precipitation and evapotranspiration (ET) have a direct effect, external solar radiation and temperature have an indirect effect through the change of contributing components. Vereecken *et al*. (2014), Martnez-Fernández & Ceballos (2003), and Robinson *et al*. (2008) looked into the influence of seasonal and climatic factors on the spatiotemporal variation of soil moisture. Martnez *et al*. (2014) examined the effect of soil hydraulic characteristics and climatic type on temporal stability and discovered that summer is the most likely season for inter-annual variances in variations of soil moisture. According to research by Pan *et al*. (2008), the key influencing factors during rainfall periods were topography and local vegetation, while during dry seasons, soil texture was the most significant. The two most significant components determining the spatiotemporal variability of moisture of the soil at remotely sensed footprint scales and at the ground, according to Joshi and Mohanty (2010), are topography and soil texture. Additionally, SSM patterns are dominated by precipitation patterns at the catchment size (along with other meteorological phenomena). In a detailed view, the size of the watershed affects the influencing elements. According to some studies (Wang *et al*., 2021; Munyasya *et al*., 2022; Guo *et al*., 2020) climate is the primary factor controlling soil moisture on a wide scale, although land use and topographical characteristics have a significant impact on the spatial variability in soil moisture in a local watershed. The likely cause is because, at a lower scale, land use and topographical elements are more prominent and climatic circumstances are more predictable, but, at a larger scale, topography, soil qualities and land use is affected by climatic factors (Guo *et al*., 2020). However, a thorough examination of the influencing factors is required.

2.14 Knowledge of Local Soil Classifications

The absence of new technology adoption in local communities, for example, for water management or agriculture, has been better understood using indigenous environmental knowledge and increased community involvement in research and implementation. By involving farmers and their knowledge of community needs in economic growth, the advantages of local expertise can be realized. Native soil knowledge is described as "the knowledge of properties of the soil (i.e., water holding capacity, infiltration, alkalinity, acidity, etc.) known by people living in a particular surroundings for some time period" (Winklerprins, 1999: 151). Native soil typologies strive to define the local environment to help people fulfill local needs, such as for consistent food production amid rainfall variability, and are the way soils are identified and categorized (Barrera-Bassols *et al*., 2006). To make native environmental knowledge understandable to outsiders, technical knowledge, such as that supplied by international soil classifications and native soil typologies, should be combined at all cost without compromising the essence of either. Finally, it is hoped that by combining local and technical knowledge, agricultural management methods will be enhanced (Winklerprins, 1999).

Conventional survey of soil results are frequently given in a way that is not user-friendly that results to underappreciated and misused by illiterate farmers in making judgments about management and land use (Grealish *et al*., 2015). Internationally recognized classification systems like Soil Taxonomy (Soil Survey Staff, 2014) and the World Reference Base (IUSS Working Group WRB, 2014), as well as national systems, are general-purpose regardless of having improved the understanding and categorization of soils around the globe. These classification systems identify and name soils using specialist language and terminology, and their application necessitates extensive knowledge and experience (Fitzpatrick, 2013). The knowledge of regional land users must be taken seriously in order to increase the indigenous relevance and impact of the survey of soil findings (Sillitoe, 1998). For its usefulness and contribution to logical and sustainable soil management, local soil knowledge is well acknowledged (Niemeijer and Mazzucato, 2003; Jyoti *et al*., 2015; Barrera-Bassols, 2000). The use of native soil knowledge in soil surveys has been shown to address practical problems and offer culturally acceptable solutions relevant to indigenous contexts in various nations and across many ethnic groups (Barrera-Bassols *et al*., 2009). While some research (Barrera-Bassols *et al*., 2009; Schuler *et al*., 2006) indicated low connections between indigenous and modern classifications, others (Oliver *et al*., 2010; Payton *et al*., 2003) reported positive relationships. Such diversity is frequently linked to variations in the examined areas' landscape structures.

According to Barrera-Bassols (2016), many rural residents are pedologists since their knowledge and comprehension of the morphological characteristics of the soil have proven to be a reliable foundation for soil usage and management, at least at the field size. Based on descriptive morphological soil properties that are significant to the user, taxonomies of local vernacular classification systems are constructed (Corbeels *et al*., 2000; Krasilnikov *et al*., 2009; Sandor and Furbee, 1996; Habarurema and Steiner, 1997). The primary classification criteria that have been most frequently reported include key soil morphological characteristics such as texture and color (Barrera-Bassols and Zinck, 2003; Sillitoe *et al*., 2004; Ettema, 1994; Shah, 1995; Talawar and Rhoades, 1998). Because classification systems are frequently not hierarchical, how soils are distinguished depends on the classifier's perceptions, presumptions, and needs (Showers, 2006). Because of this, people can relate to soils in any way that suits their requirements (Sillitoe, 1998). Indigenous soil-crop systems are based on local classification of soil, which extends beyond nomenclature of the soil.

According to Niemeijer and Mazzucato (2003), ethnopedological knowledge has the potential to adequately describe complex and changing landscapes as well as the experiences of farmers and rural residents in general. Therefore, it is important to view soil indigenous knowledge as a complementary body of information with important contributions from local experiences. This will improve the relevance of modern knowledge to the requirements of rural people. Thus, the broadest possible interpretation of land-user perspectives of soil usage and management is required in ethnopedological study. A holistic approach is required to fully capture the core of farmers' pedological wisdom (Barrera-Bassols *et al*., 2006).

CHAPTER THREE

3.0 MATERIAL AND METHODS

3.1 Description of the Study Area

The fieldwork for this study took place in three communities: Gbullung in the Kumbungu district, Nakpanzoo and Yapalsi in the Savelugu municipality, both of which are near to Tamale, the capital of the Northern Region (Figure 3.1). Field work was carried out from October to December 2021.

The study region is situated in a tropical Savannah zone with only one season of rainfall. In comparison to the southern region of the country, the temperature is high. With a mean annual temperature of 28.3 °C, the lowest minimum daily temperature is around 15 °C and is recorded in August, while the greatest maximum daily temperatures can reach up to 42 °C and are reported in March or April (Nyadzi, 2016). It experiences around 1,250 mm of rain fall on average each year (Abdul-Rahaman and Owusu-Sekyere, 2017). High rainfall variability and poor soils diminish this region's potential for agriculture (Alhassa *et al*., 2018; Nutsukpo *et al*., 2012). The research area has a dry season that lasts from November to April and a six-month rainy season that lasts from May to October each year (McSweeney *et al*., 2006). The area's agricultural production is badly impacted by the region's unimodal rainfall and other difficult climatic conditions (Quaye-Ballard *et al*., 2020; Yiran *et al*., 2012). By the year 2050, the region is expected to suffer a drop in rainfall occurrence, a rise in daily temperatures, and an increase in rainfall amount, according to projections by Owusu and Waylen (2009). Crop yield is expected to decline as a result, which might jeopardize the region's ability to ensure its own food security.

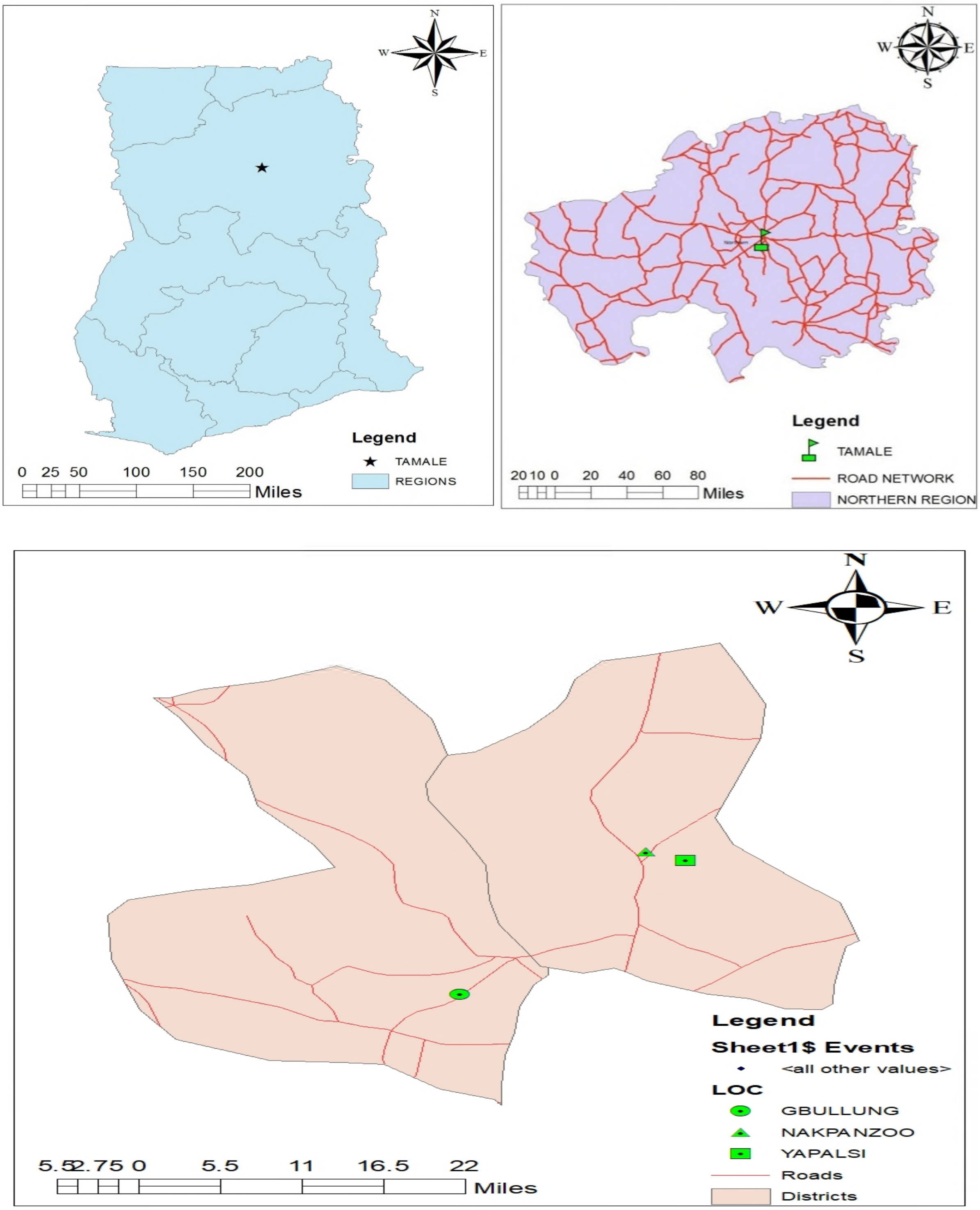

Figure 3.1 Locations of the study areas in the Kumbungu district and Savelugu municipality

(Source: B. M. Jamaldeen, 2021)

The majority of people living in the Kumbungu district and Savelugu municipality are of the Dagomba ethnic group, who depend on rearing of livestock and crop farming and for a living. Other ethnic groups that have settled in the region, like the Gonja and Ewe, depend on the fishing industry along the White Volta River for their livelihood. Some farmers in the Kumbungu district also benefit from the 470 ha Bontanga decentralized irrigation program, which is run by local groups. Water from the White Volta River's tributaries is also used by farmers in the Savelugu municipality to cultivate their land. The Guinea Savanna's usual vegetation is present, with lone trees and tall grass. Except for the lowlands, which include alluvial deposits, the soil is mostly of the sandy loam type. The primary economic activity in the districts is subsistence agriculture, which is a highly seasonal occupation. The trees in the area can withstand drought and rarely ever lose all of their leaves throughout the protracted dry season. The majority of these have economic value and are crucial sources of income, particularly for women. Notable examples are Dawadawa (*Parkia biglobosa*), which produces seeds for ingredient and many other locally used goods, and Shea trees (*Vitellaria paradoxa*), which are used to produce Shea butter (Ansah & Nagbila, 2011).

