Climate Change Perceptions and Adaptation in Agriculture: a Study of Rural Ghana

農業における気候変動の認知と適応:　ガーナ農村の事例研究

Francis Ndamani

Graduate School of Engineering
Kochi University of Technology

A dissertation submitted to
Kochi University of Technology
In partial fulfillment of the requirements
For the degree of Doctor of Philosophy

Kochi, Japan
March, 2016

Climate Change Perceptions and Adaptation in Agriculture: a Study of Rural Ghana

農業における気候変動の認知と適応: ガーナ農村の事例研究

Climate Change Perceptions and Adaptation in Agriculture: a Study of Rural Ghana

農業における気候変動の認知と適応: ガーナ農村の事例研究

Francis Ndamani

Graduate School of Engineering
Kochi University of Technology

A dissertation submitted to
Kochi University of Technology
In partial fulfillment of the requirements
For the degree of Doctor of Philosophy

Kochi, Japan
March, 2016

Supervisor:	Professor Tsunemi WATANABE
Research Advisory committee:	Professor Masataka TAKAGI
	Professor Takashi GOSO
	Professor Koji KOTANI
	Professor Masahiko KUNISHIMA

Abstract

In view of the fact that agriculture remains the largest employer of the Ghanaian workforce and constitutes the main source of food and income, the consequences of climate change on the agricultural sector cannot be underestimated. Considering that farmers are more likely to be highly affected by the effects of climate change, a clear understanding of the trends of climatic variables, risk, adaptation and farmers' perceptions could provide useful information to assist local famers make informed adaptation decisions in order to improve their livelihoods. This study therefore investigates historical rainfall variability and its relationship with annual crop production. Farmers' perceptions about long-term trends in climatic variables, climate change risks and adaptation practices are also investigated. The study also investigates the determinants of climate change risks and adaptation. Finally, the study proposes a set of indicators for evaluating and choosing appropriate adaptation practice to predicted extreme climate events.

Lawra district of the Upper West Region of Ghana is selected for the study. Secondary data include historical rainfall and crop production figures, governmental reports and literature review. Primary data is collected based on cross-sectional surveys and focus group discussions (FGDs) conducted in four communities. Twenty-five households were randomly selected from each community and the household' heads were individually interviewed. A total of 100 farmer households were interviewed using semi-structured questionnaires. The FGDs were carried out to double check the household survey data. Also, face-to-face interviews with key stakeholders were conducted. The findings show that farmers have perceived a decrease in rainfall and an increase in temperature over the past 10 years. Dry spell and drought have higher rate of occurrence annually than flood. Farmers mostly attribute climate change to human-related causes such as bush fires and deforestation. While deforestation is largely perceived as being for the purposes of fuel wood, charcoal, and farm expansion, bush fires are believed to be caused by the 'negligence' of hunters and cigarette smokers. Traditional gods and ancestral spirits are also perceived to be responsible for climate change. Others claim that climate change is caused by multiple factors.

In addition, the empirical findings show that rainfall is very erratic in the month of June, but high in the month of August. The correlation results show that production of sorghum, millet and cowpea are negatively affected by the rainfall situation for the period investigated. Furthermore, farmers in Lawra district have perceived climate risk. However, resource-poor farmers perceive risk highly than resource-moderate and resource-rich farmers. Farmers in Lawra district generally perceive climate change risk impacts in terms of agricultural production, biodiversity and forestry, health and socio-economy, and climatic variables. Resource-poor and resource-moderate farmers are more concerned about climate change risk impacts on agricultural production and climatic variables, respectively while resource-rich farmers are concerned about risks impact on health and socio-economy. The significant predictors of farmers' climate risk perception are age, education, perceived increase in droughts, dry spell, floods, pests and disease, cost of production, worsening harmattan, temperature, perceived decrease in forest area, birds and animal species, plant and forest species, soil fertility, cropping area, yield and perceived severity of consequences on human diseases and mortality, and food security and incomes. Additionally, farmers in the district possess a portfolio of adaptation options to climate change. Improved crop varieties and irrigation are ranked most important adaptation measures. However, farmers lack the capacity to implement these adaptation practices. Majority of farmers use adaptation measures to cope with dry spell, drought, improve soil fertility and crop production, and to cope with floods. The factors influencing farmers' adaptation to climate change include education, household size, annual household income, access to information, credit and membership to farmer-based organization are the most important. Also, unpredictability of weather, high farm input cost, lack of access to timely weather information and water resources are the main inhibiting factors to climate change adaptation.

The key challenge for farmers lies in how to evaluate and select the most appropriate adaptation option. This study therefore develops a set of indicators for evaluating the practices. In addition, a new model is proposed for the development of relevant decision-making indicators. The proposed model involves a six-step process. The finalized indicators and components are weighted by key experts. Since the study results reveal a high rate of occurrence of drought and dry spell, the developed indicators are applied to evaluate and select the most feasible and effective adaptation practices to drought. The AHP decision support model is applied. The findings show that the feasibility component has higher weight than the effectiveness component. Four indicators in the feasibility component (i.e., culture and tradition; knowledge, skills and past experience; cost; and competence) obtained the highest weight. In effectiveness component, resiliency, short-term response, medium-to-long term response and unintended consequences obtained the highest weight. The results of prioritization of alternative adaptation practices to drought show that irrigation and drought-tolerant varieties are most feasible and effective. Early maturing varieties and mixed farming are ranked lowest in the priority set up. The findings of this study are expected to contribute knowledge to formulating relevant climate change policies. It will also contribute to climate change risk communication in agriculture. The findings are also expected to contribute to design, development and promotion of appropriate adaptation options. Finally, the proposed model for evaluation of alternative adaptation practices to climate change is expected to improve farmers' capacity to adapt to climate change through effective and efficient decision making.

Acknowledgments

My profound gratitude goes to Prof. Tsunemi Watanabe for his unrelenting guidance throughout the period of this research. I am also grateful to Professors Masataka Takagi, Takashi Goso, Koji Kotani and Masahiko Kunishima for their vast contributions in guiding this study.

I am grateful to Prof. Lawrie Hunter for his advice and encouragement. I am also thankful to Shane-san (former Kuzume dormitory father) for his tremendous kindness and support. I would like to thank the staff of the International Relations Center (IRC) and the administrative staff of the School of Economics and Management for their unwavering assistance. I am grateful to members of the Watanabe's Laboratory, both past and present for sharing their friendship, motivation and ideas with me throughout the study period.

My regards also go to my Japanese family; Kubota san, Yamasaki san, Ogawa san, Sasaki san and my neighbors in the Espore Ogawa apartment in Tosayamada. Thank you for your kindness towards my family. Special thanks also go to staff of the Board of Education of Kami City, especially, Tamura-sensei, ERI-sensei and Nobusaki-sensei. I deeply appreciate your kindness. And also, to my former students and colleague teachers in Kataji Elementary school and Kagamino Junior High school, I say thank you.

My heartfelt appreciation goes to the Upper West Regional Director of Agriculture, Mr. Joe Faalong and his staff for their wholehearted support and contribution to this research. I would also like to thank the Lawra district director of Agriculture, Mr. Saaka Dy-Yaakah and his staff especially Constance Faar, Saanuo Mercy Grace, Tengzagh Fabian and Dominku Baa.

Deepest appreciation goes to the smallholder farmers of Lawra district, Savanna Agriculture Research Institute, Wa, and the many more stakeholders who provided relevant information for this study. Finally, my appreciation goes to the Kochi University of Technology and the Japan Student Services Organization for awarding me scholarships (i.e., SPP and JASSO, respectively) to study.

Francis Ndamani

March, 2016

CHAPTER 4: EMPERICAL ANALYSIS OF RAINFALL VARIABILITY AND CROP PRODUCTION: DISTRIBUTION, VARIABILITY AND CORRELATION

CHAPTER 5: ASSESSMENT OF CLIMATE CHANGE RISKS IN AGRICULTURE: RISK PERCEPTIONS AND DETERMINANTS

CHAPTER 6: ADAPTATION TO CLIMATE CHANGE IN AGRICULTURE: REASONS, RANKING, DETERMINANTS AND BARRIERS TO ADAPTATION

APPENDIX

List of Tables

List of Figures

CHAPTER 1: INTRODUCTION

1.1 General introduction

Available evidences point to the fact that climate change will sturdily affect the African continent [1, 2, 3, 4]. This will pose a significant threat to sustainable development, especially in the drier regions. Previous assessment has noted that climate change vulnerability is likely to intensify drought and increase potential vulnerability to future climate change especially in the semi-arid regions [5], where crop production and livestock keeping are critically important to food security. In Ghana, the effects of climate change are evidenced by reduced precipitation, increased variability of rainfall, rising temperatures, floods and desertification [6, 7]. Climate projections for the Sudan Savannah region of Ghana reveal that temperature and precipitation trends will even worsen over the next 30 – 50 years [8]. The implication is that agricultural production and food security will be severely affected in many African countries and regions [9]. Considering that agriculture remains the largest employer of the Ghanaian workforce, the consequences of climate change on the agricultural sector cannot therefore, be underestimated. Literature shows that seasonal variability in food supply and prices as a result of climate change makes it difficult for Ghana, especially the three northern regions, to meet their food demands throughout the year [10]. In view of the above, the Government of Ghana through its various ministries and departments is mainstreaming climate change into its local, regional and national policies and programmes [11] in order to help agrarian communities better adapt to extreme weather conditions associated with climate variations [12].

Adaptations are adjustments or interventions that take place to manage the losses or take advantage of the opportunities presented by a changing climate. Adaptive capacity has been defined as the ability of a system to adjust to climate change (including climate variability and extremes), to moderate potential damages, to take advantage of opportunities, or to cope with the consequences [13]. Adaptation practices are therefore pre-emptive in nature. They are designed to mitigate potential adverse effects and take advantage of the potential benefits of an envisaged change in climatic variables. Adaptation practices in agriculture are generally location-specific [14] and smallholder farmers in developing countries are generally most affected climate change [15]. In view of this, discussions of adaptation practices in agriculture need to be informed by empirical data from farmers at local-level. To ensure farmers' readiness for extreme weather events and collaboratively learn about the evolution of weather patterns, efforts to focus on farmers and their current activities, knowledge, and perceptions are essential [16,17].

It is also crucial to understand farmers' perceptions about the risks they face. In the context of climate change, risk equals the probability of climate hazard multiplied by a given system's vulnerability. Literature on adaptation and mitigation of natural hazards finds that behavioral responses to hazards depend in large part on risk perception, or "beliefs about the existence and characteristics of a natural hazard" [18].

Hence, appropriate risk perception can be seen as a prerequisite for choosing an effective risk-coping strategy, because a farmer that is not aware of the risks faced is clearly not able to manage them effectively [19].

Literature has shown that farmers have perceived climate change [20], and that, innovative practices exist, or have been developed in different parts of the world to help facilitate adaptation to climate change in the agriculture sector [21]. In Ghana, adaptation practices reported include crop diversification, change of planting date, hybrid varieties, and soil moisture conservation techniques [20, 22]. In Uganda, income diversification, digging of drainage channels, and use of drought-tolerant varieties have been reported [23]. In addition, mixed farming, mixed cropping, tree planting, use of different crop varieties, changing planting and harvesting dates, increased use of irrigation, increased use of water and soil conservation techniques, and diversifying from farm to non–farm activities have also been reported in Nigeria and in South Africa [24, 25].

In view of the foregoing, the main research challenge therefore is to clearly understand the following: how farmers perceive climate change risk, how they perceive existing adaptation practices, what factors influence farmers risk perception and adaptation to climate change and how they can effectively evaluate and choose the most appropriate adaptation practice at each point in time.

1.2 Problem statement

Climate change poses numerous uncertainties on the livelihoods of farming communities that depend on weather and climate [26, 27]. Previous research has shown that increasing rainfall variability results in droughts, and this in tend leads to a reduction in soil moisture causing a decline in agricultural productivity thereby affecting household incomes [28] and food security. In Lawra district where agriculture is basically dependent on rain-fed, a good understanding of the long-term trends in climatic variables, their association with agricultural production, and farmers perceptions about climate change are essential in formulating appropriate climate change policies and programmes to mitigate the impacts of climate change. This notwithstanding, farmers' perceptions about climate change, empirical evidence of rainfall duration and the relationship between rainfall variability and crop production have largely been uninvestigated (Figure 1.1).

Additionally, rural communities confronted with climate change risks need to use adaptation measures to mitigate the adverse effects. The type of adaptation option to pursue depend not only on the actual climate shocks, but also on how farmers perceive and cognitively process their experiences and update their perceptions of climate risk [29]. Thus, a clear understanding about farmers' perceptions of climate risk is crucial in developing appropriate adaptation measures. Knowledge about climate change risk, causes and impacts is relevant in producing appropriate content for climate change risk communication. Also, since adaptation practices in agriculture are generally location-specific [14], it is important to understand farmers' perceptions about the risks they face so as to develop tailor-made adaptation options. However, in Ghana, climate change risk identification and assessment has not been investigated in rural areas resulting in low awareness and adaptation to climate change.

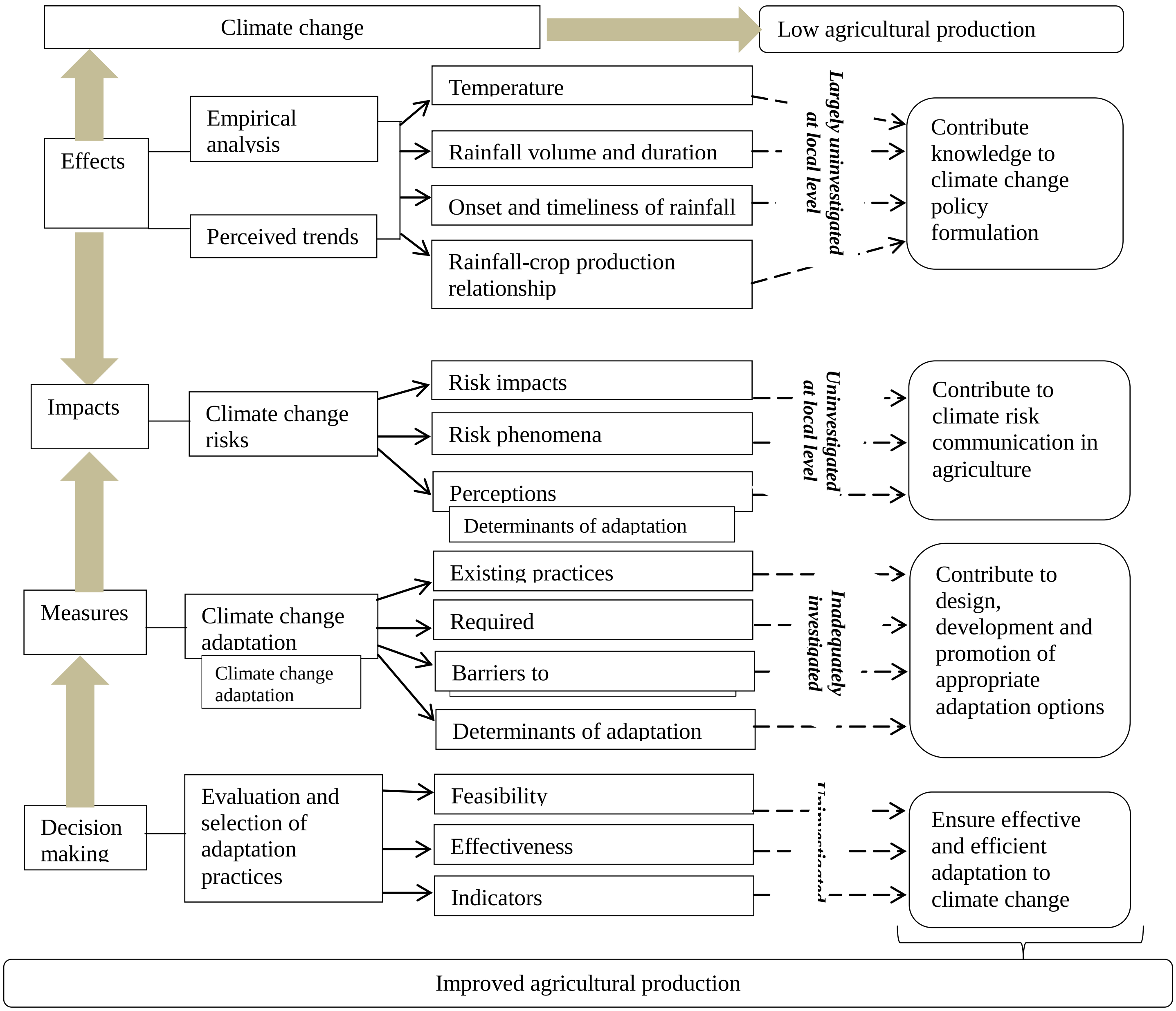


Figure 1.1 – Schematic presentation of problem analysis *(Source: Author)*

Furthermore, in Ghana, research findings have shown that although several climate change adaptation technologies and practices exist, these practices have not been comprehensively documented; hence, farmers are not able to fully take advantage of the potential benefits of adaptation [29]. In addition, findings of studies in Bangladesh and Nepal have shown that existing adaptation practices are different from farmers' perceived important practices [30, 31]. This situation has the potential to adversely affect farm-level adaptation. To ensure farmers' readiness for extreme climate events and collaboratively learn about the evolution of weather patterns, it is relevant to focus on farmers' current activities and perceptions. Farmers' willingness to accept and use prescribed measures could be enhanced if their perceptions and understanding are considered in designing such measures.

Rural farmers facing climate shocks possess a menu of potential adaptation practices. However, the adoption process requires a series of decision-making by individuals and groups. The current approach, which is traditional, is based on farmers' own experiences and judgment with limited or no information on scientifically verified indicators about feasibility and effectiveness of adaptation measures. A new and modern technique is therefore required to assist farmers evaluate and select the most feasible and effective adaptation practice to any predicted extreme weather event at the pre-season planning stage.

1.3 Objectives of the study

The main aim of the study is to qualitatively and quantitatively identify the long-term trends in climatic variables and their relationship with crop production, and to propose an evaluation model to facilitate the selection and implementation of appropriate adaptation practices for improved agricultural production.

The specific objectives are to;

1. Identify farmers' perceptions about climate change regarding long-term trends, weather extremes, causes and effects.
    - 1.1. Identify farmers' perceptions about long-term rainfall and temperature trends.
    - 1.2. Identify the rate of occurrences of extreme weather events and reasons for adaptation.
    - 1.3. Assess farmers' perceived causes and effects of climate change.
2. Analyze historical annual and seasonal rainfall variability and distribution, and to examine the relationship between rainfall and crop production.
    - 2.1. Determine the annual and seasonal variability of rainfall in Lawra district.
    - 2.2. Determine the distribution of seasonal and annual rainfall.
    - 2.3. Examine the relationship between rainfall variability and crop production in Lawra district.
3. Analyze farmers' climate change risk perceptions.
    - 3.1 Assess existing knowledge on various climate-risk phenomena and impacts.
    - 3.2Assess levels of perceived climate risks among different categories of farmers.
    - 3.3 Explore determinants of climate risk perceptions.
4. Analyze farmers' adaptation practices to climate change in agriculture.
    - 4.1 Identify and compare farmers' perceived important adaptation practices to actual practices being used.
    - 4.2. Model the determinants of adaptation practices to climate change in rural agriculture.
    - 4.3. Determine farmers' perceived barriers to climate change adaptation.

5. Develop an evaluation model for prioritizing and selecting adaptation practices to climate change.

5.1 Develop a set of indicators for assessing the feasibility and effectiveness of adaptation practices to climate change in agriculture.

5.2 Prioritize drought and dry spell adaptation alternatives in agriculture.

1.4 Research outline

The study comprises four stages as shown in Figure 1.2. The findings in each stage are discussed in terms of their contribution to improved adaptation to climate change so as to boost agriculture production at local level.

In the first part of stage 1, farmers' climate change perceptions are assessed and their perceived long-term trends of climatic variable and causes of climate change are identified. Also, based on focus group discussions, a new approach of classifying farmers' perceived effects of climate change is proposed *(i.e., agriculture production, socio-economy, environment and psychology)*. The rate of occurrence of extreme weather events *(i.e. dry spell, drought and floods)* is determined. To verify farmers' perceptions about trends of climatic variables and their effects on agriculture production, an empirical analysis is conducted and the historical distribution and variability of rainfall is determined in the second part. Using rainfall variability as an indicator, a correlation analysis is conducted to identify the key crops that are negatively affected.

To generate knowledge for effective climate change risk communication, stage 2 focuses on climate risk identification and assessment. Firstly, various climate risk phenomena are identified and classified based on risk impacts. Based on annual average income, farmers are classified into three wealth categories *(i.e., poor-resource farmers, moderate-resource farmers and rich-resource farmers)*. Subsequently, the levels of perceptions about climate change risk of each category of farmers are identified. Climate-risk perceptions of farmers are also assessed based on impacts on agriculture production, bio-diversity and forestry, climatic variables, and health and socio-economy. This is done in order to identify how different farmers perceive climate change risks. Finally, the determinants of climate change risk perception are identified. Information on demographic characteristics of farmers and risks elements *(i.e., probability, exposure and consequences)* is collected and analyzed.

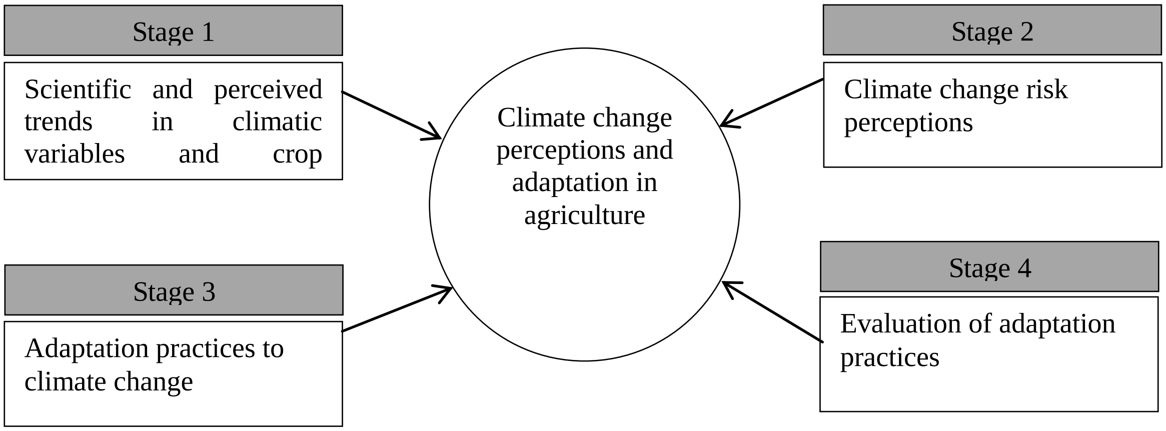


Figure 1.2 – Scope of the study (*Source: Author*)

In stage 3, adaptation practices to climate change are identified and documented. Subsequently, farmers' reasons for using adaptation options were identified and ranked. Also, a ranking system is conducted to identify farmers' perceived most important practices. This is compared to the actual adaptation practices being implemented currently. The problem confrontation index method is applied to identify the constraints to use of the most relevant adaptation measures. To provide a clear understanding of farm-level adaptation, a new method of classification of adaptation practices is proposed based on responses from farmers. Finally, to propose strategies to facilitate the development and promotion of appropriate adaptation options, the socio-economic determinants of adaptation is also investigated. Information on demographic characteristics, household income, agricultural characteristics, access to field officers, weather predictability, farmer-based organizations, subsidies and credit facilities among other factors is collected and analyzed.

To improve stakeholders' decision-making regarding development, production, promotion *(w.r.t. research scientists, agricultural field officers and government)* and farmers' selection of appropriate measures, stage 4 focuses on development of evaluation model for adaptation practices. In the first step, stakeholders and their specific roles are identified and goal set. Secondly, the key components and indicators are developed through extensive literature review, focus group discussions and face-to-face interviews with key experts. Thirdly the indicators are classified based on feasibility and effectiveness with respect to farmers, society, nature and institutions. Fourthly, based on the AHP model, a weighting score is developed for indicators using responses from agricultural experts. Finally, the indicators and adaptation options are prioritized. Thus, at each pre-season planning stage, various adaptation practices to a predicted climate event (i.e., drought or flood) are assessed based on the indicators and weights, and the adaptation option with the highest score is deemed most feasible and effective for selection and implementation.

References;

1. Adger, W.N.; Agrawala, S.; Mirza, M.M.Q.; Conde, C.; O'Brien, K.; Pulhin, J.; Pulwarty, R.; Smit, B.; Takahashi, K. **(2007)**. Assessment of adaptation practices, options, constraints and capacity. In: Parry ML, Canziana OF, Palutik of JP, van der Linden PJ, Hanson CE (eds) Climate change **2007**: impacts, adaptation and vulnerability. Contribution of working group ii to the fourth assessment report of the intergovernmental panel on climate change. Cambridge University Press, Cambridge, pp 717–743
2. Haile, M. Weather Patterns, Food Security and Humanitarian Response in Sub-Saharan Africa, Philosophical Transactions. *The Royal Society of Biological Sciences* **2005**; 360(1463), Published online. *doi: 10.1098/rstb.2005.1746*
3. Huq, S.; Reid, H.; Konate, M.; Rahman, A.; Sokona, Y.; Crick, F. Mainstreaming Adaptation to Climate Change in Least Developed Countries (LDCs). *Climate Policy* **2004**, International Institute for Environment and Development, London, UK
4. Kurukulasuriya, P.; Mendelsohn, R.; Hassan, R.; Benhin, J.; Deressa, T.; Diop, M.; Eid, H. M.; Fosu, K. Y.; Gbetibouo, G.; Jain, S.; Mahamadou, A.; Mano, R.; Kabubo-Mariara, J.; El Marsafawy, S.; Molua, E.; Ouda, S.; Ouedraogo, M.; Sene, I.; Maddison, D.; Seo, S. N.; Dinar, A. Will African Agriculture Survive Climate Change? World Bank Economic Review **2006**, London.
5. Hillel, D.; Rosenzweig, C. The Greenhouse Effect and Its Implications Regarding Global Agriculture. In Res. Bull. No. 724, **1989**. University Massachusetts, Agricultural Experiment Station
6. World Bank. Economics of Adaptation to Climate Change: Social Synthesis Report. 1818 H Street NW Washington DC, USA, 2010: 116pp
7. Owusu, K.; Waylen, P.R.; Qui, Y. **(2008)** in World Bank (2010), Economics of Adaptation to Climate Change: Social Synthesis Report, 1818 H Street NW Washington DC, USA, 116pp.
8. Minia, Z. **(2004)** in World Bank (2010), Economics of Adaptation to Climate Change: Social Synthesis Report, 1818 H Street NW Washington DC, USA, 116pp.
9. Boko, M., Niang, I.; Nyong, A.; Vogel, C.; Githeko, A.; Medany, M.; Osman-Elasha, B.; Tabo, R.; Yanda, P. **(2007).** Africa. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change , M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge UK, 433-467.
10. Ministry of Food and Agriculture (MoFA). Food and Agriculture Sector Development Policy (FASDEP II), Accra, Ghana, **2007**, 70pp.
11. Ministry of Environment, Science and Technology (MEST) **(2010)** in Würtenberger, L., Bunzeck, I. G., and X. v. Tilburg (2011). Initiatives related to climate change in Ghana: Towards coordinating efforts. Energy research Centre of the Netherlands, ECN-E--11-010. Retrieved October 20, 2011, from

http://www.ecn.nl/docs/library/report/2011/e11010.pdf

12. Adger, W.N.; Huq, S.; Brown, K.; Conway, D.; Hulme, M. Adaptation to Climate Change in the Developing World. Available online: http://www.glerl.noaa.gov/seagrant/ClimateChangeWhiteboard/Resources/Uncertainty/climatech/adger03PR.pdf (accessed on 9 May 2015).
13. Intergovernmental Panel on Climate Change (IPCC). Climate Change 2001: Impacts, Adaptation, and Vulnerability. Intergovernmental Panel on Climate Change; Cambridge University Press: Cambridge, UK, **2001**.
14. Luni, P.; Maharjan, K.L.; Joshi, N.P. Perceptions and realities of climate change among the Chepong Communities in rural mid-hills of Nepal. J. Contemp. India Stud. Space Soc. 2012, 2, 35–50.
15. Morton, F. J. The Impact of Climate Change on Smallholder and Subsistence Agriculture, *PNAS*, **2004**, 104(50): 19680-19685
16. Di Falco, S.; Yesuf, M.; Kohlin, G.; Ringler, C. Estimating the impact of climate change on agriculture in low-income countries: Household level evidence from the Nile Basin, Ethiopia. *Environ. Resour. Econ*. **2012**, 52, 457–478.
17. Jackson, L.E.; Pascual, U.; Hodgkin, T. Utilizing and conserving agrobiodiversity in agricultural landscapes. *Agric. Ecosyst. Environ.* **2007**, *121*, 196–210.
18. Nigg, J. M.; Mileti, D. Natural hazards and disasters. In Dunlap R. E., Michelson W., editors. (Eds.), Handbook of environmental sociology **2002**: pp. 272-294. Westport, CT: Greenwood Press.
19. Sulewski, P.; Kłoczko-Gajewska, A. Farmers' risk perception, risk aversion and strategies to cope with production risk: an empirical study from Poland. *Studies in Agricultural Economics* **2014**, 116: 140-147
20. Fosu-Mensah, B.Y.; Vlek, P.L.G.; MacCarthy, D.S. Farmers' perceptions and adaptation to climate change: A case study of Sekyeredumase district in Ghana. Environ. Dev. Sustain. **2012**, 14, 495–505.
21. Clements, R.; Haggar, J.; Quezada, A.; Torres, J. Technologies for Climate Change Adaptation-Agriculture Sector. X. Zhu (Ed.). UNEP Risø Centre, Roskilde, **2011**
22. Nhamo, N.; Daniel, M.; Fritz, O.T. Adaptation strategies to climate extremes among smallholder farmers: A case of cropping practices in the Volta Region of Ghana. *Br. J. Appl. Sci. Technol*. **2014**, 4, 198–213.
23. Okonya, J.S.; Syndikus, K.; Kroschel, J. Farmers' perceptions of and copping strategies to climate change: Evidence from six agro-ecological zones of Uganda. *J. Agric. Sci.* **2013**, 5, doi:10.5539/jas.v5n8p252.
24. Apata, T.G. Factors Influencing the Perception and Choice of Adaptation Measures to Climate Change among Farmers in Nigeria. Evidence From farm Households in Southwest Nigeria. Available online: http://businessperspectives.org/journals_free/ee/2011/ee_2011_04_Apata.pdf (accessed on 9 May

2015).
25. Nhemachena, C.; Hassan, R. Micro-Level Analysis of Farmers' Adaptation to Climate Change in Southern Africa. Available online: http://cdm15738.contentdm.oclc.org/utils/getfile/collection/p15738coll2/id/39726/filename/39727.pdf (accessed on 23 May 2015).
26. Al-Hassan, R.; Poulton, C. Agriculture and Social Protection in Ghana. Future Agricultures. Working Paper No. 009, **2009**
27. Athula, S.; Scarborough, H. Coping with Climatic Variability by Rain-fed Farmers in Dry Zone, Sri Lanka: Towards Understanding Adaptation to Climate Change. Australian Agricultural and Resource Economics Society (AARES), 55th Annual National Conference, 8-11 February **2011**, Melbourne, Victoria.
28. Molua L. E.; Lambi, C.M. The Economic Impact of Climate Change on Agriculture in Cameroon, Centre for Environmental Economics and Policy in Africa (CEEPA), University of Pretoria, South Africa, **2006**; 33pp.
29. Etwire, P.M. Adaptation responses of smallholder farmers to climate change and variability in Northern Ghana. Assessing the adaptation mechanisms of smallholder farmers to climate change and agrobiodiversity losses in Northern Ghana. Global change systems for analysis, Research and Training, START, **2012**, 67-212
30. Devkota, R.P.; Cockfield, G.; Maraseni, T.N. Perceived community-based flood adaptation strategies under climate change in Nepal. *Int. J. Global Warming* **2014**, 6, 113–124.
31. Uddin, M.N.; Bokelmann, W.; Entsminger, J.S. Factors affecting farmers' adaptation strategies to environmental degradation and climate change effects: A farm level study in Bangladesh. *Climate* **2014**, 2, 223–241.

