Mendel University in Brno
Faculty of Regional Development and International Studies

The Effect of Climate Change on Yam Production in Ghana:
A Case Study of Techiman Municipality

Master’s thesis

Author: BcA. Michael Tenkorang Ofori
Supervisor: RNDr. Mgr. Miroslav Horak, Ph.D.

Brno 2019
DECLARATION

The author confirms that this thesis entitled: *The Effect of Climate Change on Yam Production in Ghana, A Case Study of Techiman Municipality* is my work with the cited sources, literature and other professional sources mentioned in references.

It contains no material beforehand published by someone else nor material which has been acknowledged for the award of some other degree of the University, aside from where due affirmation has been made in content.

I agree that my work can be published, and it will be as according to Section 47b, Act No. 111/1998 Coll. on Higher Education as changed from that point and as per the Guidelines on Publishing University Student Theses.

I comprehend that my work is in line with the rights and commitments under Act No. 121/2000 Coll., the Copyright Act, as revised, precisely the way that Mendel University in Brno has the privilege to finish up a license agreement to the utilization of this work as a school work in accordance with section 60 paragraph 1 of the Copyright Act.

Hence, before closing the license agreement on the use of my thesis with another person (subject). I undertake to written statement request from the university that the license agreement in question is not in contradiction with the legitimate interests of the school, and commit to paying any contribution, if eligible, to the costs associated with the creation of the thesis, up to their actual amount.

In Brno,

Date:……………………

Signature…………………………
DEDICATION

I dedicate this research to the almighty God for His sustenance and blessings during the entire study period in the Czech Republic. I further dedicate the study to my family, especially my two daughters, Michele and Pavla, my wife; Patience Asiamah, my parents and my siblings for their moral and financial assistance, without them this study could not have been possible.
ACKNOWLEDGEMENT

This thesis is a success because of the massive support received from some amazing people. My sincere gratitude goes to the Living God for giving me life and strength to complete this study. I want to also express my heartfelt gratefulness to my mentor and supervisor, RNDr. Mgr. Miroslav Horak, Ph.D. for his enormous motivation, direction, useful suggestions and the time spent to supervise this work to a successful end. I cannot overlook the constructive criticisms of Ing. Ebo Tawiah Quartey, Ph.D. who took time off his busy schedules to criticise this work to bring it to perfection. Exceptional thanks also go to Ing. Nahanga Verter, Ph.D. for his generous sacrifices and time spent to review the data, I am thankful to all friends especially Mrs. Pavla Kotrikova, Ms L. Manova, Ms P. Petruskova, and the people of Techiman Municipality especially proxy interviewer, Alfred, whose co-operation made this study successful. The contribution of all respondents who took time off their busy schedules to answer the questionnaires is also duly acknowledged. Once again, I say thank you and God richly bless you all.
ABSTRACT

Climate change is one of the serious environmental challenges that has received much public outcry in the global world due to its consequences on agriculture, energy and industry. This study, therefore, looks to find out the impact of climate change on yam production in Ghana. The semi-structured interview guide is the instrument for data collection covering yam farmers who were purposively selected from three communities in the study area. The study suggests an increase in both maximum and minimum temperatures coupled with unreliable rainfall distribution over the last two decades as the cause. The study identifies poor yield as a significant effect of climate variability on yam production as reported by the farmers in the study area. The fundamental finding is that places are now experiencing the effects of climate change which is the average weather conditions studied over 30 years of a place such as serious sunshine, high or low rainfall, strong wind, high temperature, drought, these characteristics of climate positively or negatively impacts on food crops. It is estimated that climate change will intensify making it a global concern. The scenarios of the decrease of the rainfall and increase of the temperature are very detrimental to Ghana's agriculture, because of the already harsh climatic conditions in the country. The analysis of farmers' perception of climate change reveals a high increase in temperature and high variability in rainfall pattern. The study recommends that heat resistant yam crop that can withstand the pressures of the climatic variations exceptionally high temperatures be developed by the Crops Research Institute of Ghana.

Keywords: Climate Change, Farmers Perception, Food Systems, Ghana, Yam Production
ABSTRAKT

Změna klimatu je jedním z vážných problémů v oblasti životního prostředí, která ve většině oblastí světa vyvolala spoustu veřejných protestů kvůli tomu, že má dopad na zemědělství, energetiku a průmysl. Tato studie se snaží zjistit dopad změny klimatu na produkci jamu v Ghaně. Data od pěstitelů jamu, záměrně vybraných ze tří komunit v areálu studie, byla sesbírána během semi-strukturovaných rozhovorů. Studie naznačuje nárůst maximálních i minimálních teplot spojených s nespolehlivým množstvím srážek během posledních dvou desetiletí. Také je v ní uvedeno, že hlavní efekt variability klimatu má především vliv na špatný výnos jamu. Největším zjištěním je, že průměrné povětrnostní podmínky jako intenzivní sluneční záře, vysoké nebo nízké množství dešťových srážek, silný vítr, sucho a další podmínky, mají jak pozitivní, tak negativní vliv na sklizeň jamu ve zkoumaných obcích. Tyto klimatické podmínky, studované během posledních 30 let, jsou v současné době pod vlivem klimatické změny. Předpokládá se, že změna klimatu se zesílí a stane se problémem globálního významu. Možnost poklesu srážek a/nebo zvýšení teploty je velmi neblahá pro ghanské zemědělství, protože klimatické podmínky jsou zde již kruté. Analýzou rozhovorů s farmáry bylo odhaleno podstatné zvýšení teploty a proměnlivost frekvence dešťových srážek. Ghanský institut výzkumu zemědělství by měl vytvořit teplu odolné plodiny jamu, které by byly schopny odolat klimatickým změnám, zejm. vysokým teplotám.

Klíčová slova: změna klimatu, názor farmářů, potravinový systém, Ghana, produkce jamu
**LIST OF ABBREVIATIONS**

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Full Form</th>
</tr>
</thead>
<tbody>
<tr>
<td>AIDS</td>
<td>Acquired Immunodeficiency Syndrome</td>
</tr>
<tr>
<td>CERES</td>
<td>Crop Environment Resource Synthesis</td>
</tr>
<tr>
<td>CO₂</td>
<td>Carbon Dioxide</td>
</tr>
<tr>
<td>CTA</td>
<td>Technical Centre for Agriculture and Rural Cooperation</td>
</tr>
<tr>
<td>EPA</td>
<td>Environmental Protection Agency of Ghana</td>
</tr>
<tr>
<td>FAO</td>
<td>Food and Agriculture Organisation of United Nations</td>
</tr>
<tr>
<td>GCM</td>
<td>Global Circulation Model</td>
</tr>
<tr>
<td>GDP</td>
<td>Gross Domestic Product</td>
</tr>
<tr>
<td>GHG</td>
<td>Greenhouse Gas</td>
</tr>
<tr>
<td>GSS</td>
<td>Ghana Statistical Service</td>
</tr>
<tr>
<td>HIV</td>
<td>Human Immunodeficiency Virus</td>
</tr>
<tr>
<td>IFPRI</td>
<td>International Food Policy Research Institute</td>
</tr>
<tr>
<td>ILO</td>
<td>International Labour Organisation</td>
</tr>
<tr>
<td>IPCC</td>
<td>Intergovernmental Panel on Climate Change</td>
</tr>
<tr>
<td>IITA</td>
<td>International Institute for Tropical Agriculture</td>
</tr>
<tr>
<td>MAT</td>
<td>Mean Annual Temperature</td>
</tr>
<tr>
<td>MT</td>
<td>Metric Tonnes</td>
</tr>
<tr>
<td>MoFA</td>
<td>Ministry of Food and Agriculture – Ghana</td>
</tr>
<tr>
<td>OECD</td>
<td>Organization for Economic Cooperation and Development</td>
</tr>
<tr>
<td>SARS</td>
<td>Severe Acute Respiratory Syndrome</td>
</tr>
<tr>
<td>SRID</td>
<td>Statistics Research Information Directorate – Ghana</td>
</tr>
<tr>
<td>USA</td>
<td>United State of America</td>
</tr>
<tr>
<td>UNAIDS</td>
<td>United Nations Programme on Acquired Immunodeficiency Syndrome</td>
</tr>
<tr>
<td>UNEPA</td>
<td>United Nations Environmental Protection</td>
</tr>
<tr>
<td>UNFCCC</td>
<td>United Nations Framework Convention on Climate Change</td>
</tr>
<tr>
<td>USAID</td>
<td>United State Agency for International Development</td>
</tr>
<tr>
<td>USHCN</td>
<td>United States Historical Climatology Network</td>
</tr>
<tr>
<td>WHO</td>
<td>World Health Organisation</td>
</tr>
</tbody>
</table>
### TABLE OF CONTENTS

1.0 **INTRODUCTION** ........................................................................................................... 1

1.1 Background to the Study ....................................................................................................... 1

2.0 **AIMS AND METHODS** ....................................................................................................... 4

2.1 Aim of the study ..................................................................................................................... 4

2.2 Objectives of the Study .......................................................................................................... 4

2.3 Research Questions ............................................................................................................... 4

2.4 Research Methods ................................................................................................................ 5

2.4.1 Study Area ....................................................................................................................... 5

2.4.2 Research Approach ......................................................................................................... 6

2.4.3 Study Population ............................................................................................................. 6

2.4.4 Sampling Technique and Sample Size ............................................................................ 6

2.5 Types, Sources and Methods of Data Collection .................................................................. 6

2.6 Thematic analysis .................................................................................................................. 7

2.7 Justification of the Study ...................................................................................................... 8

2.8 Limitation of the Study ....................................................................................................... 8

2.9 Organisation of the Study .................................................................................................. 8

3.0 **LITERATURE REVIEW** .................................................................................................... 9

3.1 Introduction .......................................................................................................................... 9

3.2 Climate Change ................................................................................................................... 9

3.3 Climate Variability .............................................................................................................. 10

3.4 Global Trends of Climate Variability .................................................................................. 11

3.4.1 Evidence of global climate variability ........................................................................... 11

3.4.2 Temperature variability trend ......................................................................................... 12

3.4.3 Rainfall variability trend ................................................................................................. 13

3.5 Effects of Climate Change on Agriculture ......................................................................... 15

3.6 Climate Adaptation ............................................................................................................. 17

3.7 Agriculture, Climate Change and Food Security ................................................................. 18

3.7.1 Impacts of Climate Change on Food Availability .......................................................... 19

3.7.2 Impacts of Climate Change on Food Utilization ............................................................ 21

3.8 The Nexus between Climate Variability and Crop Production .......................................... 23
3.8.1 Temperature variability and crop production ............................................................ 23
3.8.2 Rainfall Variability and Crop Production ................................................................. 25
3.8.3 Extreme Climatic events and Crop Production ........................................................ 26
3.9 Farmers’ Perception of Climate Variability .............................................................. 27
3.9.1 Perception of the Causes of Climate Variability .................................................... 28
3.9.2 Perception of the Effects of Climate Variability .................................................... 30
3.10 Empirical Study on Effect of Climate Change on Agriculture ............................... 31
3.11 Climate Change and Agriculture in Ghana .............................................................. 32

4.0 RESULTS AND DISCUSSIONS .............................................................................. 35
4.1 Introduction ............................................................................................................. 35
4.2 Theme one : Yam Production in Ghana .................................................................. 35
4.2.1 Contribution of Yam to the overall national export ............................................. 35
4.2.2 Challenges of Yam Production in the study area ................................................. 40
4.2.2.1 Diseases and Pest .............................................................................................. 40
4.2.2.2 Soil Fertility ...................................................................................................... 41
4.2.2.3 Access to the road ............................................................................................ 41
4.2.2.4 Lack of Labour .................................................................................................. 41
4.2.2.5 Access to Land .................................................................................................. 42
4.3 Theme Two: Climate trends in Ghana and the Study area ..................................... 42
4.3.1 Trend of climate change in Ghana ........................................................................ 42
4.3.2 Rainfall and Temperature distribution in the study area ...................................... 45
4.3.3 Effect of climate change on Yam Yield .................................................................. 47
4.4 Theme Three: Response from selected farmers under study ............................... 49
4.4.1 Socio-Demographic Characteristics of Respondents ......................................... 49
4.4.2 Farmers’ knowledge about the trend of Climate Change in the Area ............... 51
4.4.3 Farmers’ knowledge on the Effect of Climate Change on Yield of Yam ............ 52
4.4.4 Farmers’ Perceptions on the Effects of Climate Change on Yam Production .... 54
4.4.5 Adaptation Strategies of the Farmers in Response to the Effects of Climate Change .......................................................... 55
5.0 Discussions ........................................................................................................... 57

6.0 CONCLUSIONS AND RECOMMENDATIONS ............................................... 59
<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td>Conclusions</td>
<td>59</td>
</tr>
<tr>
<td>6.2</td>
<td>Recommendations</td>
<td>60</td>
</tr>
<tr>
<td>7.0</td>
<td>List of tables</td>
<td>62</td>
</tr>
<tr>
<td>8.0</td>
<td>List of figures</td>
<td>63</td>
</tr>
<tr>
<td>9.0</td>
<td>REFERENCES</td>
<td>64</td>
</tr>
<tr>
<td>10.0</td>
<td>APPENDICES</td>
<td>75</td>
</tr>
</tbody>
</table>
1.0 INTRODUCTION

1.1 Background of the Study

One of the utmost critical environmental challenges that are bedevilling humankind in this 21st century is the changing climate across the globe (Datta, 2013). The magnitude of the impact of the phenomena cannot be underestimated as it has the propensity to affect the output of most crops, including root and tuber crops (Lee et al, 2012; Kotir, 2011). The 5th synthesis Report of the Intergovernmental Panel on Climate Change (IPCC) has strongly indicated that the impact of the changing climate is "unequivocal", and "unprecedented" since the mid- 20th century (IPCC, 2014). The degree of impact of the changing climate may have accelerated the inconclusive debate and research by scientists about the causes and consequences of the phenomenon and the need to develop coping or adaptive strategies.

The United Nations Framework Convention on the Climate Change ((UNFCCC), 2007) defined climate change as a modification of climate that's attributed directly or indirectly to the act that alters the composition of the planet’s atmosphere in the natural climate variability observed over comparable periods. To them, climate change involves a change in climatic variables (such as rainfall, temperature and wind speed) which is caused by both anthropogenic and natural factors over more extended periods. The most mentioned climatic variables identified to have a direct relationship with crop production, and which affect the output of various crops are temperature, precipitation and extreme weather events such as flood, windstorm and drought. IPCC (2007) also defined climate change as any possible change in the climate as a result of human activities or natural cause.

According to Tubiello (2012), the annual amount of carbon dioxide emitted into the atmosphere is about 13-15 billion tonnes, about one-third of the total emissions from human activities. The presence of carbon dioxide in the atmosphere as a result of human activities (e.g. deforestation, burning of fossil fuels and inappropriate farming practices such as slash and burn) absorb the ultraviolet radiation from the sun but prevents it from escaping through the atmosphere. Therefore, carbon dioxide warms the atmosphere and consequently affects the dynamics of climatic variables such as
temperature and precipitation. Temperature and precipitation are two most essential climatic elements that are most studied in climate research because of their immediate impact in various socio-economic sectors (e.g. agriculture and hydrology), including human well-being (Sayemuzzaman et al, 2014).

According to Lee et al (2012), the elasticity of annual climate variables indicates that warm temperatures negatively impact the production of crops and agriculture as a whole in Asia. It was therefore estimated that as soon as the annual mean temperature rises by 1%, the average agricultural output decreases by 0.346 %. Chijioke (2011) argues that, for every degree that a crop spends above 30 °C, there was a decrease in yield by 1%. He further uncovered that the accessibility of water significantly affects the sensitivity of crops with yields diminishing by 1.7 % for every degree spent over 30 °C under dry season conditions. Outrageous climatic conditions, for example, droughts supported by the dry season, and heat waves have been anticipated to have a significant effect on crops and livestock production (Walthall et al, 2012). Again, it has shown that high temperatures impact on root and tuber crops like yam and cassava to the extent that the high temperatures suppress germination, decrease the number of branches and leaves and inhibit root development, which results in low yield (Johkan et al, 2011).