Geographically, the Savelugu municipality is situated on latitude 9° 36' N and longitude 0° 49' W, with an average elevation of 168.95 m a.s.l, while the Kumbungu district is situated on latitude 9° 33' 32" N and longitude 0° 56' 55" W.

Table 3.1 Geographical locations of the selected communities

Communities	Latitude N°	Longitude W°
Gbullung (Kumbungu District)	9.49	1.00
Yapalsi (Savelugu Municipality)	9.74	0.78
Nakpanzoo (Savelugu Municipality)	9.75	0.82

(Source: Field visit, 2021)

3.2 Methodology

Step by step account of the experimental design and methodological framework as well as a description of the various methods and materials employed in the study is presented in this section. It comprises of a description of the study area with a location map (Figure 3.1). Cross-sectional data was collected from a sample of 48 smallholder farmers' perception on perceptions of temperature and rainfall characteristics, water availability, onset and duration of different seasons from the three communities. In this study, data were gathered using both quantitative and qualitative research approaches, including a review of the literature, the use of semi-structured personal interviews, key informant interviews, and focus group discussions (FGDs). Statistical Package for Social Sciences (SPSS) and Excel were both used to evaluate the data from these sources. Additionally, information was acquired from primary and secondary sources. Appendix I and II contain examples of questionnaires and FGD questions.

The study was categorized into three (3) phases as shown in (Figure 3.2);

Phase one (1): Desk studies – literature review (1st October 2021 – 30th October 2022)

Phase two (2): Field studies (data collection) consisting of sampling, key informant discussions, participatory interaction with farmers, FGDs, personal observations and individual farmer interviews with semi-structured questionnaire (11th October, 2021 - 2nd November, 2021).

Phase three (3): Data analysis and presentation using Microsoft Excel 2016 version and SPSS Statistics version 20 software (2nd November, 2021 – 31st December, 2021).

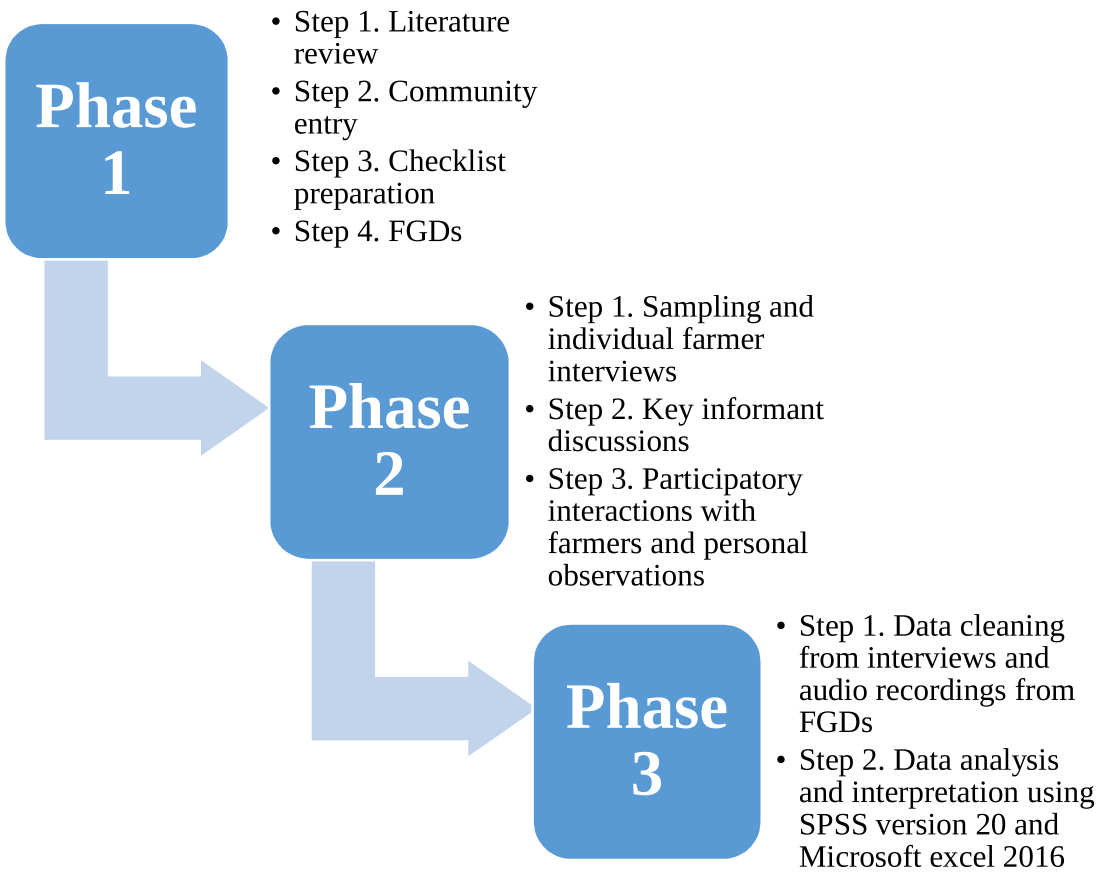

Figure 3.2 The Study Approach

(Source: B. M. Jamaldeen, 2021)

The primary target group in the study area were the rice farmers. The following methods were used to collect the primary data: key informant discussions, reconnaissance field visits, FGDs and semi-structured personal interviews and questionnaires, personal observations, and participatory interaction with 48 farmers found in three communities (16 farmers each) namely Gbullung, Nakpanzoo, and Yapalsi. Demographic details, water availability for farming, moisture of the soil, weather, and other agricultural-related facts, as well as indigenous knowledge on farming-related concerns were all subject to questions. The availability of water and weather forecast information, as well as the information requirements for agricultural decision-making, were also covered. The latter was more concerned with how farmers understood the information about soil moisture availability from various sources. The evidence gathered made it easier to comprehend why the particular farmers' group needed information on soil moisture.

3.2.1 Sampling Techniques

The sampling method was multi-stage. The Northern Region was purposefully chosen for the first stage because it is the nation's top producer of rice, accounting for around 37 % of the country's total output, and is situated in a semi-arid climate region (MoFA, 2014). Due to their contribution to the region's rice production as well as the unpredictability of their rainfall patterns in comparison to other districts in the region, Kumbungu district and Savelugu municipality were purposefully chosen among other districts for the second stage (Alhassan *et al.*, 2018). Two settlements in the Savelugu municipality and one in the Kumbungu District were arbitrarily chosen based on population and land size. From all the villages, a total of forty eight (48) smallholder rice producers were proportionally chosen using simple random sampling.

3.2.2 Focus Group Discussions (FGDs)

To learn more about the farmers' knowledge of soil and moisture conditions, current weather and climate-related stress, how moisture information is perceived, evaluated, and used in agricultural decision-making, as well as their source of climate forecast information, focus groups were held.

A checklist served as the FGDs' guide to ensure that every item was completed and that the FGDs stayed on track with the study's goals. The informal atmosphere promoted relationship-building for potential future collaborations and encouraged respondents to speak more freely and candidly about their experiences. Each discussion lasted for about an hour, and after getting permission from the group, the data was recorded digitally and afterwards written down in a field notebook.

In general, at the start of the FGDs, interviewees were asked first about their views of soil moisture, to classify soils in the community and narrate freely about different soil types. The objective was to comprehensively list all different soil types, and how these behave under different moisture conditions, and to determine which were most important to the farmers. If the group did not mention many details, additional questions about traditional moisture forecast or rainfall impacts on soil were asked to stimulate the discussion. Activities discussed with farmers are outlined in Appendix II. To further broaden the conversation, obtain a deeper understanding of the specifics of the problems being discussed, and ensure that everyone there contributed and participated equally, probing questions were posed.

Plate 3.1 A) Men FGD at Gbullung B) Women FGD at Nakpanzoo

(Source: B. M. Jamaldeen, 2021)

The data obtained from FGDs were processed by transcribing the responses from audio recordings using Microsoft word. In order to comprehend how this information is seen, evaluated, and used for agricultural decision-making among farmers, the analysis provided information on the functions of soil moisture information in farmers' responses to weather and climate related stresses.

3.2.3 Individual Interviews and Questionnaires Administration

Individual interviews were conducted at the community level using semi-structured questionnaires following the sampled marked households (Figure 3.2). The farmers were selected at random and purposefully, based on their expertise in farming.

Demographic data, water and moisture of the soil availability, weather, agricultural-related data, and local knowledge were all topics of questions. Additionally, we questioned farmers on the availability of water and weather forecast data, as well as their information needs for making agricultural decisions. The availability of moisture information from different sources as perceived by farmers, methods of examining soil moisture content at community level and water storage structures used by farmers to retain water in their fields were also investigated. The available soil moisture information sources and needs of farmers were included. The information gathered made it easier to see why the chosen farmers' group needed information about soil moisture.

Plate 3.2 Individual interviews administration at the community level

(Source: B. M. Jamaldeen, 2021)

Both open-ended and closed questions were included in the questionnaire. Five-point (excellent, good, acceptable, poor, and very poor or very accurate, accurate, acceptable, poor and very poor) and three-point (high, moderate and low) Likert scale was used in the questionnaires to assess farmers' indigenous climate knowledge, its accuracy and effects of climate change on agriculture.

3.2.4 Key Informant Discussions (KIDs)

Because of the prominence and experience of the key informant, KIDs may unintentionally be positioned as producing more valuable knowledge within the hierarchy of research methodologies.

Interviews with "ordinary" people may not provide as much information as key informants, who are thought to provide significant information (Lokot, 2021). Key informants are largely employed as a source of information on a range of themes, including kinship and family organization, the economic system, political structure, religious beliefs and practices in conventional anthropological field research (Tremblay, 1957). To put it briefly, individuals are extensively questioned over a long period of time in order to provide a reasonably comprehensive ethnographical account of the subject matter. In that specific manner, a small number of informants are interviewed in order to ensure the complete patterning of a culture. The method is ideally suited to collecting the kinds of descriptive and qualitative data that are hard or time-consuming to collect using structured methods like questionnaire surveys (Tremblay, 1957). To investigate each soil's properties in this study, two to three informants each in every community was chosen for their experience in farming. These people were selected following suggestions made from contact person in every community and the researcher observation.