CHAPTER 2: MATERIALS AND METHODS: THE STUDY AREA, SURVEY DESIGN, DATA COLLECTION AND ANALYTICAL METHODS

2.1 Introduction

The first part of this chapter discusses the study area. The socio-economic characteristics and reasons for selection of the study area are presented. The geographical location, environmental characteristics and soil characteristics are also outlined. The second part briefly discusses the different types of data collected for study. The various sources, scope, and methods of data collection are also presented and discussed. In addition, the analytical methods employed to analyze the data are also presented.

2.2 The case study

The study is conducted in Lawra district of Ghana. The district is located in the Guinea Savannah Agro-ecological zone (Figure 2.1). It lies in the north western corner of the Upper West Region of Ghana between longitude 10°30'N and latitude 2°35'W. It has two seasons: the dry season (November–April) and the rainy season (May–October). The mean annual temperature ranges from 27 to 36 °C while the mean annual rainfall is between 900 and 1200 mm and concentrated in one season. The vegetation is guinea savanna grassland characterized by shrubs and medium-sized trees, such as *shea-tree*, *dawadawa*, *baobab*, and *acacia*. The soils are mainly laterite soils developed from birimian and granite rocks. These soils are shallow sandy loam with medium coarse quartz stones. The relatively fertile soils in the district are concentrated in the top 5 cm and hence, can easily be rendered infertile or washed away.

Eighty percent of the district's total population of 100,929 is engaged in rain-fed subsistence agriculture [1]. Other livelihood activities of the people include *pito* (local beer) brewing, charcoal burning, petty trading and small-scale livestock rearing. The major crops produced include maize, sorghum, millet, and groundnut. While the first three crops are mainly staple crops, the last two are produced as cash crops. Sorghum is the most widely and intensively cultivated crop. Cowpea and maize are cropped on smaller scales. Crop production activities take place within the rainy season. Production activities start between May and June (i.e. with land preparation and crop planting activities) and ends between October and December (i.e. harvesting) depending on the crop type (Figure 2.2).

Recurrent droughts, dry spells, and floods tend to have adverse effects on crop production. In addition, a limited number of dams and dug-outs in the district makes it difficult for farmers to undertake irrigation farming. Another key challenge to agriculture in the district are soil degradation which is mostly caused by intensive livestock grazing, deforestation and extensive bush burning which usually occur within the period of November to April. The decision to select Lawra district was based on recent incidences of delayed onset of rains, dry spell, droughts and floods during the crop production season. Based on historical data from the Ghana Meteorological Agency, the district is more prone to extreme weather conditions. Other reasons included data accessibility and recommendations of the Ministry of Food and Agriculture. According to the [21], Lawra is the poorest district in the upper west region of Ghana.

Figure 2.1 - Location of Lawra district on the map of Ghana (*Source: Google maps*, *2015*)

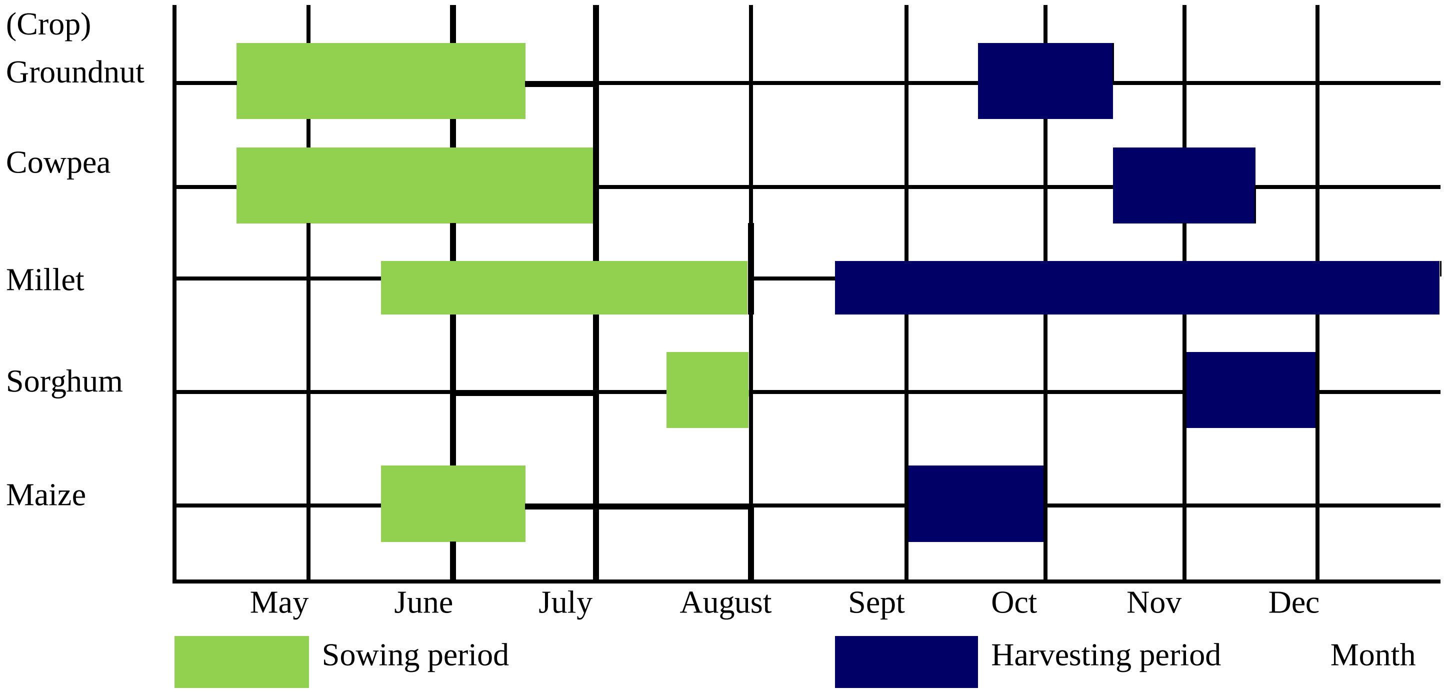


Figure 2.2 - Crop calendar; Guinea Savannah/Northern Ghana (*Source: FAO*).

2.3 Survey design and data collection

Data used in this study include both secondary and primary data. Historical rainfall and crop production volumes were used to analyze the distribution and variability of rainfall and its relationship with annual volume of crop production (Table 2.1). Monthly rainfall figures for the period 1980-2012 are provided by the Ghana Meteorological Agency. Available agricultural data for the period of 1992 to 2012 (i.e. annual crop yield), was obtained from the Regional Agricultural Development Unit (RADU). These data are analyzed to identify long-term trend of precipitation (i.e. distribution and variability). Subsequently, both crop production and rainfall datasets are analyzed to identify the relationship between precipitation and annual production volumes of key crops produced in the study area (i.e., maize, sorghum, millet, cowpea and groundnut).

In terms of primary data, cross-sectional survey data from four farming communities *(i.e., Brifo-chaa, Methuo, Kalsagri, and Oribili)* is used. A total of 100 farming households were selected randomly. Twenty-five households were randomly chosen from each community and the household' heads individually interviewed. Semi-structured questionnaires were used to investigate farmers' perceived changes in temperature and rainfall, causes and effects of climate change, and adaptation practices being used by farmers (Table 2.2). Four focus group discussions (FGDs) were conducted to double check the survey data. The participants included community leaders, men, women, youth and children. The discussions in each community focused on perceptions regarding climatic and agro-ecological changes, possible effects on agriculture, adaptation practices being used, barriers to adaptation and household characteristics. The household survey and FGDs were conducted in February and November 2014 with the assistance of three regional and four district agricultural officers. The selection of communities was based on the accessibility and knowledge of agricultural officers.

Table 2.1 Summary of secondary data collection (*Source: Author*)

No.	Key research issues for data collection	Data type	Scope	Source
1	Historical rainfall distribution and variability.	Historical rainfall (mm) Crop production figures (Mt)	1980 - 2012 (33 years) 1992 - 2012 (22 years 1992 - 2012 (22 years)	Ministry of Food and Agriculture, Ghana Meteorological Agency
2	Relationship between rainfall and annual crop production volumes.	Arable land-use data (Ha)		
3.	Climate change risk, perceptions, adaptation, barriers, determinants and community participatory planning	Literature review	Articles, reports and policy documents	

Table 2.2 – Summary of primary data: sources and methods of collection *(Source: Author)*

No.	Key issues for data collection	Data source	Number	Method of collection
1	Farmers' perceptions about climate change *(i.e., perceived long-term trends, occurrence of extreme events, causes and effects)*	Farmers, Agricultural staff, Local government officers, Research scientists	100 10 2 1	Questionnaires FGDs Face-to-face interviews
2	Climate risks perceptions and concerns among farmers *(i.e., risk perceptions, risk concerns and determinants)*			
3	Adaptation to climate change in agriculture *(i.e., reasons for adaptation, ranking of adaptation practices, determinants of adaptation and barriers to adaptation)*			
4	Evaluation and prioritization of adaptation options model			

FGDs = Focus group discussions

2.4 Analytical methods

The analytical methods used in this study are presented in Table 2.3. In the first part of analysis, the weighted average index method (WAI) is used to rank the effects of climate change on crop performance, environment, households' socio-economy and psychological threats. Similarly, the WAI is applied to rank farmers-perceived rate of occurrence of weather extremes (i.e. dry spell, drought and flood) and preference of adaptation practices to climate change.

Table 2.3 Empirical approaches and statistical methods applied in data analysis (*Source: Author*)

S/N	Analytical methods	Application
a.	**Empirical approaches**	
1	Multiple regression model	Identify the determinants of climate risk perceptions and concerns
2	Logistic regression model	Identify the determinants of adaptation to climate change
3	Precipitation concentration index	Determine the historical distribution of seasonal and annual rainfall
4	Analytical Hierarchical Process	Evaluate indicators and prioritized adaptation practices to climate change in agriculture.
5	Weighted average index	Assess the rate of occurrence of climate extremes, ranking of adaptation practices, climate change effects, climate change risks and impacts.
6	Problem confrontation index	Assess the barriers to use of adaptation practices
7	Climate change risk perception index	Assess the degree of climate change risks concerns and apprehensions by farmers.
b.	**Statistical methods**	
8	Means, percentages and frequencies	Farmers' demographic features, perceived long-term trends in climatic variables, farmers' adaptation proportions, causes of climate change, reasons for adaptation
9	Correlation	Determine the relation between rainfall and annual crop production
10	Coefficient of variation	Determine the seasonal and annual variability of rainfall
c.	**New model**	
11	New approach for developing decision-making indicators	Develop indicators for prioritizing and selecting adaptation alternatives to climate change.

Means, percentages and frequencies are used to represent farmers' perceived long-term changes in temperature and rainfall, causes of climate change and reasons for use of adaptation options. In the second part, the precipitation concentration index (PCI), coefficient of variation (CV) and correlation methods are used. The PCI is used to determine seasonal and annual rainfall distribution, while CV is applied to assess the historical variability of rainfall. Correlation analysis is conducted to verify the influence of rainfall variability on crop production using the two datasets (i.e., Crop production (Mt) and rainfall volume (mm)).

The third part applies the multiple regression method to evaluate and identify the factors influencing farmers' climate change risk perceptions. A climate change risk perception index (CRPI) is also developed and applied to assess the level of risk concerns and apprehensions held by farmers. The fourth part of analysis applies the logistic regression model to evaluate the determinants of adaptation to climate change in agriculture. Also, the problem confrontation index method is applied to determine the constraints to use of adaptation practices by farmers. In the final part, a new model is proposed for the development of indicators to assist in the evaluation and selection of adaptation practices to extreme climate events. Subsequently, the analytical hierarchical process (AHP) decision support model is applied to evaluate the indicators and the alternative adaptation practices to drought.

References:

1. Ghana Statistical Service (GSS). Population and Housing Census. **2012**.

CHAPTER 3: FARMERS' PERCEPTIONS ABOUT CLIMATE CHANGE: LONG-TERM TRENDS, WEATHER EXTREMES, CAUSES AND EFFECTS

3.1 Introduction

In this chapter, farmers' perceptions about long-term changes in climatic variables are outlined and discussed in relation to the global context. Farmers' perspective on rate of occurrence of climatic effects *(i.e., drought, dry spell and floods)* is also investigated and elaborated. Furthermore, the chapter outlines the causes of climate change based on farmers' perspective. Finally, unlike the conventional understanding of climate change effects, this study introduces new elements of climate change effects based on results of focus group discussions and survey data (i.e., crop performance, environment, households' socio-economy and psychological threats)..

3.2 Literature review

Climate change prediction models have indicated that the Sudan and Guinea Savanna zones of Ghana will continue to experience increasing temperature and decreasing precipitation trends [1]. This confirms previous findings that between 2030 and 2039 the rainy season might start in June or even later in Northern Ghana [2]. It is also projected that the standard deviation for the onset of the rainy season will increase [3], which suggests that not only will it shift but also it will become even more "erratic" [4]. The implications are that Northern Ghana would witness more extreme weather conditions such as droughts, dry spells, and floods. This situation will eventually affect agriculture, the environment, and human livelihoods. In particular, it is anticipated that adverse impacts on the agricultural sector will exacerbate the incidence of rural poverty [5].

Globally, many studies have been used to understand farmers' perceptions about climate change and its associated effects on agriculture. Although perceptions are not necessarily consistent with reality, they must be considered to address socioeconomic challenges [6]. Perception has been defined as the process by which organisms interpret and organize sensation to produce a meaningful experience of the world [7]; and that a person's perceptions are based on experiences with natural and other environmental factors that vary in the extent to which such perceptions are enabled [8]. Previous studies have shown that the way in which people experience climate shocks varies across different social groups, geographic locations, and seasons of the year, with men, women, and children all experiencing different levels of hardship and opportunity in the face of climate change [9].

Discussions of agriculture, climate change and adaptation processes need to be informed by empirical data from farmers. Adaptation practices in agriculture are generally location-specific [10]; hence, it is crucial to understand farmers' perceptions about the risks they face. To ensure farmers' readiness for extreme weather events and collaboratively learn about the evolution of weather patterns, efforts to focus on farmers and their current activities, knowledge, and perceptions are essential [11,12]. Farmers' willingness to accept and use prescribed measures could be enhanced if their perceptions and understanding are considered in designing such measures. By contrast, current models used in predictions of climate change and adaptation practices are at a global scale and need to be downscaled to accommodate realities at the community level [13]

In the Lawra district of Ghana, agriculture production is the dominant source of food and household incomes for the vast majority of rural households. Agriculture production is largely rain-fed. Farmers' dependence on an annual mono-modal rainfall pattern coupled with farm resource constraints make agriculture very vulnerable to the impacts of climate change. Results of previous studies have revealed a negative correlation between seasonal rainfall and volume of staple crops *(i.e.*, sorghum, millet, and groundnut) produced annually in the Lawra district over the past 20 years [14]. This study explored farmers' perceptions regarding long-term changes in climatic variables and the associated effects on farming. It also identified perceived rate of occurrence of extreme climatic events and causes of climate change in rural agriculture.

3.3 Materials and methods

3.3.1 Survey design and data collection

This study is based on a cross-sectional survey data from farming households across four communities. A total of 100 farming households were randomly selected for the interviews. Semi-structured questionnaires were used to investigate farmers' perceived changes in temperature and rainfall, causes and effects of climate change, and rate of occurrence of extreme climatic events. Four focus group discussions (FGDs) were conducted to double check the survey data. The household survey and FGDs were conducted between February and November 2014 with the assistance of three regional and four district agricultural officers. The selection of communities was based on the accessibility and knowledge of agricultural officers.

3.3.2 Analytical methods

Percentages and frequencies are used to represent farmers' perceived long-term changes in temperature and rainfall and causes of climate change. Mean and standard deviation were used to represent farmers' socio-economic and demographic characteristics (Table 3.1). The weighted average index (WAI) analysis has previously been applied to assess farmers-perceived important adaptation strategies in Bangladesh and barriers of adaptation to climatic change in Nepal [15, 16]. In this study, the WAI is used to rank the effects of climate change on crop performance, environment, households' socio-economy and psychological threats. Similarly, the WAI is applied to rank farmers-perceived rate of occurrence of weather extremes (i.e.

dry spell, drought and flood). Respondents were asked to score the weather extremes based on a 0-2 Likert scale (i.e 'high', 'moderate' and 'low'). The WAI was then estimated using the formula below:

$$\text{WAI} = \frac{F_2W_2 + F_1W_1 + F_0W_0}{F_2 + F_1 + F_0} \qquad (3.1)$$

where: F = frequency; W = weight of each scale; i = weight (2 = high occurrence; 1 = moderate occurrence and 0 = low occurrence)

In the case of climate change effects, the weight (i) is given as 3=high effects; 2=moderate effects; 1=low effects and 0=no effects.

Table 3.1 - Description of data variables. (*Source: Author*)

Variables	Mean	Standard Deviation
Age (15–34 years = 1; 35–54 years = 2; above 55 years = 3)	2.26	0.73
Education level (literate = 1; illiterate = 0)	0.21	0.41
Farm size (Hectares) (continuous)	4.95	1.70
Household size (continuous)	8.20	5.12
Family labor (continuous)	4.65	3.04
Annual farm income—Ghana cedi (continuous)	1909.55	949.42
Annual off-farm income—Ghana cedi (continuous)	2459.92	797.20
Farmer's adaptation (adapted = 1; not adapted = 0)	0.67	0.47

3.4 Findings and discussion

3.4.1 Farmers' perceptions of long-term temperature and rainfall changes

The majority of farmers (82%) perceived an increase in temperature over the past 10 years (Table 3.2). About 9% of respondents perceived no change, 6% perceived a decreasing change in temperature, and 3% did not know if there was a long-term change in temperature. Similar results are obtained from the focus group discussion. Generally, farmers believe that the increasing temperature trend was associated with the changes in precipitation. A total of 87% of respondents claimed that the rainfall amount has been decreasing over the past 10 years, 6% perceived no change in precipitation, and 7% gave other responses. Results obtained from FGDs proved that this perception was unanimous among farmers. Farmers attributed the perceived increasing temperature trend to decreasing precipitation.

Table 3.2 − Farmers' perception on long-term changes in climatic variables in Lawra district of Ghana (N=100). (*Source: Author*)

Variables	**% of Respondents**
Temperature	
Don't know	3
Decreasing	6
Stable	9
Increasing	82
Precipitation	
Don't know	2
Increasing	5
Stable	6
Decreasing	87

To verify farmers' perceptions regarding the precipitation trend, available historical annual rainfall data from 1980 to 2012 were obtained from the upper west regional weather station of the Ghana Meteorological Agency. The results indicate high variability rather than a clear decreasing trend in precipitation (Figure 3.1). This notwithstanding, the results of farmers' perceptions are in line with findings of previous studies reported in Southern Ghana, Nigeria, Senegal and Southern Africa that showed that majority of farmers have perceived long-term changes in climatic variables [17, 18, 19, 20]. Other studies have also shown that, in the last 100 years, there has been an average global temperature increase of 0.74 °C [21].

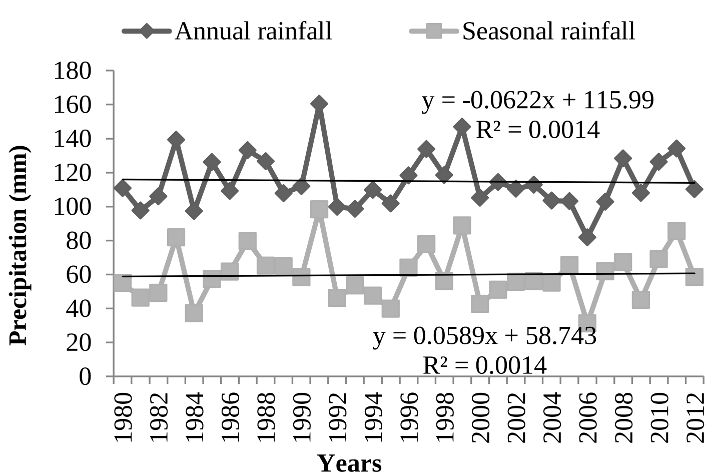


Figure 3.1 - Annual and seasonal rainfall (mm) in the Lawra district of Ghana (The rainfall data was collected directly from the office of the meteorological agency: Ghana Meteorological Agency, 2014). (*Source: Author*)

In addition, the results of discussions with the district agricultural officers confirmed the results of statistical analysis on the long-term trend in precipitation. Thus, the difference between farmers' perceptions and statistical results is due to the fact that farmers' responses are based solely on recall. The high illiteracy rate among farmers in Lawra district hinders their ability to keep formal records, and so accurately recalling long-term trends of rainfall could be difficult.

3.4.2 Perceived occurrence of weather extremes

The results of farmers' perceptions regarding occurrences of weather extremes are presented in Table 3.3. Farmers generally perceive weather extremes in terms of dry spell, drought and floods. The rate of occurrence of dry spell is ranked highest by respondents (WAI = 1.88). Drought and flood occurrences are ranked 2nd and 3rd, respectively (WAI = 0.53 and WAI = 0.30). Same results were obtained during the focus group discussions. Farmers claimed that unlike floods, dry spells occur every year during the crop production season. The respondents claimed that the frequency and severity of floods is decreasing due to decreasing rainfall trend. On the other hand, farmers indicated that the frequency and severity of drought is beginning to increase in recent times. Similar findings were reported in Wa West district of Ghana where farmers perceived higher frequency and severity of drought than floods [6]. In Uganda however, farmers were reported to have perceived higher rate of occurrence of flood than drought [22].

Table 3.3 − Rate of occurrence of weather extremes (N=100) in Lawra district of Ghana. (*Source: Author*)

Variables	**Ranking of weather extremes**			**WAI**	**Rank**
	High	**Moderate**	**Low**		
Dry spell	88	12	0	1.88	1
Drought	10	33	57	0.53	2
Flood	5	20	75	0.30	3

3.4.3. Farmers' Perceived Causes of Climate change on Agriculture

Most farmers attribute climate change to human-related causes such as bush fires (51%) and deforestation (14%). While deforestation is largely perceived as being for the purposes of fuel wood, charcoal, and farm expansion, bush fires are believed to be caused by the 'negligence' of hunters and cigarette smokers. About 9.3% of respondents also claimed that traditional gods and ancestral spirits are responsible for the perceived changes in rainfall and temperature trends. During the FGDs, farmers indicated that the gods and ancestral spirits were angry because many taboos have been broken by people (e.g., destroying sacred groves or woods, catching of sacred fish, *etc.*). Additionally, 23.3% of respondents claimed that climate change is caused by many factors, while 2.4% could not give any cause (Table 3.4). Similar findings have been reported in the Wa West district of Ghana [6] and in Northern Nigeria [5].

Table 3.4 - Farmers' perceptions about the causes of climate change in the Lawra district of Ghana (*Number of respondents* = 100). (*Source: Author*)

Cause Variable	Percentage of respondents
Deforestation	14.0
Bush fires	51.0
More than one cause	23.3
Gods/ancestral spirits	9.3
Do not know	2.4
Total	100

3.4.4 Farmers-perceived effects of climate change on agriculture

Unlike the conventional understanding of climate change effects, farmers in Lawra district generally perceive effects of climatic change on agriculture in terms of poor crop performance, environmental degradation, socio-economic challenges and psychological threats. With a WAI value of 2, poor crop performance is perceived to be the highest effect of climate change on rural agriculture (Table 3.5). Socio-economic threats and environmental degradation are ranked 2nd and 3rd with WAI values of 1.45 and 1.39, respectively. The respondents also perceived and ranked psychological threats as effects of climatic change (WAI = 1.30).

Results of the focus group discussions showed that dry spells and droughts generally cause wilting and drying up of crop plants. These culminate into poor crop development and low yields. The farmers claimed that socio-economic effects of climate change include out-migration, indebtedness, food shortage and low household incomes. The psychological effects of climate change identified by farmers included stress, depression and suicides. This is likely the case because farmers' inability to pay back farm resources borrowed from colleague farmers and relatives in the event of a climate-related crop failure can cause psychological trauma. Low incomes and food shortages can also lead to depression, sicknesses and deaths in farm households. The observation in this study that farmers link psychological threats to climate change is intriguing since it appears no studies as yet have reported similar findings.

Table 3.5 − Farmer-perceived effects of climate change on agriculture (N=100) in Lawra district of Ghana. (*Source: Author*)

Effect variable	**Ranking of effects**				**WAI**	**Rank**
	High	**Moderate**	**Low**	**No**		
Poor crop performance	100	0	0	0	2.00	1
Socio-economic challenges	54	37	9	0	1.45	2
Environmental degradation	45	49	6	0	1.39	3
Psychological threats	50	30	12	8	1.30	4

3.5 Conclusion and Recommendation

Farmers generally, have perceived a decrease in annual rainfall volumes and an increase in temperature over the past 10 years. Furthermore, this study revealed that the rate of occurrence of dry spell and drought is higher than flood. Government should therefore boost the capacity of research scientists and agricultural staff to develop and promote appropriate and effective technologies (e.g. drought-tolerant and early maturing crop varieties) to help farmers adapt to these extreme weather events. The study showed that farmers' perceptions about the causes of climate change are mostly centered on human factors (i.e., deforestation and bushfires) and gods and ancestral curses. However, the perception that climate change is caused by traditional gods and ancestral curses implies that scientists and development experts should consider the cultural and traditional beliefs of farmers when designing adaptation practices. As such, a bottom-up approach must be used to ensure that farmers' beliefs and understanding are a crucial part of the design and dissemination of adaptation practices. Also, considering that perceptions are not necessarily congruent with reality, it is essential to objectively verify the results of farmers' perceptions by conducting an empirical analysis of historical rainfall trend and its relationship with annual crop production.

References:

1. USAID. Ghana Climate Change Vulnerability and Adaptation Assessment. Available online: http://www.encapafrica.org/documents/biofor/Climate%20Change%20Assessment_Ghana_%20FINAL.pdf (accessed on 23 April 2015).
2. Jung, G.; Kunstmann, H. High-resolution regional climate modelling for the Volta Basin of West Africa. *J. Geophys. Res*. **2007**, *112*, doi:10.1029/2006JD007951.
3. Laux, P.; Kunstmann, H.; Bárdossy, A. Predicting the regional onset of the rainy season in West Africa. *Int. J. Climatol*. **2008**, *28*, 329–342.

4. Laube, W.; Schraven, B.; Awo, M. Smallholder adaptation to climate change: Dynamics and limits in Northern Ghana. *Clim. Chang.* **2009**, *111*, 753–774.
5. Farauta, B.K.; Egbule, C.L.; Idrisa, Y.L.; Agu, V.C. Farmers' Perceptions of Climate Change and Adaptation Strategies in Northern Nigeria: An Empirical Assessment. Available online: http://www.atpsnet.org/Files/rps15.pdf (accessed on 15 May 2015).
6. Kusakari, Y.; Asubonteng, K.O.; Jasaw, G.S.; Dayour, F.; Dzivenu, T.; Lolig, V.; Donkoh, S. A.; Obeng, F. K.; Gandaa, B.; Kranjac-Berisavljevic, G. Farmer-perceived effects of climate change on livelihoods in Wa West District, Upper West Region of Ghana. J. Disaster Res. 2014, 9, 516–528.
7. Lindsay, P.H.; Norman, D.A. Human Information Processing: An Introduction to Psychology. Available online: http://www.phon.ucl.ac.uk/courses/spsci/audper/SDT%20Lindsay%20&%20Norman%20App%20B.pdf (accessed on 4 August 2015).
8. Hartig, T.; Kaiser, F.G.; Bowler, P.A. Psychological restoration in nature as a positive motivation for ecological behavior. *Environ. Behav*. **2001**, 33, 590–607.
9. Ministry of Environment, Science and Technology (MEST) of Ghana. Ghana Goes for Green Growth: National Engagement on Climate Change. Available online: http://prod-http-80-800498448.us-east-1.elb.amazonaws.com/w/images/2/29/GhanaGreen.pdf (accessed on 4 August 2015).
10. Luni, P.; Maharjan, K.L.; Joshi, N.P. Perceptions and realities of climate change among the Chepong Communities in rural mid-hills of Nepal. *J. Contemp. India Stud. Space Soc*. **2012**, 2, 35–50.
11. Di Falco, S.; Yesuf, M.; Kohlin, G.; Ringler, C. Estimating the impact of climate change on agriculture in low-income countries: Household level evidence from the Nile Basin, Ethiopia. *Environ. Resour. Econ*. **2012**, 52, 457–478.
12. Jackson, L.E.; Pascual, U.; Hodgkin, T. Utilizing and conserving agrobiodiversity in agricultural landscapes. *Agric. Ecosyst. Environ*. **2007**, 121, 196–210.
13. Nhamo, N.; Daniel, M.; Fritz, O.T. Adaptation strategies to climate extremes among smallholder farmers: A case of cropping practices in the Volta Region of Ghana. *Br. J. Appl. Sci. Technol*. **2014**, 4, 198–213.
14. Ndamani, F.; Watanabe, T. Influences of rainfall on crop production and suggestions for adaptation. *Int. J. Agric. Sci*. **2015**, 5, 367–374.
15. Uddin, M.N.; Bokelmann, W.; Entsminger, J.S. Factors affecting farmers' adaptation strategies to environmental degradation and climate change effects: A farm level study in Bangladesh. *Climate* **2014**, 2: 223-241.
16. Devkota, R.P.; Cockfield, G.; Maraseni, T.N. Perceived community-based flood adaptation strategies

under climate change in Nepal. *International Journal of Global Warming* **2014**, 6: 113-124.

