T.C.
FIRAT UNIVERSITY
INSTITUTE OF SOCIAL SCIENCE
DEPARTMENT OF BUSINESS
ADMINISTRATION

TECHNOLOGY MANAGEMENT

MASTER'S THESIS

SUPERVISOR
Prof. Dr. Kenan PEKER

PREPARED
ABDUL MUMEEN IDDRISU

ELAZIĞ-2020

T.C.

FIRAT UNIVERSITY

INSTITUTE OF SOCIAL SCIENCE

DEPARTMENT OF BUSINESS ADMINISTRATION

TECHNOLOGY MANAGEMENT

MASTERS DEGREE THESIS

SUPERVISOR	PREPARED
Prof. Dr. Kenan PEKER	ABDUL MUMEEN IDDRISU

Jürimiz 10.01.2020 tarihinde yapılan tez savunma sınavı sonunda bu yüksek lisans tezini oy birliği/ oy çokluğu ile başarılı saymıştır.

Jüri Üyeleri

1. Prof. Dr. Kenan PEKER
2. Dr. Öğr. Üyesi Yeliz Gedik
3. Dr. Öğr. Üyesi Mesut Balıbey

F. Ü. Sosyal Bilimler Enstitüsü Yönetim Kurulunun …….. Tarih ve ……. Sayılı kararıyla bu seminer onaylanmıştır.

Prof. Dr. Ömer Osman UMAR

Sosyal Bilimler Enstitüsü Müdürü

ÖZET

Yüksek Lisans Tezi

Teknoloji Yönetimi

Abdul Mumeen Iddrisu

Fırat Üniversitesi
Sosyal Bilimler Enstitüsü
İşletme Anabilim Dalı
Elazığ-2020; Sayfa: XI+82

IPCC iklim sisteminin değişikliğindeki trendleri 1990 dan beri rapor etmektedir. Son raporlarda global sıcaklıkların soğuk gün ve gece sayısından dolayı arttığı yer almaktadır. Değişkenlik aynı zamanda Dünya'nın etrafındaki su döngüsü için de rapor edilmiştir. Bu kırılganlık durumunun insanın Dünya'da sürdürülebilirliğine etkileri ve eğilimleri önceden gözlenmiştir. Sub-Saharan Afrika da bunlardan büyük ölçüde etkilenecektir. Ülkenin büyük ölçüde geçim kaynağı olan tarım kırsal nüfusu önemli ölçüde etkileyecektir. Bu sadece Sub-Saharan Afrika'nın tarımı için yağışlardan kaynaklanmıyor aynı zamanda bölgenin yüksek hassasiyetteki kırılganlığından dolayı ortaya çıkmaktadır. Ekonomik gelişmenin yapısındaki nüfus artışı bölgeyi daha kötü yapıya dönüştürecektir. Şüphesiz bölgeyi mevcut ve gelecekteki kötü yapılardan veya hasarlardan korumanın yolu tarımsal adaptasyon kapasitesini tanımlamaktır. Buna ulaşmak için bölge tarımının gelişmesine yönelik teknoloji kapasitesinin geliştirilmesi gerekmektedir. Bu çalışmanın amacı Afrika'nın ekonomisinin temelini oluşturan tarımın iklim değişikliğine adaptasyon kapasitesini geliştirmek bağlamında bölgenin iklim değişikliğine hassasiyet düzeyini, yeni teknoloji ihtiyaçlarını ve teknoloji yönetimini belirlemektir. Hane halkı verileri Gana'nın Pru ve Wa West bölgelerindeki topluluklardan iki aşamalı uygulanan 174 anket ile toplanmıştır. Veriler kullanılarak Geçim İndeksi (LVI-Hahn et al., 2009), ve Teknoloji İhtiyaç Analizi (Essegbey et al., 2012) yapılmıştır. Sonuçta bölgenin iklim değişikliğine hassas olduğu belirlenmiştir. Mevcutta teknoloji kullanımının çok düşük olduğu dikkate alınarak kırsal topluluklarının

yararlanabilecekleri küçük bir tarımsal teknoloji parkı kurularak teknoloji yönetimi belirlenmiştir. Sulama sistemlerinin tarımsal verimliliği arttırmanın yanında ülkede kırsal kesimde yaşayan toplulukların kırılganlıklarını azaltmada önemli olacağı belirlenmiştir. Gana'nın kırsal toplulukları için ortak kullanım ve teknoloji geliştirmeye fırsat sağlayacak şekilde Teknoloji Parklarının kurulmasının ön etki analizleri şeklinde araştırmalar yapılması önerilmiştir.