3.2.5 Personal Observations

A total of three transit walks were carried out in each community with participating farmers to take the communities Global Positioning System (GPS) coordinates with a Garmin GPS and observed the physical context of the communities (buildings/houses, business enterprises, community members behaviors, etc.), as well as to observed the farm operations and the marketing practices. We also participated in some of the farm practices (sowing, drying of farm produce, going for fishing etc.) in order to gain a personal experience and create a bond with the participants for future collaborations. Together, the observations and the data from the transect walks gave crucial firsthand knowledge of a number of the topics covered in the focus group discussions and interviews.

Plate 3.3 Personal observations

(Source: B. M. Jamaldeen, 2021)

3.2 Data Analysis

The data were analyzed in stages. The data from interviews and FGDs needed to be cleaned in the first stage. Field notes were edited, organized, and transcribed together with transcriptions of FGD audio recordings. Data editing involved checking the quality of responses to questions as they were recorded, substituting full expressions for shorthand notes, and clarifying structures and sentences (Miles & Huberman, 1994; Dey, 2003).

Thematic analysis, which was the second stage, aimed to analyze data in relation to important themes of interest. Themes included (i) information needs of farmers (ii) water and weather stresses (iii) agricultural information (iv) soil information and so on.

SPSS and Microsoft Excel software were used to summarize the data into frequency distributions and percentages. Tables as well as graphs were constructed to provide graphical representation of the responses. Also, Pearson Chi-Square test using SPSS cross-tabulation was used to examine the differences in response to weather and climate information.

Percentages and frequencies were used to denote farmers' perceived long-term changes in temperature, rainfall, frequency of prolonged dry spells, start and end of rainfall, and also LGS perceived by farmers. Percentages were used to rate weather information and soil moisture importance on farming practices using three-point likert scale i.e., strongly agree, undecided and agree and five-point likert scale such as don't know, not important, important, very important, extremely important respectively. Similarly, the frequencies were also used in soil moisture measurement by hand feel and smell.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSIONS

4.1 Socio-economic Characteristics of Lowland Rice Farmers

The socioeconomic traits of lowland rice growers are covered in this chapter. It considers gender and educational level of lowland rice farmers, occupation of respondents, farmers' age and years of experience in growing rice as well as literacy and household size of rice farmers.

4.1.1 Gender and Educational Level of Lowland Rice Farmers

To ensure that each research community had an equal number of responders, we interviewed 16 farmers. Despite our best efforts to achieve gender parity among respondents, only a small percentage of female farmers participated in each community, with Gbullung (9 % female respondents) having the highest percentage, followed by Yapalsi (6 % female respondents) and Nakpanzoo (4 % female respondents), accounting for a total of 19 % of the female farmers surveyed. The main cause is that men predominately engage in farming activities in this region of Ghana (Gbangou *et al*., 2020b).

About 54 % of all farmers were illiterate, which is similar to the statistics for the district of 69.2 % (PHC, 2013) Table 4.1. Among the 54 % of farmers who had no formal education, 35 % were males and 19 % were females. Thus, all the female respondents had no formal education. From personal observations and interaction with the participants, there might be two underlying reasons to this. First, most girls are occupied with domestic chores and are not given enough time to attend school, as compared to their male counterparts. Second, in these communities, females are responsible for household chores because family and community believe that female education doesn't matter. However, that perception is changing with the upcoming generation (Field Survey, 2021). According to Apusigah (2004), gender encompasses the full range of relationships that control how women and men interact socially, culturally, and economically in various spheres of life. Mehta and Srinivasan (2000) provide more support for the idea that gender plays a crucial influence in how societies divide up jobs, duties, assets, and rights between men and women.

Gbullung and Nakpanzoo had the higher literacy level (50 %) followed by Yapalsi (37 %) but with the tertiary education level attained by 4 % of respondents, followed by Gbullung (2 % respondents). This demonstrates that the research area's few educated male farmers were SHS graduates, JHS & elementary leavers, as shown in (Table 4.1). Due to the low literacy among farmers in the study area, it might be difficult to transfer agricultural technologies to the farmers without extensive funding and appropriate training.

Table 4.1. Gender and educational level of respondents in the three communities

Educational level	**Male**		**Female**		**Total**	
	Frequency	%	**Frequency**	%	**Frequency**	%
No formal education	17	35	9	19	26	54
Primary	12	25	0	0	12	25
JHS	3	6	0	0	3	6
SHS	4	8	0	0	4	8
Tertiary	3	6	0	0	3	6
Total	39	80	9	19	**48**	**100**

(Source: Field survey, 2021)

More than half (54 %) of all farmers in the three villages had no formal education. That is not unexpected considering that rural groups in Northern Ghana, like the study location, often exhibit this trait. Education is crucial for adoption because, according to Umunna (2010), it improves the capacity to retain and retrieve information for later use as well as allowing one to control the rate of message inputs. Weir and Knight's (2000) findings further support the idea that extension agents find it easier to promote agricultural technologies to farmers with formal education than to those without.

To increase their level of literacy and their capacity to read and comprehend concepts particularly labels on agricultural inputs and technologies, smallholder farmers, especially women, need formal education. To increase their level of literacy and their capacity to read and comprehend concepts, smallholder farmers, especially women, need formal education, particularly labeling on agricultural inputs and technologies. Some adaptation technologies are time-consuming and necessitate a certain level of technical expertise and knowledge from farmers to be executed successfully. Ultimately, 54 % of the sampled farmers lack the ability to understand basic instructional labels on farm supplies for efficient use since they have never attended school. Additionally, it was discovered that the main barrier preventing farmers in Northern Ghana from adopting irrigation technologies was a lack of expertise on their behalf (Bawakyillenuo *et al.*, 2016; Alhassan *et al.*, 2018). Adopting adaptation measures for climate change is extremely difficult in light of this.

4.1.2 Occupations of Respondents

Other occupations cited by the interviewees include carpentry, masonry, teaching, bread selling, scrapping and fishing, and mobile money vending, in addition to those shown in Table 4.2 which are common in all the communities. Crop farming was the primary occupation of the majority of respondents (92 %) while animal rearing was the predominant secondary occupation in the study region (67 %) with the highest representation in Nakpanzoo (25 % respondents), Gbullung (22 % respondents), and Yapalsi (20 % respondents). Almost all of the respondents identified as "farmers," indicating that they were engaged in both crop cultivation and livestock raising. Therefore, farming was the predominant kind of employment for those living in the research area.

The interviews found that farmers utilized residues, by-products, and products from both crops and animals well. Animal dropping functioned as organic manure for their farms and the crop residue as food for the animals. The farmers therefore harnessed the advantages of mixed farming. A study carried out in Botswana by Tersteeg *et al.* (1993) explained that in order to adapt to very poor yields to suffice farmers demand, they have adapted strategies to spread and minimize risks like rearing of livestock and small-scale commercial activities. Also, according to DOSM (2001) in Botswana Serowe area, land is devoted to livestock production follow by settlement due to its benefits for agricultural farms and to the farmers.

Table 4.2. Primary and secondary occupations of respondents

Occupation	**Primary**		**Secondary**	
	Frequency	%	**Frequency**	%
Crop farming	44.0	92.0	1.0	2.0
Animal rearing	0.0	0.0	32.0	67.0
Butcher	0.0	0.0	4.0	8.0
Total	**44.0**	**92.0**	**37**	**77.0**

(Source: Field survey, 2021) *Note; The 2 % of the respondents who considered farming as a secondary occupation was selling basic goods and supplies in the community.

Most of respondents grow maize and groundnut as their main food crop. During FGDs, it was revealed that some of the farmers went into rice farming to supplement or generate income for paying of children’s school fees or pocket money for themselves, ceremonies, medical bills etc.

4.1.3 Age and Farmers' Years of Experience in Cultivating Rice

Most participants' age ranged between 35-44 years (31 %). Yapalsi has the greatest percentage (19 %) of older farmers in the 55–64 age range. Farmers who are working-age and between the ages of 25 and 54 predominate in farming activities (OECD, 2022).

Older farmers (45 years and older) frequently have more than 20 years' experience in growing rice, but younger farmers (those under 30 years old) rarely do, as expected (Table 4.3). Age of farmers is closely related to years of experience. Years of experience are crucial for farmers because they can apply the right agronomic techniques for coping with climate-related disasters like drought and flooding to lessen their levels of vulnerability (Alhassan *et al*., 2018).

Table 4.3. Age and farmers experience in farming among respondents

Gbullung			**Yapalsi**		**Nakpanzoo**	
Farm experience	**Frequency**	%	**Frequency**	%	**Frequency**	%
<5	6	38.0	2	13.0	1	6.0
5-10	9	56.0	6	38.0	12	75.0
11-15	0	0	4	25.0	0	0
16-20	0	0	0	0	2	13.0
>20	1	6.0	4	25.0	1	6.0
Total	**16**	**100**	**16**	**100**	**16**	**100**

(Source Field survey, 2021)

The three community farming backgrounds are diverse. In Gbullung, 38 % of farmers have fewer than five years of experience and are therefore less experienced. The most experienced farmers are found in Nakpanzoo (counted from 5 – 20+ years of farming experience). Most farmers in Gbullung, Nakpanzoo and Yapalsi (56 %, 75 % and 38 % respectively) have farm experience between 5-10 years. Generally, in the three communities, most of the respondents (56 %) have 5-10 years of experience in rice farming, some (19 %) have experienced below 5 years and very few (13 %) have experience of more than 20 years in rice cultivation. Children in such rural communities accompany their parents to the farm and help as source of family labor and gain some experience by helping their parents on the farm as well. Also, some respondents started cultivating rice at their middle age, after cultivating mostly maize and groundnut earlier on. During the survey it was observed that maize is what most landlords/husbands offered to their wives to sell in order to generate cash for other food stuff while groundnuts are used to prepare soup for the family. Because of these reasons farmers in selected communities always cultivate maize and groundnuts as a priority and they have shorter years of experience in rice production. Only five of the elder (45+) farmers had more than 20 years of rice growing experience. If an innovation is realistic for them, such farmers are more likely to adopt it and keep using it. According to the survey report, some farmers between the ages of 25 and 44 who were in the prime of their careers and had previous experience growing rice participated in the interviews. The majority of these farmers were found in Nakpanzoo (31 %) followed by Yapalsi (29 %) and Gbullung (21 %), while overall, 81 % of farmers had more than five years of experience growing rice, with 5-10 years being usual (56 % of responses). But only 19 % of the farmers had more than five years of experience growing rice.

4.1.4 Educational Level and Household Size

Each community has a different average household size in terms of the number of individuals. While the majority of household in Nakpanzoo have between 6-9 individuals or >20 and either 14-17 or >21 people in Yapalsi, many houses in Gbullung have a number of people between 6-13 and 18-21. Similar to other research in the study area (Kuivanen *et al*., 2016), the average household size in our study locations is 12 people. Farmers' levels of education range from complete illiteracy (no formal education) to tertiary degree. In the three communities, more than 50 % of farmers are illiterate, which is equivalent to the district's figures of 69.2 % (PHC, 2013). The highest household size of the respondents (2-5 to >21) in this study is with farmers who had no formal education (54 %), decreasing with those with basic education (31 %), decreasing as shown in Table 4.4. Thus, the higher the household size of the respondent the lower the educational level and vice versa. Farmers who were literate in the research area had smaller household sizes, as demonstrated in Table 4.4.