Empirical evidence in Africa supports the impact of the varying climate on crop production. Research on the effects of climatic changes in Zimbabwe demonstrates that the nation's agricultural sector which incorporates root and tuber crop production is now experiencing changing rainfall patterns, temperature increments and progressively harsh climate conditions, such as floods and droughts (Manyeruke et al, 2013). The circumstance is not distinctive in Ghana as research keeps on building up the effect of climate changes on crops. Research findings from the International Food Policy Research Institute (IFPRI) on the effect of climate change on yields of crops uncovered a general decline in yields of a considerable number of crops (e.g. maize, groundnut, yam, etc.) in the deciduous forest (Pinto et al, 2012). Deuter (2008) summarises the impacts of climate change on root and tuber crops as follows: changes in time to harvest for some crops, changes in the suitability and accessibility of cultivars for current and future production, greater seasonal variability and increased pest and disease incidence, as well as emergence of new pests, diseases and weeds.
At the local level, it is argued that the agricultural sector is the most vulnerable of all the other sectors. According to Sofoluwe et al (2013) cited in Owombo et al (2014), climate variability is the most critical limiting factor to agricultural production that can cause a severe threat to the sustainability of food production. However, it is significant to note that the vulnerability of the agricultural sector is due to its reliance on rainfall (Walthall et al, 2012). Because of the changing climate on agricultural production, the debate has now shifted from high-level advocacy on "the need to act" to a country and regional level responses on "how to adapt" (Wilby, 2007 cited in Bagamba et al, 2012). As a result of this, farmers continue to adopt different approaches to cope with the stress and damage the changing climate can impose on the country's agricultural sector (Pinto et al, 2012). United State Agency for International Development (USAID) Africa Bureau, during the seventh African Development Forum in Addis Ababa in 2010, reiterated the need for countries to employ scientific and technological innovation in adapting to the climate change situations (Sarr, 2010).

Yams (Dioscorea spp.) are annual or perennial herbaceous climbing or trailing crop plants that produce edible underground tubers. They are products of tropical regions of the World. Yam is produced throughout the length and breadth of Ghana. Yams are among the essential staple food crops in the world now mainly in tropical and sub-tropical countries (Okigbo & Ogbonnaya, 2006). Yam plays an essential role in the food economy in the majority of West African countries especially Ghana. Yam is a vital source of energy in the daily diet of many people and as such crucial to food security in Ghana. Yam provides more than 200 calories per person per day for more than 150 million people in West Africa (FAO, 2006). Although yam tubers are mostly used for their high content of carbohydrate, they also have high protein, minerals such as calcium, phosphorus, iron and vitamins B and C (Splittstoeser & Rhodes, 2009).
2.0 AIMS AND METHODS

2.1 Aim of the study

According to reports by the District Directorate of Ministry of Food and Agriculture Ghana (MoFA), rising temperature and erratic rainfall pattern which are attributed to the changing climate have been the bane of the yam farmers. Variability of the climate recently has contributed to a reduction in yam yield in Ghana (Robinson & Kolavalli, 2010). Unfortunately, the Techiman municipality happens to be one of the localities in the country that is vulnerable to climate variability and has suffered a reduction in yam yield over the years as a result of the changing climate. Since the decrease in yam production is a danger to food security with the potential to add to the risk of famine, there is the need for research to explore the extent of the effect of the climate variability on yam production.

2.2 Objectives of the Study

The essential goal of the study is to examine the effect of climate change on yam production. Specifically, the study sought to;

➢ Examine the effect of climate change (rainfall and temperature) changes on the yield of yam.
➢ Determine farmers’ perceptions of the effects of climate change on yam production.
➢ Examine the elements of adaptation to climate change by farmers in the area.

2.3 Research Questions

➢ What are the effects of climate change (rainfall and temperature) changes on the yield of yam?
➢ What are the perceptions of farmers on the effect of climate change on yam production?
➢ What are the adaptation strategies of the farmers in response to the effects of climate change?
2.4 Research Methods

2.4.1 Study Area

The Techiman Municipal Assembly is among the eleven Municipalities and Districts in the Brong Ahafo Region of the Republic of Ghana. The Techiman Municipality is in Brong Ahafo Region which lies between longitudes 10 49' east, 20 30' west and latitude 80 00' north and 70 35' south. Techiman Municipality was established under the Legislative Instrument (L.I) 2096. Techiman Municipal Assembly shares boundaries with Wenchi, Nkronza, and Techiman North in Brong Ahafo Region and Offinso-North District in the Ashanti Region. The Municipality has a land surface area of 649.0714 sq. Km. The population density is 227.7 persons per square kilometre. (GSS 2010).

According to the Ghana Statistical Service (GSS 2010), Population and Housing Census of Ghana, the total population of Techiman Municipal is 147,788 with 71,732 being males and 76,056 as females. This is very high and has an impact on the socio-economic development of the Techiman Municipality (GSS 2010). About (46.2%) households in the Municipality are engaged in agriculture, and Crop farming is the main agricultural activity with more than nine out of ten (95.4%) households engage in it. Those in livestock rearing accounts for (95.5%) and tree planting (0.4%). In the rural localities, almost eight out of ten households (75.8%) are agricultural households, but only 33% are in the urban districts. Poultry (chicken – 57.0%) is the dominant animal reared in the Municipality.

The Municipality experiences both semi-equatorial and tropical conventional or savanna climates, marked by moderate to heavy rainfall. Major rains usually begin from April and end in July. The minor rains, on the other hand, start from September to October. The mean annual rainfall ranges between 1260mm and 1660mm. The only dry season, which is highly pronounced in the Savanna zone, starts in November and lasts until March in the following year. Within this period the average highest monthly temperature of about 30\(^{0}\)C (80\(^{0}\)F) is recorded. The low monthly temperatures occur mostly between March and April with the lowest of about 20 \(^{0}\)C (79 \(^{0}\)F) occurring in August. The relative humidity is mostly high throughout the year.
2.4.2 Research Approach

A qualitative approach will be adopted for the study. In the qualitative approach, knowledge claims are based on constructivist perspectives or different meanings of individual experiences (Creswell & Poth 2017). Qualitative studies interpret the qualities of social phenomena rather than predict relations between predefined variables. Therefore, the qualitative approach is suitable for this study because it allowed the researcher to use thematic and content analysis research design which is more suitable for the study.

2.4.3 Study Population

In every research, it is always difficult to study an entire population. This is, and the necessary resources might also not be available. Moreover, considering the whole population also means that the researcher would have to deal with a large number of subjects. The target population of the study includes all yam crop farmers in the municipality. However, the accessible population are yam farmers in the three selected communities (Oforikrom, Kenten and Sansama).

2.4.4 Sampling Technique and Sample Size

The purposive sampling method will be employed to choose farmers from each community. Oforikrom, Kenten and Sansama communities will be purposively selected for being among the leading producer of yam in the municipality. Purposive sampling involves the choice of subjects who possess the information the researcher needs. The purposive sampling strategy is suitable for this study as qualitative studies are often guided by purposive sampling strategies (Tracy, 2012). In qualitative studies, researchers must make a sound decision on the number of respondents to recruit which is known as the sample size. A sample size of 30 respondents of yam farmers was selected using purposive sampling technique.

2.5 Types, Sources and Methods of Data Collection

The data gathered for this study were collected from both primary and secondary sources. Qualitative data was gathered from the respondents of the communities;
primary data would be collected from key informants such as yam farmers. Farmers were interviewed using a semi-structured interview guide. The interview was conducted with the respondents through Skype and other social media such as WhatsApp. The semi-structured interview was deemed appropriate because most of the respondents in the study communities could not read and write the English Language. Skype/WhatsApp provides an opportunity for audio or video interviewing (Anonymous, 2013). Concurrently interactive communication with direct probing is created in both; Skype encourages interviewees who have time and place limitations for face-to-face interviews to participate in research.

The flexibility may resolve the researcher’s concern to reach key informants and increase participation. Nevertheless, the selection of a disruptive environment could affect interviewee concentration and data gathering (Deakin & Wakefield, 2013). A Proxy interviewer was equally utilised within places with no or poor internet availability.

Secondary data was sourced from official and credited institutions including World Bank (WB), Food and Agriculture Organisation of the United Nations (FAO) annual stats; Statistics Research Information Directorate - Ghana (SRID), and Ministry of Food and Agriculture-Ghana (MoFA) and Ghana Statistical Service (GSS).

2.6 Thematic analysis

The qualitative data from the in-depth interviews will be analysed thematically using Dey's (1993) three-step process of describing, classification and connecting. The description involves transcribing data from the in-depth interviews into a mass of text. The classification step consists in relating the transcribed data to their major themes. Finally, the interconnecting step involves making sense of the themes to reflect the research objectives and questions. The narratives from the interviews were directly quoted to support some of the opinions from respondents. Data from interviews gave further details and explanations to the results obtained.


2.7 Justification of the Study

The result of this study is required to give direction for policymakers in designing appropriate public policies and roadmaps to increase agricultural productivity and mitigating effects of climate change on food crop production in Ghana. The study will serve as useful reference material to future researchers who would want to research into a similar area. The study will, therefore, serve as an essential document that will guide prospective researchers in their quest to researching into areas related to climate variability impact and adaptation. Finally, even though research on adaptation to climate variability seems to be on the increase, there is still the need to conduct further research to enable the sharing of different adaptive strategies adopted by farmers at different places. This analysis will go a long way to influence policymakers to allow them to document practical adaptive approach that will help reduce the adverse effect of climate variability on rural farming communities, especially those with similar environmental characteristics.

2.8 Limitation of the Study

The researcher intended to cover more communities in the district. However, due to financial constraints, time factor and mode of interview and methods, it is not possible to include most of the communities in the study area. Again, it is quite difficult getting climate data from the weather station and yam production data from the main study district which reduced the consistency of the findings.

2.9 Organisation of the Study

The study is organised into five chapters. Chapter one is made up of the Introduction and background of the study, Chapter two discusses the aims and methods which include objectives of the study, research questions, study area, research approach and study population, sampling technique and size, research instrument and data collection and analysis procedure statement of the problem, justification of the study and limitation of the study. Chapter three presents a review of relevant literature on climate change and Yam Production. Chapter four deals with the results and discussion of findings. The last chapter deals with conclusions and recommendations.
3.0 LITERATURE REVIEW

3.1 Introduction

This chapter presents a review of the literature that highlights the impacts of climate change/variability on agriculture. The chapter seeks to unearth the various views held by scholars on the nexus between climate change and yam crop production. These enabled the researcher to put the problem in its right perspective and hence, provide an in-depth understanding and appreciation of the problem under investigation. Issues and concepts of climate change and yam production are theoretically and empirically reviewed.

3.2 Climate Change

Climate change refers to diversity in the nature of the climate that can be acknowledged by changes in the mean or the variability of its properties, and that persevere for a more extended period, typically decades or longer (The Intergovernmental Panel on Climate Change (IPCC), 2014). The element of duration clearly distinguishes climate from the weather. While weather takes place over a shorter period, the climate takes place over a more extended period. Therefore, the climate is said to have changed when it varies over a more extended period. Similarly, Sumelius et al (2009) define climate change as "a change in the state of the climate measured by changes in the mean and the variability of specific properties (e.g. temperature and precipitation) that persist over decades, and that can be detected, e.g. by statistical tests". There are other important climatic elements like sunshine, wind and humidity which also influence climate in one way or the other.

However, as opined by Sayemuzzaman et al (2014), temperature and rainfall are the two most important variables that influence plant growth. The UNFCC (2007), indicated that climate is said to have changed when there is a direct or indirect alteration of the components of the global atmosphere and which adds to natural climate variability observed over comparable periods (IPCC, 2014). However, Arku (2013) defines climate change as any change in climate over time, whether it is the product of natural factors, human activity or both. A cursory look at Arku's definition
indicates that, apart from the anthropogenic factors which can cause the climate to change, there are other natural factors which can also influence the climate to change. He also emphasises the combined effect of natural and anthropogenic factors that affect climatic changes. This agrees with the argument put forward by the IPCC on the causes of climate change through its fifth assessment report. According to the report, climate change may be attributed to the natural internal processes or external forces such as variations of the solar cycles, volcanic eruptions, and persistent anthropogenic changes in the composition of the atmosphere or land use. Much emphasis is therefore laid on the anthropogenic factors causing climate change with little information on the natural causes of climate change. Operationally, climate change as used in this work refers to the resultant effect of climate variability which is either anthropogenic or natural.

3.3 Climate Variability

The term "climate variability" is often used to denote deviations of climate statistics over a given period (such as a definite year, season and month) from the long-term climate statistics relating to the corresponding calendar period. Climate variability refers to the spatiotemporal variation of climatic conditions beyond individual weather events (Christensen et al, 2007). Similarly, Houghton et al (2001) also define climate variability as the variations in the mean state and other statistical descriptions of extreme climatic condition on all temporal and spatial scales beyond that of individual weather events.

With regards to the definition by Houghton et al (2001), climate variability is seen as the climatic parameter of the region varying from its long-term mean. Again, an emphasis is also placed on the significance of spatiotemporal scales of weather events. The IPCC's (2007) definition of climate variability agrees with that of Houghton et al (2001) with emphasis placed on the dimensions of the variability. Two significant aspects of climate variability are identified: internal variability and external variability. The internal variability looks at the natural internal processes within the climate system while the external variability emphasises the human-induced external forces that influence the climate (IPCC, 2007). In the words of Lobell (2010), extreme climatic variability signifies a delicate balance between agricultural production and food
security. Lobell added that the changes in the agriculturally important elements of climate (e.g. increasing temperatures and declining levels and distribution of rainfall) are likely to reduce yields of crops such as maize, rice, among others in semi-arid regions of the world. Lobell’s definition emphasises the relationship between rainfall and food production without taking other climatic variables like temperature into consideration.

3.4 Global Trends of Climate Variability

Global trends of temperature and rainfall point to the fact the climate is changing. Mean annual temperatures have been increasing, and places in Sub-Saharan Africa and Asia continue to experience weather extremes like flood and drought respectively. With global warming, not a hiding secret whether caused by natural variability or anthropogenically induced (IPCC, 2007), it is essential to be informed and regularly updated on observed regional temperature and precipitation trends at both regional and local levels. The IPCC (2014) has projected that, if measures are not taken to reduce the generation of GHG emissions, the future temperature will continue to increase as well as extreme weather conditions such as drought in most parts of the world especially, countries in Sub-Saharan Africa.

3.4.1 Evidence of global climate variability

There is evidence to demonstrate that global climate keeps on changing. Statistical variations over the years support the fact that climate change has been happening over long periods, typically decades (VijayaVenkataRaman et al., 2011). The outcome of anthropogenic factors such as deforestation and burning of fossil fuels, the impacts of climate variability have already been observed from rising sea levels to melting snow and ice through to changing weather patterns. According to the IPCC (2007) cited in Sarker (2012), global temperature increase coupled with sea level rise and diminishing Arctic sea ice is evidence that gives credence to the fact that global climate is changing. However, the evidence presented by the IPCC failed to look at the extreme events which have also occurred as a result of the changing climate. For instance, global sea level rose to about 12-22 centimetres in the 20th century, but satellite records
confirmed that the rate of sea level rise has now almost doubled to about 3.4 millimetres (mm) per year (IPCC, 2007).

Long-term temperature data from ice sheets, glaciers, lake’s sediments, corals, tree rings, and historical records clearly show a more warming condition than the preceding decades in the 20th century (Hansen et al, 2006). Some of the extreme events include; flood and drought conditions that are characterised by climate variability and change. The changes in the global surface temperature and carbon dioxide concentration show how the climate has been changing over time and the likely consequences on the various sectors of the economy especially, the agricultural sector which is more vulnerable (Walthall et al, 2012). Mitchell et al (2000) on the contrary found no evidence of a substantial acceleration of sea level rise, in contrast to expectations from global circulation models.