17. Fosu-Mensah, B.Y.; Vlek, P.L.G.; MacCarthy, D.S. Farmers' perceptions and adaptation to climate change: A case study of Sekyeredumase district in Ghana. *Environ. Dev. Sustain*. **2012**, 14, 495–505.
18. Apata, T.G. Factors Influencing the Perception and Choice of Adaptation Measures to Climate Change among Farmers in Nigeria. Evidence From farm Households in Southwest Nigeria. Available online: http://businessperspectives.org/journals_free/ee/2011/ee_2011_04_Apata.pdf (accessed on 9 May 2015).
19. Mertz, O.; Mbow, C.; Reenberg, A.; Diouf, A. Farmers' perceptions of climate change and agricultural adaptation strategies in rural Sahel. *Environ. Manag*. **2009**, 43, 804–816.
20. Nhemachena, C.; Hassan, R. Micro-Level Analysis of Farmers' Adaptation to Climate Change in Southern Africa. Available online: http://cdm15738.contentdm.oclc.org/utils/getfile/collection/p15738coll2/id/39726/filename/39727.pdf (accessed on 23 May 2015).
21. Intergovernmental Panel on Climate Change (IPCC). Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, **2007**; Parry, M.L., Canziani, O.F., Palutik, J.P., Linden, P.J. Hanson, C.E., Eds.; Cambridge University Press: Cambridge, UK, 2007.
22. Okonya, J.S.; Syndikus, K.; Kroschel, J. Farmers' perceptions of and copping strategies to climate change: Evidence from six agro-ecological zones of Uganda. *J. Agric. Sci*. **2013**, 5, doi:10.5539/jas. v5n8p252.

CHAPTER 4: EMPERICAL ANALYSIS OF RAINFALL VARIABILITY AND CROP PRODUCTION: DISTRIBUTION, VARIABILITY AND CORRELATION.

4.1 Introduction

In recent years, rainfall anomalies have led to numerous incidences of droughts in the Lawra district of the Upper West Region of Ghana. These anomalies have the potential to cause undesirable effects on crop production and food security. This chapter therefore discusses the results of an empirical analysis of the historical distribution and variability of rainfall in the Lawra district. The precipitation concentration index (PCI) and coefficient of variation methods are used in the analysis. Subsequently, the results of correlation analysis of the influences of rainfall variability on crop production are also presented and discussed.

4.2 Literature review

Rainfall uncertainty remains a critical challenge confronting smallholder farmers in Sub-Sahara Africa. In the Upper West Region of Ghana, where crop production is solely dependent on highly unpredictable and sporadic seasonal rainfall [1], the volume, timeliness, distribution and duration of rainfall in each season are major concerns to farmers. The practice of irrigation is still minimal due to inadequate or absence of irrigation facilities in many locations in the area. This notwithstanding, the agricultural sector remains the single largest employer in the region. Majority of people in the area depend on crop and livestock production for their food needs and household incomes. Agriculture production in the region is characterized by low use of modern agricultural inputs and low productivity.

Earlier studies have observed that in Sub-Sahara Africa, rainfall is the most important climatic factor influencing the growth characteristics of crops [2, 3, 4]. Rainfall provides the water that serves as a medium through which nutrients are transported for crop development. In view of this significant role, clearly, inadequate water supply has adverse effects on efficient crop growth, resulting in low productivity. Previous findings have shown that food shortages and famines in sub-Saharan Africa are mostly result of rainfall uncertainties and associated drought [5, 6]. This is corroborated by subsequent studies that revealed that a 10% decrease in seasonal rainfall from the long-term average generally translates into a 4.4% decrease in food production [7].

Considering that the farmers in the Upper West Region rely solely on rain-fed agriculture, crop production is vulnerable to rainfall variability. Extreme variations to agro-climatic conditions, such as droughts and floods could directly affect the livelihood of the people in the region. However, the relationship between rainfall variability and crop production appears not to have been adequately investigated in the region. Although data on crop yield, production and rainfall are collected and documented on regular basis, statistical analysis has not been conducted to ascertain the influences of rainfall on crop production. Also, till now, it appears that conscious efforts have not been made to identify and document adaptation techniques required in addressing the effects of rainfall uncertainties; droughts and floods. In view of the critical importance of rainfall, a comprehensive understanding of its trends, patterns, duration and volumes is crucial for efficient crop production planning and management.

4.3 Materials and methods

The study uses thirty-three years of rainfall data (1980 -2012) obtained from the Babile weather station of the Ghana Meteorological Agency in Lawra district. Available agricultural data on annual crop production volumes and yield (*i.e. maize, sorghum, millet, cowpea and groundnut*) is obtained from the Regional Agricultural Development Unit (RADU). Only twenty-two years of data (1992-2012) was available (Table 4.1). These two datasets are compared to determine the relationship between rainfall variability and annual crop production.

Table 4.1 - Crop production (Mt) and cropped area (Ha) of main crops; (1992 –2012) (*Source: Author*)

Indicator	Maize	Sorghum	Millet	Groundnut	Cowpea
Area					
Mean	2,933	21,658	8,766	5,942	2,922
Min.	856	4,645	2,495	187	0
Max.	5,380	54,300	12,800	15,790	61,359
CV (%)	36	88	32	96	74
Production					
Mean	2,421	21,065	7,281	8,337	2,034
Min.	282	4,180	1,747	155	0
Max.	6,411	59,730	17,920	24,288	6,797
CV (%)	58	87	53	97	94
Yield					
Mean	0.83	0.97	0.83	1.40	0.70
Min.	0.33	0.90	0.70	0.83	0
Max.	1.19	1.10	1.40	1.54	0.11

CV (%)	161	99	164	101	126

Per standard procedure, the mean and standard deviation of monthly, seasonal and annual rainfall are calculated. The precipitation concentration index (PCI) and the coefficient of variation (CV) are employed as statistical measures of rainfall variability. Precipitation Concentration Index was proposed by Oliver [8] as an indicator of rainfall concentration and rainfall erosivity. Subsequently, other researchers [9] evaluated the PCI and calculated its values on seasonal and annual scales through the following formulae;

$$PCI_{annual} = 100*[\sum Pi^2 / (\sum Pi)^2] \quad (4.1)$$

$$PCI_{supra\ seasonal} = 50*[\sum Pi^2 / (\sum Pi)^2] \quad (4.2)$$

Pi = rainfall amount of the i^{th} month and

$\sum$ = summation over the number of months being assessed.

While PCI_{annual} denotes twelve months, $PCI_{supra\ seasonal}$ denotes six months of rainfall. In this study, supra seasonal is defined as seasonal (May-October). The interpretation of PCI values is given in Table 4.2

Table 4.2 - Interpretation of the precipitation concentration index (PCI) values. (*Source: Oliver,1980*)

PCI Value	**Interpretation**
> 10	Uniform precipitation distribution
11to 16	Moderate precipitation distribution
16 to 20	Irregular distribution
>20	Strong irregularity of precipitation distribution

To verify the influence of rainfall variability on crop production, correlation analysis was conducted. Previous studies have also applied rainfall variability as a predictor to determine similar relations [10, 11, 12]. Rainfall (X) is used as an independent variable and crop production (Y) as a dependent variable. Previous studies have shown that in investigating the influences of rainfall variability, it is more significant to consider crop production than yield. That is because a focus on yield tends to gloss over impact of extreme climatic conditions involving severe droughts that could result in abandonment of planted areas prior to harvest [2]. That is to say, total crop production combines the impact of climate on harvested area, yield and production and hence has greater economic significance than yield.

4.4 Findings and discussion

5.4.1 Seasonal and annual rainfall patterns

The results show a total rainfall volume of 33,799mm recorded on 2,420 rain days within the 33 years studied. Annual rainfall ranges from 463mm to 1,643mm. Seasonal rainfall accounts for approximately 90% of total annual rainfall (see Table 4.3). Total annual rainfall volumes exceed 1,200mm in 1980 and 2000 and fall below 1,000mm in 1990 and 2010.

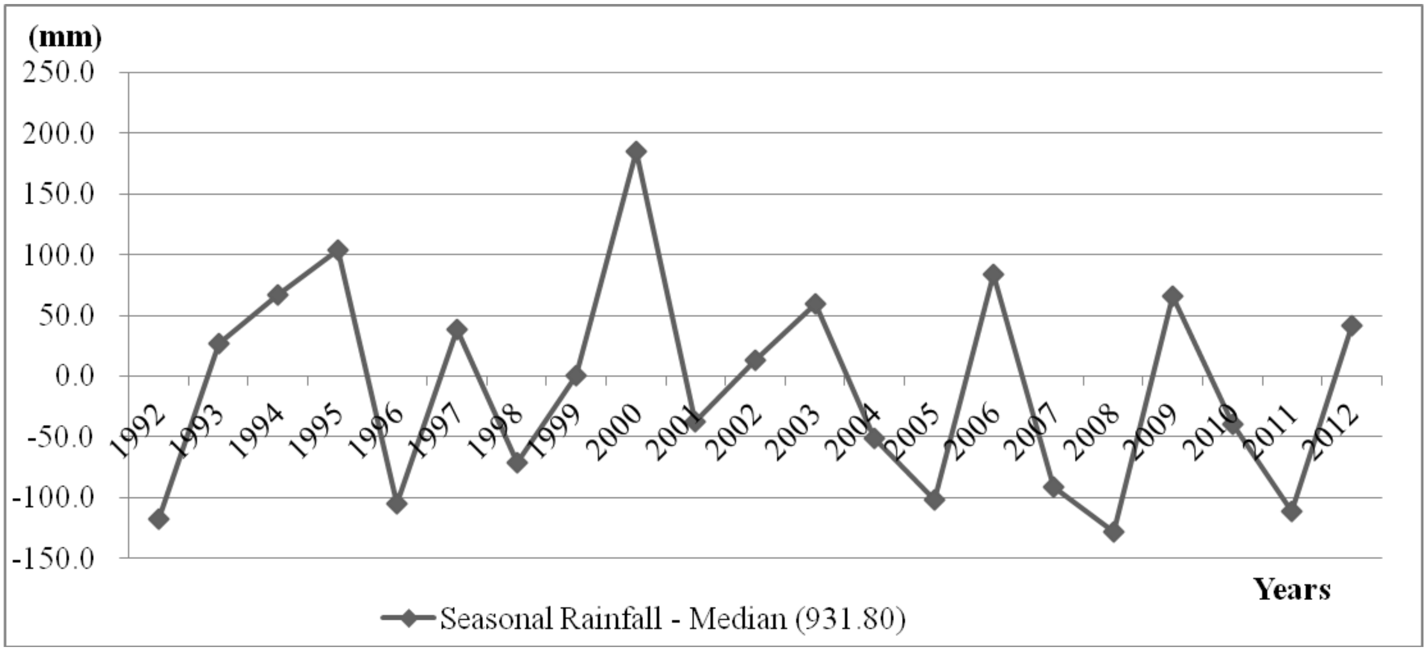


Figure 4.1 - Seasonal rainfall compared with the median (1992 - 2012). (*Source: Author*)

The seasonal rainfall ranges from 436mm to 1,583mm per year. A separate view of the average monthly rainfall totals over the 33 year period reveals that rainfall is generally highest in the month of August (see Table 4.3). Most of the seasonal rainfall occurs between July and September. This situation has the potential of causing water logging of fields. The rainfall distribution in the month of June is very erratic and could pose dangers of dry spells. Using seasonal precipitation median of 931.80mm, the results reveal a highly erratic rainfall pattern from year to year. In no particular order, ten years of below median, one year (1999) of within median and another ten years of above median precipitation is observed (see Figure 4.1).

Table 4.3 - Statistics of annual and seasonal rainfall (mm), coefficient of variation (CV) and precipitation concentration index (PCI); (1980 – 2012) (*Source: Author*)

Time/Indicator	**Annual**	**Seasonal**
Mean	1,080	914

Standard Deviation	187	175
Minimum	463	436
Maximum	1,644	1,583
CV	0.18	0.19
PCI (%)	19	11

It can be observed from Table 4.3 that rainfall variability in June is high (CV=53%). The production season starts with land preparation and crop planting activities in May and June. It can therefore be inferred that the erratic rainfall pattern in June could affect crop development at the early stages if farmers attempt to delay crop planting. Thus, it is important that farmers adjust their land preparation and crop planting dates to avoid periods of dry spell and drought in the production season. Previous findings suggest that when physically based seasonal forecasts are not available, crop management strategies and planning should be based on statistical assessment of historical rainfall records [13].

4.4.2 Annual and seasonal rainfall distribution and variability

The calculated coefficients of variation for annual and seasonal rainfall are 0.18 and 0.19, respectively (see Table 4.3).These results suggest that rainfall variability across the years and seasons is generally moderate. Nonetheless, the computed PCI annual value of 19% indicates that, on yearly basis, rainfall concentration/distribution across months is irregular. The results also suggest that monthly rainfall concentration in years of low annual rainfall volume is generally erratic. On the other hand, the PCI seasonal value of 11 suggests moderate monthly rainfall concentration. It must be stated that the period of production of the crops investigated generally coincides with the yearly rainfall season of May to October. Thus, seasonal rainfall distribution is more important than annual rainfall in respect of crop production in Lawra district.

Table 4.4 - Statistics of seasonal rainfall; 1980-2012 (*Source: Author*)

Indicator/Month	**May**	**June**	**July**	**August**	**September**	**October**
Rainfall volume (mm)						
Mean	111.10	117.95	181.25	245.10	190.97	73.79
Minimum	34.80	0.00	10.20	72.70	78.20	0.00
Maximum	204.20	257.50	380.50	369.90	396.00	763.80
CV	0.40	0.49	0.37	0.27	0.33	1.76
Rainfall (no. of days)						

Mean	8.36	9.63	12.52	15.12	14.36	5.36
Minimum	3	5	7	10	9	0
Maximum	18	14	18	23	22	17
CV	0.35	0.26	0.21	0.19	0.21	0.68

It can be observed from the results in Table 4.4 that rainfall volume and rain days tend to decrease in June which may result in dry spells. July and August are observed to have higher volumes of rainfall and this has high possibility of causing water logging of farm lands. According to previous findings on rainfall, variability and its relationship with crop production should provide the basis on which agricultural policy makers can plan for irrigation facilities to respond to the incidence of recurring droughts [12]. The findings of this study point to the need for farmers to adopt water harvesting technologies in order to deal with incidences of dry spells during the production season.

4.4.3 Relationship between rainfall and annual crop production

The results of correlation analysis show that Maize, sorghum, millet, cowpea and groundnut are negatively related with annual rainfall. However, with seasonal rainfall, sorghum, millet and groundnut show negative relationships. Only maize and cowpea show positive relationships with seasonal rainfall (see Table 4.5). Duration of seasonal rainfall is generally same for all crops and covers the period from land preparation in May-June to the crop harvesting in October-December. While the correlation coefficients for sorghum and groundnut are statistically significant, those for maize, millet and cowpea are not. These results reveal the importance of other factors (e.g. labor, fertilizer, insecticides) influencing annual crop production volumes of maize, millet and cowpea. Results of the coefficients of variation of cropped area in Table 1 appear to be closely related to total annual rainfall volumes. For instance, in 1992, cropped area of maize, groundnut and cowpea reached a lowest level at 856 ha, 187 ha and 63 ha, respectively. Similarly, the 970mm total annual rainfall volume observed that same year is the lowest recorded within the 33 years investigated. Consequently, the crop production volumes for same year (i.e. 1992) are lowest. The results also reveal that the large area of cropped land and high production volumes of crops recorded in 1995, 2000 and 2005 are directly related to the annual rainfall volumes recorded in those same years.

Table 4.5 - Correlation between crop production and annual and seasonal rainfall; 1992-2012

(*Source: Author*)

Crop/Season	**Annual**	**Seasonal**
Maize	-0.056	0.097
Sorghum	-0.046	-0.149*
Millet	-0.304	-0.130
Cowpea	-0.100	0.021
Groundnut	-0.138	-0.156*

***Significant at 0.1 level**

More specifically, the correlation between May and June rainfall is found to be strongly negative (*Correlation coefficient = -0.5*). This implies that the rainfall pattern of these months tend to move in opposite direction. Similar observation could be made from Figure 4.2. Also, as shown in Table 4.6, while annual volume of production of all the crops investigated is positively correlated with May rainfall, the relationship with June rainfall was negative. Despite the high rainfall volumes in August, all the crops except sorghum and cowpea show positive correlation. While the relationship is negative for sorghum, cowpea shows no correlation at all. Sorghum, millet and groundnut are mostly long-cycle crops planted at the beginning of the rainy season in May. Compared to other crops, sorghum [2] and groundnuts are noted to be tolerant to end of season dry spells in September. They are rather more sensitive to early dry spells in June.

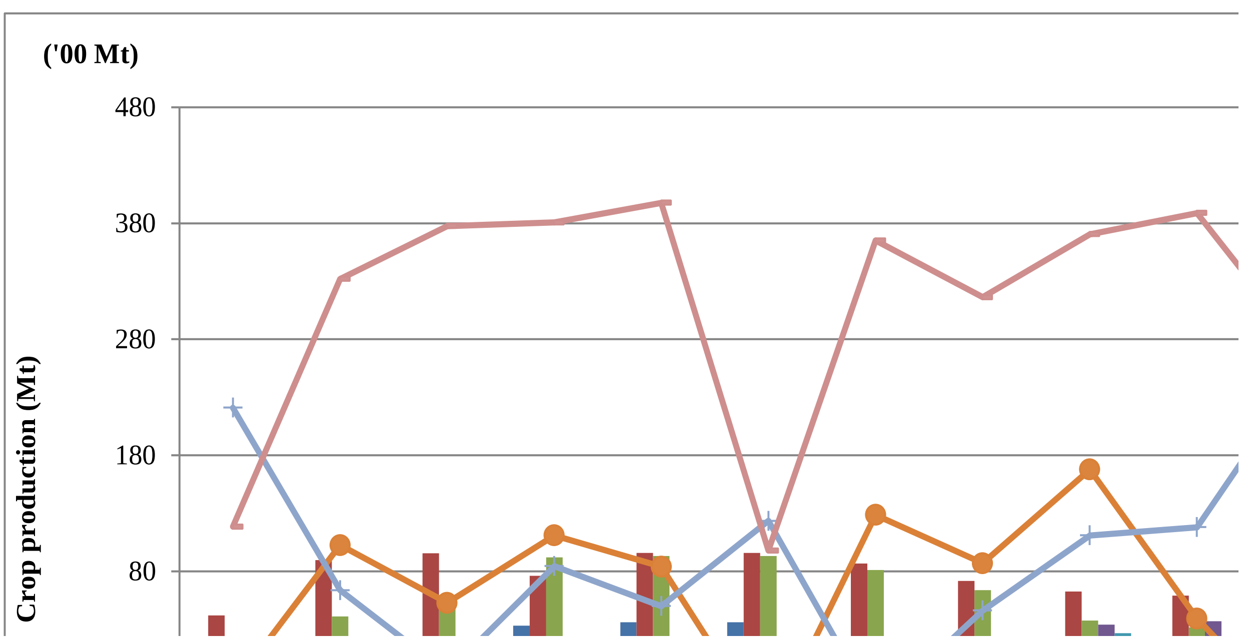


Figure 4.2 May, June and August rainfall pattern and crop production (1992-2006) (*Source: Author*)

Table 4.6 - Correlation between May, June and August rainfall (mm) and crop production (Mt); 192-2012

Crop/ Month	**Correlation coefficients**		
	May	**June**	**August**
Maize	0.47	-0.47	0.03
Sorghum	0.22	-0.09	-0.02
Millet	0.24	-0.48	0.10
Groundnut	0.15	-0.20	0.05
Cowpea	0.05	-0.17	0.00

Although the estimated correlation coefficients were not statistically significant, studies have indicated that, notwithstanding statistical significance, any form of correlation between rainfall and crop production is indicative of the fact that farmers are vulnerable [2]. Farmers therefore have to adopt the best possible mechanisms to mitigate the effects of rainfall variability. However, results of previous investigations show that some uncertainties will still arise if farmers decide to change crop production strategies in response to rainfall variability by adopting techniques such as using short duration crops [14].

4.5 Conclusion and Recommendation

The study observed a moderate inter-annual and seasonal rainfall variability over the thirty-three year period investigated. Inter-annual rainfall distribution is irregular while the seasonal rainfall is moderately distributed. Annual rainfall totals exceeded 1,200 mm and fell below 1,000 mm within every ten year period. The mean seasonal and annual rainfall was 914 mm and 1,018 mm, respectively. Seasonal rainfall variability has a direct influence on production volume of the main crops cultivated in the area. There is a negative correlation between crop production and seasonal rainfall for sorghum, millet and groundnut. The correlation for maize and cowpea was observed to be positive. The inter-annual variability of production volume of the crops investigated is high, largely as a result of the irregular/erratic inter-annual rainfall distribution. Sorghum and millet exhibited the highest variability because their cultivation period is of longer duration (June to December). Within this period, rainfall variability is high.

The findings of this study show that under any given agricultural production year, two types of rainfall situations may occur in Lawra district; (1) less than median rainfall, (2) more than median rainfall. As shown in Table 3, lower rainfall volumes may occur in June (CV=53%) as a result of lower number of rain days. On the other hand, higher rainfall volumes may also occur in August due to high volumes of rainfall. As such, the study recommends effective collaboration of stakeholders to identify, develop and implement appropriate adaptation practices to minimize the effects of rainfall variability on crop production. Figure 4.3 show the different effects of rainfall variability, adaptation practices and stakeholders in agricultural production and climate change adaptation. Adaptation practices identified in previous studies include crop diversification, change in crop, change in planting date and planting short duration crops, improved soil tillage practices, soil fertility improvement and mixed cropping [15, 16].

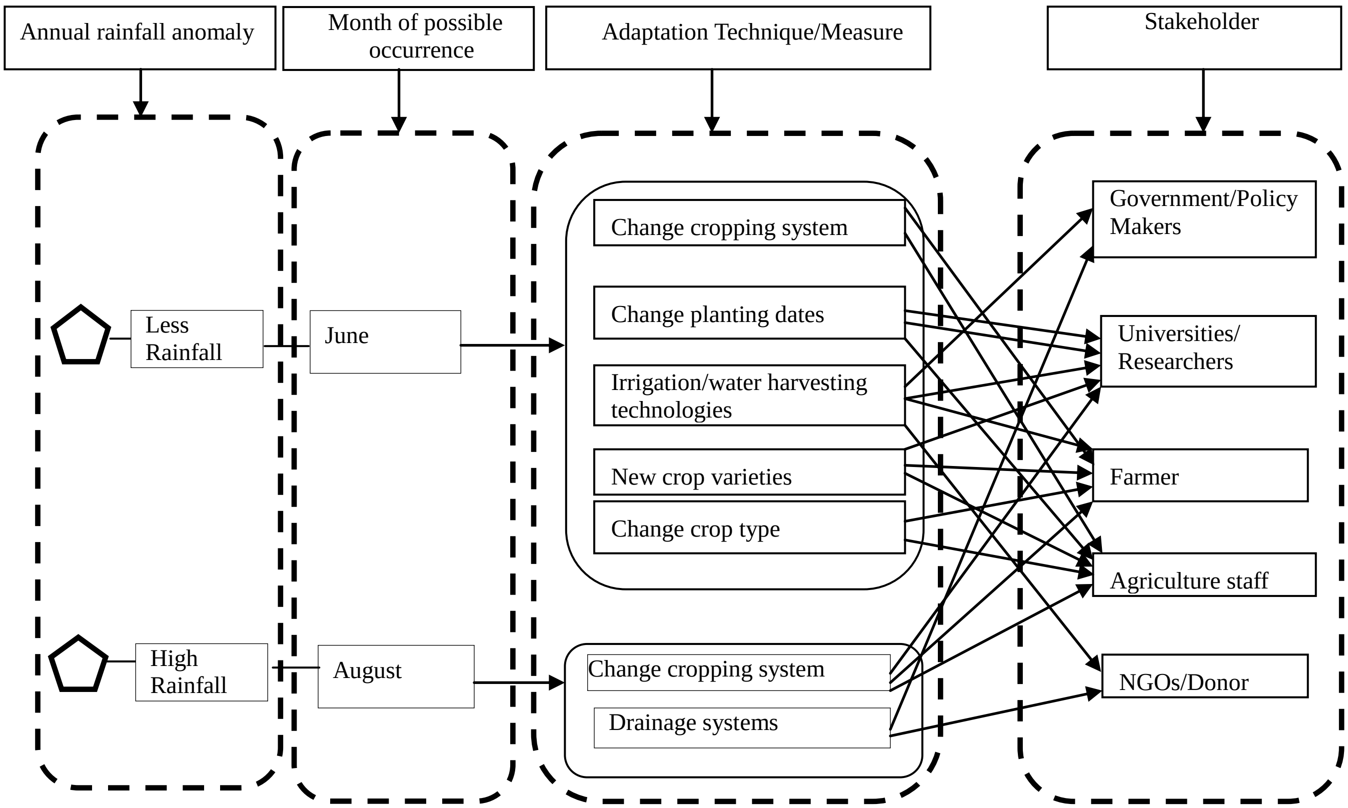


Figure 4.3 Representation of rainfall anomalies, adaptation measures and stakeholder responsibility.

More specifically, drought or dry spell periods require farmers to implement measures such as altering cropping system (e.g. mix cropping), planting dates, crop varieties (drought-resistant species) or change crop type. Based on farmers' level of awareness and access to irrigation and water harvesting facilities, they could water crops during periods of less rain. As a long term measure, government, policy makers and NGOs should develop irrigation facilities and water harvesting technologies. While research institutions and universities should develop drought-resistant and early maturing crop varieties, agriculture staff on the other hand should educate farmers on improved and modern technologies and practices. In the case of floods, medium-to-long term measures are required. Government and policy makers should design and implement effective drainage systems. Farmers on the other hand should shift their crop production activities to less flood-prone arable lands.

The findings clearly indicate the need for effective adaptation to climate change. However, since adaptation practices in agriculture are generally location-specific, it is important to adequately understand the risk faced by farmers so as to develop tailor-made adaptation options to mitigate the risks. Knowledge about climate change risk and impacts is also relevant in producing appropriate content for climate change risk communication. In view of the above, a further investigation on farmers' climate change risk perceptions is crucial.

References:

1. Ndamani, F. Analysis of Market Strategies of Farmers in the Upper West Region of Ghana: A Spatial Equilibrium Approach. *J. Dev. Sustain. Agric*. **2008**, 3:104-116.
2. Bewket, W. Rainfall variability and crop production in Ethiopia: Case study in the Amhara Region. Proceedings of the 16th International Conference of Ethiopian Studies.(ed) **2009**. Svein Ege, Harald Aspen, Birhanu Teferra, Shiferaw Bekele, Trondheim SV (eds). 2:827-836
3. Befekadu, D.; Berhanu, N. Annual report on the Ethiopian economy. Ethiopian Economic Association, Addis Ababa.(eds.) **2000**, 1: 1999/2000
4. Stern, R.D.; Dennet, M.D.; Garbutt, D.J. The start of the rains in West Africa. Journal of Climatology 1981, 1:59-68.
5. Wood, A. A preliminary chronology of Ethiopian droughts. In Drought in Africa. Dalby D, Church RJH, Bezz, **1977**
6. Pankhurst, R.; Johnson, D.H. The great drought and famine of 1888-92 in northeast Africa. In The ecology of survival: case studies from northeast African history. **1988**, 47-72. Johnson DH, Anderson DM (eds.). Lester Crook Academic Publishing, London.
7. Von Braun, J. A policy agenda for famine prevention in Africa. Food Policy Statement No.13, **1991**. IFPRI, Washington DC.
8. Oliver, J.E. Monthly precipitation distribution: a comparative index. *Professional Geographer* **1980**, 32: 300-309.
9. Michiels, P.; Gabriels, D.; Hartmann, R. Using the seasonal and temporal precipitation concentration index for characterizing monthly rainfall distribution in Spain. *Catena* **1992** 19:43–58,
10. Kori, E.; Gondo, T.; Madilonga, R.. The Influence of Rainfall Variability on Arable Land Use at Local Level: Realities from Nzhelele Valley, South Africa. Proceedings of the 2012th International Conference on Future Environment and Energy. IPCBEE **2012**, 28 © IACSIT Press, Singapoore
11. Woldeamlak, Bewket. Rainfall variability andcrop production in Ethiopia Case study in the Amhara region. Proceedings of the 16th International Conference of Ethiopian Studies. (ed). **2009**. Svein Ege, Harald Aspen, Birhanu Teferra and Shiferaw Bekele, Trondheim 2009.
12. Rugumayo, A.I.; Kiiza, N.; Shima, J. Rainfall reliability for crop production a case study in Uganda. Diffuse Pollution Conference Dublin. **2003**, 3:143-148.
13. Ravindran, C.D. Use of Rainfall Analysis in the Planning and Management of Rainfed Cotton. CICR

Technical Bulletin No: 15. **2013** (www.cicr.org.in)

14. Bezabih, M.; Di Falco, S.; Yesuf, M. Framers' response to rainfall variability and crop portfolio choice; Evidence from Ethiopia. *Environment for Development*. DP **2011**, 11-10.
15. Fosu-Mensah, B.Y.; Vlek, P.L.G.; MacCarthy, D.S. Farmers' perceptions and adaptation to climate change: a case study of Sekyeredumase district in Ghana. *Environment, Development and Sustainability* **2012**, 14:495-505. 2009.DOI: 10.1007/s10668-012-9339-7.
16. Mary, A.L.; Majule, A.E. Impacts of climate change, variability and adaptation strategies on agriculture in semi arid of Tanzania: The case of Manyoni District In Singida Region, Tanzania. *Afr. J. Environ. Sci. Technol.* **2009**, 3(8):206-218.