Table 4.4. Educational level and household size of rice farmers

Educational level	**Household size**							**Educational percentage**
	2-5	**6-9**	**10-13**	**14-17**	**18-21**	**>21**	**Total**	
No formal education	1	7	4	4	3	7	26	54.0
Basic	1	1	2	3	4	4	15	31.0
Secondary	0	3	0	0	0	1	4	8.0
Tertiary	0	1	0	0	2	0	3	6.0
Total	2	12	6	7	9	12	48	100
Household size (%)	4.0	25.0	13.0	15.0	19.0	25	100	

(Source: Field survey, 2021)

The average household size (12 people) mentioned above is higher than that of the Northern regional and national average of 7.8 and 4.5 persons respectively (GSS, 2014). That was mostly caused by the fact that the research region and communities in the Northern Region were rural, depending substantially on family labor for their agricultural activities.

4.2 The Importance of Weather Information for the Smallholder Farmers

4.2.1 Importance of Weather Information for Agricultural Decision-Making

Figure 4.1 below, shows that 57 % of the respondents think the weather information is important in agricultural decision-making, 36 % think it is very important and only few 6 % are not certain. Among the respondents who 'strongly agreed' 29 % were males and 7 % were females, while of those who 'agreed' 46 % were males and 11 % were females. However, among those who are 'undecided' females were 4 % while males were 2 %. The highest number of people who "agreed" are in Nakpanzoo (21 % respondents), followed by Gbullung (19 % respondents) and then Yapalsi (17 % respondents) community. However, those who "strongly agreed" (36 % respondents) are mostly in Yapalsi (15 % respondents), followed by Nakpanzoo (13 % respondents) and Gbullung (8 % respondents). The very few farmers (6 % respondents) who were "undecided" are in Gbullung (4 % respondents), and Yapalsi (2 % respondents).

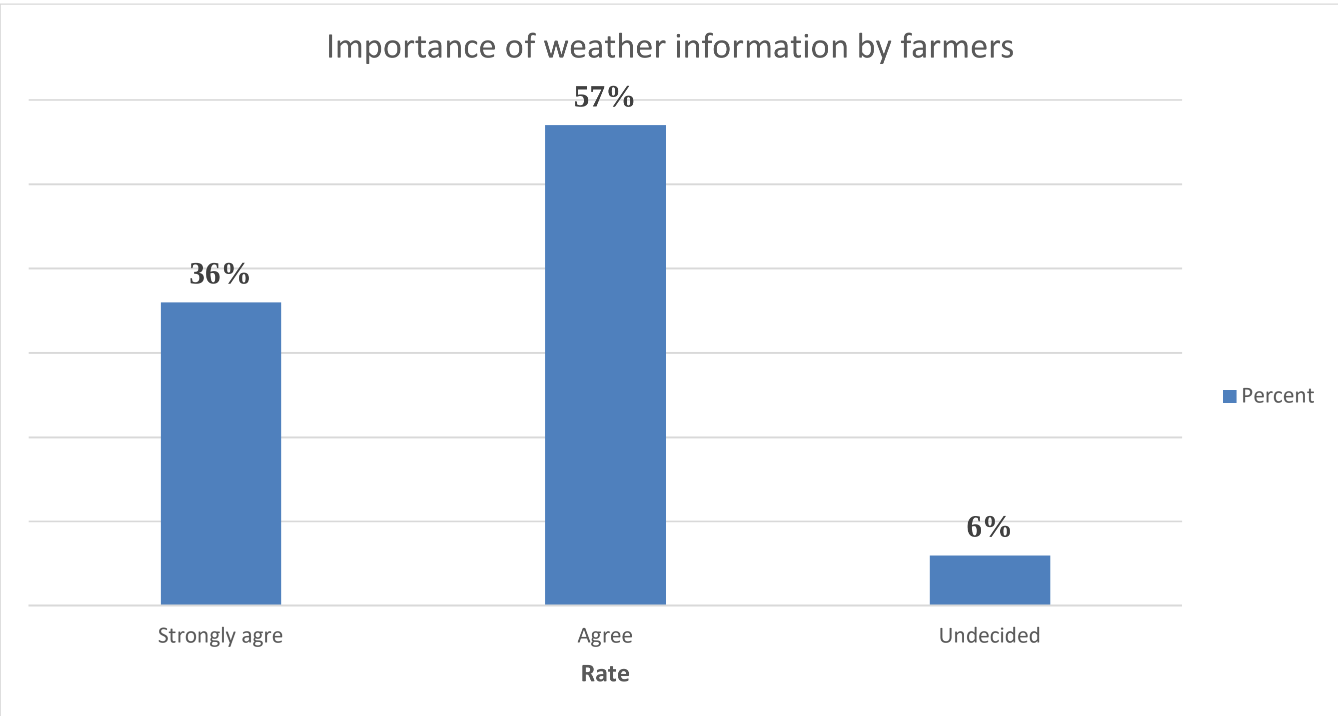

Figure 4.1 Importance of weather information as perceived by farmers in the three communities

(Source: Field survey, 2021)

Thus, we can conclude that most of the farmers appreciate the weather information importance in their agricultural decision-making.

4.2.2 Weather Information Needs

Figure 4.2 shows the weather information that is needed by farmers in the three communities to help in making their agricultural decisions. Rainfall, soil moisture, temperature and humidity are the types of information farmers use to make decisions regarding farm practices. Farmers stressed that rainfall induces soil moisture which is also affected by temperature. High rainfall means high soil moisture (on good structured & textured soil) and high temperatures would decrease soil moisture. According to this study, we found out that not all of the information needed by the farmers is readily available (particularly soil moisture). From FGDs, the information is received through family and friends and local radio stations, such as Simli FM, Zaa radio and some TV stations during agricultural programs with extension agents/officers.

The type of weather information need by farmers is presented in Figure 4.2. Among the ten (n = 10 = 100 %) different weather information combinations/subsets identified, 43 % of the respondents use rainfall, temperature and soil moisture combined to make agricultural decisions, followed by soil moisture and rainfall combined (23 %), rainfall, temperature, humidity, and soil moisture combined (9 %), and only rainfall (6 %). From FGDs, it revealed that soil moisture is a very crucial parameter when it comes to farming practices.

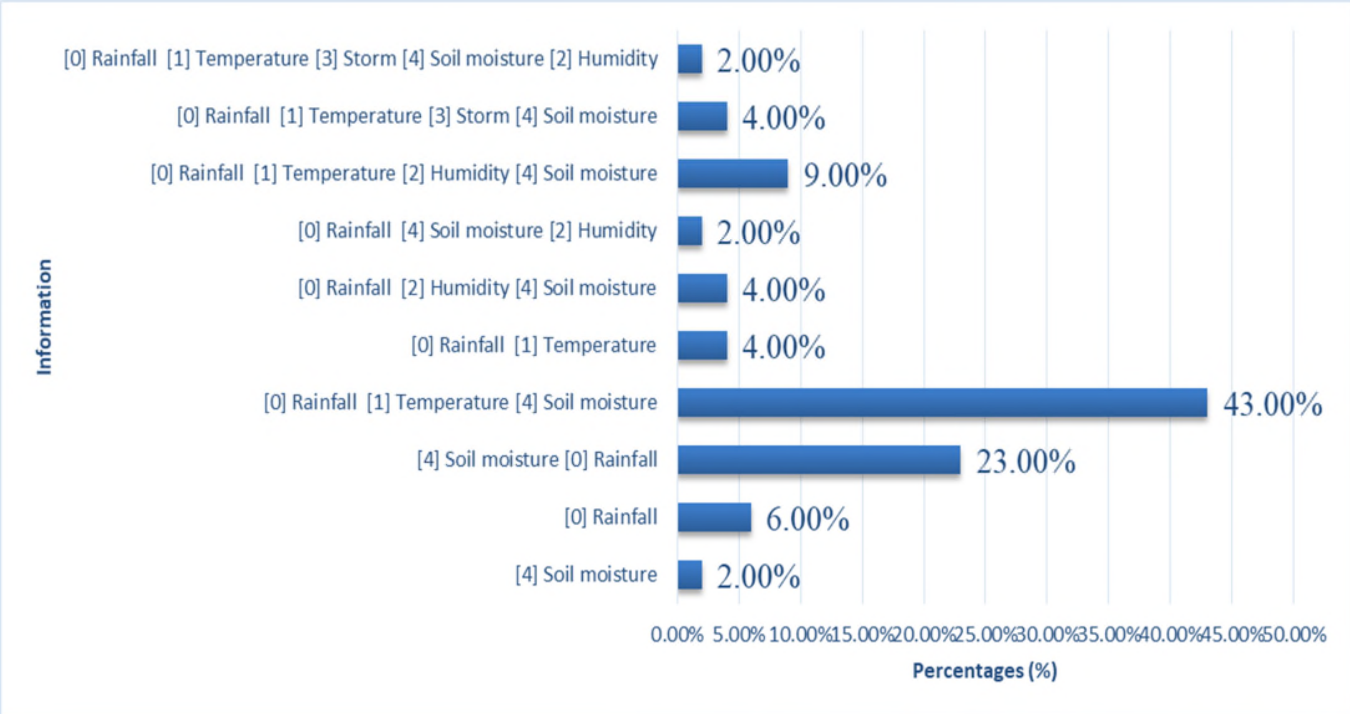

Figure 4.2 Weather information needs of farmers in the study area

(Source: Field survey, 2021)

Soil moisture is mentioned as important in almost all of the information need categories, which does shows that soil moisture information is almost always used in addition with other weather information/parameters, particularly rainfall and temperature (43 %).

4.2.3 Relationship between Importance of Weather Information and Needs of the Respondents

Descriptive statistics using cross-tabulation in SPSS was used for this analysis. The Pearson Chi-Square test showed p-values > 0.05 (0.281, 0.281 and 0.333) for respondents who strongly agreed, agreed and undecided to the importance of weather information and needs. This revealed that there is not enough evidence to reject the null hypothesis as the p-values are greater than the predetermined significance level (i.e. 0.05). In conclusion, there is no statistical significance between the farmers' response of weather information importance and needs.

4.3 Farmers' Soil Classifications (FSCs) and Moisture Importance and Measurements

4.3.1 Farmer's Soil Classifications (FSCs)

This section presents community knowledge on soil classifications.

4.3.1.1 Soil Texture

Farmers in the study communities identified four (4) major soil types based on texture and other parameters, which are comparable to Mikkelsen and Langohr classification (2004). The parameters observed were mainly drainage characteristics, water holding capacity and texture (hand feel). The following list describes four (4) major soil types and their properties in local language (Dagbani).

1. *Bihigu* (sandy soil) - Drains water rapidly, which reduces waterlogging. These soils are mostly found around home compounds and used for home gardens and not in larger scale crop production.
2. *Kuguchagla/chichali* (fine gravel) - Drains water easily and is often found within up-streams (*Kukogu*).
3. *Gbingbili* (silt) - Moderately drained, with moderate water holding capacity and a one of *batam/baa* (soils suitable for rice).
4. *Yagiri* (clay) - Poorly drained, with high water holding capacity. These soils are very hard to plough when wet and mostly found in *baani* (rice valleys). These clayey soils have numerous characteristics common in Vertisols, such as intersecting slickensides and gilgai micro relief (Mikkelsen and Langohr 2004).