Anahtar Kelimeler: Teknoloji, İklim Değişikliği, Adaptasyon, Tarım

ABSTRACT

Master Thesis

Technology Management

Abdul Mumeen Iddrisu

Firat University
Institute of Social Sciences
Department of Business Administration
Elazığ-2020; Page: XI+82

The IPCC reports since 1990 have studied the trends in the variability of our climatic system. Most recently, reports by the IPCC established that global temperatures have risen with less cold days and nights. Variability has also been recorded in the water cycle all around the world. Already observed impacts and forecasts are predicting vulnerability situations that will threaten the very existence of man on earth. Sub-Saharan African will be affected greatly by the impacts to unfold. Furthermore, agriculture which is the major source of livelihood for the rural populace will be significantly affected. The reason being not only on the dependence of Sub-Saharan Africa's agriculture on rainfall, but also due to the high vulnerability of the region to climate change. Increasing population, which is a characteristic of developing economies, will further worsen the situation of the region. The surest path to salvaging the region has been identified in improving agricultural adaptive capacity. To achieve this, the region's agriculture has to improve through technology capacity building. This study was conducted with the main objective of determining the level of vulnerability and identifying the kind of new technologies and management techniques needed to close the gap in terms of climate change adaptive capacity in Africa's agriculture. Household data was taken from selected communities in two districts of Ghana (Pru district and Wa West district). In total, 174 households were interviewed using a two phased questionnaire. The data was analysed using the livelihood vulnerability index (LVI) developed by (Hahn et al., 2009) and a modified Technology Need Assessment method as used by (Essegbey et al., 2012).

Regression analysis and descriptive statistics were also used in the result presentation. The results show that both study areas are vulnerable to climate change. Technology usage was identified to be very low with a concurrent low yields in all crops. The study identified that establishing an agricultural mini-technology park in rural communities along with establishing irrigation facilities will significantly increase agricultural productivity as well as reduce the vulnerability situation of the rural communities in the country. It is recommended that further studies should be carried on to assess the effectiveness of a technology park in the rural communities of Ghana.

Key Words: Technology, Climate Change, Adaptation, Agriculture

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

DEDICATION

This work is dedicated to all underprivileged in society who have to suffer the impacts of climate change whereas they are by far the least to contribute to it.

ACKNOWLEDGEMENT

To the Subtle who taught by pen, creator of all existence, Allah, the true existence, I give my foremost thanks and praise for causing what has happened to happen. To His beloved, my beloved, the love of whom has kept me awake by night, I send Salawaat and Salaam. My gratitude in its finest form goes to my supervisor, Prof. Dr. Kenan PEKER. He has been a father holding the hand of his beloved son through the critical journey of life. And to Shaikh Nasiruddeen of the Paragon Foundation, I say Jazaakallahu Khairan Jazaa' wa Iyyadaka bi Nasrih. Finally in this list, I send my thanks to the vice rectors (Prof. Dr. Sadettin TANYILDIZI and Prof. Dr. Halil HASAR) and Ibrahim KAYAOĞLU hoca of Fecir educational centre.

Next, my thanks goes to the lecturers of the department of Business Administration of the Firat University for taking me through the fundamentals of a field that promise me what I desire in life. Notable among them are; Dr. Hatice Gökçe DEMİREL, Dr. Cem AYDEN and Prof. Izzet TASAR. Without forgetting the God-sent, Prof. Dr. Servet SOYGÜDER.

Furthermore, I extend my thanks to the team of research assistants of the department whose inspiration I have taken after. To my brother, friend and support in ease and difficulties, Ertugrul Bugra ORHAN I say Adamsın. And to Ahmed Ihsan SIMSEK, Emre BULUT, Musa UNALAN, Mesut TURAN, Erkan GÜLTER and the others I say Thank you.

Finally, my thanks go to those whose names are written somewhere sacred within my being. The list is not innumerable but the names on the list are subtle and those who belong to the list know themselves.

ELAZIĞ-2020 **ABDUL MUMEEN IDDRISU**

CHAPTER ONE

1. INTRODUCTION

1.1. Overview

This chapter begins with an introduction as the background, linking technology, agriculture, climate change adaptation and management sciences operational within the Sub-Saharan African sub-continent (SSA). It spells out the problem statement, the objectives of the study and the research questions the study seeks to answer. It finally ends with a conclusion after stipulating the significance of the study its scope and limitation.