3.4.2 Temperature variability trend

Climate trends and extreme climatic indices derived from empirical, observed data indicate that global average surface temperatures have been on the increase since the mid-19th century with the most significant rate of change observable since the mid-1970s (IPCC, 2014). This may be attributed to the continuous generation of GHG through human activities. The recent report of the IPCC reiterates the fact that anthropogenic factors remain a significant cause of recent global warming.

Owing to the concentration of the GHG in the atmosphere, the temperature continues to rise through the GHG effect, and this has possibly contributed to the alteration of the rainfall pattern across the globe. Recent climatological studies have shown an increase in global surface air temperature by 0.76 °C from 1850 to 2005 (Bakri & Abou-Shleel, 2013). The study reveals the extent to which global temperatures increased over the last century. However, it fails to add to the discourse about the causes of the phenomenon which is fundamentally critical in analysing issues of climate variability and change.

Research carried out by Poulter et al (2013) in inner Asia which includes the semi-arid regions of northern China, Mongolia, and parts of southern Russia reveals an increase in mean annual air temperature. Similar research conducted by Cinco et al (2014) on temperature anomalies in the Philippines for the period 1951–2010 against the baseline
period of 1961–1990 demonstrates an overall increasing trend with values becoming positive in 1977 and peaking in 1998 with a +1.0 °C difference. From 1996 to 2010, the end of the observed period, positive anomalies were consistently higher than 0.5 °C with 2005 and 2006 marking the peak warm years of the first decade of the 21st century. The temperature anomaly as revealed in the research gives evidence which is consistent with a global warming climate. Further studies in Asia have also shown an increase in mean annual temperature. For instance, according to a study by Chen et al (2014), the mean annual temperature (MAT) in the whole Yangtze basin of China over the period 1955–2011 was 14.0 °C ranging from 13.4°C to 14.9 °C. The MAT increased from 12.7 °C in the upper section of the catchment to 16.0 °C in the lower basin. The study shows a variation in the increase in the annual mean temperature of the upper and lower basins.

World Bank, (2009) established based on the trends of the changing climate over the past decade, the average temperature in Ghana from the period 2010 to 2050 is predicted to range between 34 °C (Forest region, Ghana Wet Seasons) and 41 °C (Northern Savannah, Ghana Dry Seasons). This evidence shows that the climatic trend in most parts of the world especially, Sub-Sahara Africa keeps on drifting to the negative with its effects on the environment and agricultural production. It is therefore important that farmers within the Sub-region be given the needed empowerment to be able to implement effective adaptation strategies to help respond or reduce the impact of the changing climate. Similarly, a substantial linear increase in mean annual air temperature which happened between 1960 and 2001 along the coast of Ghana of about 0.9°C; the maximum temperature was increased by 2.5 °C whiles minimum temperatures were increased by 2.2 °C, during this time sea-surface temperatures showed a slight but non-significant increase during this period (Dontwi et al, 2008). Moreover, it is further projected that countries are expected to experience an increase in average temperature overall by 1°C by 2030 and by 1.4°C by 2050 (IPCC, 2007).

3.4.3 Rainfall variability trend

The study of Chen et al (2014) indicates that precipitation across the whole Yangtze basin of China is very high in comparison to many rivers elsewhere. Annual
precipitation across the entire basin averages 1024 mm and even in the driest section, the upper basin, the average is still 854 mm. The study, however, attributes the high precipitation in the Yangtze basin to the relatively small net consumption of water in relation to total annual flow in the region. In the same vein, Petrie et al (2014) demonstrated in their study at northern Chihuahuan Desert, United States, that regional precipitation exhibits trends in average event timing and magnitude. Their study, however, indicated that the compensating changes did not induce a change in the total average monsoon precipitation at the United States Historical Climatology Network (USHCN) sites over the last 100 years.

The primary reason given for no change in average total precipitation was explained to the effect that a small number of very large events could account for most of the total precipitation and that smaller events may often be insignificant regarding total precipitation. Contrary, the findings of Afzal (2011) reveals that the increasing trends in rainfall have not been temporally continuous. Instead, the results show an abrupt change in precipitation amounts around 1980 in Western Scotland. The study further notes that there was a spatial pattern in average rainfall variability. For instance, the West and South-west regions experienced the highest rainfall variability pattern. The study is deficient as to why the increasing trend in rainfall has not been temporally continuous. In the analysis of Tao et al (2011) on the characteristics of hydro-climatic changes in the Tarim River Basin in China, it was established that stations with significant increasing trends in annual streamflow were distributed mainly at the southern slope of Tianshan Mountain, which can be concluded to be as a result climatic change.

Lionello et al (2011) therefore confirm the absence of important sustained trends of severe marine storminess in the northern Adriatic during the second half of the 20th century by the analysis of hourly sea level time series and significant wave height records. Even though the study shows some relatively negative trends, the time series methodology employed was dominated by large inter-annual variability. The study further avers that cyclones which produce extreme storm surges differ from those generating high waves, and both have specific characteristics that distinguish them from other cyclones passing over northern Italy.
3.5 Effects of Climate Change on Agriculture

According to a survey by IPCC (2013), the level of Greenhouse Gases (GHG) in the atmosphere has exceeded the maximum levels of concentrations on earth from the last 800,000 years. The GHG effect is the cause of increased rainfall, constant extreme hot temperature, floods, droughts, cyclones and gradual melting of glaciers. Climate change may not always have an adverse effect on agriculture, especially in case of high latitude and high-income countries where agriculture cultivation is complemented by advanced technological implements and resources, leading to higher productivity of the land. However, this climate change is a significant barrier to developing economies.

Country-specific data on the impact of climate changes expected for the agricultural sector in most low-income countries are not enough due to a lack of data availability. A study by Hulme (1996) revealed that there are four ways in which climate would have a physical effect on crops: changes in temperature and precipitation, atmospheric carbon content, water availability, and increased frequency of extreme climate events such as flood and drought. First, the rise or decrease in temperature and precipitation will affect the distribution of agro-ecological zones. Changes in soil moisture, content, the timing and length of growing seasons will equally be affected in diversified ways around other parts of the world. Rosenzweig & Hillel (2008) stated that in middle and higher latitudes, higher temperatures would lengthen growing seasons and expand crop producing areas, thus benefiting countries in these regions, while less fertile soils in higher latitudes will affect a part of the advantages of an extended growing season. On the other hand, it is expected that higher temperatures will adversely affect the conditions for growth in lower altitudes.

Secondly, carbon dioxide effects are expected to have a positive impact as a result of greater water use efficiency and a higher rate of photosynthesis (Kurukulasuriya & Rosenthal, 2003). Also, rising carbon dioxide concentrations in the atmosphere are essential to agriculture because they increase the rate of photosynthesis and water use efficiency. However, the net result may be moderated by harmful pest and weed infestations (Rosenzweig & Hillel, 2008). Besides, Amouzou et al (2013) found that an increase in atmospheric CO\textsubscript{2} concentration by 400-550vpm enhanced maize grain yield
by 3 – 11%, but that positive effect did not offset the depressive effect of increased
temperature on ferralsols in Coastal Western Africa. Cure & Acock (1986) indicated a
limited response of maize yield to CO₂ enriched environment in nutrient-stress
conditions. Also, water availability (or runoff) is a critical factor in determining the
impact of climate change in many places, particularly in Africa. Many studies
suggested that rainfall and the duration of the growing season are critical in determining
the positive and negative effects of climate change on agriculture (Hulme, 1996).

Finally, according to Kurukulasuriya and Rosenthal (2003), agricultural losses can
result from climatic variability and the increased recurrence of severe events such as
dryness and floods or changes in precipitation and temperature variance. As outlined in
Rosenzweig & Hillel (2008), a more extended period of droughts harms water supplies
for many reasons such as plant transpiration. On the contrary, the increases in rainfall
pattern can result in soil erosion, leaching of soil chemicals, and water runoff that
carries livestock and nutrients into other water bodies.

Hulme (1996) overlooked the fact that one-way climate change can affect agriculture in
coastal areas. That is sea level rise, which can inundate producing lands. Also, it can
also increase the amount of salt in these producing lands, making some plants to have
stunted growth there. This particular point has been mentioned by Keane et al (2009).
Impacts of climate variability as well as a change in the agricultural sector are
estimated to be steady from changes in land and water regimes, mainly primary
channels of change. Changes in the regularity and strength of droughts, storms, and
flooding damages to be caused are expected. Climate change is likely to result in long-
term drought and severe adverse soil conditions and desertification, disease and pest
outbreaks on crops or livestock, also sea-level rise. Most of the vulnerable areas are
most likely to have declined in agricultural production, mainly due to reductions in crop
A significant number of the scenarios revised by Keane et al (2009) were either
accepted by the Fourth Assessment Report (AR4) or have formed part the IPCC Special
Report on Emission Scenarios (2000). Drawing from reviews on these studies, all
regions will experience an increase in temperatures towards the end of the present
century; this is accompanied by predicted changes in rainfall (though to a much more
significant degree regarding variability). Regarding the aggregate impact on agricultural production, it is established that a more considerable divergence between regions concerning output is likely to happen. Most parts especially the majority of the southern and equatorial developing countries are expected to lose regarding agricultural production, while developed countries based in the north are expected to gain.

The effects of climatic variations on agriculture (especially in Africa) have been well established through many years of field analyses, statistical reviews of observed yields, and monitoring of agricultural production (Buba, 2004). The essential climatic component is precipitation, mainly seasonal drought and the length of the growing season. The circulation of rainfall within the growing season may also affect production. Low temperatures and radiation impede production in some high-elevation regions; frost is a hazard in Southern Africa (IPCC, 2007). High temperatures can negatively affect output and quality in both semi-arid and arid regions, even though water is essential. The rise in sea-level and coastal erosion will affect groundwater through increased salinity, irrigated agriculture and low-lying coastal land in some areas from the extent of land liable to inundation and the population being at risk (IPCC, 2007).

Apart from the experimental research, crop output response to climate change differ widely based on species or kind and cultivars, the nature of soil properties, pests and the effects of carbon dioxide (CO₂) on crops, and relationship existing on CO₂, air temperature, water, mineral nutrition, air quality and the adaptive responses (IPCC, 2006). Even though high CO₂ concentration can inspire crop growth and yield, this benefit may not always outweigh the extreme effects of excessive heat and drought (IPCC, 2007).

3.6 Climate Adaptation

According to the IPCC (2014), adaptation to climate change refers mainly to the process of adjustment to the main climate or expected climate and its impact. It further explains that adaptation seeks to cause a reduction in the harm or exploit beneficial opportunities in human systems. In some natural systems, human intervention may facilitate adjustment to expected climate and its effects. On the same wavelength, the
UNFCCC (2009) cited in Nepal, C. A. R. E. (2009), defines climate adaptation as the modification in natural or human-made systems in response to the main climate or expected climatic stimuli or their effects, which moderates the dangers or exploits beneficial opportunities. Similarly, the IPCC (2007) defines climate adaptation as initiatives and measures put in place to reduce the vulnerability of natural and human-made systems against actual climate or expected climate change impacts.

Fussel (2012) however, share a different view when they defined climate adaptation as all changes in a system, compared to a case that reduces the adverse effects of climate change. Adaptation can, therefore, be regarded as the capacity of the natural or human system to adapt to climate change (including both climate variability and its extremes) to balance potentially adverse effects, to either take advantage of opportunities or to cope with the consequences it brings. This means that an individual has many opportunities and options to adapt to a condition, especially an environmental condition. Climate adaptation can, therefore, be summed as the package of strategies, processes, policies and actions that respond to the actual climate or expected climate changes so that the consequences for individuals, communities and economy are minimised (Pinto et al, 2012). Operationally, climate adaptation as used in this work refers to the various strategies adopted to respond to harsh climatic conditions.

3.7 Agriculture, Climate Change and Food Security

Agriculture is essential for food security in two ways: it produces food eaten by people; and perhaps even more critical also it provides the primary source of livelihoods for 31.3% of the world's entire workforce (ILO, 2014). In densely populated countries of Asia and the Pacific, such assign ranges from 39.3%, while in Sub-Saharan Africa, 65.9% of the working population still turn out their living from agriculture (ILO, 2014). If agricultural production in low-income developing countries of Asia and Africa is unfavourably affected by climate change, livelihoods of households of the rural poor will be at risk of augmented food insecurity (FAO, 2008). Agriculture, forestry and fisheries are all susceptible to climate. The production processes are likely to be affected by climate change. However, a food system is vulnerable when any of its
components such as; food availability, food accessibility, food utilisation and food system stability is doubtful and insecure.

3.7.1 Impacts of Climate Change on Food Availability

Because of production in agriculture, forestry and fisheries are reliant on ecosystem services, food availability in broad-spectrum is sensitive to climate variability and climate change (FAO, 2007). Such compassion is owing to the direct effects of climate change on agro-ecological conditions, for example, due to more repeated extreme weather events, rising sea levels, changing mean temperatures and precipitation patterns. In the case of fisheries, sensitivity is out of ocean acidification and changes in flow regimes (Easterling et al, 1997). Production of food and its related agricultural commodities may keep speed with increasing demand, but there are probable to be changed in local cropping patterns and farming practices (FAO, 2007).

There have been various researches on impacts that climate change could have on agricultural production, predominantly cultivated crops. In the dry and tropical regions, crop productivity is anticipated to decrease with even small local temperature increases (1-2 °C), which would add together to the threat of hunger due to reduced food availability (Easterling et al, 2007). Some 50% of total crop production comes from forest and mountain ecosystems, as well as tree crops, while crops cultivated on open, arable flat land report for only 13% of annual overall crop production (Schmidhuber & Tubiello, 2007). An estimate of impacts of climate change on agricultural production, food supply and agriculture-based livelihoods must take into consideration the characteristics of the agro-ecosystem where appropriate climate-induced changes in biochemical processes are occurring, determining the extent to which such changes will be positive, negative or neutral in their effects (FAO, 2008). The "greenhouse effect" will produce beneficial local effects where higher levels of atmospheric carbon dioxide accelerate plant growth. This is anticipated to occur mostly in temperate zones, with yields projected to increase from 10 –25% for crops with a lesser rate of photosynthetic efficiency and by 0 –10% for those with a higher degree of photosynthetic efficiency (C4 crops), provided that CO₂ quantities in the atmosphere achieve 550 parts per
20 million (IPCC, 2007). However, such effects are not likely to stimulate projections of world food supply (Lean et al, 1999).

Overgrown forests are not closed or near to be affected, although the growth of young tree stands will be improved (Manyeruke et al, 2013). Impacts of mean temperature increase will be practised differently, depending on location (Kruger and Shongwe, 2004). For example, moderate warming (increments of 1 to 3°C in mean temperature) is projected to improve crop yields in temperate regions, while in tropical and seasonally dry regions, it is expected to have negative impacts, especially for cereal crops. Average warming around 3°C is expected to have pessimistic effects on production in all regions (IPCC, 2007). The availability of meat and other livestock products will be subjective by crop production trends, as feed crops account for almost 25% of the world's cropland. Variables of climate such as rainfall, soil moisture, temperature and solar radiation, influence crops thresholds from which growth and yield are compromised (Porter & Semenov, 2005). During the European heat wave in 2003, temperatures were 6 °C above long-term means, crop yields dropped drastically, such as by 36% for maize in Italy, and by 25% for fruit as well as 30% for forage in France (IPCC, 2007). Increased concentration and frequency of storms altered hydrological cycles and precipitation variance also have long-term implications on the viability of current world agroecosystems.