CHAPTER 5: ASSESSMENT OF CLIMATE CHANGE RISKS IN AGRICULTURE: RISK PERCEPTIONS AND DETERMINANTS

5.1 Introduction

In this chapter, farmers' perceptions about climate risk phenomena and impacts are outlined and discussed. Also, based on annual average income, farmers are classified into three wealth categories (i.e., resource-poor, resource-moderate and resource-rich farmers). Subsequently, the levels of perceptions about climate change risk of each category of farmers are identified and discussed. This is done in order to determine how different farmers perceive climate change risks. Finally, the determinants of climate risk perception are evaluated and discussed based on demographic characteristics, climatic variables, biodiversity and forestry factors, agricultural production related variables, health and socio-economic and psychological factors.

5.2 Literature review

5.2.1 Risk analysis in climate change adaptation

The agriculture sector is highly sensitive to climate change. In Africa for instance, studies have shown that climate change embodies a significant threat to current production systems, infrastructures, and markets, and therefore farmers' livelihoods [1]. Furthermore, in semi-arid Africa where many people subsist on rain-fed agriculture with limited access to safety nets, climate change can exacerbate food shortage and low income conditions of the already visibly poor in society. In Ghana, studies have shown that climate change effects (e.g. rainfall variability) have led to decrease in volume of annual production of staple crops [2]. The recognition that climate change related threats to agriculture also represent threats to quality of life on a global scale has led to an increasing amount of attention to adaptation and mitigation strategies for agriculture [3, 4]

Adaptations are adjustments or interventions, which take place in order to manage the losses or take advantage of the opportunities presented by changing climate. Adaptation practices are pre-emptive in nature and are meant to lessen adverse effects and take advantage of potential benefits of an envisaged change in climatic variables. Several studies have reported various adaptation practices in agriculture [5, 6]. Notwithstanding the significant efforts that have been made in the development and dissemination of climate change adaptation options, these measures have not been utilized adequately and not integrated effectively into the agricultural development. Studies in Ghana have shown that though majority of farmers are aware of climate change, a significant number of them still do not use adaptation practices [5, 7]. This is largely due to the fact that the proposed adaptation processes have failed to adequately addressed farmers' awareness, perceptions and concerns of climate-risks.

Previous studies on agricultural conservation practice adoption have reported positive correlation between awareness of environmental problems, attitudes toward potential solutions, and willingness to adopt those solutions [8]. Furthermore, it is when situations come to be perceived as problems that attitudes regarding potential ameliorative actions are more predictive of behavior change [9]. Farmer concerns about the impacts of climate change are key to successful adaptation and mitigation [3]. Farmers' willingness to implement adaptation and mitigation policies supported by public authorities and governments also depend upon their beliefs regarding climate change and their perceptions of climate change related risks [10].

Literature has shown that appropriate risk perception can be seen as a prerequisite for choosing an effective risk-coping strategy, because a farmer that is not aware of the risks faced is clearly unable to manage them effectively [11]. Knowledge on the factors that influence farmers' perceptions of climate change related risks is critical in developing and promoting appropriate adaptation practices in agriculture thereby boosting the tempo of adaptation among farmers. This notwithstanding, climate risks perception in agriculture has not been adequately investigated in Ghana. This study therefore identified various climate-risk phenomena and explored the degree of risks perceptions among different categories of farmers in Lawra district of Ghana. The factors that influence farmers' risk perception are investigated. This study is essential for creating policy instruments to boost farmers' climate risk concern, and for the development of training programmes tailored to meet the adaptation needs of farmers.

5.2.2 The concept of risk and climate risk assessment

Risk has been defined as the result of physically distinct hazards interacting with exposed systems – taking into consideration the properties of the systems, such as their sensitivity or social vulnerability. Risk also has been described as the combination of an event, its likelihood and its consequences [12]. The perceptive approach considers risk as a set of all destructive consequences that are believed to be possible by a person who has evidence about the frequency, severity, and variability of the effects [13]. An effective climate change risk analysis in agriculture is fundamental to developing viable adaptation options to manage future anticipated risks. Literature has shown that the two important steps in climate change risk analysis include identification and assessment of current climate variability and future climate change risks and associated societal vulnerabilities [12]. These two steps form the basis for successful implementation of adaptation practices. Researchers are getting increasingly interested in risk perception largely due to the fact that findings of scientific risk assessment are sometimes at variance with the inherent way people perceive risk [14]. Previous findings have revealed that if farmers do not believe in the occurrence of climate change and/or do not perceive it to be a threat to their livelihoods, they will not likely act to adapt to or mitigate climate change [3]

5.2.3 Climate change risk perceptions and concerns among farmers

A growing body of literature exists on farmers' beliefs about the existence of climate change, their concerns, the relationship between climate change beliefs and risk perceptions, and their relationship with farmers' willingness to adapt or to support adaptation policies. Literature on adaptation to natural hazards finds that behavioral responses to hazards depend in large part on risk perception, or "beliefs about the existence and characteristics of a natural hazard" [15]. As such, behavior change is influenced by perceptions of the risks associated with a given natural hazard, which are mediated by beliefs about (1) the existence of the hazard and (2) its characteristics [16]. Studies have revealed that farmer concerns about the impacts of climate change are essential to successful adaptation and mitigation [3]. As such, appropriate risk perception can be seen as a prerequisite for choosing an effective risk-coping strategy, because a farmer that is not aware of the risks faced is clearly unable to manage them effectively [17]. Findings of studies conducted in the United States reveal that while perceptions of climate risk are central to farmer attitudes toward adaptation, concern about the potential negative impacts of climate change is an important predictor of both support for additional protective action and investment in agricultural drainage to adapt to increases in precipitation [10]. In this study, farmers are categorized into different wealth groups and their perceptions are identified and assessed.

5.2.4 Factors influencing farmers' risk perceptions

The proper perception of risk factors is the first step towards creating an effective risk management system. Literature shows that knowledge on farmers' perception of risk is essential for creating policy instruments to support agricultural risk management, and for the development of training programmes tailored to the needs of farmers [17]. Previous research studies focusing on factors determining differences in the level of risk perception have shown that farmers' perceptions are largely determined by socio-economic features of the farmers and the characteristics of their farms [18]. Previous findings have also suggested that since farmers from various countries live within different climatic and institutional conditions, differences in risk perception can be a result of either different probabilities of certain risk factors, or different farmers' mentality and awareness, or a mixture of both. [17]. Other climate risk perception predictors identified in previous studies include drought [19], yield risk and price risk for agricultural products [20, 21, 22, 23] and weather and natural disasters [23].

It must be noted that, in the conversional approach to assessing factors influencing climate risk perception in agriculture, most investigations have used mainly demographic factors (e.g., age, education, gender, household size, farming experience and income) and climatic variables (i.e., precipitation and temperature). It appears no study as yet, has applied variables pertaining to probability of perceived risk impacts on agricultural production, biodiversity and forestry, psychological, and health and socio-economy. This study therefore conducts a combined regression of the aforementioned risk impacts variables together with the psychological and demographic factors.

5.3 Materials and methods

5.3.1 Survey design and data collection

A representative sample size of 100 farmers was randomly selected. Data is collected through the use of semi-structured questionnaires and focus group discussion. For the majority of illiterate farmers, questions are translated into their local language and the responses recorded. The questions are focused on factors and variables related to agricultural activities, climate change and climate-risk perceptions and demographic features. Based on literature, two main approaches have been used to assess determinants of farmers' climate risks perceptions. The first approach is qualitative, where a Likert scale type questions or risk assessment scales are used to elicit responses from respondents [10]. The second approach uses quantitative scales where respondents are asked to indicate how climate change will affect the mean and variability of their yields [24]. This study applies the former approach because it is most ideal method to elicit respondents concerns and views on an issue based on a range of options. In the first stage of data collection, farmers are asked to respond one broad question: (1) have you perceived any form of risks on your agricultural activities due to climate change? (2) In the second stage, respondents are asked to score their level of climate risk perception based on a 1-4 Likert scale *(i.e., 'highly perceived', 'moderately perceived' and 'less perceived' and 'not sure')* (Table 5.1). Subsequently, the degree of risk perception among different categories of farmers *(i.e., resource-poor farmers, resource-moderate farmers and resource-rich farmers)* was estimated by developing a climate risk perception index (CRPI). Respondents are asked to score their level of climate risk perception based on a 1-4 Likert scale *(i.e., 'highly perceived', 'moderately perceived' and 'less perceived' and 'not sure')*. Climate risk perception index (CRPI) is estimated as follows:

$$\text{CPRI} = R_h \times 4 + R_{\text{m}} \times 3 + R_l \times 2 + R_n \times 1 \qquad (5.1)$$

R_h = frequency of respondents who graded highly perceived risk; R_m = frequency of respondents who graded moderately perceived risk; R_l = frequency of respondents who graded less perceived risk; R_n = frequency of respondents who graded not sure.

Table 5.1 – Description of variables and measurements used in data collection (*Source: Author*)

Variables		Measurement
Demographic	Age	1=15-34; 2=35-54; 3=above 54
	Gender	1=Female; 0=Male
	Education	1=Educated; 0=Illiterate
	Marital status	1=Married; 0=Single
	Average annual farm income	1= < 1,300; 2= 1,300 - 30,000 Gh Cedi 3=More than 30,000
Climate change risk perception	Risk perception	1=yes; 0=no
	Degree of risk perception	4=highly perceived; 3=moderately perceived; 2=less perceived; 1= not sure
Climatic variables	Perceived probability of droughts, floods and dry spell	
	Perceived probability of increased temperature	
	Perceived probability of worsening harmattan conditions	
Health and socio-economic	Perceived severity of consequences on human diseases and mortality	
	Perceived severity of consequences on migration	
	Perceived severity consequences on food security and incomes	
Biodiversity and forestry	Perceived probability of reduction in plant and forest species	4=high; 3=moderate; 2=Low; 1= not at all
	Perceived probability of reduction in birds and animal species	
	Perceived probability of decrease in forest area	
Agricultural production	Perceived probability of decreased crop yield	
	Perceived probability of decreased in cropping area	
	Perceived probability of increase in pests and diseases	
	Perceived probability of increase in cost of production	
	Perceived probability of decrease in soil fertility	
Psychological	Perceived ability to control risk	

The criterion for categorization of farmers into different wealth groups is developed based on discussions with farmers and agricultural officers. Findings of the discussions showed that farmers with annual average household income of less than one thousand three hundred Ghana cedi (i.e., GHC 1,300 = US Dollar 342) are generally considered as resource-poor farmers. Also, farmers whose annual average household income range between one thousand three and thirty thousand Ghana cedi (i.e., GHC 1,300 – 30,000) are classified as resource-moderate farmers. The resource-rich farmers are claimed to have annual average household income of more than thirty thousand Ghana cedi. In addition to the conversional approach to climate change risk perception analysis, this study asked farmers to score their level of risk perception with respect to four categories of climate change risk impacts. These are, agricultural production, biodiversity and forestry, health, socio-economy and climatic variables (Table 5.1). These factors are obtained from farmers, agricultural staff and literature [25].

5.3.2 Empirical approach of determinants of climate risk perception

The multiple regression analysis is used to evaluate the factors that influence farmers' climate change risk perceptions. Climate change risk perception is the dependent dummy variable in this study. To determine the dummy, a value of '1' was assigned to a farmer who has perceived any form of climate related risks and '0' if he has not perceived any risks. Farmers' climate change risk perceptions are influenced by a number of factors. Most quantitative analyses use the mono-disciplinary approach and therefore any mechanisms that affect agricultural productivity other than direct climate change effects are disregarded. However, this study uses a different approach that includes indirect effects. In this study, the independent variables for climate change risk perception are classified into five categories: demographic factors (age, gender, education and farming experience), perceived impacts on agriculture production (e.g. crop yield, cropping area, cost of production, etc.), perceived impacts on biodiversity and forestry (e.g., plant and tree species, bird and animal species, forest area, etc.), perceived impacts on health and socio-economy (household incomes, food security, migration, mortality and human disease), perceived impacts on climate variables (i.e. drought, flood, dry spell, harmattan winds) and perceived psychological impacts (e.g., ability to control risk). Respondents are asked to score their responses with respect to each of the variables using a four-point scale *(i.e., 'high', 'moderate', 'low' and 'not at all')*. Prior to running the multiple regression model, the mean scores and correlations of the independent variables were calculated to assess their relation with the dependent variable (e.g., risk perception) and with each other (Tables 5.2 & 5.3)

***Definition of climate change risk perception*:** This study defines climate change risk perception as the concerns or anxieties demonstrated by farmers about past, current and future occurrence of negative impacts on climatic variables, agricultural production, biodiversity and forestry and health and socio-economy due to climate change.

Table 5.2 – Correlations of climate change risk perception variables in Lawra district of Ghana (*Source: Author*)

Variables	Climatic impact			Health and socio-economy			Biodiversity and forestry impact			Agricultural production impact					Psychological
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Perceived probability of droughts, floods and dry spell	1.00														
Perceived probability of increased temperature	0.178	1.00													
Perceived probability of worsening harmattan conditions	.473**	0.074	1.00												
Perceived severity of consequences on human diseases and mortality	0.065	0.049	-0.138	1.00											
Perceived severity of consequences on migration	.257**	.250*	0.037	.316**	1.00										
Perceived severity consequences on food security and incomes	.576**	0.135	0.049	.220*	.659**	1.00									
Perceived probability of reduction in plant and forest species	0.176	.265**	0.048	.472**	.389**	0.142	1.00								
Perceived probability of reduction in birds and animal species	0.179	.230*	0.055	.372**	.364**	.229*	.838**	1.00							
Perceived probability of decrease in forest area	0.179	.292**	.477**	.365**	.422**	.261**	.573**	.398**	1.00						
Perceived probability of decreased crop yield	.358**	0.158	.351**	0.132	.413**	.322**	0.104	.260**	.426**	1.00					
Perceived probability of decreased in cropping area	0.154	0.014	.365**	.397**	0.19	0.017	0.122	0.114	.414**	.219*	1.00				
Perceived probability of increase in pests and diseases	0.045	.201*	0.142	.537**	0.106	0.137	.229*	.273**	.240*	.355**	.556**	1.00			
Perceived probability of increase in cost of production	.376**	0.074	.344**	0.108	.392**	.338**	0.079	0.117	.270**	.266**	.228*	0.129	1.00		
Perceived probability of decrease in soil fertility	0.02	0.116	0.076	.529**	.197*	.206*	.273**	0.152	.314**	0.1	.431**	.720**	0.041	1.00	
Perceived ability to control risk	0.097	.250*	0.138	.484**	.383**	0.034	.358**	.498**	.365**	.349**	.695**	.501**	0.05	.393**	1.00

Table 5.3 – Descriptive statistics of predictors and mean score of climate change risk perception. (*Source: Author*)

Elements	Variables	Mean	SD	Correlation with CRP
Climate risk perception (CRP)		0.93	0.26	1
Factors related to climatic variables	Perceived probability of droughts, floods and dry spell	2.87	0.34	0.106
	Perceived probability of increased temperature	2.74	0.44	0.163
	Perceived probability of worsening harmattan conditions.	2.60	0.49	0.336
Health and socio-economic factors	Perceived severity of consequences on human diseases and mortality.	2.15	0.89	0.263
	Perceived severity of consequences on migration.	2.13	0.75	-0.074
	Perceived severity consequences on food security and incomes.	2.46	0.67	0.221
Biodiversity and forestry factors	Perceived probability of reduction in plant and forest species.	2.25	0.61	0.273
	Perceived probability of reduction in birds and animal species.	2.15	0.86	0.269
	Perceived probability of decrease in forest area.	2.29	0.67	0.119
Factors related to agricultural production	Perceived probability of decreased crop yield	2.58	0.71	0.162
	Perceived probability of decreased in cropping area	1.68	1.14	0.408
	Perceived probability of increase in pests and diseases	2.12	1.04	0.234
	Perceived probability of increase in cost of production	2.22	0.71	0.086
	Perceived probability of decrease in soil fertility	2.35	0.81	0.222
Psychological factors	Perceived ability to control risk	1.64	1.13	0.156

5.4 Findings and discussion

5.4.1. General demographic characteristics of respondents

The results of respondents' demographic features are presented in Table 5.4. Majority of farmers interviewed are above thirty-five years (i.e., resource-poor=76.4%; resource-moderate=90.9% and resource-rich=81.8%). Similarly, most of the respondents have more than eleven years of farming experience (i.e., resource-poor =76.5%; resource-moderate =78.6% and resource-rich =81.8%.). In all the wealth categories of farmers, male respondents are dominant (i.e., 82.4%, 75.8% and 87.9%, respectively). The findings also showed that illiteracy rate is very high among farmers in Lawra district irrespective of wealth status (ie., 85.3%, 63.6% and 87.9%, respectively).

Table 5.4 – Demographic features of respondents in Lawra district (N=100) (*Source: Author*)

Features		Resource-poor farmers (N=34)		Resource-moderate farmers (N=33)		Resource-rich farmers (N=33)		Test statistic
		n	%	n	%	n	%	
Age distribution	15-34	8	23.5	3	9.1	6	18.2	X^2=4.826
	35-54	13	38.2	17	51.5	10	30.3	
	55 and above	13	38.2	13	39.4	17	51.5	
Marital status	Married	31	91.2	33	100.0	27	81.8	X^2=6.662
	Single	3	8.8	0	0.0	6	18.2	
Gender distribution	Male	28	82.4	25	75.8	29	87.9	X^2=1.647
	Female	6	17.6	8	24.2	4	12.1	
Education level	Illiterate	29	85.3	21	63.6	29	87.9	X^2=7.075
	Literate	5	14.7	12	36.4	4	12.1	
Farming experience	Less than 10 years	8	23.5	3	9.1	7	21.2	X^2=5.702
	11-25 years	11	32.4	16	48.5	8	24.2	
	More than 25 years	15	44.1	14	42.4	18	54.5	
Annual average income	Ghana Cedi (GHC)	<1,300		1,300 to 30,000		>30,000		
	US Dollar (USD)	<342		342 to 4,300		>4,300		

5.4.2 Farmers' climate change risk perceptions

The results of farmers' climate change risk perceptions show that 93% of respondents have perceived risk while 7% are not sure if they have perceived. While 66% of the respondents have highly perceived climate change risk, 4% has less perceived. Also, 23% of farmers have moderately perceived climate change risk in their farming activities (Figure 5.1).

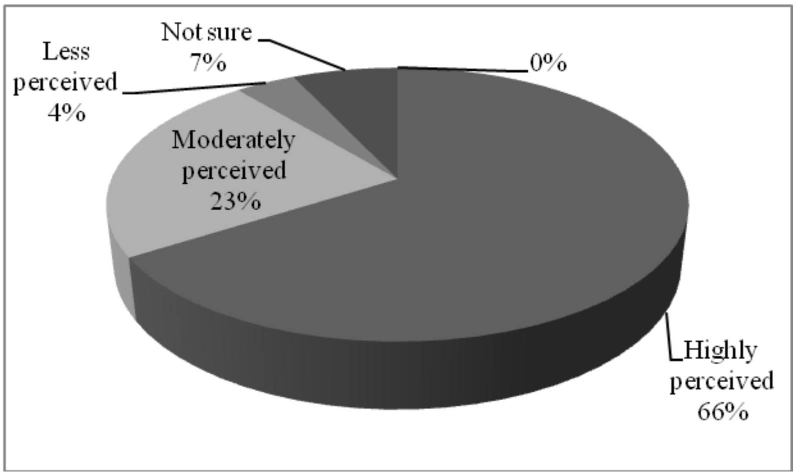


Figure 5.1 – Levels of climate change risk perceptions of farmers in Lawra district (*Source: Author*)

Results obtained from the focus group discussions showed that farmers have perceived decreasing precipitation, rising temperatures and rainfall variability. Respondents claim that the aforementioned incidences of climate change effects have culminated in low crop production. The obtained results are in line with previous findings that a significant number of farmers believed that temperature had already increased and precipitation had declined for eleven African countries [26]. The results of focus group discussion also showed that there was increase in out-migration for greener pastures in Southern Ghana due to increasing climate change risks on agriculture which is their main source of livelihood. Similar results were obtained in India where migration and poverty were identified as perceived farmers' climate change risks [25]. Other climate change risks perceived by farmers include increase in human diseases (e.g. fever), decrease in cropping area, worsening harmattan winds, increase in cost of production, decrease in food security and incomes, decrease in forest area (i.e. due to deforestation), reduction in plant, tree, birds and animal species and decrease in soil fertility

The results in Table 5.5 show that farmers in different wealth categories have different levels of climate change risk perceptions. Generally, 91% of resource-poor farmers have perceived risk highly, while 58% and 48% of resource-moderate and resource-rich farmers have highly perceived risk, respectively. In addition, 9% of resource-poor farmers perceive moderate risk while 27% and 30% of resource-moderate and resource-resource farmers perceive moderate risk respectively. Also intriguing is that 2% of resource-moderate and 5% of resource-rich farmers are not sure if they have perceived climate change risks or not. This finding is likely the case because results of the FGDs showed that moderate and rich-resource farmers have alternative sources of income (e.g. trading, artisan jobs, etc.) as such some of them were unlikely to pay attention to climate change risk impacts. Since rain-fed agriculture is the main source of livelihood of resource-poor farmers they are more likely to observe and feel the impacts of extreme climate change events. Findings of similar studies have also show that poor farmers are more concerned about climate change risks [27].

Table 5.5 – Level of climate change risk among different farmer wealth groups in Lawra district (N=100) (*Source: Author*)

Variables	Farmers' wealth groups		
	Resource poor farmers	**Resource moderate farmers**	**Resource rich farmers**
Highly perceived	91	58	48
Moderately perceived	9	27	30
Less perceived	0	13	17
Not sure	0	2	5
Total	100	100	100
X^2		14.611	

5.4.3 Farmers' perceived climate change risk impacts and phenomena

The findings show that farmers in Lawra district generally perceived climate change risk impacts in terms of agricultural production, biodiversity and forestry, health and socio-economy and climatic variables (Table 5.6). The results show that farmers have inherent concerns and apprehensions about the occurrence and consequences of climate change. Results of the FDGs reveal that perceived occurrence of drought, dry spell, floods, rising temperatures and worsening harmattan winds are risks impacts on climatic variables. Perceived increase in human diseases, mortality, migration and decrease in food security and incomes were classified under the health and socio-economic risk impact domain.

Table 5.6 - Climate change risk impacts and phenomena (*Source: Author*)

Climate change risk impacts	Climate risk phenomena
Agricultural production	Low crop yield, increase in crop diseases, increase in crop pests and insects, decrease in cropping area, increase in production cost reduction in water quality, hardening of seed bed and reduction in soil fertility.
Biodiversity and forestry	Reduction in plant and forest species, reduction in birds and animal species decrease in forest area, extinction of certain plant and forest species and extinction of certain bird and animal species
Health, socio-economy and culture	Increase in disease infection, increase in mortality, increase in poverty, reduction in household incomes, increase in migration, increase or decrease belief in God and widening of gap between rich and poor.
Climatic variables	Increase in drought, increase in dry spell, increase in floods, worsening of

harmattan conditions and rainfall variability, rising temperature

The respondents identified decreasing crop yield, cropping area, soil fertility, and increasing pests and diseases and cost of production as risk impacts on agricultural production. In addition, decreasing forest area, and reduction in plant, trees, birds and animal species are classified under biodiversity and forestry risk impacts. Previous studies have also identified similar risk phenomena perceived by farmers [19, 20, 21, 22, 23].

The results of climate change risk impacts perceived by different wealth categories of farmers are presented in Table 5.7. The findings show that resource-poor farmers are much concerned about climate change risk impacts on agricultural production (i.e., CRPI=130), while resource-moderate and resource-rich farmers are concerned about risks on climatic variables (i.e., CRPI=129) and health and socio-economy (i.e., CRPI=132), respectively. For resource-poor farmers, climate change risks impacts on climatic variables, biodiversity and forestry, and health and socio economy are ranked second, third and fourth respectively (i.e., CRPI=124, 115 and 111). In the case of resource-moderate farmers, risk impacts on agricultural production, health and socio-economy and biodiversity and forestry are ranked second, third and fourth, respectively. (i.e., CRPI=123, 107, 101). Regarding resource-rich, farmers perceived climate change risk impacts on climatic variables was ranked second (i.e., CRPI=120) while impacts on biodiversity and forestry (i.e., CRPI=113) and agricultural production (i.e., CRPI=99) are ranked third and fourth, respectively. The findings obtained from the FGDs confirmed the results of analysis. Resource-moderate and rich farmers are more able to meet the financial demands of adaptation to climate change and are therefore unlikely to perceive the full impacts on climate change risks on the farming activities.

Table 5.7– Risk perception on impact variables by different category of farmers in Lawra district (N=100) (*Source: Author*)

Variables	**Climate change risk perception index (CRPI)**		
	Resource-poor farmers	**Resource-moderate farmers**	**Resource-rich farmers**
Agricultural production	$130_{(1)}$	$123_{(2)}$	$99_{(4)}$
Biodiversity and forestry	$115_{(3)}$	$101_{(4)}$	$113_{(3)}$
Health, socio-economy and culture	$111_{(4)}$	$107_{(3)}$	$132_{(1)}$
Climatic variables	$124_{(2)}$	$129_{(1)}$	$120_{(2)}$
Chi-Square	21.852	24.953	25.704
DF	3	3	3
Pr > Chi-square	0.036	0.002	0.001

5.4 Determinants of climate change risk perception

Results of the regression model of determinants of climate change risk perception are presented in Table 5.8. Two demographic variables are significant predictors of climate change risk perception. The positive coefficient for Age indicates that older farmers are more concerned about climate change risk on agriculture than their younger counterparts. Also, the findings show that education is positive and significantly related to farmers' perceptions about climate change risk. This implies that educated farmers are more likely to be concerned about climate change risk because they are more knowledgeable due to their ability to access global, regional and country-level information and discussions about the risks and impacts of climate change. Gender, income and marital status are not predictors of climate change risk perception in agriculture. The results are consistent with findings of farmers' climate change risk perceptions in Mexico and India that showed that age, farming experience and education were significant determinants of risk perception [27, 28].

The perceived probability of increased droughts, dry spell and floods is also a significant predictor of farmers' climate change risk perceptions. Similarly, perceived likelihood of increasing temperatures and worsening harmattan winds are supported by the analytical results as significant determinants of climate change risk perception. These findings are in line with results obtained from the focus group discussions. Farmers claim that they have apprehensions and concern about abnormal variability in precipitation and temperatures trends because these factors constitute the most immediate and noticeable effects of climate change.

In the case of variables relating to risk impacts on agricultural production, perceived probability of increased in pests and disease is found to be a significant determinant of climate risk perception. This result is consistent with previous findings in Mexico which showed that farmers' experience with coffee pests is a significant predictor of climate risk perception [28]. In addition, perceived probability of decrease in crop yield, cropping area, soil fertility and increase in cost of production are all found to be predictors of farmers' climate risk perception. Results of the FGDs confirmed that farmers have perceived a decrease in crop yields and soil fertility and are concerned about the severity of future consequences of climate risk on their farm activities.

The variables pertaining to climate risk impacts on biodiversity and forestry (i.e., Perceived probability of decrease in forest area, reduction in birds and animal species and reduction in plant and forest species) were all found to be predictors of farmers' risk perceptions, but not statistically significant. These results are likely the case taking cognizance of the level of deforestation and desertification in the district. Further probe during the FGDs show that farmers relied on deforestation as alternative income source (e.g., from firewood or charcoal) since recurrent droughts and dry spell constantly cause a low crop yields. Also, the farmers claimed they are worried and concerned about a decrease in plant species and migration of certain birds and animal species due to adverse climatic effects.

With regards to health and socio-economic factors, perceived severity of consequences on human diseases and mortality, and on food security and incomes are significant predictors of farmers' climate risk perception. Perceived severity of increased migration is found not to be a predictor of risk perceptions in Lawra district. These results are quite intriguing considering the level of out-migration occurring in the district. Further probe during the FGDs show that farmers believed out-migration for greener pasture in urban towns was purely for brighter economic opportunities rather than a climate change.

Under psychological factors, farmers' perceived probability to control risk was found not to be a predictor of climate risk perception. This finding is consistent with results obtained from the FGDs. Farmers' concerns and apprehensions climate change effects turn to decrease with increased ability and skills to control or adapt to the risk. Similar findings that the long experience accumulated for generations by winegrowers in fighting powdery mildew under varying weather conditions provides a sense of confidence (controllability and manageability) that managerial skills, tend to reduce risk perceptions [29].