1.2. Background

It is an established fact that the world's climate is changing and the Sub-Saharan African region is expected to suffer a lot of the impacts (Niang et al., 2014; Serdeczny et al., 2016). The most recent IPCC publication on global warming indicates that anthropological causes contributed about 1.0 ºC within the 0.8 ºC to 1.2 ºC range (IPCC, 2018). Forecasts are estimating continuous warming up to 1.5 ºC after the year 2030 if the current rates keep on. It is this continuous anthropologically driven global warming that has produced the variations in our climatic systems resulting in increased number of hot days and night alongside decreasing number of cold days and nights, changes in the precipitation pattern of the globe and shifts in the land cover globally (IPCC, 2014). Every natural system (human established systems included) has, with time, developed certain degree of measures to adapt to the observed changes. Farmers have developed diverse ways to escape the impacts of the changing climate; some of which may by themselves be maladaptive (Antwi-Agyei et al., 2018) leading to heightened environmental degradation thereby defeating the purpose of any adaptation measure. Recent research has identified capacity building technology to be a cornerstone in building adaptive capacity (Abdul-Razak & Kruse, 2017). Governments, international institutions and non-governmental organisations have taken it upon themselves to work with research institutions in order to develop technologies that agriculturists can utilise to keep the current demand for food and clothes without compromising the fate of the future generation. Technology has played a great role in the survival of humanity and human communities from the beginning and more so in current times. Agriculture, which up till now sustains the energy needs of the human race (Mwangi & Kariuki, 2015) has been influenced by technology great.

Technology today has been used to supply enough food to sustain humanity (Kapur, 2018). The influence of technology on agriculture ranges from cultivar development, land preparation, agricultural field practices, harvesting and postharvest technologies (Rothstein, 2007). Cultivar development specifically, is targeted at raising breeds that are adaptive and tolerant to the biotic stress in their communities alongside making the best use of inputs in order to produce higher yield to feed the ever increasing population of the world (Brummer et al., 2011). Mechanisation which for some time now has received research attention is geared towards reducing the drudgery on farm activities as well as increasing the efficiency in producing higher quality products (Sims, Hilmi, & Kienzle, 2016). These advances are important to the changing climate coupled with the changing demographics of the SSA region. Kebebe (2018) expound on the main factors that mostly lead to low or no adoption of improved technologies developed by African researchers. The paper concluded on the point that, weak or missing innovation systems functions including knowledge diffusion, market development, policy advocacy among others is the reason for the gap in technology adoption in Africa. Another reason is the top-to-down nature of the earlier researches which advocated technologies which do not significantly improve the adopters' situation. The use of fertiliser and intensive irrigation systems for instance were found to not significantly improve the production of animal keepers as they do to crop producers (Bizimana & Richardson, 2019). Adopters of new technologies soon give up if the results delay (Katengeza et al., 2019), when the project that introduced the technology finally ends or due to peer group influence (Gatto et al., 2019). Many other factors contributed to the technology gap that still persist in the agricultural system of Africa relative to the developed countries. Without improved modern technologies, the climate change adaptation gap that exist in Africa's agriculture is not a surmountable obstacle.

The population of the SSA region which in the 1990s faced a serious problem with health and social services though with a higher rate of growth (Ohadike, 1996), is today in the second stage of population transition (Anthony et al., 2017) and is projected to hold more than half of the world's additional population between 2019 and 2050 if the expected 1 billion population is added (United Nations, 2019c). Amidst the world's aging population, the SSA region will hold half of the world's child population (Anthony et al., 2017) with the current growth rate of 2.66 % (World Population Review, 2019) which implied that current policies and developmental trajectories must change to suit that phenomenon. Notwithstanding the fact that SSA agriculture employs about half of the total workforce, it is also true that malnourishment has been persistent in the region over the years (OECD/FAO, 2016). This, chiefly has been attributed to the low technological outlook of the region's agricultural system compared to the practices in Asia and the Americas where intensification and mechanisation are the order of the day. Technological changes in the agricultural system of the SSA region are today much important not only due to increasing in population, malnourishment and economic impact on the stability of the region, but also due to the impacts that are envisaged and the need to develop instant adaptive measures to curtail severe damages.