Although projections suggest that regular carryover stocks, food aid and international trade should be capable of coping up with limited to small area food shortages that are likely to the outcome from crop losses owing to rigorous droughts or floods, now they are being questioned in view of the price change that the world has experienced since 2006. According to (FAO, 2008) the universal food price indicator rose by 9% in 2006 and by 37% in 2007. The price boom has been accompanied with much higher price instability than in the past, especially in the cereals and oilseeds sectors, it reflects reduced inventories, healthy relationships between agricultural commodity and other markets, and occurrence of greater market ambiguity in general (Schmidhuber & Tubiello, 2007). It has triggered extensive impact on food price inflation, which is fuelling debates about the future direction of agricultural commodity prices in importing and exporting countries, rich or poor. It gives rise to uncertainties that a
world food crisis similar in significance to those of the early 1970s and 1980s may be imminent, with little panorama for a quick rebound as the impact of climate change takes their toll (FAO, 2008).

Agriculture is susceptible to climatic variability and weather conditions, such as droughts, floods and severe storms. Food production may gain from a warmer climate, but the increased potential for droughts, floods and heat waves will pose challenges for farmers, thereby affecting their farming activities. These perceived adverse effects on farming activities are already obvious and have been reported in some parts of south-east Nigeria (Umunakwe, 2011). Okoroh (2011) also stated that the impacts/effects of climate change on agriculture are observed a decrease in crop yield. Additionally, the enduring changes in climate, water supply and soil moisture could make it less feasible to continue crop production in specific regions (United Nations Environmental Protection Agency (UNEPA), 2012).

### 3.7.2 Impacts of Climate Change on Food Utilization

Utilisation refers to proper use of food and includes the existence of suitable food processing, proper storage practices, sufficient knowledge application of nutrition, child care and adequate health as well as hygiene services (FAO, 2000). Food insecurity is usually linked with malnutrition because diets of people who are unable to gratify all of their food needs usually do not contain a high amount of staple foods and are deficient in the variety needed to satisfy nutritional requirements (FAO, 2008). A shortfall in the availability of wild foods and limits on small-scale horticultural production due to the insufficiency of water or labour resultant from climate change could influence nutritional status critically (Schmidhuber & Tubiello, 2007). On the other hand, undernourishment increases the risk for both acquiring and dying from infectious diseases. For example, in Bangladesh, both impacts of drought and lack of food were linked with an amplified menace in mortality from diarrheal illness (Aziz et al, 1990).

In broad-spectrum, the main impact of climate change on nutrition is expected to be felt indirectly, through its effects on incomes and capacities to procure foods. Moreover, low-calorie consumption often goes hand-in-hand with micronutrient malnutrition (Dixon et al, 2002). Mothers who endure chronic caloric or micronutrient deficiencies
are more probable to have low birth weight babies (FAO, 2006). In outcome, they pass their undernourishment on to the next generation (Black et al, 2008; World Bank, 2006; FAO, 2004). Physiological utilisation of foods consumed also affects nutritional status, and in turn, it is exaggerated by illnesses (FAO, 2006).

Climate change will cause modern patterns of pests and diseases to emerge, affecting plants, animals and humans thereby would pose new risks for food security, food safety and human health. Increased incidence of water-borne diseases is experienced in flood-prone areas. Projected climate-change related exposures are likely to affect the health status of millions of people, particularly those with low adaptive capacity. This can happen through; increased deaths, disease and injury due to heat-waves, floods, storms, fires and droughts; increases in malnutrition, increased occurrence of cardio-respiratory diseases, altered spatial distribution of some infectious-disease vectors; and enlarged load of diarrheal diseases (FAO, 2008).

Climate change also causes changes in vectors for climate-responsive pests together with diseases, and appearance of new diseases that could affect both the food chain and people's physiological ability to obtain essential nutrients from foods consumed (Schmidhuber & Tubiello, 2007). Adults affected by malnutrition might have a low body mass index or nutritional oedema (retention of fluid). If emaciated adults continue to have inadequate food, health care into old age will remain malnourished and less proficient in assisting in caring for children (Victora et al, 2008). Vector changes are useful certainty for pests and diseases that flourish only at precise temperatures and under specific humidity as well as irrigation management regimes. That exposes crops, livestock, fish and humans to new risks to which they have not yet adapted. They will also place new pressures on caregivers within the home, who are often women, will continue to give that service to sick people and not to participate in food production processes. Malaria is anticipated to change its scattering due to climate change (IPCC, 2007).

Many people may be prone to vector- and water-borne diseases through flooding linked to sea-level rise. Health risks can also be related to changes in diseases from either increased or decreased precipitation, thereby reducing people's capacity to utilise food
effectively and often resulting in the need for improved nutritional intake (IPCC, 2007). Owing to a substantial number of people that may be affected, malnutrition associated with extreme climatic events may be one of the majority essential consequences of climate change (Confalonieri et al, 2007). In a situation whereby, vector changes for pests and diseases can be anticipated, different varieties and breeds that can be resistant to the likely new arrivals should be introduced as an adaptive measure (Schmidhuber & Tubiello, 2007). A recent rise in the appearance of new viruses may also be climate-related, although this link is uncertain. Viruses such as HIV/AIDS, avian flu, SARS and Ebola have a variety of implications for food security. Risk includes livelihoods of small-scale poultry operations in the case of avian flu, and additional nutritional requirements of affected citizens in the case of HIV-AIDS (WHO, 2005). Currently, HIV/AIDS affects 33 million people, 70% in Sub-Saharan Africa and is scattering hastily in some other developing regions (UNAIDS, 2004).

3.8 The Nexus between Climate Variability and Crop Production

3.8.1 Temperature variability and crop production

Globally, especially in developing countries, climate variability cause yield declines for their most important crops (Sudarkodi & Sathyabama, 2011). Temperature is an essential element that limits the growth of plants and crops. Some level of relationship, therefore, seems to exist between temperature and the yields obtained from the cultivation of crops. High temperatures affect some crops and cause a reduction in yield (Sudarkodi & Sathyabama, 2011) which ultimately impact food security. The study of Deressa & Hassan (2007) using the Ricardian model reveals that a marginal increase in temperature in summer and winter caused a reduction in crop yield and revenue per hectare. The decrease in the yield and income of farmers has a significant impact on the livelihoods of the farmers as well as some of the socio-economic roles they play in the family.

Additionally, Basak (2009) studied the impact of climate variability and change on rice production in Bangladesh using the simulation model. The study showed a drastic reduction in crop yield from 13.5 to 2.6% and from 28.7 to 0.11% when the maximum temperature was increased by 2 °C and 4 °C. The model shows that, even though both
maximum and minimum temperature cause a reduction in crop yield, the effect of high temperatures on yield is high as compared to the effect of low temperature on yield. According to the IPCC (2012), high temperatures and extreme weather events are predicted to increase in Sub-Sahara Africa and South Asia with a resultant effect on growth and yield of most crops in these regions which will activate severe concerns about food security. Even though climate warms and minimum average temperatures increase, years that show low maximum temperatures are likely to draw closer to achieving the temperature optimum, which may cause an increase in yield that is the case today during years when average temperatures were below the optimum (Walthall et al, 2010).

Conversely, Welch et al (2010) exemplified in their study that higher minimum temperatures reduce yields, while higher maximum temperature increases yields. They further explained that maximum temperatures would cause a reduction in yield only when the level of rising is significantly above a critical or optimum level. However, it is important that the impact of high and low temperatures on crops depend on the type of crop under consideration.

Another critical area of agriculture that is significantly affected by temperature increase is vegetable crops. Vegetable crops need some optimum amount of temperature for growth and development, and beyond that optimum level crops suffer. For instance, higher temperatures induce floral differentiation and flower stalk development in lettuce plants, both of which decrease yield and quality of the crop. High temperature affects the flowering and development of cucumber and causes a reduction in yield; and high temperatures during flowering induce flower abscission, malformed flowers, and pollen sterility in tomato plants thereby resulting in poor flowering and fruit (Johkan et al, 2011). Similarly, Datta (2013) emphasised the fact that high temperature can impact significantly on crops and cause a drastic reduction in yield. This, therefore, reinforces the need to employ adaptation strategies to help cope with the impact. The study of Welch et al (2010) showed that high temperature has no adverse effect on crop yield unless the amount of heat is beyond the optimum requirement of the crop.
3.8.2 Rainfall Variability and Crop Production

Crop production is influenced by climate variability in the area of rainfall availability (Johkan et al., 2011). Precipitation has a direct relationship with crops with an increase or decrease in precipitation having an impact on output (Walthall et al., 2012). Kassie et al. (2014) opine that rainfall variability does not necessarily affect crop yields directly but indirectly limits the impact on the application of agricultural inputs such as fertiliser thereby affecting crop yield. Example corn is vulnerable to excessive moisture in the early growth stages and can cause a reduction in plant growth, while a reduction in the amount of water in the soil leads to less growth and yield if the stress occurs during the grain filling period (Hatfield & Prueger, 2011).

Kassahun (2009) indicated that the IPCC uniform climate scenarios revealed a decrease in rainfall of a place would cause a decrease in yield and farmers can lose their entire net revenue from crops if rainfall decreases by 14%. Similarly, the study of Molua & Lambi (2006) shows a decrease in net revenues when precipitation declines, or temperature rises across farms in Cameroon. The studies, therefore, give credence to the fact that rainfall has some level of influence on crops. While an increase in rainfall influences an increase in crop yield, a reduction in precipitation also causes a decline in the net yield of crops especially crops that need a considerable amount of water to survive. There is, therefore, a direct relationship between precipitation and crop yield. Thus, in the event of low rainfall, it is therefore important to adopt irrigation to ensure that crops get the proper quantity of water for their growth.

It is essential to recognise the fact that, notwithstanding the above impacts, climate variability has on crop production, there are equally some positive impacts as well. For instance, Sudarkodi & Sathyabama (2011) opine that the high concentration of atmospheric carbon dioxide which is believed to cause warming conditions and affect crops but instead intensifies the photosynthesis actions on crops and increase the overall yield. According to them, the doubling up of carbon dioxide increases photosynthetic rates by as much as 30 to 100%. Again, Lee et al. (2012) also aver that high temperatures and very high precipitations in summer increases agricultural production. Even though the dynamics of how high temperature may lead to crop
increase is not precise, it is quite clear that an increase in rainfall may lead to an increase in yield especially with crops that need a more considerable amount of rainfall like rice.

### 3.8.3 Extreme Climatic events and Crop Production

Droughts and flooding are one of the extreme climatic conditions that hinder the development of most crops especially, rain-fed crops. Easterling et al (2007) suggest that the sensitivity of societal infrastructure to extreme climatic events cannot be over-emphasised. For instance, it is explained that extreme conditions (such as droughts, flooding) can have a significant effect on crop yields than optimal mean conditions. Inefficient water usage in most parts of the world and inefficient distribution systems in developing countries cause a considerable reduction in the availability of water. The availability of water to a large extent has high sensitivity to the changing climate with severe water stress conditions affecting crop productivity, especially vegetable crops (Pena & Hughes, 2007). In addition to the elevated temperatures, decreased precipitation could cause reduction of irrigation water availability and increase in evapotranspiration leads to severe crop water-stress conditions (IPCC, 2007). Therefore, water significantly affects the yield and quality of vegetables with drought conditions severely reducing the productivity of crops. Drought causes the rise of solute concentration in the environment such as soil leading to the flow of water out of plant cells. This leads to an increase in the solute concentration in plant cells, thereby lowering the water potential and disrupting membranes and cell processes such as photosynthesis (Pena & Hughes, 2007).

Most crops are intolerant to flooding and production is often limited due to the excessive nature of the moisture brought about by torrential rains. Most crops are highly sensitive to flooding, and genetic variation concerning this character is limited, particularly in tomato. In general, damage to vegetables by flooding is due to the reduction of oxygen in the root zone which inhibits aerobic processes (Pena & Hughes, 2007). The overall effect of the decrease in the oxygen of plants is that most crops are likely to suffer severe losses with an adverse effect on food security. For instance, according to Naeve (2002), the effect of flooding for six days may potentially cause
significant depression of yields with more extended periods of flooding causing overall
damage to the entire stand.

3.9 Farmers’ Perception of Climate Variability

Climate variability is a phenomenon that is perceived differently by different people.
People's perception may be based on their indigenous knowledge or to some extent,
their educational background. Also, it is essential to note that, the perception of people
on the changing climate may be regionally biased as different people across different
regions may perceive climate variability differently. Myriads of evidence from many
African countries reveals that large numbers of farmers observed that the climate has
become hot and the rains are equally less predictable which are shorter in duration
(Gbetibouo, 2009). According to the study of Tunde (2011) on farmers' perception of
climate variability on agriculture in Nigeria, the majority of farmers (47.2%) in the
region perceived climatic variability as delayed rainfall. Also, the study alluded that
22.2% perceived climate variability as high temperature, 5.6% said it is flooded, 2.8%
observed it as unusual rainfall, and 22.2% perceived it as an undefined season. The
author, therefore, concluded that farmers in Nigeria perceived climate variability as an
increase in temperature and inadequate/ excessive rainfall, flooding and changes in the
weather pattern. These variations as observed by the farmers in the country will inform
the decision of farmers on the kind of adaptation strategies to implement to help cope
with the variations and its effects.

Ogalleh et al (2012) studied local perceptions and responses to climate change and
variability in Laikipia in Kenya. According to the study, rainfall was observed to be
decreasing while temperature and wind were observed to be on the increase. The author
alluded that, farmers did not experience these variations in the 1960s, 1970s and the
1980s but started experiencing these weather and climatic oscillations after the 1980s.
The perception of the farmers in this region stems from the various observations made
by farmers over the decades which showed some anomalies that had never been
experienced in the past. A similar study conducted in Zimbabwe by Mudombi (2011)
revealed that farmers in Zimbabwe especially, the Murewa district perceive climate
variability as an increase in drought conditions, heavy precipitation and violent storms
which were never experienced in the past decades. The findings show that smallholder farmers in Zimbabwe perceive the changes in the timing of seasons, and characteristics within seasons, e.g. extreme events such as droughts, floods and destructive hailstorms becoming more common.

Moreover, Mubaya (2010) avers that most smallholder farmers (80%) in Zambia and Zimbabwe were aware of the changes in climate over the years. The study further avers that farmers in the two regions perceived climate variability as floods and excessive rainfall coupled with the oscillations in the weather patterns over the years. It is clear from the study that, even though most farmers in Zambia and Zimbabwe perceived flood and excessive rainfall as evidence of a changing climate, a section of the farmers in Zambia (10%) and Zimbabwe (18%) forming the minority indicated that they had not seen any changes in the climate.

Kemausuor et al (2011) on farmers’ perception of climate change in the Ejura Sekyedumasi in Ghana shows that the majority of farmers (82%) perceive climate change as evident through the warming temperature and changes in rainfall timing from 1993 -2006. A greater number of farmers (93%) established the fact that there has been irregular and unpredictable rainfall pattern which has culminated in a reduction in precipitation with the potential to cause drought. The study further recommends that farmers should be given enough education on their farming practices as well as enhancing their adaptive capacities to help them respond positively to the changing climate. Mengistu (2011) studied farmers' perception and knowledge of climate change and their coping strategies in Adiha, Nigeria. The results revealed that about 75% of farmers perceived that the temperature of Adiha had increased in the last two decades. Conversely, 90% of the respondents observed changes in rainfall patterns over the previous two decades, and 70% noticed a decrease in the amount of rainfall. This shows that farmers and for that matter, local people in Nigeria are very much familiar with the changing climate through some observations made over the years.

3.9.1 Perception of the Causes of Climate Variability

The cause of climate variability is one of the controversial issues in recent climate discourse. While some people attribute the causes of climate variability to
anthropogenic factors, others perceive it to emanate through natural elements. Some schools of thought even move further to attribute the causes to spiritual factors especially, those who are dogmatic in some religious sects. All these perceived causes give a plethora of dimensions of the origins of the phenomenon and the persistent ongoing debate. The study of Mubaya et al (2010) on farmers’ perceptions regarding climate change and variability as a threat to livelihoods in Zimbabwe and Zambia showed that, a majority of farmers in the study areas perceived the causes of climate variability to natural factors and as a natural phenomenon without any intervention being responsible for the variability. Some of the natural reasons that were cited included natural changes in winters, low or high temperatures and changes in wind movement as experienced in the two countries. These show that most of the farmers in the two countries downplayed anthropogenic factors which are widely asserted as one of the significant causes of climate variability. However, some farmers in Monze (33%) and Sinazongwe (17%) in Zambia recognised human-induced factors such as deforestation as a major cause of climate variability. Also, some farmers in Lupane (45%) and Lower Gweru (27%), in Zimbabwe alluded the causes of climate variability to the wrath of cultural spirits and God who has meted out such punishment on them for some wrongdoing. This means that the level of perception of people on the causes of climate variability has some relationship with the degree of one’s experience and religious inclination to a more significant extent.