Table 5.8 Estimated results of determinants of climate risk perception of farmers in Lawra district (N=100) (*Source: Author*)

Variables		**B**	**SE B**	**β**	**VIF**
Demographic features	Age distribution	0.086	0.155	0.388**	1.708
	Gender distribution	-0.022	0.207	-0.054	5.094
	Marital status	-0.042	0.187	-0.220	2.306
	Education level	0.072	0.205	0.015**	4.294
	Income	1.221	0.084	0.458**	5.442
Factors related to climatic variables	Perceived probability of droughts, floods and dry spell	0.015	0.217	0.185**	0.024
	Perceived probability of increased temperature	0.096	0.112	0.113*	0.255
	Perceived probability of worsening harmattan conditions	0.016	0.072	0.011*	0.039
Health and socio-economic factors	Perceived severity of consequences on human diseases and mortality	0.268	0.104	0.056*	0.524
	Perceived severity of consequences on migration	-0.125	0.069	-0.042	0.469
	Perceived severity consequences on food security and incomes	0.125	0.069	0.188*	0.469
Biodiversity and forestry factors	Perceived probability of reduction in plant and forest species	0.221	0.095	0.144	0.645
	Perceived probability of reduction in birds and animal species	0.433	0.169	0.199*	0.665
	Perceived probability of decrease in forest area	0.046	0.079	0.213*	0.129
Factors related to agricultural production	Perceived probability of decreased crop yield	0.155	0.447	0.413*	1.123
	Perceived probability of decreased in cropping area	0.265	0.096	0.131*	1.608
	Perceived probability of increase in pests and diseases	0.128	0.036	0.100*	0.688
	Perceived probability of increase in cost of production	0.081	0.045	0.204**	0.434
	Perceived probability of decrease in soil fertility	0.281	0.077	0.132*	0.799
Psychological factors	Perceived ability to control risk	-0.262	0.055	-0.017	0.736
R square			0.832		
F for change in R square			7.702		

5.5 Conclusion and Recommendation

Generally, farmers have perceived climate change risk. It is observed that farmers in Lawra district generally perceive climate risk impacts in terms of agricultural production, biodiversity and forestry, health and socio-economy, and climatic variables. Resource-poor farmers are concerned about climate risk on agricultural production, while resource-moderate and resource-rich farmers are concerned about risk impacts on climatic variables, and health and socio-economy, respectively. Factors related to impacts on climatic variables and agricultural production are significant determinants of farmers' climate change risk perception. The psychological factor (i.e., perceived ability to control risk) is not a predictor of risk perception. Biodiversity and forestry related factors are also found to be predictors of climate change risk perception. In terms of impact on health and socio-economy, probability of increase in human disease and mortality, and decrease in food security and incomes are predictors of risk perception. Finally, demographic features such as education and age are significant predictors of risk perception while gender, marital status and income status are not.

Based on the results, it is essential for governments and policy makers to make climate risk communication and awareness an integral part of climate change policy. The risk impacts of climate change on human health, migration and other socio-economic factors need to be adequately identified and mainstream into climate risk communication policy. This will improve farmers' concern about, and ensure enhanced adaptation to climate change.

The findings are worth further investigation to identify how perceptions of the different wealth category of farmers are influenced by the various climate risk phenomena and impacts identified in this study. The outcome of such an investigation will further enhance the formulation of appropriate climate risk communication models and policy to meet different target groups.

In view of the fact that most farmers are already aware of climate change risks, it is crucial to identify the adaptation options required to mitigate the risks. Thus, a critical analysis of the reasons for adaptation, portfolio of adaptation practices, and determinants and barriers to adaptation to climate change in agriculture is needed.

References:

1. Müller, C.; Cramera, W.; Hare, W.L.; Lotze-Campena, H. Climate change risks for African agriculture. *PNAS* **2011**, 108:11, 4313–4315, doi: 10.1073/pnas.1015078108

2. Ndamani, F.; Watanabe, T. Influences of rainfall on crop production and suggestions for adaptation. *Int. J. Agric. Sci*. **2015**, 5, 367–374.
3. Howden, S.M.; Soussana, J.F.; Tubiello, F.N.; Chhetri, N.; Dunlop, M.; Meinke, H. Adapting Agriculture to Climate Change. *Proc Natl Acad Sci* **2007**, 104(50):19691–19696
4. McCarl, B.A. Analysis of climate change implications for agriculture and forestry: an interdisciplinary effort. *Clim Change* **2010**, 100(1):119–124
5. Ndamani F.; Watanabe, T. Farmers' perceptions about adaptation practices to climate change and barriers to adaptation – a micro-level study in Ghana. *Water* **2015**, 7:9, 4593-4604
6. Okonya, J.S.; Syndikus, K.; Kroschel, J. Farmers' perceptions of and copping strategies to climate change: Evidence from six agro-ecological zones of Uganda. *J. Agric. Sci*. **2013**, 5, doi:10.5539/jas. v5n8p252.
7. Fosu-Mensah, B.Y.; Vlek, P.L.G.; MacCarthy, D.S. Farmers' perceptions and adaptation to climate change: A case study of Sekyeredumase district in Ghana. *Environ. Dev. Sustain*. **2012**, 14, 495–505.
8. Prokopy, L.S.; Floress, K.; Klotthor-Weinkauf, D.; Baumgart-Getz, A. Determinants of agricultural best management practice adoption: evidence from the literature. *J Soil Water Conserv* **2008**, 63(5):300–311
9. McCown, R.L. New thinking about farmer decision makers. In: Hatfield JL (ed) The farmer's decision. *Soil and Water Conservation Society*, Ankeny, **2005**, pp 11–44
10. Arbuckle, J.G.; Morton, L.W.; Jon Hobbs, J. Farmer beliefs and concerns about climate change and attitudes toward adaptation and mitigation: Evidence from Iowa. *Climatic Change* **2013**, DOI 10.1007/s10584-013-0700-0
11. Pennings, J.; Leuthold, R. The role of farmers' behavioral attitudes and heterogeneity in futures contracts usage. *American Journal of Agricultural Economics* **2000**, 82:4. 908-919.http://dx.doi.org/10.1111/0002-9092.00090
12. FAO. Climate change impacts on livestock production systems and community based adaptations in Nepal, by D.B. Singh, National Consultant for the Strengthening Capacities for Disaster Preparedness and Climate Change Management in the Agriculture Sector (TCP/NEP/3201 [D]). **2010**. Kathmandu.
13. Crawford-Brown, D.J. Risk-Based Environmental Decisions: Methods and Culture; Kluwer Academic Publishers: New York, NY, USA, **1999**.
14. Ropeik, D. Risk perception in toxicology-part I: Moving beyond scientific instincts to

understand risk perception. *Toxicol. Sci*. **2011**, 121, 1–6.

15. Nigg, J.M.; Mileti, D. (2002). Natural hazards and disasters. In R. E. Dunlap & W. Michelson (Eds.), Handbook of environmental sociology **2002**, 272-294. Westport, CT: Greenwood Press.
16. Arbuckle, J.G.; Morton, L.W.; Jon Hobbs, J. Understanding Farmer Perspectives on Climate Change Adaptation and Mitigation: The Roles of Trust in Sources of Climate Information, Climate Change Beliefs, and Perceived Risk. *Environment and Behavior* **2015**, 47:2, 205–234, DOI: 10.1177/0013916513503832
17. Sulewski, P.; Kłoczko-Gajewska, A. Farmers' risk perception, risk aversion and strategies to cope with production risk: an empirical study from Poland. *Studies in Agricultural Economics* **2014**, 116:140-147 http://dx.doi.org/10.7896/j.1414
18. Borges, J.A.R.; Machado, J.A.D. Risks And Risk Management Mechanisms: An Analysis of the Perceptions of Producers Of Agricultural Commodities. *Interdisciplinary Journal of Research in Business* **2012**, 2:5, 27-39.
19. Greiner, R.; Patterson, L.; Miller, O. Motivation, risk perceptions and adoption of conservation practices by farmers. *Agricultural Systems* **2008**, 99 (2-3), 86-104. http://dx.doi. org/10.1016/j.agsy.2008.10.003
20. Wilson, P.N.; Luginsland, T.R.; Armstrong, D.V. (1988): Risk Perception and Management Responses of Arizona Dairy Producers. *Journal of Dairy Sciences* **1988**, 71, 545-551. http://dx.doi. org/10.3168/jds.S0022-0302(88)79588-0
21. Patrick, G.F.; Musser, W.N. 1997. Sources of and responses to risk: factor analyses of large-scale US cornbelt farmers, in R.B.M. Huirne, J.B. Hardaker and A.A Dijkhuizen (eds), Risk Management Strategies in Agriculture; State of the Art and Future Perspectives. Manshholt Studies No. 7. Wageningen: Wageningen Agricultural University, 45-53. Cited by Meuwisen et al., 2000.
22. Meuwissen, M.P.M.; Huirne, R.B.M; Hardaker, J.B. Risk and risk management: an empirical analysis of Dutch livestock farmers. *Livestock Production Science* **2008**, 69, 43-53. http://dx.doi.org/10.1016/S0301-6226(00)00247-5
23. Palinkas, P.; Székely, C. Farmers' perceptions on risk and crisis risk management, in M.P.M. Meuwissen, M.A.P.M. Asseldonk and R.B.M. Huirne (eds), Income stabilization in European agriculture. Design and economic impact of risk management tools. Wageningen: Wageningen Academic Publishers, **2008**, 97-122.
24. Rejesus, R.M.; Mutuc-Hensley, M.; Mitchell, P.D.; Coble, K.H.; Knight, T.O. US

Agricultural Producer Perceptions of Climate Change. *Journal of Agricultural and Applied Economics* **2013**, 45(4): 701-718.

25. Sarkar, S.; Padaria, R.N. Farmers' Awareness and Risk Perception about Climate Change in Coastal Ecosystem of West Bengal. *Indian Res. J. Ext. Edu*. **2014**, 10 (2),
26. Maddison, D. The perception of and adaptation to climate change in Africa. CEEPA. Discussion paper no.10. Centre for Environmental Economics and Policy in Africa. **2006**. Pretoria, South Africa: University of Pretoria.
27. Moghariya D.P.; Smardon, R.C. Rural perspectives of climate change: A study from Saurastra and Kutch of Western India. *Public Understanding of Science* **2012**, 0(0) 1 –18
28. Frank, E.; Eakin, H.; López-Carra, D. Risk Perception and Adaptation to Climate Risk in the Coffee Sector of Chiapas, Mexico. Conference on International Research on Food Security, Natural Resource Management and Rural Development. Tropentag **2010.**
29. Weber, E. Perception and expectation of climate change: Precondition for economic and technological adaptation. Psychological perspectives to environmental and ethical issues in management. M. Bazerman, D. Messick, A. Tenbrusel and K. Wade-Benzoni (eds) Jossey-Bass, San Francisco: **1997**, 314-341.

CHAPTER 6: ADAPTATION TO CLIMATE CHANGE IN AGRICULTURE: REASONS, RANKING, DETERMINANTS AND BARRIERS TO ADAPTATION

6.1 Introduction

This chapter outlines the proportion of farmers using adaptation practices against climate change. The specific reasons accounting for usage of adaptation options are also identified and elaborated. More importantly, farmers most preferred adaptation options are compared to the actual measures being used. To provide a clear understanding of farm-level adaptation, a new method of classification of adaptation practices is proposed based on responses from farmers (i.e., crop production improvement practices, soil management, irrigation water conservation and environmental improvement practices). Subsequently, the socio-economic factors influencing farmers' climate change adaptation decisions are outlined and discussed. In addition, this chapter discusses the critical barriers impeding the use of climate change adaptation practices. It is expected that the findings and recommendations of this study will prompt governments to mainstream barriers and choice factors of adaptation practices into climate change related policies, projects and programmes.

6.2 Literature review

Based on the scope of observed impacts of climatic variability over the last three or four decades, the West Africa sub-region is generally acknowledged to be the most vulnerable to the vagaries of climatic change [1]. Empirical studies have shown that high temperatures have resulted in reduced crop yield in Ghana [2, 3]. In recent times, the increasing incidences of droughts, late rains, floods, decreasing annual precipitation and increasing temperatures in northern Ghana [4, 5] have become a major concern. In view of this, farmers need to use adaptation practices in order to cope with the effects of climatic change. Studies have shown that without adaptation to climatic change, farmers will become more vulnerable and agricultural production will be severely affected [6]. Adaptation lessens adverse effects and takes advantage of benefits of changes in climatic variables. Earlier studies show that irrigation, improved crop varieties, crop diversification, farm diversification, change of planting dates and income generating activities are among the adaptation practices mostly used by farmers [7, 8]. Although smallholder farmers are likely to be highly affected by the effects of climate change due to their lack of capacity to adequately adapt, research shows that just a few of them use adaptation options [9]. Hence, a clear understanding of the factors that influence farmers' adaptation decision is essential in designing appropriate policies to promote effective adaptation in the agricultural sector [10].

Previous studies have reported that farmers' adaptation to climate change is determined by factors such as education, age, farming experience, gender, access to extension, credit, markets, farm income and farm size [11, 12, 13]. This study therefore hypothesized that household size, gender, education, farm size, access to credit, and membership to farmer-based organizations have significant influence on adaptation to climate change farmer level. Based on that, the objective of this study is to identify socio-economic factors influencing farmers' adaptation to climatic change in Lawra district of Ghana.

6.3 Materials and methods

6.3.1 Survey design and data collection

Data used in this study is collected from four communities. Socio-economic household surveys and focus group discussions (FGDs) were conducted in all four communities in November, 2014. Also, face-to-face interviews with key stakeholders were conducted. A total of 100 farmer households were interviewed using semi-structured questionnaires. Twenty-five households were randomly selected from each community and the household' heads individually interviewed. The FGDs were carried out to double check the household survey data. The participants included community leaders, men, women, youth and children. The discussions in each community focused on adaptation practices being used by farmers, reasons for adaptation, factors influencing adaptation and barriers to adaptation to climate change. Summary statistics of the collected data is shown in Table 6.1

Table 6.1 − Definition of variables used in the study in Lwara district of Ghana (N=100). (*Source: Author*)

Variable	Measurement
Adaptation	1=adapted; 2=not adapted (dummy variables)
Age	1=15-34; 2=35-54; 3=55 and above
Education	1=literate; 0=illiterate
Gender	1=Female; 0=Male
Farming experience	Number
Household size	Number
Family labor	Number
Farm size	Hectares
Annual household income	Amount
Rainfall pattern	0=decreasing; 1=increasing; 2=stable; 3=don't know
Temperature pattern	0=decreasing; 1=increasing; 2=stable; 3=don't know
Drought	1=Yes; 0=No
Flood	1=Yes; 0=No
Dry spell	1=Yes; 0=No
Access to weather information	1=Yes; 0=No
Market access	1=Yes; 0=No
Access to loan/credit facilities	1=Yes; 0=No
Access to agricultural subsidies	1=Yes; 0=No
Access to agric. Extension services	0=4 days; 1= less than 4 days; 2= more than 4 days
Farmer-based organization membership (FBO)	1=Yes; 0=No
Use of adaptation practices	1=Yes; 0=No
Improved crop varieties	1=Yes; 0=No
Crop diversification	1=Yes; 0=No
Farm diversification	1=Yes; 0=No
Change of planting date	1=Yes; 0=No
Income generating activities	1=Yes; 0=No
Agroforestry practice	1=Yes; 0=No
Irrigation	1=Yes; 0=No

6.3.2 Analytical methods

Frequencies, percentages, and means are the basic descriptive statistical tools used to represent farmers' adaptation proportions, reasons for adaptation and actual adaptations options being implemented. In determining farmers' perceived importance of adaptation practices, respondents are requested to score selected practices based on a 0–3 scale, where 0 is the least important practice and 3 is the most important practice. The adaptation practices were then ranked using the weighted average index (WAI):

$$\text{WAI} = \frac{\sum Fi\,Wi}{\sum Fi} \tag{6.1}$$

where F = frequency of response; W = weight of each score; and i = score (3 = highly important; 2 = moderately important; 1 = less important; 0 = not important).

Previous studies have also applied the weighted average index (WAI) to assess farmers' perceived important adaptation strategies in Bangladesh and barriers of adaptation to climate change in Nepal [14,8]. To identify the critical constraints that hinder farmers from using adaptation practices, a ranking was conducted using the Problem Confrontation Index (PCI). Respondents were asked to grade their perceived barriers based on a 0–3 Likert scale. The PCI value was estimated using the formula below:

$$\text{PCI} = P_n \times 0 + P_1 \times 1 + P_m \times 2 + P_h \times 3 \tag{6.2}$$

where:

PCI = Problem Confrontation Index;

P_n = Number of respondents who graded the constraint as no problem;

P_l = Number of respondents who graded the constraint as low;

P_m = Number of respondents who graded the constraint as moderate;

P_h = Number of respondents who graded the constraint as high.

6.3.3 Empirical model of adaptation determinants

The dependent variable in this study is whether a household has 'adapted' or 'not-adapted' any adaptation practices to climatic change. Based on discussions with MOFA staff, literature review and field observations, the adaptation practices identified included improved crop varieties (drought-tolerant and early maturing crops), crop diversification (mixed cropping and crop rotation), farm diversification (mulching, composting, ridging and terracing), change in planting date, income generating activities, irrigation practice (dry season gardening) and agroforestry. Adaptation is the dependent dummy variable. To determine the dummy, a value of '1' is assigned to household that has adopted at least one of the adaptation options and '0' if it has not adopted. Independent variables included gender, education, farming experience, household size, farm size, annual household income, access to credit, access to information, access to subsidies, membership to farmer-based organizations (FBOs), access to markets and access to extension services (Table 1).

The logistic regression model is used to identify the factors that determine farmers' adaptation to climatic change. Previous research findings have shown that logit models are the most appropriate econometric models to apply in evaluating qualitative dependent variables that have dichotomous groups (i.e. 'adapted' and 'not adapted') while the independent variables are categorical, continuous and dummy [15]. These models are commonly and widely used since they guarantee that the estimated probability increases lie within the range of 0 to 1 and displays a sigmoid curve conforming to the theory of adoption. This study used the functional form of the logistic regression model, presented by Agresti [16]. In this model, the dependent variable becomes the natural logarithm of the odds when a positive choice is made:

$$\ln\{P_x/(1- P_x)\} = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \ldots + \beta_k X_{ki} \quad (6.3)$$

where: P_x = probability of adaption; $(1-P_x)$ = probability of non-adaption; i = i^{th} observation in the sample; β_1, $\beta_2 \ldots \beta_k$= regression coefficients of the explanatory variables; X_1, $X_2 \ldots\ldots X_k$ = explanatory variables; β_0 = Constant term.

6.4 Findings and discussion

6.4.1. Farmers' Adaptation to Climate Change

Although an overwhelming majority of farmers recognized climate change, 33% of respondents still do not use any adaptation practices (Table 6.2). The FGDs revealed that increased access to agricultural extension officers has impacted positively (67%) on farmers' implementation of adaptation options. Similar findings were reported in Bangladesh, where more than 75% of respondents were using adaptation practices [14]. However, a previous study conducted in the Sekyedumase district of Ghana showed that less than 44% of farmers use adaptation measures due to lack of funds [9].

Table 6.2 - Proportion of farmers by adaptation classification and reasons for adaptation in the Lawra district of Ghana *(Number of respondents= 100).* (*Source: Author*)

Adaptation classification	**Percentage of respondents**
Adapted	67
Not adapted	33

6.4.2 Reasons for adaptation

Farmers' reasons for using adaptation practices are presented in Table 6.2. Majority (95 %) of respondents use adaptation measures to cope with dry spell effects on crop plants (Table 6.3). Also, 94 % and 75 % of farm households adapted to cope with drought effects and improve crop production, respectively. The results also showed that 74 % of respondents used adaptation practices to improve soil fertility while 34 % adapted to cope with effects of floods. Results of the FGDs showed that farmers use drought-tolerant and early maturing varieties and change of planting date to adapt to dry spells, droughts and floods. Farmers also use crop rotation and mixed cropping strategies to reduce effects of dry spell on crop plants. Some of the farmers claimed that they used composting and mulching to conserve soil moisture and improve soil fertility in order to increase their crop production. The FGDs also showed that farmers adopted terracing and ridging methods to reduce the effects of floods.

Table 6.3 − Reasons for adaptation to climatic change (N=67) in Lawra district of Ghana. (*Source: Author*)

Reasons for adaptation	% of respondents	Mean	Std. Dev.
Cope with flood	34	0.59	0.494
Improve soil fertility	74	0.84	0.367
Improve crop production	75	0.64	0.483
Cope with drought	94	0.99	0.103
Cope with dry spell	95	0.96	0.202

6.4.3. Farmer-perceived importance of adaptation practices

The ranking of adaptation practices based on farmers' perceived importance is presented in Table 6.4. Among the seven adaptation practices, improved crop varieties and irrigation practice rank first and second with WAI of 2.15 and 2.09, respectively. The increasing incidence of drought and dry spells makes drought-tolerant crop varieties and irrigation preferable to farmers. On the other hand, income-generating activities and agroforestry practice are ranked the least important with WAI of 0.77 and 0.74, respectively. Results of FGDs showed that farmers considered trading and agroforestry as capital-intensive activities. Crop diversification, farm diversification, and change of planting date are ranked as moderately important.

Table 6.4 - Farmers' ranking of adaptation practices in Lawra district, Ghana (*N= 100).*

Adaptation Practice	Frequency by Each Level of Importance				WAI	Rank
	Highly Important	Moderately Important	Less Important	Not Important		
Improved crop varieties	35	48	14	3	2.15	1
Irrigation	30	51	17	8	2.09	2
Crop diversification	14	76	8	2	2.02	3
Farm diversification	7	67	23	3	1.78	4
Change of planting date	10	44	26	20	1.44	5
Income generating activities	3	20	28	49	0.77	6
Agroforestry practice	0	9	56	35	0.74	7

The results of actual adaptation measures being implemented by farmers are presented in Table 6.5. Majority of the respondents (51%) use crop diversification strategies in response to climatic variability. Changing planting date is chosen by 22 % while 12 % chose improved crop varieties. Farmers also use farm diversification measures (6 %), income generating activities (6 %) and irrigation (2 %) to mitigate the effects of climate change on their farming activities. About 1% of the respondents also undertake agroforestry.

Table 6.5 − Actual adaptation practices being used by farmers in Lawra district of Ghana (N=67). (*Source: Author*)

Adaptation practices	% of respondents	Actual adaptation measures
Crop diversification	51	Crop rotation and mixed cropping
Change planting date	22	
Improved crop varieties	12	Drought-tolerant and early maturing varieties
Farm diversification	6	Reduce farm size and composting/mulching
Income generating activities	6	Petty trading and 'pito' brewing
Irrigation	2	Dry season gardening
Agroforestry	1	Tree planting

It can be inferred from Tables 6.4 and 6.5 that although farmers rank improved crop varieties (e.g., drought-tolerant and early maturing crops) and irrigation as the most important adaptation strategies, only 14% actually implemented measures in these categories. The majority of respondents (51%) use crop diversification activities (i.e., mixed cropping and crop rotation). Similar findings were reported in Northern Nigeria [17]. Feedback from the group discussions showed that most farmers did not have access to improved crop varieties; hence, they could not implement their most preferred measure. Results of the group discussion showed that farmers are generally aware of the annual recurrent dry spells and droughts. Also, although they view irrigation as the most important solution to these extreme climatic events, they failed to rank it as such. This is because, according to farmers, water resources such as dams and dugouts are very limited in the district. Field observation showed that most of the available water bodies for irrigation are broken down.

6.4.4 Farmers' perceived classification of adaptation practices

Generally, farmers in Lawra district categorize climate change adaptation options in terms of crop production improvement, soil management, infrastructure improvement and development, and environmental improvement practices (Table 6.6).

Table 6.6: Farmers' perceived classification of adaptation practices in Lawra district. (*Source: Author*)

Category	Adaptation practice	Specific practices
Crop production improvement practices	Improved crop varieties	Use of drought-tolerant varieties
		Use of early maturing varieties
	Crop diversification	Crop rotation
		Mixed cropping
		Change of planting date
Soil improvement practices	Farm diversification	Mulching
		Composting
	Mixed farming	Reduce land size
		Increase land size

Environment improvement practices	Agroforestry	Tree planting
Infrastructure improvement and development practices	Irrigation	Dry season gardening Dams and dug-outs Terracing and ridging

Results of the FGDs show that an overwhelming majority of respondents classified drought-tolerant varieties, early maturing varieties, crop rotation, mixed cropping, mixed faming and change of planting dates as strategies meant to directly improve crop production under climatic variability. They also claimed that mulching, composting, reduction of farm and increasing of farm size are adaptation strategies related to soil improvement.

6.4.5 Determinants of adaptation to climate change

Results of the logistic regression model of determinants of adaptation to climate change are presented in Table 6.7. Prior to the analysis, the contingency coefficient test was applied to identify and omit independent variables that are strongly correlated to each other. Thus, age of household head, and agricultural subsidies were removed due to their strong co-linearity with farming experience and agricultural credit, respectively. Access to agricultural extension services was also removed because of its weak correlation with adaptation. The study results showed that education was positive and significantly related to farmers' decision to adapt to climate change. Previous studies have shown that there is a positive relationship between educational level of the household head and adoption of improved technologies [18]. This implies that, farmers with higher levels of education are more likely to use improved technologies in order to adapt to climate change. This is particularly so because educated farmers are more knowledgeable due to their ability to access information pertaining to climate change and adaptation options.

The results also showed that the probability of adaptation increases with increase access to information. This implies that farmers with access to timely weather information and other extension services are more likely to adapt to climatic change. Similar findings have been reported in Nepal and Southern Africa [19, 13]. In addition, results of the study showed that the likelihood of adaptation to climatic change was higher with large household size than with small households. Similarly, earlier investigations have shown that the tendency of larger households to adapt to climatic change is higher probably due to their higher endowment of labor [20]. Furthermore, the study results showed that the probability of adaptation to climatic change increases with increase access to credit facilities. This result is consistent with previous findings that access to credit is an important variable which commonly has a positive effect on adaptation behavior [21], hence adaptation to climatic change [9]. Household income was also positively related to adaptation. This result is in line with previous findings that showed that wealthier farmers are more likely to use adaptation practices in response to climate change than poor farmers [12]. It is also been reported that per capita income has a positive influence on farmers' adaptation decisions [13].

Table 6.7 - Estimated results of logistic regression model (N=100) in Lawra district of Ghana. (*Source: Author*)

Variable	**Coefficient**	**Std. Error**	***p* Value**
Intercept	8.419	2.561	0.001
GEND	-0.316	1.73	0.855
FRMINEXP	-1.829	1.196	0.126
EDU	7.363*	2.765	0.008
HHSZ	5.48*	2.134	0.010
FRMSZ	-3.221*	1.625	0.047
HHINC	1.627	1.289	0.207
WINFOACC	4.572*	1.612	0.005
MRKTACC	0.635	1.51	0.674
CREDACC	3.405*	1.568	0.030
FBOMEMB	1.672	1.405	0.234
Pseudo R^2		0.754	

**indicates significant level at 5 %; GEND = Gender; FRMINEXP = Farming experience; EDU = Education; HHSZ = Household size; FRMSZ = Farm size; HHINC = Household income; WINFOACC = Weather information access; MRKTACC = Market access; CREDACC = Access to credit facilities; FBOMEMB = Membership to farmer-based organization.*

Results of the study also revealed a positive relationship between membership to farmer-based organization (FBOs) and adaptation to climate change. This is consistent with earlier research findings in Nepal and Bangladesh that showed that farmers belonging to cooperative organizations have higher likelihood of using adaptation practices due to their capacity to share information - discuss problems, share ideas and take collaborative decisions [8, 19]. Also, the results revealed that access to market is positively related to adaptation. Results of the focus group discussions showed that farmers' decision to adopt crop diversification was based on availability of market. This result is consistent with findings reported in Southern Africa [13].

On the other hand, the probability of adaptation decreases with farming experience. The FGDs revealed that farmers with longer farming experience are older persons. This implies that the likelihood of adaptation to climate change decreases with older farmers. This finding is confirmed by results of previous studies that showed that older farmers generally lack interest and incentive to adapt to climatic change [8, 22]. However, studies in Ethiopia have also shown a positive relationship between the number of years of experience in agriculture and the adoption of improved agricultural technologies [23]. Also, the estimated results showed that the probability of adaptation is higher with small farm sizes and lower with large farm sizes. The FGDs results showed that the adaptation investment (i.e. irrigation facilities, improved seeds and fertilizer) for large farm sizes was huge. Some previous studies have also reported similar findings [24]. The results also showed that male farmers are more likely to use adaptation measures against climatic change than female farmers. This finding is confirmed by results of previous studies that showed that in Sub-Saharan Africa, women household heads have lower levels of education, less access to markets and credit and other inputs [25], hence, they are less likely to meet the investment demands of climatic change adaptation. Similar studies have also revealed that women are less able to diversify income sources and adapt to climate change because of other domestic responsibilities and less control of financial resources [26].

6.4.6. Perceived constraints to adaptation to climate change

Results of the problem confrontation index are presented in Table 6.8. With a PCI value of 215, unpredictable weather is ranked the most critical impediment to use of adaptation options. High cost of farm inputs, lack of access to timely weather information, and lack of water resources are ranked the second, third, and fourth most pressing problems, respectively. This is likely the case, because in Ghana, the main sources of weather information are television and radio broadcasts and from colleagues who visited peri-urban towns during market days. The majority of farmers surveyed did not have electronic gadgets and hence could not readily access weather information. Also, the FGDs showed that farmers in the Lawra district operate under limited resources due to limited agricultural credit and subsidies. Field observations showed that the limited number of irrigation facilities (*i.e.*, dams and dugouts) are either broken down or dried out. Similar barriers to adoption have been reported in South Africa [13] and Nigeria [27].

Table 6.8 - Estimated results of problem confrontation index *(Number of respondents = 100)*. (*Source: Author*)

Constraints to Adoption	**Degree of Constraint**				**PCI**	**Rank**
	High	**Moderate**	**Low**	**No Problem**		
Unpredictable weather	35	48	14	3	215	1
High cost of farm inputs	14	76	8	2	202	2
Lack of access to timely weather information	7	67	23	3	178	3
Lack of access to water resources	10	44	26	20	144	4
Lack of access to credit facilities	2	32	11	55	81	5
Lack of access to agricultural subsidies	3	20	28	49	77	6
Poor soil fertility	0	9	56	35	74	7
Limited access to agricultural extension officers	3	19	7	71	54	8
Limited access to agricultural markets	0	0	24	76	24	9
Inadequate farm labor	0	1	19	80	21	10
Limited farm size	0	0	13	87	13	11

6.5 Conclusion and Recommendation

This study showed that some farmers are already adjusting their farming activities in response to droughts, dry spells, and floods. The FGDs showed that increased access to agricultural extension officers has impacted positively on farmers’ implementation of adaptation options. This study identified a number of factors that determine farmers’ adaptation to climatic change. These factors include education, household size, household income, access to information, access to credit, access to markets and membership to FBOs. Also, the study identified unpredictability of weather, high farm input cost, lack of access to timely weather information and limited access to water resources as the most critical barriers to adaptation. Considering the above, this study recommends that governments and development partners should mainstream the determining factors of adaptation and barriers to adaptation into climate change related policies, projects and programmes. There is also the need for construction of dams and dug-outs so that farmers can undertake dry season gardening and irrigation farming.