Plants that grow on a particular land also help in the farmers' soil type identification. Examples of information gathered by farmers for each crop are:

1. The crop best adapted to particular soil type
2. The end of sowing period
3. The time of harvest of specific crops

4.3.1.2 Crop Suitability

In terms of crop suitability, the soils classified above fall into three (3) types:

1. "*Kukogu*" is suitable for crops that are not water loving, thus cannot stand in water for a very long period such as groundnut, maize, beans, millet etc.
2. "*Baa (ni)/batam*" is suitable for water loving crops (e.g lowland rice etc.) because it has high water holding capacity. These are found in lowland/downstream areas of the community lands.
3. "*Bakukogu*" name is derived from two words 1) "*Baa*" and 2) "*Kukogu*", taking from the names of the previous two soil types. It has medium to high water holding capacity. Plowing and crop cultivation (e.g maize, groundnut etc.) is only possible at early stage of rainy season and the harvest too is done early in order not to be affected by the floods later in the season.

4.3.1.3 Organic Matter Content

The color of topsoil helps in this categorization.

1. Dark soil (*tankpa sabinli*) - High organic matter content soil, mostly found in down-streams.
2. Brown soil (*tankpa ziesabinli*) - Moderate organic matter content.
3. Red soil (*tankpa zie*) - Low organic matter content, found in the up-streams.

The results of this study are comparable in terms of soil names and at the same time differ from Mikkelsen and Langohr (2004) in terms of grouping. During his study, the farmers classified their soils in two systems/levels, in the first level the soils are grouped into *Kukogu* and *Bani* which is subdivided into five and two types, respectively. This study has identified less soils types as compared to Mikkelsen and Langohr (2004) which seems related to the loss of indigenous knowledge among younger generations.

4.3.2 Importance of Soil Moisture for Smallholder Farmers

Farmers were asked to rank the soil moisture importance on a five-point Likert scale in terms of: don't know (no idea), not important, important, very important and extremely important as shown in Figure 4. 3.

From the survey, it was revealed that about 94 % respondents used soil moisture as an indicator for agricultural decision-making and therefore, soil moisture conditions are very crucial in their farming activities. Also from the focus group discussions, it is clear that farmers are aware that no crop cultivation is possible without soil moisture. Only 6 % either gave wrong information or they really don't consider moisture to be important in their farming activities. Among the 6 % respondents, 4 % were under 25 years' males and 2 % females above 25 years. Thus, all of the respondents above 25 year group did take soil moisture into account, except one female. When asked about the importance of soil moisture according to the farm practices all the farmers including the 6 % who answered "not taking moisture into account" ranked moisture importance high in this regard.

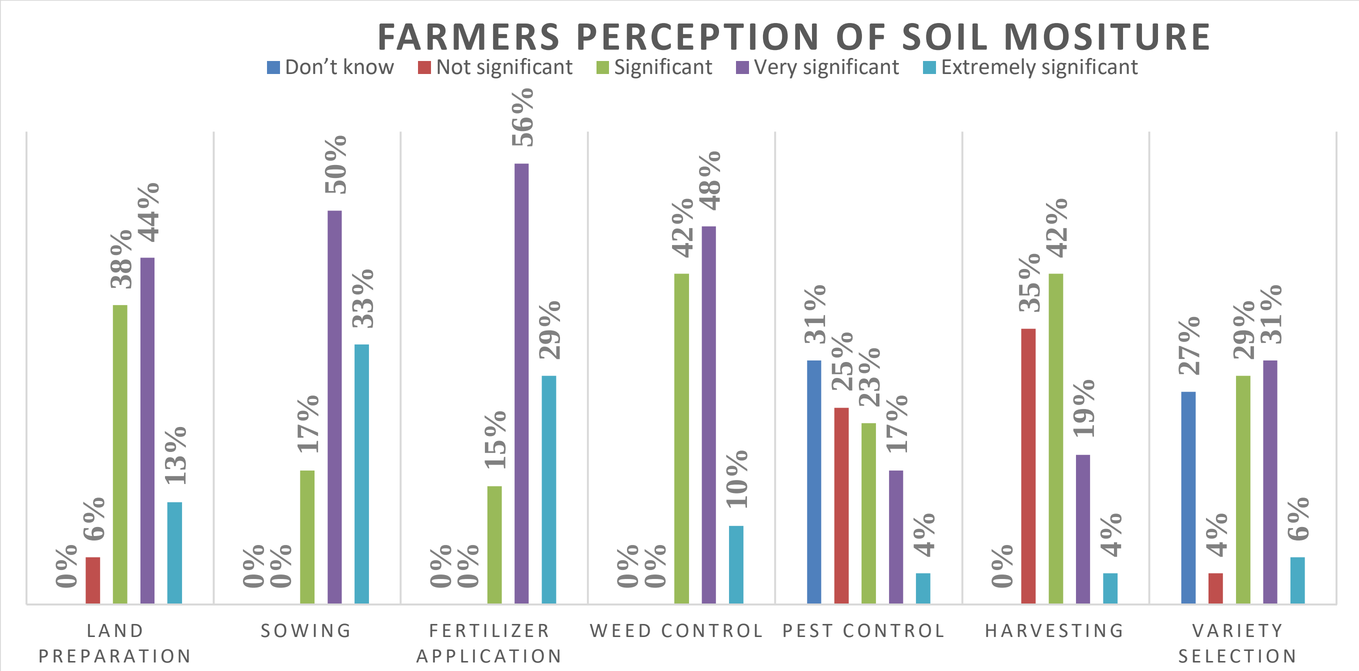

Figure 4. 3 Farmers' perception on the importance of soil moisture in farming decision-making during different crop production stages

(Source: Field survey, 2021)

Figure 4. 3 revealed that about 31 % respondents consider soil moisture condition very important when selecting a rice variety and because of the occurrence of drought they prefer varieties that can withstand water stress, and about 44 % and 48 % respondents consider soil moisture very important in land preparation and weed control, respectively. Among these percentages 31 %, 44 %, and 48 % are 2 %, 8 % and 6 % females respectively. Regular or early weeding as practiced by farmers minimizes unnecessary competition between the rice crop and other unwanted plants in the farm for soil nutrients.

According to one respondent: *"no driver will agree to use tractor to plow on dry land/soil as it is unhealthy to the machine and the operator, and weeding during drought period is a threat to the crops as the land is exposed to sun, causing rapid evaporation"*. During the survey, the participants also reported that *"covering the field with the weeds residue after weeding would help reduce the exposure of land to scorch sun thereby minimum evaporation"*.

Respectively 50 % and 33 % respondents considered moisture condition very important and extremely important during sowing, while 56 % respondents considered soil moisture very important during fertilizer application and 29 % extremely important. Among the 50 %, 33 %, 56 %, and 29 % comprised of 6 %, 6 %, 10 % and 2 % females, respectively. Also 35 % considered it not important during harvesting (including 4 % females). This might be due to spatial variation in slope and soil type within the farmlands of the respondents (personal observation, 2021). Practices such as dibbling before sowing and inorganic fertilizer application on rice fields are secure ways to abate the impact of climatic stressors than engaging in sowing of the local varieties, land rotation and mixed cropping (Alhassan *et al*., 2018). Some farmers grow rice in lowlands, while others on uplands and because of this, 73 % of the respondents harvest early depending on the availability of combine harvester and labor, while the remaining 25 % harvest at the end of the season, when the rain stops. To sum up, about 33 % respondents considered moisture extremely important during sowing of which 6 % were females, 29 % consisted of 2 % females during fertilizer application, 13 % during land preparation and 10 % which consisted of 2 % females during weed control.

As stated by the respondents: *"When you make a mistake or fail during sowing then you're doomed to loss and the same is the case in fertilizer application stage. The cost of fertilizers is high, sometimes they are unavailable and is devastating to lose it or getting it wasted on the farm"*.

4.3.3 Local Soil Moisture Determination Methods

In general, the soil moisture is determined by feeling the ground to determine if it is wet or dry, squeezing the soil to observe water extract, measuring stickiness of the soil and using of cutlass.

About 58 %, which is more than half of the farmers carry out soil moisture measurement by hand feel and smell (Figure 4. 4). However, 52 % of the farmers determine moisture of the soil at root zone and the rest measuring it at the surface. These approaches, will only provide an indication of soil wetness or dryness and not specifics required for exact agricultural decisions. The data obtained from the participants shows a high degree of resemblance. However, the females provided more details information on the smell method than their male counterparts during the female FGD.

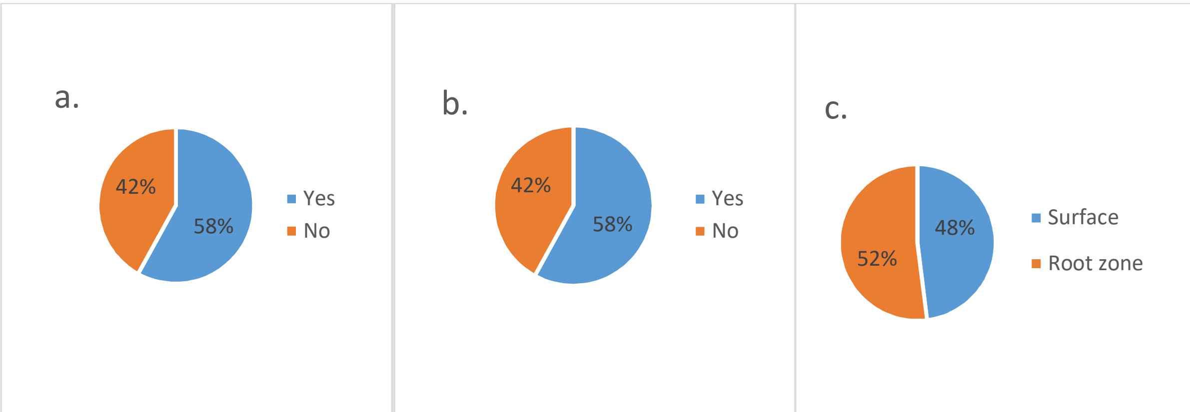

Figure 4. 4 a) percentage of farmers determining soil moisture by feeling, b) farmers determining soil moisture by smell, and c) depth of soil moisture determination

(Source: Field Survey, 2021)

Most of the farmers do not have access to scientific soil moisture information. They depend mainly on the indigenous methods presented below.

1. **Cutlass and Hand Feel**

The cutlass is pressed into the soil. How deep and easily it penetrates into the soil gives information about the moisture content.

2. **Observations**

Water layer on the surface of the soil, furrows or in trenches made by tractor plow after rain helps in moisture information. This method is used by experienced farmers.

3. Footprint

The footsteps of farmer on the field are also used to determine the soil moisture. This method involves details of how deep the foot of observer gets stuck, how easily it prints and how it marks the field. Animal footprints can also be used if the farmer know when they traffic in the farm.