Similarly, Tunde (2011) on the perception of climate variability on agriculture and food security in Ondo State, Nigeria, revealed that majority of the farmers (50%) attributed the causes of climate variability to natural causes. However, 27.8% said anthropogenic activities cause it while 22.2% alluded the cause of the changing climate to God's annoyance. The study recommended that local communities should be made to take part in the debate on climate change. When local communities are involved in climate variability discourse, they will be enlightened to appreciate some of the scientific underpinnings of the causes of the phenomenon and the appropriate strategies to adapt to cope with the situation. Again, policymakers will be abreast with the indigenous knowledge available and the need to build on that knowledge to empower the local people to adopt effective adaptive strategies.
Contrarily, Abaje et al (2014) on climate variability and change impact and adaptation in Katsina State, Nigeria, show a different perception as the majority of the respondents perceived the causes of the climate variability to be primarily spiritual. According to the study, (83%) of the respondents opined that community disobeying God is one of the major causes of change in the climate. This, therefore, adds another dimension to the climate change discourses in the area of the origins of the phenomenon. The study, therefore, concluded that non-scientific proven causes (community disobeying God) are a major cause of climate variability and change as believed by the majority of the respondents.

3.9.2 Perception of the Effects of Climate Variability

There are varieties of ways by which people perceive the impact of climate variability. The perception of people stems from their observations and experiences of the oscillations in the temperature and rainfall regimes of their respective localities. It is worth noting that the changing climate affects food crop farmers in most parts of sub-Saharan Africa. For instance, there have been myriads of empirical studies on how farmers perceive the level of impact of climate variability on crop production.

According to one study by Abaje et al (2014) on climate variability and change, impacts and adaptation strategies in Katsina state, Nigeria, the decline in crop yield was identified by farmers as one of the major implications of an increase in temperature, high rainfall variability, and high incidence of flood occurrences. The consequence of such a reduction in crop yield will cause an increase in the price of food crops in the area. This will have future repercussion on food availability and a threat to food security. There is a need for stakeholder engagement to help put up appropriate strategies to enable farmers to cope with the effects due to the extent of the impact. This will alleviate hunger as projected by the IPCC in its series of assessment reports and to also help achieve the Millennium Development Goal (MDG) of eradicating hunger.

Similarly, Mubaya et al (2010) aver that the most contributory factors leading to low crop yield as perceived by farmers in most districts in Zambia and Zimbabwe were droughts and most rivers drying up. One principal effect of the small crop yield identified in the two countries (Zambia and Zimbabwe) as indicated by the study during
this period was food insecurity which led to hunger. The study, therefore, concluded that the reduction in crop yield could have a significant impact on the income and livelihoods of farmers which could hinder them from taking up social responsibilities.

Moreover, the study of Ogalleh et al (2012) on how local people perceive and respond to the variability and changes in climate in Kenya reveal that smallholder farmers in the country observed an increased incidence of crop diseases and livestock diseases as some of the significant impacts of climate variability. Excessive rainfall and drought conditions have the potential to cause a crop failure with severe consequences for food availability and accessibility. Again, the reduction in crop yield and livestock through diseases has the potential to threaten farmers’ livelihoods and make them more vulnerable to poverty.

3.10 Empirical Study on the impact of Climate Change on Agriculture

Most of the empirical investigations centre on the effect of climate change on agriculture in the USA. Examples of studies include investigations are Nordhaus (1991), Dinar & Mendelsohn (2009) and Mendelsohn et al (2001). These analysts presumed that agriculture frameworks in the USA would promptly adjust to climate change, by presenting new advanced technologies, new varieties of crop and cultivations so that there would be insignificant changes in yields and net profits. These outcomes would almost certainly stretch out to other Institutions for Economic Cooperation and Development (OECD) nations, recommending that agriculture in developed nations is less delicate to climate change. Notwithstanding, less is known about the impacts of climate change in developing nations, particularly Africa and Ghana specifically.

Molua (2002) sees that an expansion in rainfall amid yield development is a positive covariate of income in Southwestern Cameroon. This infers, for a region whose agriculture depends on rainfall, an increase in rainfall combined with improved culturing practices could enhance the economic returns from farms. Along these lines, irrigation during the growing season, particularly amid droughts, would be profitable for increasing yields. He utilised an econometric function which legitimately relates farming income and precipitation to assess the centrality of methods of adaptation by
farmers statistically. Thus, agro-climatic investigations by Akong’a et al (1988) thought about the impacts of climatic variability on agriculture, with much stress on adapting to drought. Drought seasons in sub-moist and semi-dry zones were seen to have prompted the failure of yield and reliance on different sources of income to purchase food for sustenance or relief. Schulze et al (2006) utilised the ACRU/CERES high breed model to assess the effect of climate change on maize in South Africa. The researchers subjected the varied topography of South Africa into 712 homogeneous zones, each related with a particular sort of vegetation, soil, and climate. Day to day estimations of temperature (least and greatest), rainfall, wind speed and solar radiation were utilised in crop assessment, given the CERES-Maize model. For three situations of climate change, yields will in general decline in the semi-bone-dry west.

Even though developing countries are more vulnerable to climate change sensitivity (Gadedjisso-Tossou, 2014). Mendelsohn et al (2001) in their investigation of the sensitivity of climate and development reasoned that development directly affects climate sensitivity. Besides, farmers in developing nations are at present more climate-delicate than farmers in progressively developing nations. Joining this climate sensitivity with the higher temperatures at latitudes proposes that low latitudes agriculture would be harmed if warming happened today (IPCC, 2007). About whether this is the circumstance or not is unknown in Africa or and Ghana specifically. This research will add to narrowing this gap in knowledge.

### 3.11 Agriculture and Climate Change in Ghana

According to EPA (2000), Global warming has led to environmental changes in Ghana. That is, over the 30 years covering 1961-1990, annual total rainfall declined by 20%, and streamflow or runoff in the river basin systems decreased by 30%, as temperature increased by 1 °C (EPA, 2000). Furthermore, it is estimated that the mean daily temperature will rise between 2.5 to 3.2 °C in the year 2100, whereas annual total rainfall will decline by 9-27% by the same year. A stream flows in all the river basins are expected to decrease by 15-20% by 2020 and 30-40% by 2050. Notably, Ghana has been experiencing long periods of drought and erratic rainfall, particularly in the arid north (Savannah) and along the coast. Unpredictable climatic conditions like an early
onset of rains and untimely cessation of rainfall during the crop-growing season have also been experienced. Unusual rainfall has also been observed during the minor crop season (namely, during September and November) in the forest-savanna transition zone. Sometimes exorbitant rainfall causes floods. The present dimensions of temperature and dissipation rates are on the increase in Ghana, especially in the Guinea savannah, seaside savannah zones and Sudan savannah.

Climate change could apply unfriendly impacts on agriculture in Ghana. For instance, it has been discussed that the high temperatures and high dissipation rates have increased water pressure and at last causes decreases in harvested yields (EPA, 2000). Moreover, high temperatures and decreases in surface water accessibility because of temperature consequences for runoff waters, just as decreases in underground water accessibility because of climate-incited declining rates of recharge of aquifers have additionally happened in Ghana. It has been evaluated, for example, that climate change is probably going to cause a decrease in groundwater(aquifer) of 22% in the Volta basin system, 17% and 5% decrease in groundwater in the Pra and Ayensu system respectively by 2020 (EPA, 2000) Unfriendly climate change could lead to reduced yield. For instance, farmers in the Upper East Region have bemoaned the inability of the millet crop, though farmers in the Northern Region have recorded rice crop failure because of change in climate (Ofori-Sarpong, 2001). Farmers observations concerning climate change demonstrate that farmers know about climate changes like the postponed beginning of rainfall, increment in day length, and irregular droughts amid the applicable yield developing season and harvest failure because of unfavourable climate change. Proof of climate change (explicitly, decrease in rainfall) in the Sekyere-West District of Ghana has been given explained by Owusu (2002). Likewise, the effect of climate change on agriculture and farmers' adapting procedures in Navrongo and Bawku (the dry areas of Ghana) have been examined by Ofori-Sarpong (2001). The mean yearly rainfall for the thirty years 1931-1960 was 1087.6 mm while the mean for the second 30-year time span 1961-1990 was 986.1 mm, which means that the initial 30-years were wetter than the last 30 years in the arid Upper East Region (Ofori-Sarpong, 2001). From the sixty years, 30 years are drought years (drought here
characterised as a period amid which rainfall falls underneath the mean). Ofori-Sarpong (2001) indicated that drought is endemic in the Upper East Region.

Moreover, in the course of the last 30-40 years, a reduction in yearly and month to month rainfall figures in the Upper East Region happened (Ofori-Sarpong, 2001). Additionally, the yearly mean and month to month temperatures have expanded, which could likewise be a sign of climate change (Ofori-Sarpong, 2001). The investigation was performed just in the Upper East Region, with a specific climatic condition (hot and dry climate). The available studies add to bridging this gap in information by broadening the analysis the entire nation, which would catch the impacts of various climatic conditions; subsequently, adding to investigations in the impacts of climate change on agriculture in Ghana.

Owusu (2002) saw that total rainfall in the Sekyere-West District reduced from 1493.1 mm in 1960 to 1164.0 mm in 1999. He further noted proof of drought conditions in the monthly rainfall seasons in some annual rainfall pattern (the growing seasons) and that in 1992, which was a regular drought year, every one of the months aside from May recorded rainfall underneath the long-term mean, while water balance recorded an eight-month rather than a five-month drought period in the long-term mean water balance. Besides, in 1998, the raining season was reduced to just five months rather than the mean seven months (Owusu, 2002) thus in Owusu's investigation, rainfall was the main climatic factor considered. The present examination incorporates a new climatic component, explicitly, temperature. Hamid (1984) deduced in his examination in the Upper West territory of Ghana that rainfall regularity is the key consideration which controls the main agriculture season in the region. He argued that the battle for enough food supply by the general population of this region is constrained by the beginning, length and end of the raining season.
4.0 RESULTS AND DISCUSSIONS

4.1 Introduction

This chapter focuses on the analysis of the effect of the climatic change on yam production as well as farmers' perceptions of the effects of climate change on yam production in Brong Ahafo Region specifically Techiman Municipality. The analyses summarise qualitative data from the two topics with a deep inspection and analysis of the statements made in the literature review applauding the positive impact of the crop in the both domestic and foreign economic endeavour to the country. Respondents’ views were sought as well as on literature analysis and data studies. In-depth interviews were adopted to gather qualitative data from the respondents to formulate the themes especially theme 3.

4.2 Theme One: Yam Production in Ghana

Yams (Dioscorea spp.) are annual or perennial herbaceous climbing or trailing crop plants that produce edible underground tubers. They are origins to tropical regions of the World. Yam is produced throughout the length and breadth of Ghana. Commercial production areas in Ghana include Wenchi, Mampong, Ejura, Kintanpo, Atebubu, Yendi, Tamale, Bole, Wa, and Kete-Krachi (Twumasi, 1981). Yam belongs to the genus Dioscorea (family Dioscoreaceae). They are annual or perennial tuber-bearing and climbing plants with over 600 species in which just a small portion are cultivated for food and medicine (IITA, 2009). Six species out of the over 600 species are grown for food in the tropics (Hahn et al., 1987). Dioscorea rotundata (white yam) and Dioscorea alata (water yam) are noted as the most economical and popularly cultivated species of yam in Ghana due to their high yielding qualities. Also, Dioscorea rotundata is the most widely grown and preferred yam species in Ghana. A large number of white yam varieties exist with the popular cultivars in Ghana being Pona, Tela, Dente, Serwaa and Doben. Yams are part of the essential staple food crops in the world particularly in the tropical and sub-tropical countries (Okigbo & Ogbonnaya, 2006). Yam plays a significant role in the food economy in most West African countries especially Ghana. Yam is a substantial source of energy in the daily diet of many people and as such
crucial to food security in Ghana. Yam is estimated to contribute over 200 calories per person per day for more than 150 million people in West Africa (FAO, 2006). Although yam tubers are mostly used for their high content of carbohydrate, they also have high protein, minerals such as calcium, phosphorus, iron and vitamins B and C (Splittstoeser & Rhodes, 2009). Economically, the essential part of the yam is the tuber. They can vary greatly in shape and size and makes manual harvesting difficult and has so far prevented any in harvesting. Cultivated yams mostly produce cylindrical tubers with a brownish periderm and a firm white flesh which can be very heterogeneous in size and weight. Yam is important for food, income generation, socio-cultural activities and use for medicinal purposes in many countries in West Africa (FAO, 2010).

The role played by yam in the food economy in West Africa cannot be overemphasised. Yam contributes over 200 calories per person per day for more than 150 million people in West Africa (FAO, 2006). It ranked first among 20 most important food and agricultural commodities in Ghana and Togo in 2005 (FAO, 2006) and regarded as the most nutritious of the tropical root crops (Wanasundera & Ravindran, 1994). Yam is a vital source of carbohydrate (energy), minerals (such as phosphorus, calcium and iron), vitamins (A and C) and dietary fibre (Bradbury & Holloway, 1988). Yam is also another good source of protein. It contains approximately four times as much protein as cassava and is the only major root crop that exceeds rice in protein content in proportion to digestible energy (Bradbury & Holloway, 1988).

According to the data from FAO 2017, table 1 shows that the total area harvested globally has increased from 1,15 million (Ha) in 1961 to 8.5 million (Ha) in 2017. There were increases in the yield as well from 72,34 thousand (Hg/Ha) in 1961 to 85,29 thousand (Hg/Ha) in 2017. Over 39 million tonnes and 73,01 million tonnes of yam were produced in 2000 and 2017 respectively worldwide. Out of the total production in 2017, 92.20% came from West Africa. Nigeria is the leading producer produced 66.6 % being 47,94 million tonnes of global yam production. This is followed by Ghana with 7,95 million tonnes with a contribution of 11% to the world production value. The changes and development of yam could partially be a result of modern farm inputs.
Table 1: Annual Yam production in the World, West Africa, Ghana, Nigeria, 1961–2017

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Yield (Hg/Ha)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ghana</td>
<td>73,333</td>
<td>52,825</td>
<td>128,847</td>
<td>154,841</td>
<td>169,600</td>
<td>170,694</td>
</tr>
<tr>
<td>Nigeria</td>
<td>77,778</td>
<td>56,373</td>
<td>98,984</td>
<td>130,109</td>
<td>84,748</td>
<td>80,917</td>
</tr>
<tr>
<td>West Africa</td>
<td>77,908</td>
<td>70,022</td>
<td>100,341</td>
<td>119,284</td>
<td>87,570</td>
<td>84,556</td>
</tr>
<tr>
<td>World</td>
<td>72,345</td>
<td>69,256</td>
<td>98,285</td>
<td>115,087</td>
<td>88,280</td>
<td>85,297</td>
</tr>
<tr>
<td>Area harvested (Ha,’000)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ghana</td>
<td>150</td>
<td>223</td>
<td>261</td>
<td>385</td>
<td>430</td>
<td>466</td>
</tr>
<tr>
<td>Nigeria</td>
<td>450</td>
<td>816</td>
<td>2,647</td>
<td>2,8689</td>
<td>5,390</td>
<td>5,925</td>
</tr>
<tr>
<td>West Africa</td>
<td>868</td>
<td>1,427</td>
<td>3,638</td>
<td>4,387</td>
<td>7,229</td>
<td>7,961</td>
</tr>
<tr>
<td>World</td>
<td>1,151</td>
<td>1,788</td>
<td>4,034</td>
<td>4,930</td>
<td>7,833</td>
<td>8,561</td>
</tr>
<tr>
<td>Production (MT ’000)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ghana</td>
<td>1,100</td>
<td>1,178</td>
<td>3,363</td>
<td>5,960</td>
<td>7,296</td>
<td>7,953</td>
</tr>
<tr>
<td>Nigeria</td>
<td>3,500</td>
<td>4,600</td>
<td>26,201</td>
<td>37,328</td>
<td>45,678</td>
<td>47,943</td>
</tr>
<tr>
<td>West Africa</td>
<td>6,759</td>
<td>9,994</td>
<td>36,507</td>
<td>52,328</td>
<td>63,305</td>
<td>67,312</td>
</tr>
<tr>
<td>World</td>
<td>8,324</td>
<td>12,385</td>
<td>39,644</td>
<td>56,738</td>
<td>69,148</td>
<td>73,019</td>
</tr>
</tbody>
</table>

Source: FOASTAT, 2017

Figure 1 below shows fluctuations and inconsistent yam production in Ghana, and this could be a result of a change in climate in the area, unattractiveness and labour-intensive nature of yam production. However, the majority still engage in the farming of yam because there are no other opportunities available to them (Verter & Becvarova, 2015).
From figure 1 above it is evident that yam production in Ghana increased from 2.1 million tonnes in 1995 to 3.9 million tonnes in 2002. However, yam production decreased to 3.8 million tonnes in 2003. There were declines in production between 1993 and 1994 production reduced from 2.7 million tonnes to 1.7 million tonnes. Figure 1 above continues to show the increases in a total area of hectares planted to yam from 1961 to 2017 may be attributed partly due to the shifting cultivation system. Additionally, increases in yam products over the period understudy could be as a result of the introduction of high yield varieties introduced by the Roots and Tubers Programme, which ended in 2004. The Programme was a project which provided farmers in both Ashanti and Brong Ahafo Regions with short term credit and inputs to boost yam production.