Farmers' access to timely weather information also needs to be prioritized to help farmers in their production decision-making processes (e.g., selection of adaptation options). The Ghana Meteorological Agency and agricultural staff need to be properly trained and resourced to collect, collate, and disseminate accurate weather information timely and widely. Also, the government should boost the capacity of scientists and agricultural staff to develop and promote appropriate and effective technologies to help farmers adapt to climate change. In addition, the prevailing high cost of farm inputs and lack of credit facilities and subsidies require the government to ensure that agricultural loans with flexible terms are made available to farmers to boost their capacity to adapt to the changing climate.

Considering that farmers already possess a portfolio of adaptation practices to climate change, the key challenge then, is how to evaluate and select the most appropriate adaptation option. A new model is required to assist farmers to prioritize and select most feasible and effective adaptation practice to predicted extreme climate events. Such a model will help governments, researchers, non-governmental organizations (NGOs), and farmers to develop and implement adaptation measures that are feasible and effective.

References

1. Intergovernmental Panel on Climate Change (IPCC). Climate change: The scientific basis **2007**. Available at: http://www.ipcc.ch/. [Accessed March 7th 2015]
2. Stephens, C.S. Some Empirical Evidence of Global Warming in Ghana. Ghana *Journal of Science* **1996**, 31: 31-36
3. Stutley, C. Innovation Insurance Product for the Adaptation to Climate Change Project Ghana (IIPACC), Crop Insurance Feasibility Study. Accra **2010.** http://seguros.riesgoycambioclimatico.org/DocInteres/eng/Ghana-Crop-Insurance.pdf [Accessed March 9th 2015]
4. Yengoh, G.T.; Armah, F.A.; Onumah, E.E.; Odoi, J.O. 2010. Trends in Agriculturally-Relevant Rainfall Characteristics for Small-Scale Agriculture in Northern Ghana. *Journal of Agricultural Science* **2010**, 2: 3-16.
5. Stanturf, A.J.; Warren Jr, M.L.; Charnley, S.; Polasky, S.C.; Goodrick, S.L.; Armah, F.; Nyako, Y.A. Ghana Climate Change Vulnerability and Adaptation Assessment **2011**.

http://www.encapafrica.org/documents/biofor/Climate%20Change%20Assessment_Ghana_%20FINAL.pdf. [Accessed April 7th 2015]

6. Smit, B.; Skinner, M.W. Adaptations options in agriculture to climate change: A typology. *Mitigation and Adaptation Strategies for Global Change* **2002**, 7: 85-114.
7. Maddison, D. The perception of and adaptation to climate change in Africa CEEPA**.** Discussion paper No. 10., **2006**. Centre for Environmental Economics and Policy in Africa. Pretoria, South Africa: University of Pretoria.
8. Uddin, M.N.; Bokelmann, W.; Entsminger, J.S. Factors affecting farmers' adaptation strategies to environmental degradation and climate change effects: A farm level study in Bangladesh. *Climate* **2014**, 2: 223-241.
9. Fosu-Mensah, B.Y.; Vlek, P.L.G.; MacCarthy, D.S. Farmers' perceptions and adaptation to climate change: a case study of Sekyeredumase district in Ghana. *Environment, Development and Sustainability* **2012**, 14: 495-505.
10. Mabe, F.N.; Gifty, S.; Samuel, D. Determinants of Choice of Climate Change Adaptation Strategies in Northern Ghana. *Research in Applied Economics* **2014**, 6: 75-94
11. Deressa, T.T.; Hassan, R.M.; Ringler, C.; Alemu, T.; Yesuf, M. Determinants of farmers' choice of adaptation methods to climate change in the Nile Basin of Ethiopia. *Global Environmental Change* **2009**, 19: 248-255.
12. Gbetibouo, G.A. Understanding farmers' perceptions and adaptations to climate change and variability. The case of the Limpopo Basin, South Africa. IFPRI Discussion paper No. 00849, **2009**. International Food Policy Research Institute, Washington, D.C., USA. Available at: www.ifpri.org. [Accessed March 9th 2015]
13. Nhemachena, C.; Hassan, R. Micro-Level Analysis of Farmers' Adaptation to Climate Change in Southern Africa. IFPRI Discussion Paper 00714, **2007**. International Food Policy Research Institute, Washington, D.C. http://cdm15738.contentdm.oclc.org/utils/getfile/collection/p15738coll2/id/39726/filename/39727.pdf [Accessed March 9th 2015]
14. Devkota, R.P.; Cockfield, G.; Maraseni, T.N. Perceived community-based flood adaptation strategies under climate change in Nepal. *International Journal of Global Warming* **2014**, 6: 113-124.
15. Long, S.T.; Freese, J. Regression Model for Categorical Dependent Variables Using Stata **2006**. A Stata Press Publication, Collage Station, Texas.
16. Agresti, A. An Introduction to Categorical Data Analysis. **1996.** John Wiley & Sons. Inc.,

USA.

17. Farauta, B.K.; Egbule, C.L.; Idrisa, Y.L.; Agu, V.C. Farmers' Perceptions of Climate Change and Adaptation Strategies in Northern Nigeria: An Empirical Assessment. Available online: http://www.atpsnet.org/Files/rps15.pdf (accessed on 15 May 2015).
18. Igodan, C.O.; Ohoji, P.E.; Ekpere, J.A. Factors associated with the adoption of recommended practices for maize production in the Lake Basin of Nigeria. *Agricultural Administration and Extension* **1990**, 29: 149-156.
19. Tiwari, K.T.; Rayamajhi, S.; Pokharel, R.K.; Balla, M.K. Determinants of the climate change adaptation in rural farming in Nepal Himalaya. International Journal of Multidisciplinary and Current Research **2014**, 2: 2321-3124.
20. Oyekale, A.S.; Oladele, O.I. Determinants of climate change adaptation among cocoa farmers in Southwest Nigeria. *ARPN Journal of Science and Technology* **2012**, 2: 154-168
21. Caviglia-Harris, J. Sustainable Agricultural Practices in Rondônia, Brazil: Do Local Farmer Organizations Impact Adoption Rates? Department of Economics and Finance, **2002**. Salisbury University.
22. Shiferaw, B.; Holden, S. Resource degradation and adoption of land conservation technologies in the Ethiopian highlands: Case study in Andit Tid, North Shewa. *Agricultural Economics* **1998**, 27: 739-752.
23. Kebede Y.; Gunjal, K.; Coffin, G. Adoption of new technologies in Ethiopian agriculture: The case of Tegulet-Bulga District, Shewa Province. *Agricultural Economics* **1990**, 4: 27-43.
24. Acquah, H.D. Farmers Perception and adaptation to climate change: A willingness to pay analysis. *Journal of Sustainable Development in Africa* **2011**, 13: 150-161.
25. Blackden, C.M.; Wodon, Q. Gender, time use and poverty in sub-Saharan Africa. World Bank Working Papers 73, **2006**. World Bank: Washington, D.C., USA.
26. Röhr, U. Gender, climate change and adaptation. Introduction to the gender dimensions. Background Paper prepared for the Both Ends Briefing Paper, Adapting to climate change: How local experiences can shape the debate. **2007**. http://www.unep.org/roa/amcen/Projects_Programme/climate_change/PreCop15/Proceedings/Gender-and-climate-change/Roehr_Gender_climate.pdf [Accessed March 9th 2015]
27. Kandlinkar, M.; Risbey, J. Agricultural impacts of climate change: If adaptation is the answer, what is the question? Clim. Chang. **2000**, 45, 529–539.

CHAPTER 7: INDICATORS FOR ADAPTATION DECISION-MAKING UNDER CLIMATE CHANGE: THE EVALUATION MODEL

7.1 Introduction

This chapter presents a new approach to the development of a set of indicators for selection of adaptation practices against climate change. The six-step process of the approach is discussed in detail. Seventeen indicators are proposed for use in prioritizing and selecting appropriate adaptation measures to extreme climate event. The weighting criteria of the seventeen indicators and components is presented and discussed. The final part of this chapter outlines a simulation process where the AHP model is applied to the components and indicators to prioritize and select the most ideal adaptation practice to drought in agriculture.

7.2 Literature review

Under the prevailing effects of climate change on agriculture, choosing the most feasible and effective adaptation practice in any given season is crucial to boosting agricultural production. While choosing an appropriate climate adaptation strategy is pivotal to increasing crop production, selecting a wrong strategy can be detrimental to crop production and food security.

The adoption process requires a series of decision-making by individuals. Before a technology is adopted, the individual must first be aware of it. After awareness, the technology may be rejected immediately or the adoption process may continue with the individual developing interest in the technology. The technology may be rejected after the initial interest or the individual may proceed to the next stage of comparing the technology with other existing practices. If the outcome is favorable, the technology would be not rejected but tested on a small scale to see if it works for them. The technology is then adopted if it passes the test [1].

The traditional approach of selecting adaptation strategies is based on farmers' own experiences and judgment with limited or no information on empirical weather forecast and scientifically verified and available adaptation options. Recent reports of increased variability in crop production due to climate change [2] imply that the traditional method is not effective. Thus, a technique is needed for assessment of adaptation practices based on indicators including availability and accessibility, cost-effectiveness, weather forecast, adaptive capacity to the ecology, compatibility with societal norms and traditions, flexibility, and institutional capacity.

Indicators are measures used to quantify or qualitatively describe phenomena that are not easily measured directly, but which society considers valuable to monitor over time. For many decades, indicators have been used to communicate information about complex systems or phenomena in a way that is relatively simple to understand. Indicators are useful for sharing the results of technical analysis or for monitoring characteristics of systems, such as fisheries, to inform public decisions [3]. In particular, indicators have become very useful in monitoring 'sustainable development' [4] —a complex and often ambiguous concept that cannot be measured directly

Also, a set of indicators have the potential to serve as a powerful decision-making tool for communities, businesses, policy makers, organizations and governments to reduce vulnerability and resource waste by assessing and identifying most feasible strategies based on stakeholders' perceptions. Standard of judgments, opinions and choices of people vary from one individual to the other. Peoples' preferences at any point in time are dependent on 'state of mind', current perceptions, past experiences, future expectations, environmental lifestyle, ecosystem ethic, the context of observation and tradeoffs. The most important issue therefore is how to use the large and varied perceived individual information [5] to determined feasible and effective strategies.

Considering the current conditions of increasing environmental and economic vulnerability due to climate change, and the availability of various adaptation practices, the key question being constantly asked is; how can we determine the most feasible and effective adaptation practice to a predicted extreme weather event? By developing relevant indicators of feasibility and effectiveness, a decision making model could be applied to assess and select the most appropriate adaptation option.

Literature shows that many methods exist for setting priorities in agricultural research. These include Mathematical Models, Scoring, Checklist, Rule of Thumb, Domestic Resource Cost, economic Surplus, Cost-Benefit, and Simulation [6]. Previous studies have found the 'scoring method' more useful to the complicated requirements related to the agricultural decision making process [7]. Other findings have deemed a combination of the scoring method with others methods to be relevant in decision making [8, 9, 10]. To avoid the limitations of the scoring method, the 'Analytical Hierarchy Process' (AHP) was suggested [11] as a way to avoid the deficiencies of the scoring method while ensuring participation and transparency in line with a standard procedure. The AHP model is a powerful and flexible tool for decision-making. It allows decision makers to systematically evaluate various elements based on decision hierarchy tree by comparing them to one another in pairs. The decision makers can use concrete data about the elements, or they can use their judgments about the elements' relative meaning and importance [11].

The AHP model has previously been applied to investigate management decisions in administrations; transportation planning, planning, energy resource allocation, urban planning, setting priority for energy and environmental research projects, prioritization of electricity industries, design of renewable energy systems, identification of favorable fuels in transportation industries, evaluating machine tool alternatives and technology assessment [12, 13, 14, 15, 16, 17, 18, 19, 20]. The model has also been used to investigate decisions in the agriculture sector [21]. Literature has shown that the AHP model can help the farmer set priorities and make the best decision when both qualitative and quantitative aspects of a decision need to be considered [22].

This study therefore proposes a new approach to developing indicators for evaluation of agricultural adaptation practices to climate change. The study also applies the AHP decision support model to determine the relative importance of the developed components and indicators. Further, the adaptation practices to drought in agriculture are also evaluated and prioritized for easy selection.

7.3 Materials and methods

Focus group discussions (FGDs), face-to-face interviews, field observations and literature review were the main tools used in gathering information for the study. In the first stage of data collection, four FGDs were conducted in four communities; one in each community. The participants in each community included community leaders, men, women, youth and children. The purpose of the discussions was to brainstorm the status of agricultural production, impacts of climatic change, verify and select most applicable indicators for assessment of adaptation practices. The field observations were conducted to obtain a clear view of the adaptation practices being used. In the second stage, face-to-face interviews were conducted with stakeholders and experts from different organizations *(i.e., Ministry of Food and Agriculture, Savanna Agriculture Research Institute, Ghana Meteorological Agency, National Disaster Management Organization and the local government)*. In the final stage, the developed indicators were sent to key experts for evaluation and validation. A total of six FGDs were conducted; one each with the regional and district agricultural staff in Wa and

Lawra respectively and four in the aforementioned communities.

After validation of the developed components and indicators of adaptation selection, the AHP decision support model was applied to a specific case study. Since drought and dry spell has higher rate of occurrence, the indicators and AHP model are applied to prioritized and select the most appropriate adaptation practices against drought in agriculture.

7.4 The proposed model

In developing indicators for evaluating sustainability and effectiveness, a two-step process is often used. The first step involves determining the scope and identifying the measured criteria while the second step focuses on developing and applying the indicators [23]. Based on this approach, the important criteria should include understandability, ease of measurement, accuracy, reasonableness and practicability, acceptability, and emphasis at the policy level [23, 24, 3, 25]. This approach has largely been used in previous studies to develop indicators to evaluate sustainability of the ecological system, agro-biodiversity and the fisheries ecosystem.

Based on the above approach, this current study proposes a new approach for developing indicators. The new approach is particularly important because agriculture and climate change are diverse and complex in nature. The knowledge, skills, resources and logistics needed for farm-level adaptation to climate change are equally diverse, and under the control of different stakeholders. Thus, the current study proposes a six-step process for creating a set of indicators at community-level. The steps are: identifying stakeholders, setting the goal, setting the components, developing the indicators, setting alternative practices, and calculating, integrating results and making a decision (Figure 7.1).

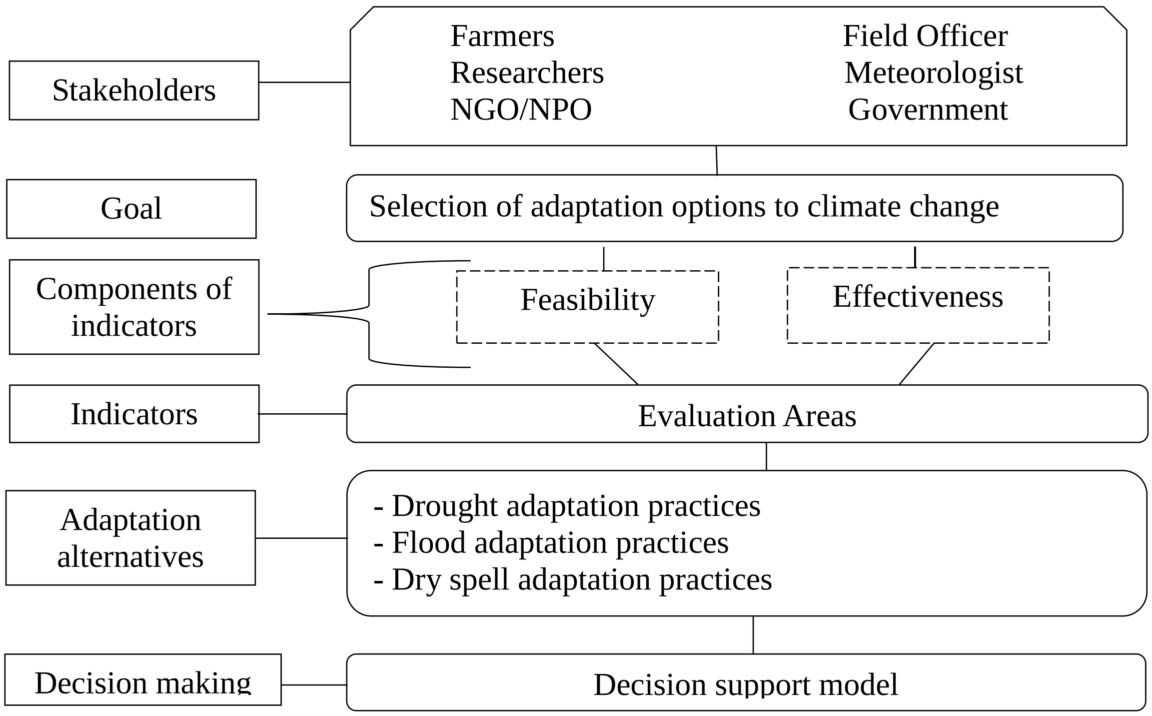


Figure 7.1: Outline of indicators development process (*Source: Author*)

7.4.1 Identification of stakeholders

Based on literature and discussions with farmers and key experts, the under-listed stakeholders are identified for development and implementation of the indicators (Table 7.1).

Table 7.1 - Summary of stakeholders and responsibilities (*Source: Author*)

Stakeholders	Responsibilities
Farmers	Evaluate, select and Implement of adaptation practices
Field officers	Provide technical back-stopping to farmers and collaborate with other players to develop and promote adaptation
Research scientists & Engineers	Develop and produce adaptation options
Meteorologist	Provide weather information to guide the development, selection and implementation of adaptation options
Local government	Provide the policy framework and resources for promotion of effective farm-level adaption to climate change

Farmers are the core beneficiaries of the indicators. Since the indicators are designed to improve farmers' decision making under climate change, their responses to questions regarding commitment, cost, knowledge and skills, cultural compatibility, ecological compatibility, ease of use and accessibility are relevant in determining the effectiveness and sustainability of adaptation practices for any extreme weather events are relevant. Agricultural field officers are the principal change agents in agricultural development. They serve as a medium through which knowledge and skills are passed down to farmers from research scientists and government. The role of field officers in climate change adaptation decision making is critical in the sense that they serve as the core providers of technical back-stopping to agricultural producers. Their responses to issues surrounding technical and environmental compatibility ease of use, inter-generational equity and fairness, affordability, knowledge and skills, reproducibility, comparative effectiveness and accessibility are essential to deciding the most appropriate adaptation strategy for any extreme climate event.

Research scientists and engineers play a crucial role in undertaking activities aimed at developing effective and sustainable adaptation measures and supporting implementation of the adaptation process. The research-extension-farmer linkage committee (RELC) collaborates to highlight knowledge gaps and develop technologies to address climate change effects. Meteorologists are responsible in providing accurate and timely climate projections needed for effective planning and decision making under climatic change. Researchers, engineers, government and field officers need clear and reliable weather forecast information so as to plan, develop and promote appropriate adaptation strategies. Therefore, the Meteorological agency plays a critical role in climate change adaptation decision making. Policy formulation and financing of climate change adaptation is crucial to increasing agricultural production. The main roles for government therefore is to provide policy framework, finances, information and raise awareness needed for timely action for improved farmer adaptation to climate change. Therefore, government's strong commitment, political leadership, effective administration and co-ordination and clear targets and objectives are central for effective decision making and adaptation.

7.4.2. Development of components and indicators

Face-to-face interviews and focus group discussions with stakeholders and experts suggested that indicators for decision making and selection of adaptation practices should measure feasibility and effectiveness. Hence, they should pertain to availability, accessibility, cost, compatibility with societal norms and traditions, adaptive capacity to the ecology and inter-generational equity, consistency with meteorological predictions, and institutional capacity and willingness to support and/or develop the identified practices within a given time. Furthermore, the indicators should be simple, understandable, precise, applicable, and relevant in terms of effectiveness and sustainability. Results of the FGDs with farmers confirmed these criteria for development and verification of the indicators. The developed components and indicators are presented in Table 7.2

A. Feasibility of the adaptation practice at farmer-level is evaluated by indicators such as cultural and traditional compatibility, cost, knowledge, skills and past experience.

1. ***Culture and tradition:*** This represents the degree to which an adaptation measure conforms to the cultural beliefs and traditions of the locality. The decision of a community to accept and use an adaptation option is influenced by the degree to which it fits into the cultural setting. Hence, to foster farmers' acceptance and commitment, the proposed adaptation practices should address the beliefs and traditions of the local people.
2. ***Knowledge, skills, & past experience:*** This represents individual's adaptability and maintenance ability of the measure. Principally, the decision to use a recommended adaptation measure is motivated by self-interest and undertaken voluntarily by the farmer. Factors that could influence farmers' decision to choose and commit to a particular measure include knowledge and skills, past experience and resource availability. The inherent simplicity of the adaptation practice is essential to avoid an incompatibility and complications in integrating into the farming operations. Previous studies have shown that, in the farming context where operations are characterized by a high degree of routine work and the use of expensive machine equipment, the introduction of a technology that is not compatible with existing practices and infrastructure is likely to be difficult [26]. The adaptation strategy to be chosen should therefore exhibit high flexibility and compatibility with other measures. Farmers should have the requisite skills to conduct the maintenance and repair works. Field observations revealed a number of broken dams and

dug-outs that were constructed several years ago. Discussions with the agricultural field officers and farmers revealed that the maintenance cost involved was huge. Also, the farmers and officers lacked the requisite skills to carry out the repairs by themselves. Terraces that were constructed for water conservation have also been destroyed. Afforestation projects were also in a bad state. Thus, for an adaptation strategy to be effective and sustainable, its future maintenance; repair of unexpected breakdowns, replacement of lost or faulty parts should be relatively easier, cost effective and simple. Thus, for an adaptation strategy to be effective and sustainable, its future maintenance; repair of unexpected breakdowns, replacement of lost or faulty parts should be relatively easier, cost effective and simple.

3. ***Cost:*** This refers to farmers' economic ability and accessibility to the adaptation option. The transaction cost of adaptation strategies is usually of critical importance to farmers. To choose an adaptation practices, a farmer needs to, as a matter of priority, assess his financial conditions to ascertain whether he can meet the monetary demands of the strategy. Accessibility of the strategy (e.g. materials and logistics) is also very critical in forming a firm adaptation decision. As such, farmers must have ready information on which measures are readily accessible. In the case of improved crop varieties, stakeholders need to be sure that the seeds are with the seed marketing companies or the agricultural development unit. For drip and sprinkle irrigation, farmers need to be certain that the materials and logistics are readily accessible and affordable in the market so as to take an informed decision.

Table 7.2 Components and indicators for evaluation adaptation alternatives to climate change in agriculture (*Source: Author*)

Components	**Players**	**Key indicators**	**Sub-indicators**
Feasibility	Farmer	Culture & tradition	1. Communal or group adaptability
		Knowledge, skills, & past experience	2 Individual adaptability
			2. Individual maintenance ability
		Cost	3. Individual affordability
			4. Labor availability
	Institutions	Competence	5. Technical ability of non-farmers
		Finance	6. Economic ability of non-farmers
		Scientific basis	7. Weather information availability and accuracy
		Timeliness	8. Timely provision and assistance by non-farmers
	Nature	Land	9. Land availability
		Water	10. Water resource availability
		Soil	11. Nature of soil
Effectiveness	Farmer	Resiliency	12. Recovery from climatic shocks:
		Short-term response	13. Short term effectiveness
		Medium-long term response	14. Medium-long term effectiveness
		Frequency of unintended consequences	15-1. Unintended consequences
		Criticality of unintended consequences	15-2. Unintended consequences
	Society	Current society	16-1. Equity
		Future generation	16-2. Equity
		Vulnerable group	17. Equality
	Nature	Robustness	18. Coping ability

B. Feasibility at institutional level is evaluated by competence, finance, scientific basis and timeliness.

4. ***Competence:*** Demonstrable skills and knowledge of researchers and engineers to develop adaptation technologies is crucial. The development of new or improved adaptation practices such as new crop varieties and irrigation facilities require specialized skills. In addition, agricultural information is necessary for effective farm management and adaptation to climatic change. Therefore, it is essential for field officers to have the requisite information, skills and knowledge to guide farmers in the implementation of the identified adaptation measure. Also, considering the increasing frequency of extreme weather events being reported globally, development and dissemination of reliable and accurate climate prediction information is critical to effective agricultural decision-making. Agricultural stakeholders need to be certain about the reliability and accuracy of weather forecast information so as to choose the most appropriate adaptation measure. Thus, the meteorological agency should provide accurate, reliable and timely weather predictions.
5. ***Finance:*** This represents availability, sufficiency and timeliness of funds to researchers, engineers and field officers to develop and promote the required climate change adaptation technique. Researchers and engineers need funding to purchase the logistics and resources required to develop an identified technology. Similarly, field officers require funds to carry out their guidance and supervisory duties so as to ensure farmers effectively implement the adaptation technique. Meteorologists also require timely and adequate funding to undertake their weather forecast and dissemination activities. Availability of an adaptation technique for an identified extreme weather event is therefore contingent on government's willingness to make funds available and timely.
6. ***Scientific basis:*** This pertains to the presence of sufficient scientific and conceptual basis for developing the adaptation practice. It also denotes the presence of a fundamental process covering key aspects, components and procedure. It must also be consistent with weather forecast predictions.
7. ***Timeliness:*** This denotes availability and accessibility of the adaptation practice within the required season or time. In the case of provision of improved crop varieties, this indicator is largely dependent on the availability of skilled and adequate number of research scientist to develop the adaptation strategies. It is also partly contingent on the timely release and sufficiency of funds. This indicator is also important in the provision of irrigation facilities where a farmer's

decision to use drip or splash irrigation against a predicted drought or dry spell depends on whether the resources and logistics will be available at the right time.

C. Feasibility of the adaptation option with respect to nature is evaluated by resource availability.

8. ***Resource availability:*** Access to water, land, soil and labor are important determinants of a farmer's decision to use adaptation measures. Water resource availability is a critical factor for a farmer who needs to take a decision regarding using irrigation as a measure against drought and dry spell. The absence of dams, dug-outs and water harvesting materials makes irrigation and dry season gardening impossible. Additionally, a farmer who is planning to use crop rotation, mixed farming or agroforestry need to be sure of the size of land available to him. Soil quality is also of critical importance for implementation of certain climate change adaptation measures in agriculture. To change crop type, use improved crop varieties or to engage in agro-forestry, it is essential to consider the soil suitability of the farm area so as to take the most appropriate decision. Also, some adaptation practices are labor intensive; hence farmers with smaller household sizes and limited financial resources to pay for hired-labor may not be able to implement them. Responses on land and labor availability will help farmers to make wise decisions. They will also assist researchers, field officers and government to develop and promote appropriate adaptation practices to meet the needs of different categories of farmers.

D. Effectiveness of adaptation practices with respect farmers is evaluated with indicators such as resiliency, short-term response, medium-to-long-term response, unintended consequences (e.g., frequency and criticality)

9. ***Resiliency:*** This indicator measures the capacity of the adaptation option to recover from climate change related stress such as drought, dry spell or flood. The measures must not be susceptible to irreversible damage from climatic change. Research scientists, engineers and agricultural officers are generally technically capable to provide accurate information on the rate of recovery of adaptation practices
10. ***Short-term responses:*** This measures the effectiveness of the adaptation option in the short-run. It pertains to the adaptive capacity of the measure within a given production season. To be considered for selection, the proposed measure (e.g. improved crop varieties, irrigation and agroforestry) should have the ability to adjust and respond successfully to the effects of climate

change. The presence of adaptive capacity has been shown to be a necessary condition for the design and implementation of effective adaptation strategies so as to reduce the likelihood and the magnitude of harmful outcomes resulting from climate change [27]. To be considered for selection, proposed adaptation measures such as improved crop varieties, irrigation and agroforestry should have the ability to adjust and respond successfully to the effects of climatic change.

11. ***Medium-to-long term response:*** Making informed decision on adaptation choices also require information on reproducibility of the available adaptation options. Also, for purposes of sustainability, farmers need to know if the resources and material for the identified adaptation practices are reproducible locally and in different context. Water harvesting technologies and improved crop varieties need to be reproducible. For purposes of sustainability, farmers need to know if the resources and material for the identified adaptation practices are reproducible locally and in different context. Water harvesting technologies and improved crop varieties need to be reproducible.
12. ***Unintended consequences:*** The development and implementation of new and improved technology could result in unintended consequences on the society and agro-ecological system thereby affecting effectiveness and sustainability. For instance, it is known that introducing irrigation to arid locations leads to an increase in malaria risk. The original thought was that malaria risk subsided rather quickly as families improved thanks to better farming conditions. Therefore, in taking decision on which adaptation strategy to implement, farmers need to know about the presence of any adverse effects and the frequency and criticality of such consequences.

E. Effectiveness of adaptation practices with respect society is assessed by such as equity (w.r.t. current and future regenerations) and equality (w.r.t. vulnerable groups)

13. ***Equity:*** This indictor assesses issues of fairness and sustainability for current and future generations. The inter-generational equity and fairness indicator therefore describes the extent to which an adaptation strategy is likely to affect the opportunities, livelihoods and adaptation capacity of future generations. Thus, for adaptation option to be selected, stakeholders must be certain that it has no/or has minimal adverse effects on future generations.
14. ***Equality:*** This pertains to issues of usability by women and physically-challenged farmers. Studies have shown that the poor, the majority of whom are women living in developing countries, are disproportionately affected by climate change [28]. Yet, the FGDs revealed that

women turn to be left out during development, trial and implementation of improved technologies in agriculture. Thus, the design of afforestation and reforestation projects, development of irrigation infrastructure and improved varieties and implementation of farm and crop diversification strategies need to address the concerns of women farmers who are generally vulnerable and resource constrained. In particular, prioritizing the needs of vulnerable groups in both development and climate policy processes is critical [29]. Thus, in developing adaptation strategy such as irrigation, there is need to consider the special needs of the physically challenged farmers in the community.

15. ***Robustness:*** This indicator assesses the ability of the measure to cope with climate risk. For informed decision-making, it is important for farmers to know whether or not the adaptation practice has a proven track record.