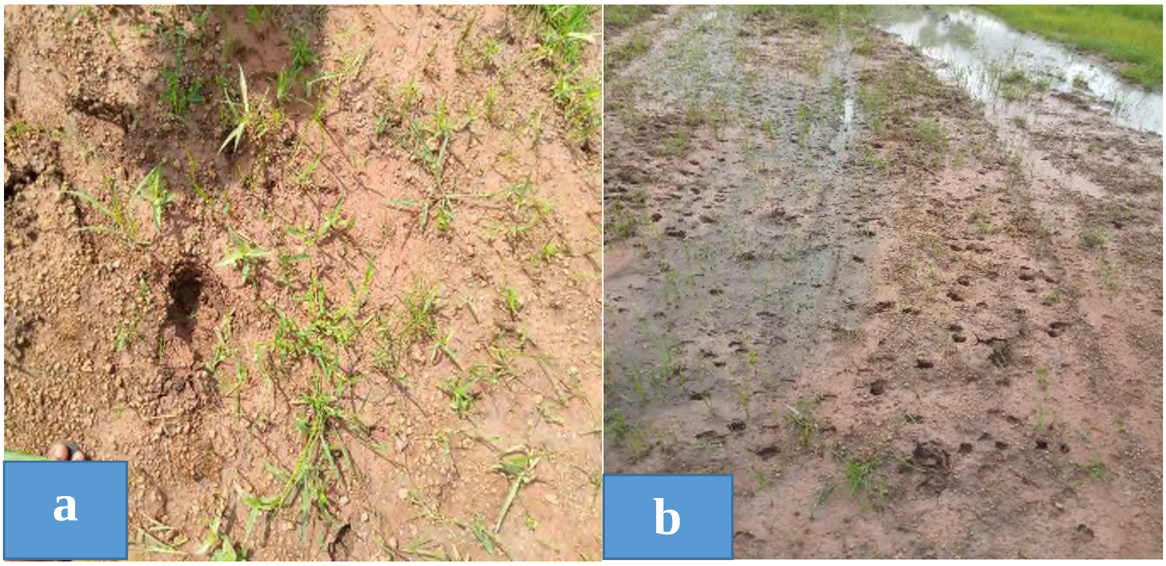

Plate 4.1 Example of a) Farmers footprint b) Animal footprints

(Source: Field survey, 2021)

4. Color and Smell

The color of topsoil was of great importance in farmers' soil moisture identification. However, the farmers' subsoil information was found to be vague. This information is gained by continuous practice on the field. For example, clay soils "*Yagiri*" are brighter when the moisture content is low and dark when wet. The smell is very difficult to describe, but can be identified on the field. From focus group discussions the women described it as similar to rotten egg but not as that strong.

Plate 4.2 Color of the same soil at different moisture conditions

(Source: Field survey, 2021)

5. **Plant Indicators**

Wild plants that grow on particular soils are used to determine the moisture condition of that soil. Example: a local plant called "bulaasan" also known as sambaŋ kandigu (*Sida acreta* or *Sida acuta Burm f.*). It grows on loamy sandy soils and fine sandy loam. According to respondents, these plants are not found on clay soils. However, water lilies (*Nymphaeaceae sp.)* grow on clay and silt clay loam soils. Also, uprooting the plant to observe the moisture in the clod of soil surrounding the root zone can help in this method.

Several indigenous indicators utilized by farmers are shown in Table 4.5. These data were gathered through interactions and interviews centered on soil moisture. To determine the soil's moisture level and link it to agricultural activities, farmers employ both plant and animal indicators. During interviews, the farmers mentioned four plant species and a few animal species. If they see that, for example, cat can completely hide behind the seasonal weeds (i.e., *gbingbani)* (A tall grass used for making mats) at beginning of rainy season, then sowing activities are approved. Another way to tell is by looking at the Shea tree's (*Vitellaria paradoxa*) fruits. According to the farmers who took part in this study, it is a favorable time for planting when the shea fruit begins to ripen. A plant called "Karifi maalam" (*Evolvulus asinoides*) at its matured stage is used as an indicator. It is a tiny herb with multiple tiny seeds that can be used to pinpoint the right crops to plant at what time, such as rice, maize, and groundnuts. On the basis of observation of the dawadawa tree (*Parkia biglobosa*), any type of crop can also be sown. Additionally, the presence of earthworms suggests that it is a favorable time to plant because they signal an effective rain event.

Since numerous plant species have historically been utilized as indicators, the natural vegetation is a crucial factor. Some plants offer data on the deficiencies in certain minerals and nutrients. Others list the crop variety that is most well-suited to the soil. Unfortunately, today's young farmers are less interested in it and instead only use fertilizer to avoid nutrient inadequacies. There are less dependent on the use of the indicator plants, thereby losing sustainable agriculture management system practices (Mikkelson and Langhor, 2004).

Table 4.5. Local indicators to monitor soil moisture conditions

Indicator	Name	Description	Season
Flora	Seasonal weeds (e.g., *gbingbani*)	The growth height of these weeds are used by farmers as an indicator. They could tell if it's time for sowing by observation of small animals' ability to hide within those weeds. Examples of crops sow using this indicator are groundnuts, pepper transplanting etc.	Rainy (April – May)
	Shea tree (*Vitellaria paradoxa*)	Ripening fruits carry a message to the farmers as to when and what to sow. Some of the crops sown by this indicator are cereals such as maize, rice etc.	Rainy (May – June)

	Dawadawa tree (*Parkia biglobosa*)	Time of harvesting of this fruit is used as an indicator. Crops grown by this are groundnuts, cereals etc.	Rainy (May – June)
	Karifi maalam (*Evolvulus asinoides*)	The start of fruiting of this plant is used as an indicator to sow many shallow rooted crops such as groundnut, pepper, rice, beans etc.	Rainy (April – May)
Fauna	Earth worms	The presence of worms a day after rain indicates effective rainfall and depicts the main rainy season. Any type of crop can be grown using this indicator.	Rainy (Mid – April to May)

Note; Some of these dates/periods changes according to the season.

Plate 4.3 Plants used as indicator for time of sowing A) Karifi maalam (Evolvulus asinoides) and B) Pirinkpag (in Dagbani)

(Source: Field survey, 2021)

Soil moisture is the basic parameter that all respondents consider when to start sowing. The following observations were obtained from the respondents. From the survey, about 50 % of the respondents used planting date indicator.

1. **Dates – Planting Calendar**

The planting date of previous years is compared with the present year to make informed decisions. Some farmers count up to two or three first rains before they decide when to plant.

A statement from a farmer says:

"The first rain is considered 'movilasaa' (false rain) and is of no use to sowing but gives farmers information to start preparation toward the main season, 'shagini' (rainy season)".

The soil is considered suitably moist if two more rains fall after the "movilasaa".

2. **Plant Indicators**

The focus group discussion shows that some farmers in the study area used certain plants as an indicator. After the first rain, the growth of certain plants is used in decision-making regarding sowing. A statement from a participant:

"Plants growth carries a message to every farmer when the soil would be suitable for sowing".

3. **Subsequent Rains are an Indicator of Shagini (Rainy Season)**

Some farmers wait for such events but others think is not advisable because rains are uncertain and some rice fields get flooded fast, thus making plowing impossible or the seeds to get carried away from the farm by runoff.

4.4 Evaluation of Farmers' Perceptions on the Effects of Climate Change and Adaptation Practices

This section discusses how farmers in the study areas perceive climate change effects and methods of its mitigation. Respondents claimed that some climate variables such as rainfall and temperature were affected by the changes in climate (in this study, for the past 30-40 years).

4.4.1 Farmer's Perception of Long-Time Changes in Climate Variables

Respondents observed clearly the changes in the ecosystem. Table 4.6 shows the respondents view on some climate variables.

Majority (56 %) of the respondents observed decreased rainfall, followed by 25 % of those who observed an increased trend, 7 % observed different rainfall pattern every year, and then 4 % observed no changes while 8 % do not pay attention to the phenomena (Table 4.6). This is supported by Gbangou *et al*. (2020) who asserted that the study area showed a decreasing trend of seasonal rainfall. Additionally, Kemausuor *et al*. (2011)'s findings revealed that a sizable proportion of people believed that precipitation had reduced in areas where there had been less rain than usual and most crops were moisture stressed.

About 67 % of the respondents observed increased temperature, 15 % observed decreased, 8 % observed no changes, and 10 % have no clue about the phenomena. This reveals that majority of respondents considered overall temperature increased. This is further corroborated by Kemausuor *et al*. (2011), who discovered that most of the farmers surveyed thought the climate had warmed significantly. Additionally, at least certain areas of Northern Ghana are experiencing an increase in mean temperature for the years 1931 to 1990, which is combined with an increase in erratic rainfall (Kranjac-Berisavljevic *et al*., 1999, in Mikkelsen & Langohr, 2004). According to Maharana *et al*. (2018), there was an increase of 0.15 ^{o}C in each of the previous decades (from

1950 to 2014). According to studies conducted in a number of different developing nations, most farmers believe that over the past decade or two, temperatures have gotten warmer and rainfall has decreased (Mubaya *et al*., 2010; Deressa *et al*., 2011; Gbetibouo, 2008; Dinar *et al*., 2012).

Table 4.6. Farmers perceived long-term changes of rainfall and temperature

Variable	Rank				
	Increased	**Decreased**	**Same**	**Different every year**	**Don't know**
Rainfall	25 %	56 %	4 %	7 %	8 %
Temperature	67 %	15 %	8 %	-	10 %

(Source: Field survey, 2021)

4.4.2 Farmers Perceptions on Frequency of Prolonged Dry Spells, Rainfall Onset and Cessation Dates and Length of Growing Season

4.4.2.1 Prolonged Dry Spells

Frequency of prolonged dry spells is increased as perceived by the respondents in the three communities is presented in Table 4.7 below.

The highest number of the respondents 50 % claimed that prolonged dry spells have increased in the locality, followed by 29 % of those who believed dry spells have decreased. According to Gbangou *et al*. (2020) study area shows an increasing trend of dry spells frequency. A study conducted in Ejura-Sekyedumase district showed that the decreased precipitation consequently increased the frequency of droughts (Kemausuor *et al*., 2011). Among the study communities, Gbullung in Kumbungu district had the highest number of respondents (22 %) followed by Nakpanzoo (18 %) and Yapalsi (13 %) in the Savelugu municipality. This showed rainfall in the two districts was not perceived as similar and this could be due to spatial variability of rainfall among communities in different districts of Northern region of Ghana which is guinea Savanna ecological zone known of its erratic rainfall, supported by Alhassan *et al*. (2018). A total of 15 % of the respondents were not observant regarding the dry spells, with 10 % in Gbullung and 5 % in Yapalsi community. About 6 % of the people do not observed any changes in the frequency of prolonged dry spells.

Table 4.7. Farmers' perception of climate change on frequency of prolonged dry spells

Variables		Frequency	Percent	Valid Percent	Cumulative Percent
	Decreased	14	29.0	29.0	29.0
	Don't know	7	15.0	15.0	44.0
	Increased	24	50.0	50.0	94.0
	Normal	3	6.0	6.0	100.0
	Total	48	100.0	100.0	

(Source: Field survey, 2021)

4.4.2.2 Onset and Cessation of Rainfall

Almost all of the indicators used by farmers are based on farming season, in order to know the start of farming season or its cessation. Table 4.8 presents the percentages of respondents who observed changes in the onset and cessation of rainfall. Among the respondents who answered questions regarding the onset of rainfall 44 % perceived the rains to be early. Also, the same percentage (44 %) of farmers perceived it as late, 6 % perceived rains starting dates as normal, or did not know the difference (6 %). Thus, the onset of rainfall (season) perception is evenly shared between those who perceived it as "early" and that of those who perceived it to be "late".