4.2.1 Contribution of Yam to the Overall National Export

The importance of Yam to the domestic role of ensuring maximum food security cannot be underrated, it dates back over decades, significant proportion of the Ghanaian population consume Yam, its ability to endure the harsh and unfriendly climate conditions throughout the year makes its importance unchallenged by any other crop, its quality, endurance and wide consumption is akin to Cocoyam. Yam is instrumental in the Ghanaian foreign exchange earnings; such an assertion is factually accentuated since Ghana holds the enviable title as the highest exporter of the crop worldwide. (Wasswa, 2015).

Table 2 intends to evaluate the importance of yam production to the GDP of the country against another tuber crop which also has cross-culture dietary importance. Within 1990 and 2002, Yam and Cocoyam from 3% to 10% of the total horticultural export commodity according to research carried out by (Sagoe, 2006). Table 2 statistically makes analysis between the two major tuber crops being Cocoyam and, Yam, our primary focus, first we looked at the data in terms of the quantity of yield contributed to the overall net export captured in the yearly national export metadata, and secondly considered their contribution to the net export in terms of percentage.

The inclusion of the number of exporters is valuable in evaluating the success and failure of the yam industry, a critical look at the data holistically, indicates that the rise
in Yam production increases simultaneously with the increase in the number of exporters, a trend which could be rationally credited to the propensities in the rise in the contribution of the crops to the net national export quota.

Table 2: The contribution of Cocoyam and Yams in the overall national exports and the number of exporters, 1990–2002

<table>
<thead>
<tr>
<th>Years</th>
<th>Quantity (Mt)</th>
<th>Contribution to Net Export (%)</th>
<th>Number of Exporters</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990</td>
<td>2121.8</td>
<td>3.37</td>
<td>61</td>
</tr>
<tr>
<td>1991</td>
<td>3051.2</td>
<td>7.45</td>
<td>120</td>
</tr>
<tr>
<td>1992</td>
<td>2328.07</td>
<td>9.57</td>
<td>143</td>
</tr>
<tr>
<td>1993</td>
<td>3574.06</td>
<td>7.79</td>
<td>112</td>
</tr>
<tr>
<td>1994</td>
<td>5322.78</td>
<td>7.81</td>
<td>188</td>
</tr>
<tr>
<td>1998</td>
<td>7531.55</td>
<td>6.16</td>
<td>215</td>
</tr>
<tr>
<td>1999</td>
<td>9938.51</td>
<td>7.78</td>
<td>243</td>
</tr>
<tr>
<td>2000</td>
<td>12648.29</td>
<td>9.21</td>
<td>278</td>
</tr>
<tr>
<td>2001</td>
<td>14654.7</td>
<td>9.59</td>
<td>280</td>
</tr>
<tr>
<td>2002</td>
<td>13344.33</td>
<td>9.73</td>
<td>249</td>
</tr>
</tbody>
</table>


Being a common dietary supplement for almost all the cultures in the country, Yam becomes the most consumed crop next to rice and maize. Its production and process and all factors that account for its success are of utmost interest to the state, its contribution to foreign earnings and its appreciable per capita consumption make it a crucial economic growth factor. The graphical illustration in figure 2 then assesses yam and other non-traditional crops in terms of their role in the country’s GDP.

Figure 2 below focuses on a broader analysis between Yam and other equally important non-traditional crops regarding their contribution to the total national export from the years in retrospect. The rationale is to highlight the indisputable indispensability of Yam in both its’ domestic and international importance of the country. The contribution made by yam in the net export of the country, which directly affects the GDP of the country per the illustration is not steady and may as well seem insignificant in the foreign exchange earnings, yet the country is the largest exporter of the crop in Africa. The initial perception created in the mind of the observer may be an inadequate assessment of yam, basically out of the competing crops on the data, yam is the only
crop exported without addition of value, it is exported in its raw state, again climate change has affected the crop and continuous to undermine the industry unpredictably, this could explain the fluctuations existed in the graph so far as yam is concerned.

Figure 2: Yam evaluated among other Non-traditional exports in Ghana
Source: MoFA and Agriculture sector development Policy.

4.2.2 Challenges of Yam Production in the study area

Brong Ahofo region and for that matter, Techiman municipality was independent in the production of crops; however, the farmers in the study area have encountered many challenges. Apart from climate change, low yield in the study region can be ascribed to national economic policies, less support given to farmers and disease and pest, soil fertility access to road and lack of labour and land among others.

4.2.2.1 Diseases and Pest

Diseases and pests associated issues have been recognised as another constraint to Yam production in the study area and agriculture. The agents which cause the diseases affect the quality of the Yam tubers by making them unattractive to the consumers, the impact of the diseases also reduces the quantity of yam produced. The invasion of the fungi
pathogen and parasites can be through a natural opening or wound that occurs during growing process, harvesting, transportation and storage. These include parasitic nematodes; insects such as tuber and leaf beetles; fungi such as tuber rot, leaf spot, and other viruses (Aba et al., 2013).

4.2.2.2 Soil Fertility

Low soil fertility and inadequate available plant nutrients (phosphorus and nitrogen) are part of the main limitations to agricultural productivity in Ghana. The imperatives identified with low soil fertility has been identified as the primary source of the declining production of food in Ghana (MoFA., 2016). The sterility of soils is another crucial constraint in yam producing areas of West Africa (Lebot 2009). Research carried out in Nigeria by Agbaje et al. (2005) saw yam yields decrease by 50% in 5–6 years because of declining soil fertility. The increasing population has likewise added pressure on the persistent land farming on the same piece of land and the limited period of fallow has prompted quick exhaustion of soil supplements and reduced yields. However, Soil fertility is of extreme importance for advancing crop nutrition to achieve economic crop production.

4.2.2.3 Access to the road.

Transport enhances the movement of people and goods and facilitates national integration and development in general. A significant amount of produce goes waste in the rural communities directly because farmers encounter difficulty in sending their goods from the farm to the market centres on time. This partly because there are no accessible roads linking the remote rural farms to the consumers in the cities, in places where the roads exist they are poorly maintained and not motorable during the raining season due to its feeder nature, perishable crops such as tomatoes, yam etc. rot before they eventually get to the market.

4.2.2.4 Lack of Labour

Labour is essential in agriculture production and yam production due to its labour-intensive nature. As a result of rural, urban migration caused by development in the country, labour starts moving from the agriculture sector due to increasing opportunities in high productivity sectors. A similar trend can be seen in Ghana as people move from rural farming communities to urban centres for other opportunities in
areas of education and jobs. The effect is labour shortage leading to low yield because less farmland is cultivated, delay in harvesting eventually causing some such as crops to damage on the farm.

4.2.2.5 Access to Land

According to Achaw (2010), small-scale farmers complained about land as a primary factor of production. Human activities in crude farming practices and the increasing population in Ghana and Brong Ahafo have also contributed to the loss of farmland because we convert forest and farmlands into places of residence therefore only the wealthy can succeed in getting most farmlands in their possession leaving the poor with limited access to large scale farmland. Again, most landowners prefer to sell lands for higher sums money for construction and building purposes instead of renting to farmers who are sometimes unable to pay for the rent.

4.3 Theme Two: Climate trends in Ghana and the Study area

4.3.1 Trend of Climate Change in Ghana

Figure 3 below served as a point of information that guided my perception of the situation, and same influenced my line of questioning, it looks at the average trend of climate variation from the years as depicted according to years.

![Figure 3: National Average Rainfall Distribution of Ghana 2011–2017](Source: SRID, 2017)
According to figure 3 above, the rainfall in Ghana since 2011 has been irregular, and it has effects on the farming season. The national average rainfall in 2017 recorded 1080mm which was much better than 2016 which recorded 834mm below the average water content for the proper growth of yam. Rainfall in 2017 is considered better because the climate of Yam has been classified as tropical. According to the Koppen-Geiger climate classification, the average annual rainfall for yam is 1035 mm.

FOA (2017) has revealed in figure 4 below that the annual rainfall in the country is highly variable on inter-annual and inter-decadal timescales, causing identification of long-term trends.

![Figure 4: Average Monthly Temperature and Rainfall for Ghana from 1961–1990](image)

Source: FOASTAT 2017

However, according to figure 4, reports from EPA indicate that environmental changes in Ghana are as a result of global warming. According to EPA, in the thirty years covering 1961-1990, annual total rainfall declined by 20%, and runoff water in the river basin systems decreased by 30%, as temperature increased by 1 °C (EPA, 2000). According to McSweeney et al, (2008) in the 1960s, rain in Ghana was notably higher and reduced to unusually low levels in the late 1970s and the early years of 1980s. This resulted in an overall nation-wide decreasing trend in the period 1960 to 2006 of an average 2.3mm/month (2.4%)/decade. Besides, another study conducted by Dontwi et al (2008) with specific reference to the Coastal areas in Ghana shows a significant
linear decrease trend from 1961 to 2000 (decrease of about 1000 mm) with marked cycling of higher and lower rainfall years with a seeming six-year interval. Comparison of the mean annual rainfall differences between 1951-1970 and 1981-2000 at meteorological stations across Ghana also indicate less rainfall (Owusu & Waylen, 2009 cited in Stanturf et al, 2011). The reduction of rainfall in Ghana between the periods of 1981-2000 may have partly stemmed from the severe drought condition experienced in 1983, which culminated in hunger and famine in the country with most people travelling to other parts of the world. The reduction in rainfall did not only affect the flora, but it also affected the fauna and aquatic species. Again, the decrease in rainfall goes a long way to affect plant growth. There is, therefore, the fear that the reduction in rainfall among countries in Sub Saharan Africa such as Ghana may continue to worsen the food security situation since most of the crops cultivated on the continent are rain-fed.

Figure 5: Average Monthly Temperature and Rainfall for Ghana from 1991–2016
Source: FOASTAT 2017

It was evident from figure 5 that the two bracing months January and December have been recorded low rainfall, the country experience high temperatures from January to March, it steadily drops from April through to August and rises again from September till November. From Figure 5, June and September with a value of 160.41 mm and 166.06 mm respectfully are heavy rainy months, November through to February are
mostly dry seasons, with little or no rainfall at all. These periods are suitable for harvesting and it also commission preparation periods for the next farming season.

4.3.2 Rainfall and Temperature distribution in the study area.

Figure 6: Average monthly rainfall for Brong Ahafo Region from 1991–2015

According to the World Bank, the temperature trend from the period 2010 to 2050 shows warming in all regions of Ghana especially in the Northern, Upper East, and Upper West regions records the highest temperature. However, Brong Ahafo region will record the lowest temperature. Techiman Municipality located in the Forest-Savanna Transition Zone Forecasted changes in precipitation range from 46% decreases to 36% increases in wet season rainfall (World Bank 2010). It is indicated from figure 6 that the rainfall pattern in the study region of Brong Ahafo is very less in January, February, November and December. The maximum rainfall was recorded in September and July with 205.68mm and 193.45 mm respectfully whiles the temperature is rather very high in February at 29.38 °C till it drops in August to 25.66 °C and rises again from September till November and begins to drop again in December as shown in figure 7. According to the study by Stanturf et al (2011), it was realised that temperatures in the 3 Northern regions would increase from 2.1–2.4 °C by 2050. However, they predicted an increase in the Ashanti, Western, Eastern, Central,
and Volta regions from 1.7 – 2.0 °C, and that of Brong Ahafo region shown in figure 7 which is the study area will be 1.3–1.6 °C.

![Average monthly Temperature for Brong Ahafo Region from 1991–2015](Image)

Figure 7: Average monthly Temperature for Brong Ahafo Region from 1991–2015

The percentage change of the regional rainfall as shown in figure 8 affirms the unpredictability of rainfall distribution in the ten regions of Ghana. Brong Ahafo which host the study area recorded a considerable high change in the volume of rain of about 22.4%. This occurred during the period the crops were at the vegetative stage endangering the proper growth of the crop because it creates an enabling environment for pest and other damaging micro-organisms to flourish, resulting in low-quality yields whiles the Upper West recorded the uppermost decrease of over 22% which was a result of the late onset of rain equally endangering the overall yield of crop production.

![Regional Rainfall Distribution](Image)

Figure 8: Regional Rainfall Distribution
Source: Meteorological Services Agency, Ghana.
4.3.3 Effect of climate change on Yam Yield

Though the impact of temperature on the health of the crop is well established, its impact on yam production is lowly unparallel to rainfall. From figure 9 though temperature constantly fell under 30 degrees in all the months, rainfall pattern was practically setting the pace for the prospect of the crop’s yield.

Yam is typically a dry season crop, though it deserves some amount of rainfall to flourish, too much water tends to be counter-productive to it. In the months when rainfall ascends it correspondingly cause production to fall, at the same time when production is seen to raise, we also espy that rainfall pattern is dropping.

Data shown in table 3 took into cognisance the pattern of yam yield, under the influence of the arbitrary changes in the weather conditions. Another implication is that excessive annual rainfall can also affect the yield of yam crops. Okringbo & Ominikari (2017) found that high rainfall could affect yam crops and affect its yield. This finding is in line as temperature increases, and rainfall pattern becomes more unpredictable, crop yields drop significantly, and extreme weather occurrences such as heavy winds, thunderstorms and floods destroy farmlands which can lead to crop failure. The variations in the years indicated in table 3 incontrovertibly show a strong reaction of yam production with both the two variables, thus, rainfall and temperature. From the
year 1991 to 2015, yam production has not been consistent, the variation of yam production measured in tons correlate with the inconsistency of rainfall and temperature. The character of the statistics from 1991 up to 2000 changed slightly showing a positive trend, irrespective of the variation in rainfall and temperature, this could be attributed to the growing number of people engaging in yam production across the major zones of yam production in the country as well the increase in areas harvested also shown in table 1 above.