7.5. The simulation process: Application of the indicators and the AHP decision support model

Required data is collected through a paired comparison questionnaire. The questionnaire is developed based on the hierarchy tree (Figure 7.2). Using a rating scale (Table 7.3), the pair-wise comparison process elicits qualitative judgments that show the strength of decision makers' preference in a specific comparison. The comparisons are then transformed into a set of numbers that denote the relative priority of indicators and alternatives in a consistent manner. For the purposes of this simulation, agricultural officers are requested to respond to several pairwise comparisons. The result of the survey questionnaire technique is then used as input for the AHP. Microsoft excel is used to analyze the data. In this study, the first task in the development of the AHP decision model is to determine the alternatives. The alternatives pertain to adaptation practices to drought conditions in agriculture. Six drought adaptation practices are analyzed in the model.

Alternative 1: Drought-tolerant varieties;
Alternative 2: Early maturing varieties
Alternative 3: Mixed farming;
Alternative 4: Irrigation
Alternative 5: Mulching/composting;
Alternative 6: Agroforestry

The second task is to develop the decision hierarchy tree. In AHP approach, every decision making subjects can be explained within a hierarchical structure. Thus, the prioritization of adaptation practices to drought in Lawra district is structured into a hierarchical form so that the problem will appear more systemic (Figure 7.2). The determination hierarchy is made up of four tiers; goal, components, indicators and alternative adaptation practices. The goal is to prioritize and select the most ideal adaptation practice to drought in agriculture. The components are feasibility and effectiveness. The indicators used comprise eight feasibility and nine effectiveness indicators. Definition of abbreviations is shown in Table 7.4.

Table 7.3 - Pair-wise comparison

Level of Importance	**Definition**	**Explanation**
1	Equal importance	Both criteria contribute equally to the level intermediately above
3	Moderate importance	Judgment slightly favors criteria *i* than criteria *j*
5	Strong importance	Judgment strongly favors element *i* than element *j*
7	Very strong importance	Criteria *i* is favored very strongly than criteria *j*
9	Extreme importance	There is evidence affirming that criteria *i* is favored than criteria *j*
2,4,6,8	Intermediate value between above scale values	Absolute judgment cannot be given and a compromise is required
Reciprocal	If criteria *i* has one of the above non-zeros numbers assigned on it when compared with criteria *j*, *j* has the reciprocal value when compared to *i*	Criteria *i* inverse each other with criteria *j*

Source: [11]

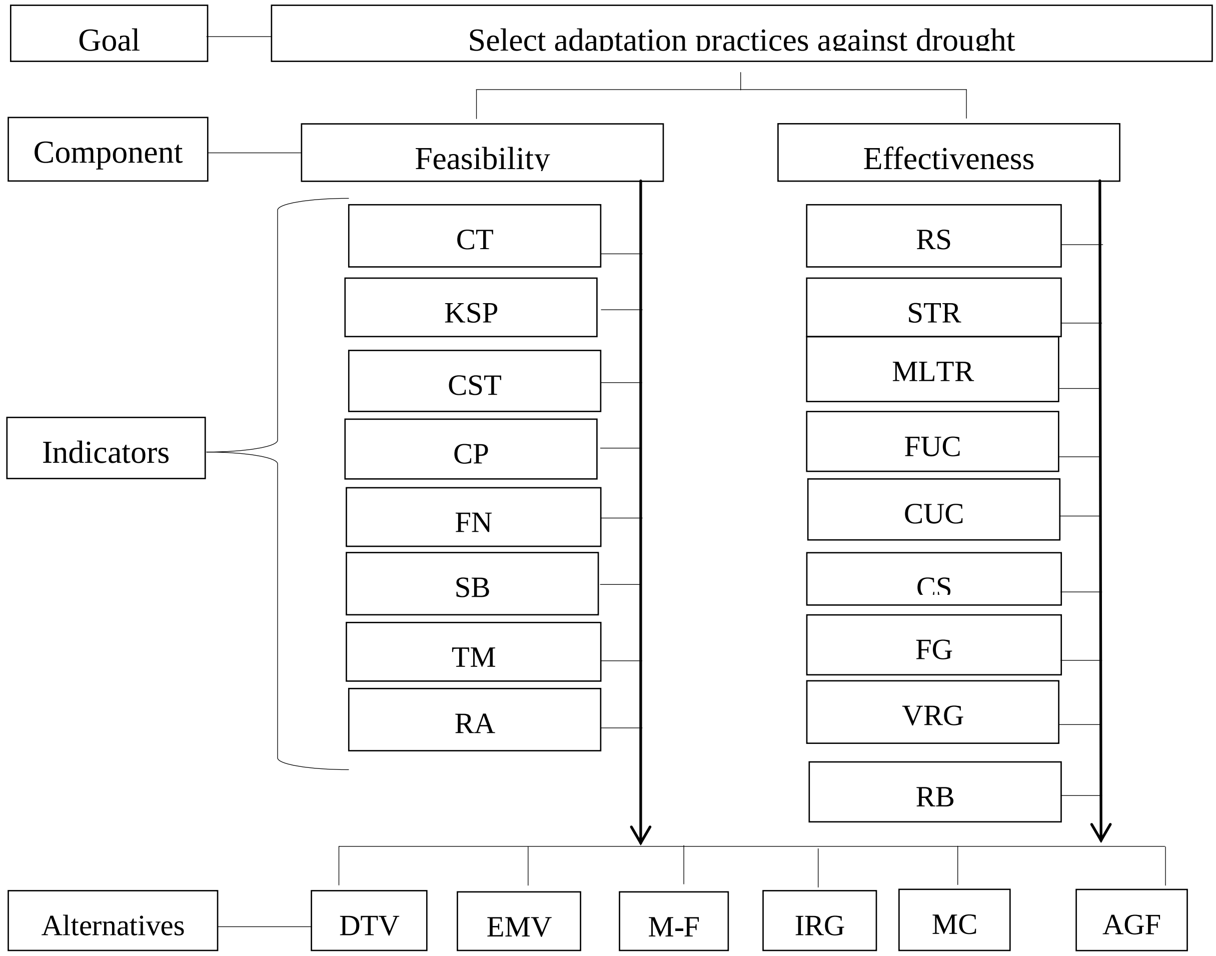


Figure 7.2 - Prioritization hierarchy tree of adaptation practices to drought (*Source: Author*)

Table 7.4 – Variables and abbreviations used (*Source: Author*)

No.	Variable	Abbreviation	No.	Variable	Abbreviation
1	Culture & tradition	CT	13	Criticality of unintended consequences	CUC
2	Knowledge, skills, & past experience	KPS	14	Current society	CS
3	Cost	CST	15	Future generation	FG
4	competence	CP	16	Vulnerable groups	VRG
5	Finance	FN	17	Robustness	RB
6	Scientific basis	SB	18	Drought-tolerant varieties	DTV
7	Timeliness	TM	19	Early maturing varieties	EMV
8	Resource availability	RA	20	Mixed farming	M-F
9	Resiliency	RS	21	Irrigation	IRG
10	Short-term response	STR	22	Mulching/composting	MC
11	Medium-long term response	MLTR	23	Agroforestry	AGF
12	Frequency of unintended consequences	FUC			

The third task is calculation of paired comparisons, weight coefficients of matrixes and consistency rate. Since the assessment is based on quality, a square matrix is formed corresponding to the number of components which are placed in rows and columns. Then, these options are compared with each other in a binary manner by respondents and numerically scored according to standardized table, and presented in the matrix columns. Data matrix, A, is generally positive and reverse; and its components are indicated by a_{ij}. So, considering the reversibility property of $a_{ij} = 1/a_{ij}$, simply the comparisons by a number of n(n-1)/2 times are needed in a matrix of n.n. On the other hand, when the assessment is based on quantity, the assessed components are measured by the same basis [30].

$$A = \begin{pmatrix} a_{11} & a_{12} & \cdots & a_{1j} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2j} & \cdots & a_{2n} \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots & a_{ij} & \cdots & \cdots \\ a_{m1} & a_{m2} & \cdots & a_{mj} & \cdots & a_{mn} \end{pmatrix} \quad (7.1)$$

Where; a_{ij} is the element of matrix A in the i^{th} row and the j^{th} column

To obtain the weighting factor (eigenvector) of matrix A above, three steps were used.

1. Multiplication of matrix A by using equation 1 below to obtain A^2

$$a_{ij}^2 = \sum_{k=1}^{n} a_{ik} . a_{kj} \quad (7.2)$$

Where; a_{ik} is the element of matrix A in the i^{th} row and the k^{th} column and a_{kj} is the element of matrix A in the k^{th} row and the j^{th} column.

2. Summation of elements of each row in matrix A^2 by using equation 2 below to obtain matrix B

$$b_i = \sum_{j=1}^{n} a_{ij} = a_{i1} + a_{i2} + \cdots + a_{ij} + \cdots + a_{nj} \quad (7.3)$$

Where b_i is the i^{th} elements in matrix B which is expressed as:

$$B = \begin{pmatrix} b_1 \\ b_2 \\ \cdots \\ b_j \\ \cdots \\ b_m \end{pmatrix} \quad (7.4)$$

By adding up all the elements in matrix *B*, equation 3 is obtained

$$\sum_{i=1}^{n} b_i = b_1 + b_2 + \cdots + b_n \tag{7.5}$$

3. To obtain the eigenvector of matrix *B*, the results from equation 3 are further nominalized to obtain matrix *C* by using equation 4.

$$C = \begin{pmatrix} b_1 / \sum_{i=1}^{n} b_i \\ b_2 / \sum_{i=1}^{n} b_i \\ \cdots \\ b_j / \sum_{i=1}^{n} b_i \\ \cdots \\ b_m / \sum_{i=1}^{n} b_i \end{pmatrix} \tag{7.6}$$

The final stage involves the calculation of the consistency rate. Since the comparisons of indicators and alternatives were done in a paired series by decision makers, inconsistency will generally occur. Therefore, studies have recommended the use of consistency index (CI) and consistency ration (CR) to check for the consistency associated with the comparison matrix [31]. A matrix is assumed to be consistent if and only if $a_{ij}=a_{kj}.a_{ik}$ (with i, j, k=1,2,3…n). If all components of matrix *A* are consistent, then

$$a_{ij} = \frac{W_i}{W_J} \tag{7.7}$$

Finally, the consistency ratio (CR) is determined:

$$CR = \frac{\text{CI}}{\text{RI}} \tag{7.8}$$

Where CI is consistency index and RI is the random index which represents average consistency index over a number of random entries of same order reciprocal matrices shown in Table 7.5. CR is acceptable if it is not greater than 0.10. If it is greater than 0.10, the judgment matrix will be considered inconsistent. To rectify an inconsistent judgment matrix, the judgments of decision-makers must be reviewed.

Table.7.5 - Reference values of RI (Alonso and Lamata's values)

N		3	4	5	6	7	8	9	10
RI	100000	0.5245	0.8815	1.1086	1.2479	1.3417	1.4056	1.4499	1.4854

7.6. Findings and discussion

The results of pair-wise comparison by experts on the components and indicators are shown in Table 7.6. Feasibility component has the highest weight of 0.667 while the effectiveness component has a weight value of 0.333. Four indicators in the feasibility component (i.e., culture and tradition; knowledge, skills and past experience; cost; and competence) obtained the highest weight. In effectiveness component, resiliency, short-term response, medium-to-long term response and unintended consequences obtained the highest weight. These results are in line with previous research findings that suggest that values, perceptions and customs, traditions affect the capability of communities to adapt to risks related to climate change [32]. Other studies have highlighted cost as a determinant of adaptation [33].

Table 7.6 – Estimated value of components and indicators (*Source: Autho*r)

Component	**Estimated value**	**Indicators**	**Estimated value**
Feasibility	0.667	Culture & tradition	0.390
		Knowledge, skills, & past experience	0.227
		Cost	0.124
		competence	0.098
		Finance	0.048
		Scientific basis	0.031
		Timeliness	0.048
		Resource availability	0.035
Effectiveness	0.333	Resiliency	0.423
		Short-term response	0.218
		Robustness	0.126
		Current society	0.067
		Criticality of unintended consequences	0.046

Frequency of unintended consequences	0.034
Future generation	0.029
Vulnerable group	0.029
Medium-long term response	0.390

The results of prioritization of alternative adaptation practices to drought are presented in Table 7.7. Irrigation and drought-tolerant varieties are observed to be most feasible and effective (i.e., 7.02 and 6.88, respectively). Early maturing varieties and mixed farming are ranked lowest in the priority set up (i.e., 5.54 and 4.85, respectively). The outcome of the results and discussions in this chapter is expected to improve farmers' capacity to adapt to climate change through effective and efficient decision making.

Table 7.7 – Estimated weights of alternative adaptation practices (*Source: Author*)

Indicators/alternative practices	DTV	EMV	M-F	IRG	MC	AGF
Culture & tradition compatibility	1.56	1.17	0.78	1.17	1.17	1.17
Knowledge, skills, & past experience	0.91	0.68	0.68	0.91	0.68	0.45
Cost to famer	0.37	0.25	0.25	0.50	0.25	0.50
Competence of field officer	0.39	0.39	0.29	0.29	0.39	0.20
Finance to develop	0.10	0.10	0.10	0.19	0.10	0.10
Scientific basis	0.12	0.00	0.00	0.00	0.00	0.00
Timeliness	0.14	0.19	0.14	0.14	0.14	0.14
Resource availability	0.14	0.10	0.10	0.10	0.10	0.07
Resiliency to climate shock	1.69	1.27	1.27	1.69	1.27	1.27
Short-term response	0.44	0.44	0.44	0.87	0.65	0.65
Medium-long term response	0.38	0.25	0.25	0.50	0.38	0.50
Frequency of unintended consequences	0.13	0.20	0.20	0.13	0.20	0.20
Criticality of unintended consequences	0.09	0.14	0.14	0.09	0.00	0.14
Impact on current society	0.10	0.10	0.07	0.10	0.07	0.10
Impact on future generation	0.11	0.09	0.00	0.11	0.09	0.11
Vulnerable group	0.09	0.09	0.06	0.09	0.06	0.06
Robustness	0.11	0.09	0.09	0.11	0.09	0.09
TOTAL	**6.88**	**5.54**	**4.85**	**7.02**	**5.63**	**5.75**

Drought-tolerant varieties =DTV; Early maturing varieties=EMV; Mixed farming=M-F; Mulching and composting=MC; Irrigation=IRG; Agroforestry=AGF

***References*:**

1. Etwire, P.M. Adaptation responses of smallholder farmers to climate change and variability in Northern Ghana. Assessing the adaptation mechanisms of smallholder farmers to climate change and agrobiodiversity losses in Northern Ghana. Global change systems for analysis, Research and Training, START, **2012**, 67-212
2. Ministry of Food and Agriculture (MoFA). Food and Agriculture Sector Development Policy (FASDEP II), Accra, Ghana, **2007**, 70pp.
3. Boyd, H.; Charles, A. Creating community-based indicators to monitor sustainability of local fisheries. *Ocean & Coastal Management*, **2006**, 49(5-6) 237-258.
4. WCED. Our common future. World conference on environment and development. Oxford: Oxford University Press; **1987**. p. 43.
5. Hyman, E.L. The uses, validity, and reliability of perceived environmental quality indicators. *Social Indicators Research*, **1980**, 9:85-110 0303-8300/81/0091-0085
6. Braunschweig, T. Priority Setting in Agricultural Biotechnology Research, ISNAR. **2000.**
7. Contant, R.B.; Bottomley, A. Priority Setting in Agricultural Research. Working Paper No. 10. **1988**. The Hague: International Service for National Agricultural Research.
8. McGalla, A.F.; Ryan, J.G. Setting Agricultural Research Priorities: Lessons from the CGIAR Study. *American Journal of Agricultural Economics* **1992,** 74 (5): 1095-100.
9. Collion, M-H.; Gregory, P. Priority Setting at CIP: An Indicative Framework for Resource Allocation. International Potato Center (CIP) and International Service for National Agricultural Research (ISNAR), **1993**.
10. Franzel, S.; Jaenicke, H.; Janssen, W. Choosing the Right Tree: Setting Priorities for Multipurpose Tree Improvement. Research Report No.8. **1996**. The Hague: International Service for National Agricultural Research.
11. Saaty, T.L. The Analytic Hierarchy Process. **1980**. New York, McGraw – Hill.
12. Ferrari, P. A method for choosing from among alternative transportation projects. *European Journal of Operational Research* **2003**, 150: 194-203.
13. Ramanathan, R; Ganesh, L.S. Energy resource allocation incorporating qualitative and quantitative criteria: an integrated model using goal programming and AHP. *Socio-Econ. Plann. Sci.* **1995**, 29 (3): 197-218.
14. Bose, R.K.; Anandalingam, G. Sustainable urban energy-environment management with multiple objectives. *Energy* **1996**, 21 (4): 305-318.
15. .Kagazyo, T.; Kaneko, K.; Akai, M.; Hijikata, K. Methodology and evaluation of priorities for

energy and environmental research projects. *Energy* **1997**, 22 (2/3): 121-129.

16. Kablan, M. Prioritization of decentralized electricity options available for rural areas in Jordan. *Energy Convers. Manage.* **1997**, 38 (14): 1515-1521.
17. Chedid, R.; Akiki, H.; Rahman, S. Decision support technique for the design of hybrid solar-wind power systems. IEEE Trans. *Energy Convers*. **1998**, 13 (1): 76-83.
18. Poh, K.L.; Ang, B.W. Transportation fuels and policy for Singapore: an AHP planning approach. *Comput. Ind. Eng*. **1999**, 37: 507-525.
19. Ayag, Z.; Ozdemir, R.G. A fuzzy AHP approach to evaluating machine tool alternatives. *Journal of Intell Manuf.* **2006**, 17: 179-190.
20. Herkert, J. R.; Farrell, A.; Winebrake, J.J. Technology choice for sustainable development. *IEEE Technol. Soc. Mag.* **1996**, 15 (2): 12-20.
21. Alphonce, C.B. Application of the analytic hierarchy process in agriculture of developing countries. *Agricultural System* **1997**, 53(1): 97-112.
22. Pažek K.; Rozman Č., application of analytical hierarchy process in agriculture. Izvorni znanstveni članak **2003**, UDK = 631
23. Food and Agriculture Organization of the United Nations. FAO technical guidelines for responsible fisheries No. 8. **1999**. Indicators for sustainable development of marine capture fisheries. FAO, Rome.
24. Garcia, M.; Staples, J.; Chesson, J. The FAO guidelines for the development and use of indicators for sustainable development of marine capture fisheries and an Australian example of their application. *Ocean & Coastal Management* **2000**, 43(7), 537-556.
25. UNESCO. A handbook for measuring the progress and outcomes of integrated coastal and ocean management. IOC Manuals and Guides, 46; ICAM Dossier, 2. **2006**. Paris.
26. Aubert, B.A.; Schroeder, A.; Grimaudo, J. IT as enabler of sustainable farming: An empirical analysis of farmers' adoption decision of precision agriculture technology. *Decis Support Syst* **2012**, 54:510–20.
27. Brooks, N.; Adger, W.N. Assessing and enhancing adaptive capacity. In B. Lim and E. Spanger-Siegfried (Eds.) Adaptation Policy Frameworks for Climate Change: Developing Strategies, Policies and Measures **2005**, pp 165-181. UNDP-GEF. Cambridge University Press.
28. Aguilar, L. Women and climate change: Vulnerabilities and adaptive capacities. Climate Connections. State of The World 2009 report, **2009**. World Watch Institute
29. Eriksen, S.; Aldunce, P.;, Bahinipati, C.S.; Martins, R.D.; Molefe, J.S.; Nhemachena, C.; O'Brien, K.; Olorunfemi, F.; Park, J.; Sygna, L.; Ulsrud, K. When not every response to climate change is

a good one: Identifying principles for sustainable adaptation. *Climate And Development* **2011**, 3: 7–20 doi:10.3763/cdev.2010.0060

30. Mortazavi, M.; Ghanbari, L.; Rajabbeigi, M.; Mokhtari, H. Prioritizing agricultural research projects with emphasis on analytic hierarchy process (AHP). EFITA conference **2009**, 31-39
31. Saaty, T. L. How to Make a Decision: The Analytic Hierarchy Process. *European Journal of Operational Research* **1990**, 48, 9-26.
32. IPCC (Intergovernmental Panel on Climate Change). Climate change 2007: impacts, adaptation and vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change,M. L. Parry, O. F. Canziani, J.P. Palutikof, P. J. van der Linden and C. E. Hanson (eds). Cambridge University Press, Cambridge, UK. **2007,** 976 p.
33. Nhemachena, C.; Hassan, R. Micro-Level Analysis of Farmers' Adaptation to Climate Change in Southern Africa. Available online: http://cdm15738.contentdm.oclc.org/utils/getfile/collection/p15738coll2/id/39726/filename/39727.pdf (accessed on 23 May 2015).

CHAPTER 8: CONCLUSION AND RECOMMENDATION

Generally, farmers are aware of climate change. Majority of them have perceived a long-term decrease in precipitation and increase in temperature. The rate of occurrence of dry spell and drought is higher than flood in Lawra district. Farmers believe that the causes of climate change are mostly centered on human factors (i.e., deforestation and bushfires) and gods and ancestral curses. Farmers in the district generally classify climate change effects in terms of crop performance, socio-economy, environment and psychology.

Empirically, the district has experienced moderate inter-annual and seasonal rainfall variability over the past thirty-three years. Generally, the inter-annual rainfall distribution has been irregular. Seasonal rainfall variability has a negative influence on annual production volumes of sorghum, millet and groundnut. Also, there is high seasonal variability of production volume of the crops investigated. This is due to the observed irregular seasonal rainfall variability. Sorghum and millet exhibit the highest variability because their cultivation period is of longer duration (June to December). It is also observed that under any given agricultural production season, two types of extreme climate conditions may occur in Lawra district; (1) less than median rainfall in the month of June (2) more than median rainfall in the month of August. This implies that, while drought or dry spell may occur in June, floods could occur in August.

Farmers are also aware of the different climate risk phenomena and impacts on their livelihoods. Resource-poor farmers are concerned about climate risk on agricultural production, while resource-moderate and resource-rich farmers are concerned about risk impacts on climatic variables, and health and socio-economy, respectively. Climate risk impacts are generally perceived in terms of agricultural production, biodiversity and forestry, health and socio-economy, and climatic variables. The significant predictors of farmers’ climate risk perception are age, education, perceived increase in droughts, dry spell, floods, pests and disease, cost of production, worsening harmattan, temperature, perceived decrease in forest area, birds and animal species, plant and forest species, soil fertility, and perceived severity of consequences on human diseases and mortality, and food security and incomes.

Farmers in Lawra district are already adjusting their farming activities in response to droughts, dry spells, and floods. Increased access to agricultural extension officers in certain parts of the district has impacted positively on farmers’ use of adaptation options. Generally, adaptation is used in response dry spell and drought. However, other farmers use adaptation as a means to improve soil fertility and crop production. Farmers classify climate change adaptation options in terms of crop production improvement, soil management, irrigation and water conservation and environmental improvement practices. Farmers' perceived most important adaptation practices are different from the practices being implemented. The most critical constraints to use of most preferred adaptation options include unpredictability of weather, high farm input cost, lack of access to timely weather information and limited access to water resources. The factors influencing farmers' adaptation to climate change are education, household size, household income, access to information, access to credit, access to markets and membership to FBOs.

The proposed approach for evaluation of the adaptation practices is based on relevant indicators derived through focus group discussions, literature review and face-to-face interviews with key experts. The indicators are developed based on a six-step process (i.e., identifying stakeholders, setting the goal, setting the components, developing the indicators, setting alternative practices, and calculating, integrating results and making a decision). A total of seventeen indicators are developed and classified into two broad components (i.e. feasibility and effectiveness). The components and indicators are ranked for easy prioritization and application. It is expected that at each pre-season planning stage, various adaptation practices to a predicted climate event (i.e., dry spell, drought or flood) are identified and prioritized based on the components and indicators. Since earlier findings in this study suggested a high rate of occurrence of drought and dry spell in Lawra district, the developed indicators are applied to evaluate and select the most feasible and effective adaptation practices to drought. The AHP decision support model is applied. The simulation results of AHP show that the feasibility component has higher weight than the effectiveness component. The results of prioritization of alternative adaptation practices to drought show that irrigation and drought-tolerant are most feasible and effective. Irrigation and agroforestry are ranked lowest in the priority set up.

8.2 Recommendations

Findings of the study clearly point to the need for government to boost the capacity of research scientists and agricultural staff to develop and promote appropriate and effective adaptation practices to help farmers adapt to extreme climatic events. Agriculture staff on the other hand should educate farmers on the improved and/or modern technologies and practices to climate change. As a long term measure, government, policy makers and NGOs should develop irrigation facilities and water harvesting technologies. More specifically, there is the need for construction of dams and dug-outs so that farmers can undertake dry season gardening and irrigation farming. In the case of floods, medium-to-long term measures are required. Government and policy makers should design and implement effective drainage systems. Farmers on the other hand should shift their crop production activities to less flood-prone arable lands. Also, the perception that climate change is caused by traditional gods and ancestral curses implies that scientists and development experts should consider cultural and traditional beliefs of farmers when designing adaptation practices. As such, a bottom-up approach must be used to ensure that farmers' beliefs and understanding are a crucial part of the design and dissemination of adaptation practices.

In addition, it is essential for governments and policy makers to make climate risk communication and awareness an integral part of climate change policy. The risk impacts of climate change on human health, migration and other socio-economic factors need to be adequately identified and mainstream into climate risk communication policy. This will improve farmers' concern about, and ensure enhanced adaptation to climate change.

Furthermore, governments and development partners should mainstream the determining factors of adaptation and barriers to adaptation into climate change related policies, projects and programmes. The Ghana Meteorological Agency should be adequately trained and resourced to collect and disseminate accurate and timely weather information. Additionally, government should ensure that flexible terms of agricultural credits are made accessible to farmers so that they can meet the financial demands of adaptation.

Farmers and field officers need to further understand and apply the proposed model at every pre-season planning stage to select the most feasible and effective adaptation option based on their individual situations. Empirical results of the adaptation practices prioritization and selection model should guide government, researchers and agricultural field officers to develop and promote practices that are deemed most feasible and effective based on the indicators.

In this study, the results of AHP are based on data from agricultural officer. However, since farmers are the key players in the implementation of adaptation alternatives, future studies should consider expert judgments from the farmers themselves.

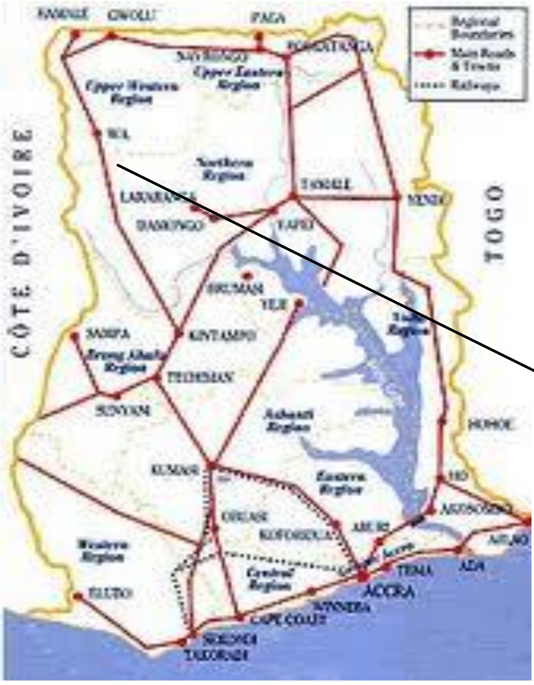
8.3 Further studies

The current study applies a static model to investigate the factors influencing adaptation to climatic change in agriculture. As such, the model, for example, does not explain how different wealth categories of farmers take decisions on adaptation. Therefore, to make it clearer on whether wealthier farmers or poorer farmers are more likely to adapt to climatic change, a dynamic model should be applied in future investigations.

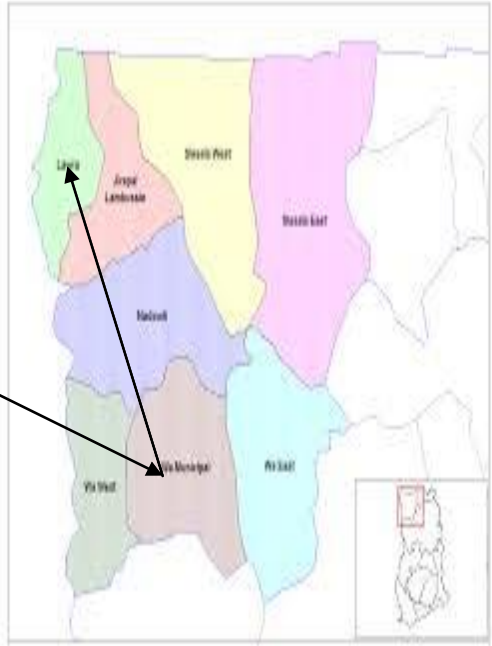
Additionally, the findings of the climate change risk perception assessment worth further investigation to identify how perceptions of the different wealth category of farmers are influenced by the various climate risk phenomena and impacts identified in this study. The outcome of such an investigation will further enhance the formulation appropriate climate risk communication models and policy to meet different target groups.

APPENDIX

APPENDIX 1: ROAD MAP AND TRAVEL DISTANCES



Map of Ghana



Map of Upper West Region

No.	From	To	Distance (km)
1.	Accra	Wa	712
2.	Wa	Lawra	85
3.	Wa	Brifo-cha	55
4.	Brifo-cha	Lawra	30
5.	Lawra	Kalsagri	20

APPENDIX 2: FIELD SURVEY QUESTIONNAIRES

A. Summary of questionnaire used to elicit data on farmers' perceptions about climate change and adaptation.

Name of respondent……………………Questionnaire Number…………

Part I: Basic information

1. Age: (1) 15 – 34 (2) 35 – 54 (3) 55 and above

2. Sex: (0) Male (1) Female

3. Marital status: (0) Married (1) Single

4. Educational status: (1) Literate (0) Illiterate

5. Years of experience in farming: (1) less than 10 years (2) 10-25 year (2) More than 25 years

6. Secondary occupation (Main): (0) None (1) Livestock (2) business/trade (3) rural artisan

Part II: Household information

1. Size of farm (acres)
2. Number of members in household
3. Number of household members who work on the farm
4. Average number of man- days on the farm
5. Main source of household income: (1) Agriculture (0) Others
6. What is the total amount of annual income from farm? (Gh Cedis)
7. Secondary sources of household income: (0) None (1) Livestock (2) business/trade (3) rural artisan (4) remittances
8. What is the total amount of annual off-farm income? (Gh Cedis)

Part III: Experiences about patterns and effects of climate change

1. What is the pattern of rainfall over the past 10 years: (0) decreasing (1) increasing (2) stable
2. In a particular season, how long do the rains last: (1) 3-4 months (2) less than 3-months (3) more than 4-months
3. Do you normally experience drought during the production season? (1) Yes (0) No

If YES, which month?