Majority of the respondents (67 %) perceived the cessation of rainfall to be early, followed by 21 % who perceived it as late, and 4 % perceived it as normal and 8 % of the respondents did not have any view on this. Overall, the perception of farmers on rainfall onset is early or late and early end of rainfall.

Table 4.8. Farmers perceived changes on the onset and cessation of rainfall

Variable	Rank			
	Early	Late	Normal	Don't know
Onset of rainfall	44.0 %	44.0 %	6.0 %	6.0 %
Cessation of rainfall	67.0 %	21.0 %	4.0 %	8.0 %

(Source: Field survey, 2021)

4.4.2.3 Length of the Growing Season

The LGS view by respondents in the three communities is presented in Table 4.9. About 42 % claimed an increased length of growing season in the communities. In contrast, 35 % perceived it to be decreasing, followed by 21 % of those who do not observe any changes in the LGS and 2 % non-observers (i.e., those who do not have any idea about the situation). Most of the respondents who experienced "increased" length of growing season were in Gbullung community (15 % respondents), followed by Nakpanzoo (13 %) and Yapalsi (10 %) community, respectively. Also, majority of the people in Gbullung experienced "increased" length of growing season, whiles majority of the respondents (17 %) in Nakpanzoo claimed "decreased" length of growing season. In Yapalsi community, the same number experienced "increased" and/or "decreased" length of growing season. Again, not all of the respondents were able to answer this question.

Table 4.9. Farmers' perception of climate change on length of the growing season

Perception		Frequency	Percent	Valid Percent	Cumulative Percent
	Decreased	17	35.0	35.0	35.0
	Don't know	1	2.0	2.0	37.0
	Increased	20	42.0	42.0	79.0
	Same	10	21.0	21.0	100.0
	Total	48	100.0	100.0	

(Source: Field survey, 2021)

4.4.3 Adaptation Practices Regarding Perceived Climate Change Effects

Respondents who perceived the effects of change in climate (i.e., flood and drought) on their farming practices used adaptation measures to reduce its effects. Two methods were identified as adaptation measures for flood, namely: 1) creation of drainage channels, 2) diverting water away from the fields at the up-stream (Table 4.10). 37 % of the respondents used these methods, with majority 35 % using channel creation and only 2 % uses diversion of runoff water. However, remaining of the respondents (63 %) are not using any measure. Those people claim either no knowledge about how to control the flood water, or don't have the resources (to afford tractor services or hire labor) and/or don't experience these kinds of extreme on their fields. Sadly, limited farmers have access to official lending institutions that may help them finance their agricultural endeavors. This study, which is corroborated by Bawakyillenuo *et al*. (2016), reveals that a major barrier to farmers in Northern Ghana Savannah zone adopting irrigation practices is a lack of financial resources.

Table 4.10. Flood adaptation measures used by farmers

Method	Respondents
Create drainage channels	35 %
Diverting the water away from the field	2 %

(Source: Field survey, 2021)

The drought incidents had four (4) responding methods identified by farmers: i.e., bunds construction to accommodate the runoff water, irrigation farming, application of organic manure to improve the soil water holding capacity and leaving the weeds residue to serve as dry mulch, as presented in Table 4.11. However, they are also people who do not use any of the measures identified. 69 % of the respondents determine drought by soil appearance, while 31 % ascertain it by the crop appearance (wilting). About 12 % of the respondents uses any of the four (4) measures, whiles majority of 88 % do not use any of those measures. Out of those who apply conservation measures, 4 % use bunds, 2 % adapt irrigation farming, another 4 % use dry mulch and 2 % use organic manure. Despite being unpopular with smallholder farmers, using manure is recognized as an efficient way to increase soil fertility (Alhassan *et al*., 2018). This is similar with research showing that farmers in Tanzania's Manyoni District increased the organic matter of their soil by letting animals to graze on cropland after harvest (Lema and Majule, 2009). The finding that creating bund and diversion of runoff water as drought adaptation practices corresponds with the finding of Alhassan *et al*. (2018) and contrary to a report by Etwire *et al*. (2013). This could be explained by the fact that creating bunds to conserve the little water from the few rains or creating drainage channels to prevent flooding as a result of heavy rains may be a better way to ensure the soil is moist enough for rice growth because the rainfall pattern is erratic and unpredictable.

Table 4.11. Drought adaptation measures used by farmers

Method	Respondents
Bunds	4 %
Irrigation	2 %
Leaving the cleared weed residue to conserved water (as dry mulch)	4 %
Organic manure	2 %

(Source: Field survey, 2021)

Note: 88 % who uses no measure in case of drought also include people who pray to God or make sacrifices in order to get good rains.

During the survey, several farmers claimed that satiating the gods through sacrifice and/or prayer may lower the frequency of drought caused by a protracted period without rain and the occurrence of floods caused by erratic precipitation. This supports a previous result that households in Zimbabwe's Chiredzi District reacted to climatic change and variability through religious celebrations and prayers (Mapfungausi and Munhande, 2013).

The reason for the low adaptation with the identified two major climate extremes could be attributed to low literacy of farmers by governmental and other organizations in the districts.

CHAPTER FIVE

5.0 CONCLUSIONS & RECOMMENDATIONS

5.1 Conclusions

This research was carried out with the aim of assessing the level of knowledge and perceptions of farmers on soil, climate and weather information for farm practices and decision making in two districts of the Northern region of Ghana. The study employed descriptive statics and Likert type scale methods for analysis using SPSS and Microsoft Excel software versions 20 and 2013, respectively.

The interviews were conducted with 16 farmers in each community to achieve the objectives of this study. There was much effort to get an equal number of respondents. A total of 81 % male and 19 % female respondents, respectively, participated in the interviews. The highest female participation was in Gbullung, followed by Yapalsi and Nakpanzoo communities. About 54 % of farmers were illiterate and among them, 35 % were males and all of the female (19 %) participants. The 46 % literate farmers were all men.

Below are the key findings;

1) Most (57 %) of the respondents agreed to the weather information importance in agricultural decision-making. This revealed that farmers placed lots of emphasis on the importance of weather variables. Rainfall, temperature and humidity are the major weather variables farmers used, in addition to soil moisture, to make decisions on farm practices.
2) Farmers classified the community soils by their own local classification which determines the soil in terms of moisture holding ability, texture, organic matter content

and crop suitability. Moreover, they used the soil moisture as an indicator for agricultural decision-making and therefore this is very crucial in their farming activities. Farmers harvest their rice fields depending on the availability of combine harvester, labor and as well as soil moisture levels. Cutlass & hand feel, soil color & smell, observations and footprint depth and plant uproot are the farmers soil moisture determinations methods. These methods are either for surface or root zone soil moisture measurement.

3) The farmers reported that, drought and flood are the major climate change extremes they could identify. They used between two (creation of drainage channels and diversion of water away from the fields) to four (creation of bunds, irrigation, application of dry mulch and organic manure) adaptations measures to reduce the severity of the perceived effects of flood and drought respectively. The percentage of farmers who used the flood and drought adaptation practices was less than 50 % which reveals low adoption rate of these adaptation practices among the respondents.

Thus, farmers possessed an intimate knowledge of soil moisture and despite the effects of change in climate, they strategize and use adoptive measures to lessen severity of climate events.

5.2 Recommendations

The following recommended are made for further investigation and also for policy and decision makers.

1) Soil properties should be examined through transect works on the fields of the farmers selected for the interview and compare to the farmers' soil classifications in terms of texture, organic matter content and land suitability to gain more insights into land use and demographic characteristics of the area.

2) Soil moisture knowledge of farmers should be further investigated to quantify soil moisture conditions in terms of low, medium and high moisture and what practices to carry out based on the percentage of soil moisture identified.
3) Local land use cover and management, climate and weather recordings could be used to keep track of changes in the local environment.
4) Policy, decision-makers and relevant ministries should work substantially to enhance capacity building through farmer trainings and develop or promote existing good/best techniques and practices in order to increase the adaptation measures of change in climate and to boost agriculture productivity.
5) Vulnerability studies should be done to identify the most affected groups of farmers and implement interventions/policies to help improve their resilience.
6) Farmers should organize themselves into groups and register it through government or Non-governmental organizations and use the groups as collateral to access and collect credit to help in their farming activities and also hire farm machinery (i.e., tractor/harvester) when its service is most needed.

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APPENDIX I

Understanding soil moisture need questionnaire – WAGRINNOVA

SECTION 1 (S1): DEMOGRAPHIC INFORMATION OF FARMER

Community: …………………………… Date of interview: …… /……../…….

Enumerators name………………………….. . Number…………………

Farmer name………………………………… Number………………………………

S1Q1. Age: [0] under 25 [1] 25-34 [2] 35-44 [3] 45-54 [4] 55-64 [5] above 65

S1Q2. Gender: [0] Female [1] Male

S1Q3. Marital status: [0] Single [1] Married [2] Divorced [3] Widowed

S1Q4. What is your household size? [0] 2-5 [1] 6-9 [2] 10-13 [3] 14-17 [4] 18-21 [5] 21+

S1Q 5. How many people are engaged in the farming activities? ....

S1Q6. Educational background: [0] No formal education [1] Basic [2] JHS [3] SHS/ technical /vocational [4] Tertiary.

S1Q7. Are you the land owner? [0] No [1] Yes

S1Q8. Are you into animal production? [0] No [1] Yes

If Yes, please specify…......

S1Q9. Are you engaged in any non-farm employment (off-farm work)? [0] No [1] Yes

If Yes, please specify…….

S1Q10. Number of years in farming...................

S1Q11. Number of years in rice farming...................

S1Q12. Are you a member of any farmer organization/association? [0] No [1] Yes

If yes, please state………………………………………………………..

S1Q13. Do you receive any visit from extension agents on your rice production? [0] No [1] Yes

If yes, how many times in a growing season? ....

S1Q14. What kind of information do you receive?................

S1Q15. Do you have access to credit to engage in your rice farming? [0] No [1] Yes

If yes, in what form? [0] In cash…………. [1] In kind (specify)……………….

If yes, from which organization?..

S1Q16. Do you have access to subsidized fertilizer for your rice cultivation? [0] No [1] Yes

S1Q17. How many acres/ha of rice are you cultivating?.....................

SECTION 2 (S2): WATER AND WEATHER STRESSES

S2Q1. What water challenges do you face during rice cultivation?

…………………………………………………………………………………………………

S2Q2. How often do water stress challenges affect your crop?

[0] Almost always [1] Often [2] Sometimes [3] Rarely [4] Never

S2Q3. How often do you face problems in rice production due to flooding?

[0] frequently (every year) [1] Occasionally (in some years)

[2] Rarely (very rare amongst years) [3] Never

S2Q4. What do you think is the main cause of flooding in your rice field(s)?