Table 3: Impact of variability in Rainfall and temperature on Yam Production for Ghana between the years 1991–2015

<table>
<thead>
<tr>
<th>Year</th>
<th>Yam production '000</th>
<th>Annual Total Temperature (°C) variation</th>
<th>Annual Total Rainfall (mm) variation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1991</td>
<td>2,632</td>
<td>27.34</td>
<td>108.77</td>
</tr>
<tr>
<td>1996</td>
<td>2,275</td>
<td>27.51</td>
<td>100.69</td>
</tr>
<tr>
<td>2000</td>
<td>3,363</td>
<td>27.44</td>
<td>84.59</td>
</tr>
<tr>
<td>2001</td>
<td>3,547</td>
<td>27.57</td>
<td>87.57</td>
</tr>
<tr>
<td>2003</td>
<td>3,813</td>
<td>27.68</td>
<td>100.32</td>
</tr>
<tr>
<td>2004</td>
<td>3,892</td>
<td>27.68</td>
<td>93.65</td>
</tr>
<tr>
<td>2006</td>
<td>4,288</td>
<td>27.59</td>
<td>107.32</td>
</tr>
<tr>
<td>2007</td>
<td>4,376</td>
<td>27.6</td>
<td>109.88</td>
</tr>
<tr>
<td>2008</td>
<td>4,895</td>
<td>27.34</td>
<td>101.11</td>
</tr>
<tr>
<td>2009</td>
<td>5,778</td>
<td>27.61</td>
<td>103.4</td>
</tr>
<tr>
<td>2011</td>
<td>6,295</td>
<td>27.78</td>
<td>99.43</td>
</tr>
<tr>
<td>2012</td>
<td>6,639</td>
<td>27.5</td>
<td>89.28</td>
</tr>
<tr>
<td>2013</td>
<td>7,075</td>
<td>27.65</td>
<td>95.87</td>
</tr>
<tr>
<td>2014</td>
<td>7,119</td>
<td>27.89</td>
<td>98.97</td>
</tr>
<tr>
<td>2015</td>
<td>7,296</td>
<td>27.97</td>
<td>85.18</td>
</tr>
</tbody>
</table>

Source: Food and Agriculture Statistics (FAOSTAT) and World Bank

The traditional adaptation strategies adopted by the local people is also a force to reckon with in analysing the trend from 2000 to 2015. Analysis of the data reveals that the higher the precipitation, the higher the temperature. The temperatures as well indicate changes, the temperature within the years 1991 to 2000 were higher than the years from 2000 to 2015. This reveals that the higher the temperature, the higher the rainfall respectively. It is evident that high temperature and high rainfall causes a reduction in yam yield and hence affects the general production of yam.
Figure 10 is shown the varying trend yield of yam in the study area from 2003 to 2010, and this shows the trend in yam yield and rainfall variability. The increase in yield of yam recorded in 2003, 2009 and 2010 can be attributed to the moderate rainfall distribution during planting and growing period. The occurrence of low yield 2004 and 2008 could be attributed to the low rainfall especially during the planting and growing. The period 2005 and 2007 recorded a steady period of yield, and this can be as a result of even distribution of rain, and during this period there was a percentage change of minus 2.5% between 2009 and 2010.

![Graph showing varying trend yield of yam from 2003 to 2010](image)

Figure 10: Estimated Average Crop Production (000 Mt) in Brong Ahafo. Source: MoFA.

### 4.4 Theme Three: Outcome from selected farmers for the study

#### 4.4.1 Socio-Demographic Characteristics of Respondents

The socio-demographic characteristics of respondents are represented in table 4. Out of the 30 participants, 24 of them representing 80% were males while the remaining 6 representing 20% were females. This implies that a more significant proportion of the respondents were males with the females forming the least percentage group. Again, the sex distribution gives credence to the fact that males dominate yam farming in the municipality. This could be attributed to the labour and energy demands of yam cultivation. Generally, most of the farmers (70%) were between the ages of 31 and 40.
This was followed by those between the ages of 41 and 50 with a frequency of 6(20%) of the total respondents.

Table 4 continues to show that the level of education of the farmers in the study area. Again, three respondents (10%) were aged between 20 and 30 years. Since the majority (70%) of the farmers were within the age group of 31 and 40, the implication is that the farming population is generally youthful and has a relatively higher potential for sustainable yam production. However, the relatively more significant number of farmers within the age category of 41 and 50 also implies that the farming population is ageing gradually and therefore has the tendency to affect the yam business.

Table 4: Socio-Demographic Characteristics of Respondents

<table>
<thead>
<tr>
<th>Variables</th>
<th>Response</th>
<th>Frequency</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gender</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>24</td>
<td>80</td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>6</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>30</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td><strong>Age</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20-30 years</td>
<td>3</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>31-40 years</td>
<td>21</td>
<td>70</td>
<td></td>
</tr>
<tr>
<td>41-50 years</td>
<td>6</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>30</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td><strong>Educational Level</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>15</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>Primary</td>
<td>3</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>JHS/Middle</td>
<td>9</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>SHS</td>
<td>3</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>30</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td><strong>Years of farming in the area</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-5 years</td>
<td>1</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>6-10 years</td>
<td>2</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>11-15 years</td>
<td>4</td>
<td>13</td>
<td></td>
</tr>
<tr>
<td>16-21 years</td>
<td>17</td>
<td>57</td>
<td></td>
</tr>
<tr>
<td>21 years and above</td>
<td>6</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>30</td>
<td>100</td>
<td></td>
</tr>
</tbody>
</table>

Source: Own work

The reason why the aged dominate in yam cultivation in these three communities may be because the aged own the lands and therefore have greater access to the land which invariably pushes them into the farming business. Again, the low number of the youth into yam business could be attributed to the fact that the majority of the youth had
formal education as compared to the aged. As a result, the aged have no choice but to engage in farming which is the predominant occupation in the area.

The levels of education identified include Primary, Middle/Junior High School (JHS) and Secondary. Operationally, farmers who have attained these levels are those who have completed those levels, possibly, with appropriate certificates. Generally, it is evident that, out of the total of 30 respondents, Half of them (50%) had no formal education. This was followed by farmers who had formal education up to the Middle school or JHS level (30%) of the total respondents. Again, three respondents (10%) each had education up to the primary school level and secondary school level respectively. This shows that most of the interviewee had no or little educational attainment which may influence their adaptive strategies through the adoption of traditional strategies instead of scientific strategies in responding to the impact of climate change.

4.4.2 Farmers knowledge about the trend of Climate Change in the Area

During the interview, 98% of the respondents said that they are aware of climate change and they have observed climate change in the area and indicated events like strong winds, floods and droughts. Most of the respondents said that temperature has been increasing over the past two decades. The reason for the rise or increases in maximum temperature in the municipality may be partly due to the extent of bad farming practices (e.g. slash and burn) coupled with deforestation that characterises farming activities in the area.

The reality about the causes of the increasing temperature trend in the municipality was reinforced by the assertion made by one of the respondents who retorted that:

“"The result of deforestation in this area is the high temperature we are experiencing these days. If we keep cutting down trees, the temperature will increase more than what we are experiencing today” J. Nsiah (personal communication, 2018).

Similarly, most of the farmers also acknowledged the increasing trend in temperature over the years.
A female interviewee in one of the communities had this to say:

“The warming condition of this area keeps increasing year by year. This is making it difficult for us to even sleep in our rooms. If it happens so, some crops that do not need excessive heat are negatively affected.

Asantewa (personal communication, 2018).

The implication for the rise in temperature in the district is the fact that this will increase the rate of evaporation and cause a reduction in soil moisture. When evaporation increases, the result is that the amount of soil moisture lost through vaporisation will also increase thereby leaving little or no moisture to support plant growth. In effect, a crop such as a yam which needs some considerable amount of water to grow will be affected. This anomaly could potentially lead to a reduction in yam yield in the municipality. However, it was observed during the interview that, even though the onset of the rainy season delays in the municipality, the amount of rainfall has increased.

K.Manu (personal communication, 2018) said that:

"It does not normally rain, but when it does, it comes heavily which mostly destroy our farms. Since most of us depend on farming for our livelihoods, a reduction in yield affects us a lot especially in taking up social responsibilities like sending our children to school”.

It is equally important to ascertain the high amount of rainfall in the municipality as stated by the respondents may be due to the high-temperature recordings which potentially increased evapotranspiration rates.

4.4.3 Farmers’ knowledge on Effect of Climate Change on Yield of Yam

How climate variability has impacted immensely on yam production of the whole country is evidently accentuated in the trend of production on a yearly basis, since the viability of the crop is not contingent on too much or too less of water and temperature, climate dynamism contributes a lot to the wellbeing of the crop, the sporadic pattern of rainfall in the country disturbs the natural order of growth and maturity of the crop rendering farmers helpless and hopeless of a promising future.
Impacts of climate change mainly caused by extreme weather events (drought and flooding) on fauna and flora in the study area are believed to encompass loss of biodiversity, land degradation as well as deforestation and eventually lead to reducing yield and natural habitats. During interview discussions, it was reported that climate change caused weak resource people to live without having enough food to meet their requirements, especially in drought years.

R. Roger (personal communication, 2018) stated that:

Reduced rainfall is linked to reduced moisture availability in soils, leading to poor growing conditions and consequently, low crop production. Also, extended dry day spells and increased the frequency of high rainfall may lead to frequent disastrous flooding, during the rainy season and extended periods of severe low flows of water during the dry season.

S.Yeboah (personal communication, 2018) said that:

Suggests that "due to fluctuations of temperature and rainfall for a long period, yam crops did not get proper soil moisture to enable yam crop to absorb nutrients from the soils. That affected crop growth makes more susceptible to pests and diseases in turn affecting crop productivity."

K. Ampaw, has been in tuber crops production for more than two decades, his major crop of production is yam, in the interview he related that the yield of yam produce is not consistent, he added that the decline in yam yield is a recent phenomenon, though, he could not directly attribute it climate change but he did not, however, rule out the possibility.

Another implication is that excessive annual rainfall can also affect the yield of yam crops. This result is also consistent with the study of Okringbo & Ominikari (2017) who found that high rainfall could affect yam crops and affect its yield. Okringbo & Ominikari (2017) also found out that as temperature increases, and rainfall pattern becomes more unpredictable, crop yields drop significantly, and extreme weather occurrences including floods, thunderstorms, heavy winds can destroy farmlands which
leads to crop failure. It is evident that high temperature and high rainfall causes a reduction in yam yield and hence affects the general production of yam.

### 4.4.4 Farmers’ Perceptions on the Effects of Climate Change on Yam Production

The issue of perception is very vital in climate change analysis as people have diverse views and opinions on the phenomena across space and time (Kotir, 2011). Majority of the respondents perceived the effects of climate change on yam to be poor yield. This implies that most of the farmers perceived that climate change could have some degree of impact on yam yield with the overall effect on its sustainable supply. Most farmers linked the effects of changes in rainfall pattern to at least one stage of the crop production process. It became clear from the interview discussion that variability or changes in rainfall pattern in the form of delayed rainfall affect crops especially yam at their critical stage of developing tubers thereby resulting in a drastic reduction of output which is a significant function of food security.

According to M. Asare (personal communication, 2018) retorted that:

> “In fact, prolonged drought and erratic rainfall affect our yield to the extent that, it even becomes a disincentive to go to the farm. This is because you may not even harvest 100 tubers of yam from the farm”.

Another female interviewee stated that;

> "Due to fluctuations of temperature and rainfall for a long period, crops did not get proper soil moisture to enable the crop to absorb nutrients from the soils. That affected crop growth makes it more susceptible to pests and diseases in turn affecting crop productivity”. A. Matilda (personal communication, 2018).

The decline of yam productivity was a good indicator of the impact of climate change in the area as most of the yam grown in the area depend on rain-fed agriculture. Generally, a decrease or increase in rainfall pattern and increased temperature in the study area resulted in a decrease in crop production and productivity.
As an affirmation, the impact of the delayed rains on yam outputs was further stressed by one of the farmers who met unanimous support from all others during the interview discussion. Elder David (personal communication, 2018) remarked that:

"my son, this your climate change has really caused us great harm because, the delayed rains of recent years result in the development of small sizes of yam tubers to the extent that even a little child can easily lift it, meanwhile this was not so some years past. I can say confidently that this can never be attributed to soil infertility or other factors because the soil is fertile enough since we allow land to fallow for years. Sometimes too, when the rain ceases (for about a month or more) after few days of early showers, it becomes disastrous to the yam crop especially after germination since it does not get enough water to develop and mature the tuber in time."

A similar observation concerning how unpredictable and unreliable rainfall has become a threat to agricultural activities. The study of Eludoyin et al (2017) revealed a there was a decrease in the yield of sorghum in Nigeria in the year 2000 when rainfall reduced. However, as the amount of rainfall increased in 2002 and 2004, the yield of maize increased. This indicates the effect that increases or decrease in rainfall have a higher propensity of determining the yield of crops especially, grains.

About 68% of the farmers indicated that changes in temperature affect crop yield, especially during the tuber development stage. Farmers also acknowledged the impact of changes in temperature on land preparation, germination and maturation stages of crop production. Emphases from the interview have it that except for mulching (an adaptation measure) that shields the tubers of yam from the high intensity of the incoming solar radiation (high temperatures), in most cases the tubers become heated up in the soil and get rotten.

4.4.5 Adaptation Strategies of the Farmers in Response to the Effects of Climate Change

This section explores the various adaptation measures employed by farmers in the study area to combat climate change impact on their crops. Climate adaptation is essential
because of the shocks and risks that are visited by farmers. Generally, out of the total of 30 interviewees, 12 changed their farming location while a majority of the respondents, (18) did not. This concludes that even though some of the farmers relocated to other places for reasons such as the loss of soil fertility, there were still a considerable number of respondents who did not change location.

During the interview, a farmer W. Kwame (personal communication, 2018) opined that:

“It is not easy changing farm location because of the tenure of land. Apart from the family land which I have my share, securing another piece of land will mean buying one. However, since I do not have money to buy one, it means I have to stick to what I have now”.

Crop diversification was also found to be another adaptive measure that was preferred by the farmers in the event of climate change affecting yam production. About 70% of the respondents employed crop diversification as an adaptive strategy. The reason why a majority of the farmers diversified to other crops was that it provided them with the opportunity to absorb the shock of the climatic variation. This finding supports the view of Uddin et al (2014) who noted that farmers adopt crop diversification to reduce the overall farm risk and expand opportunities for farm profit, which generally boost their average incomes.

Table 5 below indicates the other crop diversified into by farmers in the study area and other districts. This confirms the fact that crop diversification has been adopted to mitigate the impact of the change in the climate.

<table>
<thead>
<tr>
<th>District</th>
<th>Maize</th>
<th>Rice</th>
<th>Cassava</th>
<th>Yam</th>
<th>Cocoyam</th>
<th>Plantain</th>
<th>G/Nuts</th>
<th>Cowpea</th>
</tr>
</thead>
<tbody>
<tr>
<td>Techiman</td>
<td>32,792</td>
<td>–</td>
<td>184,955</td>
<td>284,186</td>
<td>16,639</td>
<td>80,237</td>
<td>522</td>
<td>902</td>
</tr>
<tr>
<td>Sene</td>
<td>14,077</td>
<td>3,213</td>
<td>286,314</td>
<td>446,215</td>
<td>–</td>
<td>–</td>
<td>3,432</td>
<td>–</td>
</tr>
<tr>
<td>Nkoranza</td>
<td>78,760</td>
<td>–</td>
<td>125,875</td>
<td>177,925</td>
<td>2,924</td>
<td>3,641</td>
<td>2,292</td>
<td>2,529</td>
</tr>
<tr>
<td>Wenchi</td>
<td>26,880</td>
<td>–</td>
<td>135,128</td>
<td>170,300</td>
<td>8,858</td>
<td>7,699</td>
<td>608</td>
<td>1,547</td>
</tr>
<tr>
<td>Sunyani</td>
<td>71,147</td>
<td>–</td>
<td>121,920</td>
<td>7056</td>
<td>9250</td>
<td>49112</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>152,509</strong></td>
<td><strong>3,213</strong></td>
<td><strong>732,272</strong></td>
<td><strong>1,078,626</strong></td>
<td><strong>28,421</strong></td>
<td><strong>91,577</strong></td>
<td><strong>6,854</strong></td>
<td><strong>4,978</strong></td>
</tr>
</tbody>
</table>

Source: MoFA
During the interview, the application of agrochemicals was found to be a significant adaptive measure that was common to almost all the farmers in the area. Generally, it was observed that most farmers used agro-chemicals. Spatially, about 90% of the respondents applied agro-chemicals (e.g. fertiliser) as an adaptive strategy to improve the fertility of the soil. This finding is predictable with the investigation of Tshiala and Olwoch, (2010) who observed that the use of agro-chemicals especially fertiliser is an excellent adaptation strategy that improves crop yield.