4. Do you normally experience flood during the production season? (1) Yes (0) No
   If YES, which month?
5. Do you normally experience dry spell during the production season? (1) Yes (0) No
   If YES, which month and for how many days?
6. What is the pattern of temperature over the past 10 years? (0) decreasing (1) increasing (2) stable

Part IV: Effects of prevailing rainfall and temperature patterns

1. Do the prevailing rainfall and temperature patterns affect crop production? (1)Yes(0)No
   If YES, how?
2. Do the prevailing rainfall and temperature patterns affect the environment? (1)Yes(0) No. If YES, how?
3. Do the prevailing rainfall and temperature patterns affect you psychologically? (1)Yes (0) No. If yes, how?
4. Do the prevailing rainfall and temperature patterns affect the socio-economy? (1)Yes (0) No. If YES, how?

Part V: Access to weather information, markets, extension services and pre-season planning

1. Do you get information on rainfall and other weather events? (1) Yes (0) No
   If yes, from where? (1) Meteorological staff (2) Agric. Extension officer (3) Radio/ television
2. Do you have access to market for your farm produce? (1) Yes (0) No
3. Do you have ready access to agricultural loans/credit facilities? (1) Yes (0) No
4. Do you have access to agricultural subsidies? (1) Yes (0) No
5. Do you have access to Agric. Extension officers? (1) Yes (0) No
   If yes, how many visits per month? (0) 4 (1) Less than 4 (2) More than 4
6. Do you share farming and weather information with colleague farmers? (1) Yes (0) No
7. Do you have collaborative pre-season planning meetings with colleague farmers?
   (1) Yes (0)No
8. Do you have collaborative pre-season planning meetings with Agric. Staff, NGOs, Meteorological agency, research scientists, EPA, local government, etc? (1) Yes (0) No

9. Do you belong to any farmer-based organization? (1) Yes (0) No. If NO,why?
10. Following from question 10, if YES, how many meetings do you hold in a month?
11. Do you normally experience pest outbreak in the production season? (1) Yes (0) No

Part VI: Adaptation to climate change

1. Do you adopt any strategies or measures to reduce the effects climate change on your farming activities? (1) Yes (0) No

If yes, where do get the modern strategies or measures from? (0) Colleague farmers (1) Agriculture officer (2) NGO (3) Others

3. Preference of adaptation practices; (1) highly (2) moderately (3) Less (4) Not at all

Adaptation practices	**Response**
Improved crop varieties	
Irrigation	
Crop diversification	
Farm diversification	
Change of planting date	
Income generating activities	
Agroforestry practice	
Improved crop varieties	

4. Actual adaptation practices being used (1) Yes (2) No

Adaptation practices	**Response**	**Specific practices**
Improved crop varieties		
Irrigation		
Crop diversification		
Farm diversification		
Change of planting date		
Income generating activities		
Agroforestry practice		

Improved crop varieties		

5. Which of the following is your main reason for using adaptation strategies to climate change? (1) Reduce effects of drought (2) Reduce effects of floods (3) Reduce effects of dry spell (4) Increase production (5)

B. <u>Summary of questionnaire used for assessment of climate risk perception among farmers</u>

Part II: Climate risk perception

1. Do you think some forms of risks exist due to climate change? (1) Yes (2) No
2. What is the level of your climate risk perception? (3) High (2) Moderate (1) Low (0) No
3. Do you think climate risk on agriculture will increase? (1) Yes (2) No

Part III: Determinants of climate risk perception.

4. How do the factors in Table 1 below influence your risk perception about climate change?

Table 1: Fill the right-column with the appropriate number ---- (3) High (2) Moderate (1) Low (0) Not at all

No.	Factors	Response
1	Decrease soil fertility	
2	High cost of production	
3	Increase pest and disease attack	
4	Decrease crop yield	
5	Early drying up of dams and dug-out in off-season	
6	Decrease in area under crop cultivation	
7	Decrease in forest area	
8	Increase desertification	
9	Decrease in number of certain plant and tree species	
10	Extinction of certain bird and animal species	
12	Increase in human disease infection and mortality	
14	Increase in poverty	
15	Increase in out-migration	
16	Decrease in household food security and incomes	
17	Increase belief in God or ancestral spirits	
18	Increased temperatures	
	Ability to control risk	
19	Increased drought, dry spell and flood	

20	Increased rainfall variability	
21	Increased severity of hamattan winds	

5. What is the level of your climate risk perceptions regarding the following variables in Table 2 below

Table 3: Fill the right-column with the appropriate number ---- (3) High (2) Moderate (1) Less (0) Not at all

No.	Variables	Response
1	Agriculture	
2	Biodiversity and forestry	
3	Human health, cultural and socio-economic	
4	Climatic variables	

C. Summary of questionnaire used for developing indicators to assess adaptation practices to climate change

Main objective: To develop a set of indicators that can evaluate feasibility and effectiveness of adaptation practices to climate change in agriculture at the pre-season planning stage.

1. In Table 1 below, please indicate if the sub-indicators aptly describe the corresponding key indicators and hence, can measure the main components. Kindly fill in the right column using (1) if you AGREE or (0) if you DON'T AGREE.

Components	**Players**	**Key indicators**	**Sub-indicators**	Response
Feasibility	Farmer	Culture & tradition	Communal or group adaptability	
		Knowledge, skills, & past experience	Individual adaptability	
			Individual maintenance ability	
		Cost	Individual affordability	
			Labor availability	
	Institutions	Competence	Technical ability of non-farmers	
		Finance	Economic ability of non-farmers	
		Scientific basis	Weather information availability and accuracy	

		Timeliness	Timely provision and assistance by non-farmers	
	Nature	Land	Land availability	
		Water	Water resource availability	
		Soil	Nature of soil	
Effectiveness	Farmer	Resiliency	Recovery from climatic shocks:	
		Short-term response	Short term effectiveness	
		Medium-long term response	Medium-long term effectiveness	
		Frequency of unintended consequences	Unintended consequences	
		Criticality of unintended consequences	Unintended consequences	
	Society	Current society	Equity	
		Future generation	Equity	
		Vulnerable group	Equality	
	Nature	Robustness	Coping ability	

2. Using the scores in Table 2 below, kindly complete the pairwise comparisons of the indicators in Tables 3 & 4

Level of Importance	Definition	Explanation
1	*Equal importance*	Both criteria contribute equally to the level intermediately above
3	*Moderate importance*	Judgment slightly favors criteria *i* than criteria *j*
5	*Strong importance*	Judgment strongly favors element *i* than element *j*
7	*Very strong importance*	Criteria *i* is favored very strongly than criteria *j*
9	*Extreme importance*	There is evidence affirming that criteria *i* is favored than criteria *j*
Reciprocal	If criteria *i* has one of the above non-zeros numbers assigned on it when compared with criteria *j*, *j* has the reciprocal value when compared to *i*	Criteria *i* inverse each other with criteria *j*

Table 3: Pairwise comparison of indicators for measuring feasibility of adaptation practices to climate change

Feasibility Indicators		Code	Same indicators in left column							
			A	B	C	D	E	F	G	H
Feasibility of adaptation practice in the context of farmers	Culture & tradition	A								
	Knowledge, skills, & past experience	B								
	Cost	C								
Feasibility of adaptation practice in the context scientists, engineers, AEAs, government	Competence	D								
	Finance	E								
	Scientific basis	F								
	Timeliness	G								
Feasibility of adaptation practice in the context nature	Land, water and soil	H								

Others: Kindly suggest any other indicators needed to determine the feasibility of adaptation practices to climate change in a farmer's pre-season planning stage

Table 4: Pairwise comparison of indicators for measuring effectiveness of adaptation practices to climate change

Effectiveness indicators		Code	Same indicators in left column								
			A	B	C	D	E	F	G	H	I
Effectiveness of adaptation practice in the context of farmers	Resiliency	A									
	Short-term response	B									
	Medium-long term response	C									
	Frequency of unintended consequences	D									
	Criticality of unintended consequences	E									
Effectiveness of adaptation practice in the context of society	Current society	F									
	Future generation	G									
	Vulnerable group	H									
Effectiveness of adaptation practice in the context nature	Robustness	I									

Others: Kindly suggest any other indicators needed to determine the effectiveness of adaptation practices to climate change in a farmer's pre-season planning stage.

Comments: Freely comment on suitability or otherwise of any of the indicators in Tables 2 and 3

Thank you for your kind co-operation

APPENDIX 3: FIELD SURVEY PHOTOS

Meeting with the District Chief Executive and Administrative director, Lawra district

Meeting with Mr. Shaibu, Savannah Agriculture Research Institute, Wa

Meeting with the Regional Director and staff of MOFA, Wa

Training of agricultural field officers on field questionnaires, Lawra

Focus group discussions with community members and questionnaire administration

Field observations

Dry season gardening

APPENDIX 4: SIMULATION RESULTS OF PROPOSED EVALUATION MODEL

4.1 Steps in calculating priority weights of the AHP model using Microsoft Excel

1. Create Matrix *A* using expert judgments
2. Create Matrix *B* by squaring Matrix *A* (This involves the algebra)
3. Create Matrix *C* by squaring Matrix *B*
   Continue creating the Matrices in this form until the 'normalized eigenvalues do not change

Hint:

To create a Matrix, taking note that Matrix *B* is Matrix *A* squared,

1. Highlight the area where the 'data values' of Matrix *B* should be.
2. Enter "=MMULT(G6:N13,G6:N13)" without the quotes in the top formula box above the worksheet.
3. Press SHIFT+CTRL+ENTER.
4. In a Matrix, 'Eigenvector' of row is the sum total of all the values in the cells of that row; SUM(D15:I15)
5. Normalized eigenvalue of a row is the eigenvector of that row divided by sum of the range of eigenvectors; J15/(SUM(J$15:J20)

4.2 Results of weights of indicators and adaptation alternatives using the AHP model

A. Calculation of weights of the feasibility indicators

Stage 1: Formation of matrix A using expert judgments

Matrix A: Pairwise comparison for feasibility indicators of adaptation practices

Feasibility Indicators		Code	Same indicators in left column							
			A	B	C	D	E	F	G	H
Feasibility of adaptation practice in the context of farmers	Culture & tradition	A	1	3	4	5	7	9	6	8
	Knowledge, skills, & past experience	B	1/3	1	3	3	5	7	4	6
	Cost	C	1/4	1/3	1	2	3	5	2	4
Feasibility of adaptation practice in the context scientists, engineers, AEAs, government	competence	D	1/5	1/3	1/2	1	3	5	2	3
	Finance	E	1/7	1/5	1/3	1/3	1	2	1	2
	Scientific basis	F	1/9	1/7	1/5	1/5	1/2	1	1	1
	Timeliness	G	1/6	1/4	1/2	1/2	1	1	1	1
Feasibility of adaptation practice in the context nature	Resource availability	H	1/8	1/6	1/4	1/3	1/2	1	1	1

Stage 2: Calculation of priorities

Matrix B: normalized eigenvector									Eigvec	Normalized
Culture & tradition	8.00	14.52	28.63	36.80	70.50	112.00	66.00	94.00	430.45	0.390
Knowledge, skills, & past experience	4.93	8.00	15.40	20.73	40.83	67.00	40.00	56.67	253.56	0.230
Cost	2.83	4.56	8.00	10.58	21.92	36.58	22.83	31.00	138.31	0.125
competence	2.33	3.75	6.55	8.00	16.57	27.63	18.53	24.60	107.96	0.098
Finance	1.14	1.92	3.40	4.21	8.00	13.02	8.99	11.68	52.37	0.047
Scientific basis	0.72	1.27	2.29	2.78	5.19	8.00	5.54	7.15	32.94	0.030
Timeliness	1.02	1.84	3.45	4.45	8.42	13.25	8.00	11.33	51.76	0.047
Resource availability	0.78	1.40	2.53	3.16	5.96	9.21	6.08	8.00	37.12	0.034
										1.000

Matrix C: normalized eigenvector									Eigvec	Normalized
Culture & tradition	604.67	1031.21	1885.08	2392.38	4655.16	7487.11	4798.51	6491.19	29345.3	0.390
Knowledge, skills, & past experience	350.93	599.72	1097.23	1391.56	2703.75	4343.38	2783.85	3765.99	17036.4	0.226
Cost	191.45	327.60	600.30	761.79	1478.62	2373.73	1518.96	2056.99	9309.4	0.124
competence	151.33	259.03	475.13	603.63	1171.85	1881.42	1201.31	1628.85	7372.5	0.098
Finance	74.90	128.01	234.73	298.40	580.13	932.41	594.94	807.04	3650.6	0.049
Scientific basis	47.96	81.83	150.00	190.79	371.36	597.47	381.12	517.06	2337.6	0.031
Timeliness	73.60	125.52	229.66	291.63	567.53	912.90	584.32	791.08	3576.2	0.048
Resource availability	53.60	91.45	167.52	212.95	414.45	666.77	425.84	577.32	2609.9	0.035
										1.000

Matrix D: normalized eigenvector									Eigvec	Normalized
Culture & tradition	2859282.9	4883721.4	8944804.6	11360992.0	22088304.2	35504476.7	22700711.3	30754679.6	139096972.8	0.390
Knowledge, skills, & past experience	1660866.3	2836802.8	5195762.7	6599247.6	12830392.7	20623397.9	13186112.8	17864399.1	80796982.0	0.227
Cost	907575.4	1550164.6	2839216.3	3606149.4	7011143.1	11269607.3	7205511.9	9761954.7	44151322.7	0.124
competence	718437.2	1227111.8	2247528.8	2854636.8	5550037.6	8921047.5	5703889.7	7727580.7	34950270.0	0.098
Finance	355520.5	607238.7	1112194.1	1412623.8	2746452.5	4414610.7	2822586.5	3824018.1	17295245.0	0.048
Scientific basis	227538.6	388641.6	711820.3	904100.2	1757772.2	2825421.7	1806499.5	2447432.2	11069226.2	0.031
Timeliness	348347.7	594986.1	1089750.5	1384116.7	2691031.7	4325532.2	2765638.3	3746859.8	16946262.9	0.048
Resource availability	254105.4	434018.3	794929.9	1009659.3	1963002.7	3155306.9	2017421.4	2733186.0	12361630.1	0.035
										1.000

- Eigenvalues in matrix *D* are pretty much the same as those in matrix *C*. So, it is reasonable to believe that any additional matrices won't create any eigenvalues substantially different from these.

- Priority values are the "normalized eigenvalues" in the last matrix of stages 2 on the last column in the right-side of Matrix *D*.

Stage 3: Calculation of consistency index (CI)

3. a. Weighted rating for each row

Row 1:	3.24
Row 2:	1.88
Row 3:	1.03
Row 4:	0.81
Row 5:	0.40
Row 6:	0.26
Row 7:	0.39
Row 8:	0.29

	Matrix A							
Code	A	B	C	D	E	F	G	H
A	1	3	4	5	7	9	6	8
B	1/3	1	3	3	5	7	4	6
C	1/4	1/3	1	2	3	5	2	4
D	1/5	1/3	1/2	1	3	5	2	3
E	1/7	1/5	1/3	1/3	1	2	1	2
F	1/9	1/7	1/5	1/5	1/2	1	1	1
G	1/6	1/4	1/2	1/2	1	1	1	1
H	1/8	1/6	1/4	1/3	1/2	1	1	1

3.b. Approximation of lambda (max)

Row 1:	8.297
Row 2:	8.297
Row 3:	8.297
Row 4:	8.297
Row 5:	8.297
Row 6:	8.297
Row 7:	8.297
Row 8:	8.297
Average	8.297

Each row produces an approximation of lambda (max), which should be close to *n* (*n*= total number of indicators in the comparison). In this case, *n* is 8 because there are 8 indicators are being compared. If any row lambda (max) is less than *n*, then, there may be a problem of inconsistent ratings in the pairwise comparison matrix (i.e., matrix A).

3.c. Calculate consistency index (CI)

CI = (Lambda (max) - n)/ (n-1), where *n* is the number of elements that are compared in matrix *A*

CI= 0.0424

RI= 1.4056 (Alonso and Lamata's value)

Stage :4 Calculation of consistency ratio (CR)

CR = 0.0302

CR is calculated as CI divided by RI, where RI is the average CI from random matrices. RI values may be difference across research studies. Here we use Alonso and Lamata's value (0.5245) for 3 elements in the pair-comparison matrix (i.e., matrix A).

CR > 0.10 indicates that there is a concern of inconsistency in pairwise comparison.

B. Calculation of weights of the effectiveness indicators

Matrix A:

Effectiveness indicators		Code	Same indicators in left column								
			A	B	C	D	E	F	G	H	I
Effectiveness of adaptation practice in the context of farmers	Resiliency	A	1	5	5	7	7	8	9	9	9
	Short-term response	B	1/5	1	3	5	5	6	7	7	7
	Robustness	C	1/5	1/3	1	3	3	4	5	5	5
	Current society	D	1/7	1/5	1/3	1	2	2	3	3	3
	Criticality of unintended consequences	E	1/7	1/5	1/3	1/2	1	1	2	2	2
Effectiveness of adaptation practice in the context of society	Freq. of unintended consequences	F	1/8	1/6	1/4	1/2	1	1	1	1	1
	Future generation	G	1/9	1/7	1/5	1/3	1/2	1	1	1	1
	Vulnerable group	H	1/9	1/7	1/5	1/3	1/2	1	1	1	1
Effectiveness of adaptation practice in the context nature	Medium-long term response	I	1/9	1/7	1/5	1/3	1/2	1	1	1	1

Matrix B: Calculation of priority (i.e., normalized eigenvector)										Eig vec	Normalize
Resiliency	9.00	19.66	37.07	70.50	89.50	114.00	139.00	139.00	139.00	617.72	0.424
Short-term response	5.51	9.00	16.03	32.90	46.90	61.60	75.80	75.80	75.80	323.55	0.222
Robustness	3.49	5.68	9.00	17.57	26.57	35.60	43.13	43.13	43.13	184.17	0.127
Current society	3.11	1.93	3.24	4.95	9.00	13.50	18.68	22.35	22.35	22.35	96.00
Criticality of unintended consequences	2.61	1.26	2.35	3.60	6.50	9.00	12.68	14.85	14.85	14.85	65.08
Frequency of unintended consequences	0.88	1.77	2.73	4.96	6.96	9.00	11.04	11.04	11.04	48.38	0.033
Future generation	0.76	1.53	2.31	4.18	5.76	7.71	9.00	9.00	9.00	40.24	0.028
Vulnerable group	0.76	1.53	2.31	4.18	5.76	7.71	9.00	9.00	9.00	40.24	0.028
Medium-long term response	0.76	1.53	2.31	4.18	5.76	7.71	9.00	9.00	9.00	40.24	0.028
											1.000

Matrix C										Eigvec	Normalize
Resiliency	983.1	1841.8	2927.9	5455.0	7664.0	10249.8	12256.7	12256.7	12256.7	53635.1	0.423
Short-term response	503.9	953.6	1518.0	2822.2	3945.8	5270.8	6298.7	6298.7	6298.7	27611.6	0.218
Robustness	290.7	550.8	880.0	1638.5	2286.9	3051.2	3648.5	3648.5	3648.5	15995.2	0.126
Current society	399.9	154.0	291.6	467.0	870.9	1215.3	1620.3	1938.8	1938.8	1938.8	8496.6
Criticality of unintended consequences	338.2	105.5	199.0	318.7	594.9	831.7	1109.1	1327.7	1327.7	1327.7	5814.3
Frequency of unintended consequences	78.5	147.7	236.2	441.0	617.2	823.8	985.9	985.9	985.9	4316.1	0.034
Future generation	65.8	123.7	198.2	370.2	518.1	691.3	827.7	827.7	827.7	3622.8	0.029
Vulnerable group	65.8	123.7	198.2	370.2	518.1	691.3	827.7	827.7	827.7	3622.8	0.029
Medium-long term response	65.8	123.7	198.2	370.2	518.1	691.3	827.7	827.7	827.7	3622.8	0.029
											1.000

Matrix D										Eig vec	Normalize
Resiliency	7619425.9	14357028.2	22948974.9	42801506.9	59879549.8	79920460.4	95624977.3	95624977.3	95624977.3	418776900.7	0.423
Short-term response	3925697.2	7397168.7	11823992.1	22052514.1	30851395.5	41176909.2	49268177.9	49268177.9	49268177.9	215764032.5	0.218
Robustness	2272764.2	4282571.4	6845502.7	12767325.9	17861394.3	23839302.6	28523749.2	28523749.2	28523749.2	124916359.4	0.126
Current society	7541005.9	1206498.0	2273403.9	3633950.7	6777577.9	9481772.2	12655148.2	15141910.5	15141910.5	15141910.5	66312171.8
Criticality of unintended consequences	6372702.9	825259.4	1555027.0	2485654.2	4635931.8	6485643.0	8656271.7	10357253.8	10357253.8	10357253.8	45358294.6
Frequency of unintended consequences	612637.4	1154381.8	1845234.8	3441502.4	4814652.0	6426034.4	7688768.7	7688768.7	7688768.7	33671980.1	0.034
Future generation	514046.9	968608.8	1548287.0	2887675.6	4039848.7	5391914.7	6451444.6	6451444.6	6451444.6	28253271.0	0.029
Vulnerable group	514046.9	968608.8	1548287.0	2887675.6	4039848.7	5391914.7	6451444.6	6451444.6	6451444.6	28253271.0	0.029
Medium-long term response	514046.9	968608.8	1548287.0	2887675.6	4039848.7	5391914.7	6451444.6	6451444.6	6451444.6	28253271.0	0.029
											1.000

- Eigenvalues in matrix *D* are pretty much the same as those in matrix *C*. So, it is reasonable to believe that any additional matrices won't create any eigenvalues substantially different from these.

Calculation of consistency index (CI)

a. Weighted rating for each row

Row 1:	3.98
Row 2:	2.05
Row 3:	1.19
Row 4:	0.63
Row 5:	0.43
Row 6:	0.32
Row 7:	0.27
Row 8:	0.27
Row 9:	0.27

Code	Same indicators in left column								
	A	B	C	D	E	F	G	H	I
A	1	5	5	7	7	8	9	9	9
B	1/5	1	3	5	5	6	7	7	7
C	1/5	1/3	1	3	3	4	5	5	5
D	1/7	1/5	1/3	1	2	2	3	3	3
E	1/7	1/5	1/3	1/2	1	1	2	2	2
F	1/8	1/6	1/4	1/2	1	1	1	1	1
G	1/9	1/7	1/5	1/3	1/2	1	1	1	1
H	1/9	1/7	1/5	1/3	1/2	1	1	1	1
I	1/9	1/7	1/5	1/3	1/2	1	1	1	1

b. Approximation of lambda (max)

Row 1:	9.399
Row 2:	9.399
Row 3:	9.399
Row 4:	9.399
Row 5:	9.399
Row 6:	9.399
Row 7:	9.399
Row 8:	9.399
Row 9:	9.399
Average	9.399

(3) Calculate consistency index (CI)

CI = (Lambda(max) - n)/ (n-1), where n is the number of elements that we compared in matrix *A*.

CI=0.04988
RI=1.4499 (Alonso and Lamata's value)

Calculation of consistency ratio (CR)
CR = 0.034

C. Results of priority weights of adaptation alternatives

C.1 Scoring data by agricultural officer

Indicators	DTV	EMV	M-F	IRG	MC	AGF
Culture & tradition compatibility	4	3	2	3	3	3
Knowledge, skills, & past experience	4	3	3	4	3	2
Cost to famer	3	2	2	4	2	4
Competence of field officer	4	4	3	3	4	2
Finance to develop	2	2	2	4	2	2
Scientific basis	4	0	0	0	0	0
Timeliness	3	4	3	3	3	3
Resource availability	4	3	3	3	3	2
Resiliency to climate shock	4	3	3	4	3	3
Short-term response	2	2	2	4	3	3
Medium-long term response	3	2	2	4	3	4
Frequency of unintended consequences	2	3	3	2	3	3
Criticality of unintended consequences	2	3	3	2	0	3
Impact on current society	3	3	2	3	2	3
Impact on future generation	4	3	0	4	3	4
Vulnerable group	3	3	2	3	2	2
Robustness	4	3	3	4	3	3

C.2 Calculating priorities by using the weights of indicators and scores of the adaptation alternatives

Indicators/alternative practices	Weights	DTV		EMV		M-F		IRG		MC		AGF	
		Score	Estimate	Score	Estimate	Score	Estimate	Score	Estimate	Score	Estimate	Score	Estimate
Culture & tradition compatibility	0.390	4	1.56	3	1.17	2	0.78	3	1.17	3	1.17	3	1.17
Knowledge, skills, & past experience	0.227	4	0.91	3	0.68	3	0.68	4	0.91	3	0.68	2	0.45
Cost to famer	0.124	3	0.37	2	0.25	2	0.25	4	0.50	2	0.25	4	0.50
Competence of field officer	0.098	4	0.39	4	0.39	3	0.29	3	0.29	4	0.39	2	0.20
Finance to develop	0.048	2	0.10	2	0.10	2	0.10	4	0.19	2	0.10	2	0.10
Scientific basis	0.031	4	0.12	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Timeliness	0.048	3	0.14	4	0.19	3	0.14	3	0.14	3	0.14	3	0.14
Resource availability	0.035	4	0.14	3	0.10	3	0.10	3	0.10	3	0.10	2	0.07
Resiliency to climate shock	0.423	4	1.69	3	1.27	3	1.27	4	1.69	3	1.27	3	1.27
Short-term response	0.218	2	0.44	2	0.44	2	0.44	4	0.87	3	0.65	3	0.65
Medium-long term response	0.126	3	0.38	2	0.25	2	0.25	4	0.50	3	0.38	4	0.50
Frequency of unintended consequences	0.067	2	0.13	3	0.20	3	0.20	2	0.13	3	0.20	3	0.20
Criticality of unintended consequences	0.046	2	0.09	3	0.14	3	0.14	2	0.09	0	0.00	3	0.14
Impact on current society	0.034	3	0.10	3	0.10	2	0.07	3	0.10	2	0.07	3	0.10
Impact on future generation	0.029	4	0.11	3	0.09	0	0.00	4	0.11	3	0.09	4	0.11
Vulnerable group	0.029	3	0.09	3	0.09	2	0.06	3	0.09	2	0.06	2	0.06
Robustness	0.029	4	0.11	3	0.09	3	0.09	4	0.11	3	0.09	3	0.09
	TOTAL	**55**	**6.88**	**46**	**5.54**	**38**	**4.85**	**54**	**7.02**	**42**	**5.63**	**46**	**5.75**

C.3 – Estimated priorities of adaptation alternatives

Indicators/alternative practices	DTV	EMV	M-F	IRG	MC	AGF
Culture & tradition compatibility	1.56	1.17	0.78	1.17	1.17	1.17
Knowledge, skills, & past experience	0.91	0.68	0.68	0.91	0.68	0.45
Cost to famer	0.37	0.25	0.25	0.50	0.25	0.50
Competence of field officer	0.39	0.39	0.29	0.29	0.39	0.20
Finance to develop	0.10	0.10	0.10	0.19	0.10	0.10
Scientific basis	0.12	0.00	0.00	0.00	0.00	0.00
Timeliness	0.14	0.19	0.14	0.14	0.14	0.14
Resource availability	0.14	0.10	0.10	0.10	0.10	0.07
Resiliency to climate shock	1.69	1.27	1.27	1.69	1.27	1.27
Short-term response	0.44	0.44	0.44	0.87	0.65	0.65
Medium-long term response	0.38	0.25	0.25	0.50	0.38	0.50
Frequency of unintended consequences	0.13	0.20	0.20	0.13	0.20	0.20
Criticality of unintended consequences	0.09	0.14	0.14	0.09	0.00	0.14
Impact on current society	0.10	0.10	0.07	0.10	0.07	0.10
Impact on future generation	0.11	0.09	0.00	0.11	0.09	0.11
Vulnerable group	0.09	0.09	0.06	0.09	0.06	0.06
Robustness	0.11	0.09	0.09	0.11	0.09	0.09
TOTAL	**6.88**	**5.54**	**4.85**	**7.02**	**5.63**	**5.75**

Drought-tolerant varieties =DTV; Early maturing varieties=EMV; Mixed farming=M-F; Mulching and composting=MC; Irrigation=IRG; Agroforestry=AGF

APPENDIX 5: LIST OF PUBLICATIONS AND CONFERENCES

4.1 Journals

1. Ndamani Francis, Tsunemi Watanabe. Farmers' perceptions about adaptation practices to climate change and barriers to adaptation – a micro-level study in Ghana. *Water*, Vol. 7(9), 4593-4604. **2015**

2. Ndamani Francis, Tsunemi Watanabe. Determinants of adaptation to climate change – a micro level analysis in Ghana. *Scientia Agricola*, ISSN 1678-992X. *(Accepted for publication)*

3. Ndamani Francis, Tsunemi Watanabe. Influences of rainfall on crop production and suggestions for adaptation. *International Journal of Agricultural Sciences*, Vol. 5 (1), 367-374. **2015.**

4. Ndamani Francis, Tsunemi Watanabe. Effects of rainfall on arable land-use and recommendations for adaptation. *International Journal of Agriculture and Crop Sciences*, Vol. 8 (2), 270-282. **2015**

5. Ndamani Francis, Tsunemi Watanabe. Rainfall variability and crop production in Northern Ghana---A Case of Lawra District. *Internet Journal of the International Symposium on Social Management Systems. Journal of Society for Social Management Systems*. **2014**, ID. SSMS-1056

4.2 Conferences

Ndamani Francis, Tsunemi Watanabe. Rainfall variability and crop production in Northern Ghana---A Case of Lawra District. *Journal of Society for Social Management Systems*. *International Symposium on Social Management Systems. SSMS* **2013**, Sydney, Australia, December 2013