....

S2Q5. What do you do when (if) you face flooding in your rice field(s)?

....

S2Q6. What measures do you put in place to save your rice farm from flood should in case it happens? ....

S2Q7. What do you think is the main cause of drought on rice fields?

....

S2Q8. How often does drought affect your rice production, if any?

[0] Almost always [1] Often [2] Sometimes [3] Rarely [4] Never

Please specify e.g. 1 time in 3 years..

S2Q9. What do you do when (if) you face drought in your rice field(s)?

....

S2Q10. What measures do you put in place to save your rice from drought should in case it happens?...

S2Q11. Do you measure drought based on soil moisture condition? [0] No [1] Yes

If yes, how does the soil moisture look like……………………………………………..…..

S2Q12. Do you have any problem with salinity? [0] No [1] Yes

If yes, Please specify...

S2Q13. Do you think climate change increases the occurrences of flood and drought?

[0] No [1] Yes

If No, what does?..

S2Q13. If yes, how will you rate the effect of climate change on agriculture in the district.

Effect variable	High	Moderate	Low
Poor crop performance			
Socio-economic challenges			
Environmental degradation			
Psychological threats			

SECTION 3 (S3): AGRICULTURAL INFORMATION

S3Q1. Do you have access to any agricultural information that play a role in your farming decision making? [0] No [1] Yes

S3Q2. If yes, from where? Please list (multiple answers)……………………………………….

S3Q3. If no, why?..

S3Q4. How often do you receive this information?

(0) not often (1) often (2) most often (3) very often

S3Q5. What kind of information do you receive?

1. water availability (1) seasonal weather forecasts (2) input prices and availability (3) crop/variety selection (4) disease control (5) market prices (6) soil moisture (7) others (specify)…………………………………………………………………………

S3Q6. Does the information provided meet your needs? [0] No [1] Yes [2] not really

S3Q7. What other information do you need?...

S3Q8. How much do you depend on weather information for agricultural decision-making?

[0] Almost always [1] Often [2] Sometimes [3] Rarely [4] Never

S3Q9. How do you access rainfall/climate information now?

[0] TV [1] Radio [2] Newspaper [3] Mobile (sms, voice call, app: ....)

[4] Peer farmers [5] Extension officers [6] Other (specify:...)

SECTION 4: (S4): SOIL INFORMATION (all questions are related to rice production)

S4Q1. Are you aware of the concept of soil moisture? [0] No [1] Yes

If No, please specify why……………………………………………………………...

S4Q2. Do you have an alternative name for soil moisture in your area?

....

S4Q3. Do you use soil moisture information as an indicator for agricultural decision-making?

[0] No [1] Yes

S4Q4.In which decisions of the following do you take soil moisture into account?

Variable	0 Not significant	1 significant	2 Very significant	3 Extremely significant	4 Don't know
Land preparation					
Sowing					
Fertilizer application					
Weed control					
Pest control					
Harvesting					
Rice varieties					
Which other decisions do you consider soil moisture					

S4Q5. If you had information regarding soil moisture, how will you use it?

....

S4Q6. What makes you decide if the soil is OK to start sowing?

……………………………………………………………………………………………………

S4Q7. How do you decide if there's enough rain/water on the ground to start sowing?

……………………………………………………………………………………………………

S4Q8. When you think about the onset (beginning) of the rain, do you also consider the date in your decision to start sowing?

……………………………………………………………………………………………………

S4Q9. Do you consider other factor(s) to inform your decision to start sowing? [0] no [1] yes

If yes, specify………………………………………………………………………..

S4Q10. Do you visit your fields before you decide on sowing? [0] No [1] Yes

S4Q11. Do you examine soil moisture by hand feeling? [0] No [1] Yes

If yes, please explain...

S4Q12. Do you examine soil moisture by smell? [0] No [1] Yes

S4Q13. How do you examine your soil moisture content at the various stages in rice production?

Activity	Ways of examining soil moisture
Land preparation	
Sowing	
Fertilizer application	
Weed control	

Pest control	
Harvesting	
Other activities (specify)	

S4Q14. Do you satisfy with the examination? [0] No [1] Yes

If No, why?..

S4Q15. What do you suggest can be done to examine the soil moisture?...

S4Q16. Is the soil color important to you? [0] No [1] Yes

S4Q17. How do you categorize the condition of soil in terms of water content?

[0] Soft when there's rain? [1] Hard when there's no rain? [2] Do you have/use specific categorization?

....

S4Q18. Do you decide to harvest your rice based on the end of the rainy season?

[0] No [1] Yes

S4Q19. If No, how do you decide when to harvest?

....

S4Q20. Do you receive soil moisture information from any other source? [0] No [1] Yes

If Yes, from where/which organisation?.................

If Yes, what kind of data e.g. real time or forecasts? ………………..

S4Q21. Do you use soil bunds or other water retaining feature? [0] No

[1] Yes

If Yes, mention them...........

If No, why? …………..

S4Q22. For which soil type do you measure soil moisture/water content?

[1] Sandy soil [2] Silty soil [3] Clay soil [4] Loamy soil [5] Saline soil

S4Q23. Do you measure surface soil moisture/water (upper 5cm) or root zone soil moisture/water (upper 100cm of soil) or both?

[1] Surface soil [2] Root zone soil [3] Both

S4Q24. What are the instruments that you currently employ in determination of soil moisture/water content?...

S4Q25. What is the range of soil moisture/water content that your measurements cover?...

S4Q26. Do you consider moisture content to be the water content in your soil samples or do you consider moisture content to include water and other volatiles in the soil?

[1] Same as water content [2] Include water and other volatiles

S4Q27. Do you encounter any problems with your soil moisture/water content measurements?

[0] No [1] Yes

If Yes, please specify...........

S4Q28. What methods are employ to ensure your moisture/water content measurements are accurate?...

S4Q29. Do you believe that better techniques of measurements are required for more accurate soil moisture/water content?

[0] No [1] Yes

If Yes, please specify…………………………………………………………………………………….

SECTION 5 (S5): INFORMATION NEEDS

S5Q1. How would you rate your understanding of local weather?

[0] Excellent [1] Somewhat [2] Poor

S5Q2. Do you think that weather information is important to make agricultural decisions?

[0] Strongly agree [1] Agree [2] Undecided [3] Disagree [4] Strongly disagree

S5Q3. What kind of information do you need to make agricultural decisions? (multiple answers could be provided)

[0] Rainfall [1] Temperature [2] Humidity [3] Storm [4] Soil moisture [4] Other (specify:...)

S5Q4. How advanced information should be for rice crop related decision-making?

[0] Real-time [1] 1-day in advance [2] 2/3 days in advance

[3] 1-week in advance [4] 2-weeks in advance [5] 1-Month in advance

[6] 3-Months / seasonal forecast

SECTION 6 (S6): Farmers observations over the past years (climate indices)

S6Q1. What are your observations about the patterns of the following climate indices the past 30-40 years?

Rainfall amount	□ Increased □ Decreased □ Same □ Different every year □ Don't know
Temperature	□ Increased □ Decreased □ Same □ Different every year □ Don't know

Onset of rainfall	□ Early onset □ Late onset □ Normal □ Don't know
Termination of rainfall	□ Early □ Late □ Normal □ Don't know
Frequency of prolonged dry spells	□ Increased □ Decreased □ Normal □ Don't know
Length of the growing season	□ Increased □ Decreased □ Same □ Don't know

SECTION 7: (S7): ADAPTATION TO CLIMATE CHANGE

S7Q1. Do you think the following affects your adaptation to climate change?

Constraints to adoption	**Strongly agree**	**Agree**	**Undecided**	**Disagree**	**Strongly disagree**
Unpredictability of weather					
High cost of farm inputs					
Lack of access to timely weather information					
Lack of access to water resources (e.g. dams)					
Lack of access to credit facilities					
Lack of access to agricultural subsidies					
Poor soil fertility					

Limited access to agricultural extension officers					
Limited access to agricultural markets					
Inadequate farm labor					
Limited farm size					

APPENDIX II

Focus group discussions (FGDs) – Checklist

Good morning and welcome to our session. Thanks for taking the time to join us to talk about this program in the community. My name is Baba M. Jamaldeen, MPhil student of West African Center for Water, Irrigation and Sustainable Agriculture (WACWISA) and assisting me is Abdulai Issahaku Kantongsung a teaching assistant for University for Development Studies (UDS). We're both with the UDS. We are here to ask you (focus group members) for your help purposely to obtain information about your understanding of soil moisture information for agricultural decision-making. Monitoring the soil moisture will help a farmer to determine when to carry out an activity on the field. We want to know what you know and don't know about soil moisture, water stresses in your farmlands, understand how you perceived and tackled it, and how you used the information for adoptive farming decisions. The success of rain fed agriculture strongly depends on how you (farmers) are able to match your decisions regarding farm practices to the prevailing weather. This is very essential for sustainable agricultural practices which will lead to better yields and minimum risk of crop failure. We are having discussions like this with several groups around Savelugu district.

You were invited because you have engaged in small-scale rain fed lowland rice production, so you're familiar with what rice farmer does, and you all live in this section of the community.

There are no wrong answers but rather differing points of view. Please feel free to share your point of view even if it differs from what others have said. You don't need to agree with others, but you must listen respectfully as others share their opinions. Keep in mind that we're just as interested in negative comments as positive comments, and at times the negative comments are the most helpful.

You've probably noticed the microphone. We're tape recording the session which means one person at a time because we don't want to miss any of your comments. People often say very helpful things in these discussions and we can't write fast enough to get them all down. We will be on a first name basis today, and we won't use any names in our reports. You may be assured of complete confidentiality. The reports will go back to the UDS to help them plan future policies and programs.

Well, let's begin. Let's find out some more about each other by going around. Tell us your name.

1) What is your view about this topic?
2) What is the local name for soil moisture?
3) What do you know about it?
4) How do you categorized your soils?
5) Do you receive scientific forecasts?

6) How was the scientific forecast information (quality) of last year? Why do you think so?
7) How was the traditional/natural forecast information (quality) of last year? The traditional forecasts here are related only to precipitation, temperature, and soil moisture dryness and wetness. Explain your answers
8) What indigenous forecast parameters did you observe last? Please explain
9) How often do you use soil moisture information during growing season? Explain how in each activity: Land preparation, plowing, weeding, fertilizer application and harvesting.
10) Did you observe the soil moisture condition (wet, normal and dry) at your field last year? If yes, please explain in terms of soil color and smell
11) If we give the wettest soil moisture as 100 % (assume saturated) and the driest soil moisture as 0 % (assume wilting point), what was the percentage of soil moisture condition of last year?
12) How was the degree of soil moisture last year? Is it dry, normal, or wet?
13) Do you think the soil moisture condition is strongly related to precipitation event? Please explain your answer
14) How does the level of rainfall (light, medium and heavy) affect soil moisture condition? Please explain
15) Do you think we can use the precipitation forecasts to indicate the soil moisture condition? Please explain
16) Any other specific questions raised by the participants related to precipitation, temperature, and soil moisture?

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A short summary by assistant moderator of the discussion to the participants, and also to see if the team did miss anything or cover everything?