Most of the farmers prefer to use mixed cropping as an alternative adaptive approach. Quoting directly from a female respondent in the study area;

E. Victoria (personal communication,2018) indicated “We have used mixed cropping for years and have realised that it is the best adaptation measure so far. This is because whenever there is an extreme climatic event such dry spells, windstorm or delayed rains, and some of the crops are affected negatively, others remain unaffected thereby providing yield which mono-cropping would not give”.

5.0 Discussions

The debate on climate change within the academic circles, though, highly contested and inconclusive, its impact on the ecosystem is undeniable when considered from an objective angle. Scientific evidence claiming the existence of climate change and how it impinges on the cycle of the universal ecosystem production is convincing.

Yam, as stated earlier on in the introduction, forms a significant part of the daily diet of the people of Ghana. Consequently, its production becomes important for governments over the years, the crop is grown in the Brong Ahafo, Western, Upper, Northern, and the Ashanti regions.

On the bases of the statistics of production of the crop from 1990 to 2000, the major Yam producing regions were considered high when production annually was beyond 300 Metric tons, and the Brong Ahafo and the Eastern and Northern regions regularly meet the mark, the Techiman Municipality contributing the highest tons (Sagoe, 2006). Those categorised in the middle were those regions whose production capacities were
between 100 thousand to 200 thousand Metric tons whereas those with less than 100 thousand Metric tons were the less productive regions.

The causes of climate change, was not an important discourse within the yam farming folks, whereas they were only conversant with the variation in their produces, moreover, the changing raining pattern they were less informed about the causes of such unfortunate occurrences and were able to articulate deforestation and indiscriminate logging as one of the potent causes of climate change.

It was also found out that the idea of climate change is not a reserve for the academicians, its knowledge is universal and almost a household name in farming communities around the world, in fact, since the effects of climate change is severely felt on the life of vegetations and to a more considerable extent the agricultural economy, traditional farmers, are well informed on the issue, with all other factors of production reliable and constant. Delay in rainfall which is attributed to climate change which in turn could be associated to the destruction of the ozone layer following irresponsible anthropogenic activities and natural forces, efficiency in yam production is unpredictable and in the worst case in a very steep decline in the case study area.

The impact of climate variability on agricultural activities could not be visible with a dismissive observation since its occurrence takes place in a gradual unnoticeable fashion. The establishment of the UN organisations was to all intent and purposes predicated on the requirement to prevent a third World War. However, as the world grows, the primary objective of the Organization was drastically redirecting its energies and resources into tackling the realities of the world, such as diseases, hunger, terrorism and global warming/climate change. Climate change as part the worlds’ challenges is more pressing, and a protracted threat to human existence and its impact is borderless.

The topic has become a preoccupation for academic and governmental institutions; it is against this background that IPPC was established within the UN system, mandated with the responsibility to collect data, keep and share them to researchers and countries, in order to provide suitable and effective all-important adaptation strategies. The major threats to the realization of these noble objectives is the issue of which policy should be a priority to governments depending on their economic statuses, while other
countries believe they have a more pressing home issues to deal with, thereby passing the issue of Climate change to the second fiddle, the more economically empowered countries believe that it should be a primary concern for all countries big or small, weak or strong, rich or poor.

Another issue has to do with which country is responsible for the major part of the anthropogenic activities that culminate into the climate change, moderate representatives of this idea hold that, though poor countries are signatories to the various pact of adaptation strategies, the distribution of emission should not be equally slapped on all countries, they propose that advanced industrialized countries should be held more accountable for the problem. The supporters of the same idea are more cynical and sceptical about the whole idea are convinced that climate change is a tool in the hands of the industrialised countries to stifle and to discourage industrialisation in less developed countries they are adamant in implementing the policies.

However, one another issue that is being debated is whether climate change should be treated as a problem in the first place, before looking for a solution. Since the topic is very dicey and inconclusive, I could not pontificate but be authoritative base on the outcome of the research study. The result of climate change on yam yield is non-negotiable on the strength of my research findings, and the volume of pieces of evidence furnished me through the literature review, corroborating the global ubiquity of climate change admonish humanity of the dire predictable consequences of climate change, and as such the problem.

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

The study revealed that there were rainfall and temperature fluctuations between farming seasons and year to year, this posed a great threat to yam production in the study area because the agriculture sector of Ghana is very susceptible to climate change variability as the Agric sector mostly depends on rainfall. The study indicated that farmers had a clear perception that climate had changed and involved late or early onset of rain, torrential rains and a long period of drought changed variability in rainfall and
temperature. Most of the farmers knew about cutting down of trees and bush burning to be the causes of climate change without knowledge about the scientific implication of climate change. From the study results, it is evident that climate change is being felt in almost all parts of Ghana where most of the people depend solely on rainfed and natural resources for their survival. To most of the farmers, prolonged drought and intermittent rainfall not only do they reduce the size of yam tubers, but it also creates a conducive environment for pest and other destructive micro-organisms to flourish, this to them serves as a significant disincentive for them to go into farming and this adversely affects rural livelihoods and revenue from yam production.

The findings of this study support the devastating impact of climate change on yam production in Techiman Municipality in the Brong Ahafo region of Ghana, the study revealed that the quality of yam production within the area under review continues to dwindle in the amount of output every year. Yam production was affected because farmers depend entirely on rainfall for cultivation. In acknowledging the impact of climate change on the produce of yam, the adaptation and mitigating strategies by farmers in the area included shifting cultivation, expanding of area cultivated, mixed cropping, the use of fertilisers, diversification into other crops and vegetable farming. Livestock rearing and bush following have also been some of the practices to mitigate the effects of the phenomenon, even though they also come with their problems, however, to them, these new or traditional ways have profoundly altered the trend of production lost over the years.

### 6.2 Recommendations

Climate change is a natural phenomenon and therefore cannot be prevented by a man no matter how devastating its impacts on earth systems might be. However, it is prudent to heed to various recommendations from research outcomes to cope with the situation as it persists. The following can be recommended based on the data collected.

- First, to address national food insecurity, there is a need for MoFA through their arms of extension services to translate the available knowledge and experiences
from farmers on climate change mitigation into action through the design and implementation of evidence-based interventions, pragmatic policies of adaptation applicable to the topography of the study area.

➢ Access to weather information by yam farmers could reduce the adverse effects of climate variability on their activities. Effort should be made to provide a forecast of the weather regularly through the electronic media such as the radio stations and extension officers in the district to update farmers on the weather dynamics to enable them to plan well for their yam crop activities.

➢ Local farmers must be encouraged to adopt modern agricultural production, the use of more improved variety and climate resistant crops and productivity-enhancing technology.

➢ The government and its development partners must invest in agricultural modernisation such as mechanisation and irrigation facilities so that farming could be all year round in the locality.

➢ While the debate should be depoliticised, ordinary farmers should be involved in the discussion of the topic, so that decision made would be well informed from a bottom-up approach through circumstantial input produced by real tillers of the land.

➢ Other environmental factors such as soil fertility should be examined to ascertain its impact on Yam production.

➢ Data and bookkeeping on climatic elements and food crops should be collected and stored by government officials at the district level for other researchers and stakeholders.
7.0 List of tables

Table 1: Annual Yam production in the World, West Africa, Ghana, Nigeria, 1961–2017…………………………………………………………………………………37

Table 2: The contribution of Cocoyam and Yams in the overall national exports and the number of exporters, 1990 to 2002……………………………..39

Table 3: Impact of variability in Rainfall and temperature on Yam Production for Ghana between the years 1991 to 2015……………………………48

Table 4: Socio-Demographic Characteristics of Respondents……………………………………………………………………………………………………50

Table 5: Production of Major Crops in the study area and some district 2010………………56
8.0 List of figures

Figure 1: Production/Yield quantities of Yams in Ghana 1961–2017.........................37
Figure 2: Yam evaluated among other Non-traditional exports in Ghana......................40
Figure 3: National Average Rainfall Distribution of Ghana 2011–2017..........................42
Figure 4: Average Monthly Temperature and Rainfall for Ghana from 1960–1990........43
Figure 5: Average Monthly Temperature and Rainfall for Ghana from 1991–2016........44
Figure 6: Average monthly Rainfall for Brong Ahafo Region from 1991–2015..............45
Figure 7: Average monthly Temperature for Brong Ahafo Region from 1991–2015.......46
Figure 8: Regional Rainfall Distribution .................................................................46
Figure 9: Average rainfall and temperature rate on Yam production..........................47
Figure 10: Estimated Average Crop Production (000 MT) in Brong Ahafo...............49
9.0 REFERENCES


Basak, J. K. (2009). Climate change impacts on rice production in Bangladesh: result from a model. *Published by Unnayan Onneshan (www.unnayan.org), Dhaka, Bangladesh*.


United Nations Environmental Protection Agency (UNEPA), (2012). Available at: http://www.epa.gov/climatechange/impacts-adaptation/health.; assessed on 3rd May 2018


10.0 APPENDICES

Appendix 1: Interview Guide

Dear Respondent,

The motivation behind this questionnaire is to collect data for a study on *the effect of climate change on yam production in Ghana*. This study is purely for academic purposes, and respondents are guaranteed the confidentiality of the information provided.

Thank you

1. Sex..............................................................................................................
2. Age..............................................................................................................
3. Level of education........................................................................................
4. Years of farming

**Effects of climate change on yam production in Ghana**

5. Are you aware of climate change in the municipality?
6. Have you observed any change in temperature for the past two decades?
7. In your opinion, have you observed any change in rainfall pattern in the municipal for the past two decades?
8. How does this variability in climate manifest themselves in this community?
9. How frequent have you observed this/these manifestation(s)
10. In your opinion, what has been the trend in temperature over the past years
11. In your opinion, what has been the trend in rainfall pattern over the past years
12. Have you experienced any drought condition over the last ten years?
13. In your own opinion, how does high temperature affect yam yield?
14. In your own opinion, how does high temperature affect yam availability?
15. In your own opinion, how does rainfall change affect yam production
16. Does rainfall change affect yam yield?
17. If yes, what is the degree of effect?
18. How do you perceive climate change to be?
19. How do you perceive the effect of climate change on agriculture?
20. Do you think the climate is changing at a rate that is significantly affecting yam availability?
21. What are the human factors responsible for climate change in your locality?
22. Which on-farm adaptation options do you adopt in the event of crop failure due to the changing climate?

Appendix 2: Average Monthly Temperature and Rainfall for Ghana from 1991-2016

<table>
<thead>
<tr>
<th>Months</th>
<th>Rainfall (Mm)</th>
<th>Temperature(°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>8.75</td>
<td>27.2</td>
</tr>
<tr>
<td>February</td>
<td>25.3</td>
<td>29.49</td>
</tr>
<tr>
<td>March</td>
<td>60.84</td>
<td>30.09</td>
</tr>
<tr>
<td>April</td>
<td>113.36</td>
<td>29.56</td>
</tr>
<tr>
<td>May</td>
<td>146.59</td>
<td>28.54</td>
</tr>
<tr>
<td>June</td>
<td>160.41</td>
<td>27.07</td>
</tr>
<tr>
<td>July</td>
<td>145.13</td>
<td>26.06</td>
</tr>
<tr>
<td>August</td>
<td>141.81</td>
<td>25.63</td>
</tr>
<tr>
<td>September</td>
<td>166.06</td>
<td>26.16</td>
</tr>
<tr>
<td>October</td>
<td>131.95</td>
<td>27.1</td>
</tr>
<tr>
<td>November</td>
<td>39.42</td>
<td>27.66</td>
</tr>
<tr>
<td>December</td>
<td>13.08</td>
<td>26.98</td>
</tr>
</tbody>
</table>

Source: FOASTAT 2017

Appendix 3. Selected Non-traditional export commodities against Yam between 2005-2016

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Cocoa paste</td>
<td>34,403,613</td>
<td>139,751,514</td>
<td>744,859,566</td>
<td>1,421,952,300</td>
<td>2,714,536,319</td>
<td>3,750,601,914</td>
</tr>
<tr>
<td>Cocoa Butter</td>
<td>33,468,122</td>
<td>86,755,662</td>
<td>140,623,930</td>
<td>172,033,419</td>
<td>210,458,471</td>
<td>232,778,683</td>
</tr>
<tr>
<td>Canned tuna</td>
<td>54,849,916</td>
<td>99,149,233</td>
<td>129,150,213</td>
<td>158,942,587</td>
<td>195,607,467</td>
<td>216,999,136</td>
</tr>
<tr>
<td>Cocoa confectionery</td>
<td>1,275,732</td>
<td>10,028,187</td>
<td>9,437,384</td>
<td>9,775,489</td>
<td>10,125,707</td>
<td>10,305,493</td>
</tr>
<tr>
<td>Yam</td>
<td>10,951,355</td>
<td>14,551,433</td>
<td>12,860,195</td>
<td>13,211,210</td>
<td>13,571,805</td>
<td>13,755,777</td>
</tr>
<tr>
<td>Cashew Nuts</td>
<td>5,497,632</td>
<td>10,779,329</td>
<td>24,972,230</td>
<td>26,081,628</td>
<td>27,240,312</td>
<td>127,302,837</td>
</tr>
<tr>
<td>Total Net Exporter</td>
<td>140,446,370</td>
<td>361,015,358</td>
<td>1,061,903,518</td>
<td>1,792,230,919</td>
<td>3,171,540,081</td>
<td>4,351,743,840</td>
</tr>
</tbody>
</table>

Source: Ministry of Food and Agriculture; the Republic of Ghana food and Agriculture sector development Policy
Appendix 4: Average monthly rainfall and Temperature for the Brong Ahafo Region from 1991 to 2015

<table>
<thead>
<tr>
<th>Months</th>
<th>Rainfall (Mm)</th>
<th>Temperature(°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>10.6</td>
<td>27.14</td>
</tr>
<tr>
<td>February</td>
<td>19.1</td>
<td>29.38</td>
</tr>
<tr>
<td>March</td>
<td>62.86</td>
<td>29.53</td>
</tr>
<tr>
<td>April</td>
<td>124.57</td>
<td>28.88</td>
</tr>
<tr>
<td>May</td>
<td>137</td>
<td>28.15</td>
</tr>
<tr>
<td>June</td>
<td>156.75</td>
<td>26.69</td>
</tr>
<tr>
<td>July</td>
<td>193.45</td>
<td>25.9</td>
</tr>
<tr>
<td>August</td>
<td>177.91</td>
<td>25.66</td>
</tr>
<tr>
<td>September</td>
<td>205.68</td>
<td>26.08</td>
</tr>
<tr>
<td>October</td>
<td>144.66</td>
<td>26.62</td>
</tr>
<tr>
<td>November</td>
<td>27.87</td>
<td>27.4</td>
</tr>
<tr>
<td>December</td>
<td>7.12</td>
<td>27.03</td>
</tr>
</tbody>
</table>


Appendix 5: National Average Rainfall Distribution (* Provisional for 2017)

<table>
<thead>
<tr>
<th>Year</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
<th>2016</th>
<th>2017</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rainfall</td>
<td>993</td>
<td>995</td>
<td>1160</td>
<td>977</td>
<td>908</td>
<td>834</td>
<td>1080</td>
</tr>
</tbody>
</table>

Source: SRID, 2017