Africa and West Africa in particular (where Ghana is situated) has been identified by the IPCC report to record the highest increase in land temperature by the end of this century (IPCC, 2014). This will further worsen the vulnerability due to low climate change adaptive capacity recorded in the region. According to (Tambo, 2016), the communities under their studies recorded very low indices to climate resilience. These communities are not very different from other communities within the region. In some instances, vulnerability of other communities even surpasses the study area. Increasing vulnerability in this manner has been attributed to lack of awareness and weak resources and institutional access to the mostly peasant farmers within the region (Williamsa et al., 2018). This is in line with the report of the IPCC to build climate change adaptive capacity by injecting financial and information resources in the region; since that effort is the surest way to significantly reduce the current and the forecasted climatic impacts (IPCC, 2014). This notwithstanding, farmers have taken it upon themselves to adapt to their changing environment.

Adaptation measures carried out by farmers take different forms; this include on-farm measures and livelihood diversification measures. Some of the on-farm adaptive measures include the use of improved crop varieties with high yielding and draught tolerance capacity, changing planting dates and adoption of good agricultural practices (Adu et al, 2018; Tachie-Obeng et al., 2013). The livelihood diversification strategies as identified by Antwi-agyei *et al.*, (2018) included cutting and selling of firewood, rearing of animals, indulging in petty trade, fishing, relying on social network and engaging in waged labour among others. These measures are very important in that, they lead to the development of economic resources and indicate the level of awareness of the farmer to the changing climate which Abdul-razak and Kruse, (2017) identified as among the four most important determinants of adaptive capacity; Antwi-agyei *et al.*, (2018) also indicated that some of the measures can lead to maladaptation as they further contribute to the worsening of the changing climate. It is hence very relevant to put systems in place that will increase the capacity of the extension officers and improve the understanding of farmers of climate change. These two were identified by Tambo (2016) as the measures that will effectively improve the adaptive capacity of farmer of peasant scale. Capacity of the extension officer should not only be limited to educating farmers on the reality of climate change but should also be geared towards introduction of new technologies that researchers have found to improve adaptive capacity.

It is clear today that both human and natural systems will be seriously affected by the impacts of the changing climate (Hoegh-Guldberg et al., 2018). SSA has been predicted to be one of the hard-hit by the forecasted impacts due to the high vulnerability of the region (Niang et al., 2014). On heat and temperature, (Serdeczny et al., 2016) explained that all the models have predicted a shift of more than three standard deviation above the historical norm especially for the West African region; a standard which constitute extreme heat of the environment. This is in line with the recent report by the IPCC which indicates that the SSA will experience more hot days and nights, and an overall higher temperature above the global average be it 1.5 °C or 2.0 °C above preindustrial levels (Hoegh-Guldberg et al., 2018). Spatial and temporal variations have been observed over the SSA region in terms of precipitation and are expected to continue up to the end of the century (Niang et al., 2014). This is particularly worrying considering the predominantly agrarian economies of the region with only about 6 % irrigation (Mango et al., 2018). Thus, the region has witnessed an influx of governmental policies on revamping irrigation (Woodhouse et al., 2017). Impacts observed so far are expected to increase the rates of aridity (Serdeczny et al., 2016) and droughts in the region which will be detrimental to the energy production and consumption (Kabasa & Sage, 2009). Apart from malnutrition which has stricken the SSA region, the changing climate is expected to increase the prevalence and resurgence of pest and pathogens for humans, animals and crops which will greatly affect the health of the populace of the region especially for children and pregnant women (Niang et al., 2014). Farmers within the region are not ignorant of the changes that is going on and thus have been making adjustment in their daily lives to cope with the changes. An instance can be cited of the maize farmers in some regions of Ghana who have adopted different tactics ranging from cultivar selection to planting and harvesting time (Tachie-Obeng et al., 2013). Some of the adaption strategies peasant farmers do adopt, apart from posing to be maladaptive are often outdated and incapable of satisfying the current and future food demand (Antwi-Agyei et al., 2018). This implies that the region demands the introduction and management of new technologies.

White & Bruton (2011) defined technology management as the connection of "engineering, science, and management disciplines to plan, develop, and implement technological capabilities to shape and accomplish the strategic and operational objectives of an organization." The fact that current technological advancements are growing exponentially (Horrocks & Walker, 2019) coupled with the need to optimise the productivity of agriculture to meet global trends at this crucial moment of climate vulnerability makes it more important to manage our innovations and technologies in the SSA region. Measures used to counter the impacts of the climate (Antwi-Agyei et al., 2018) are mostly intuitively driven devoid of a systematic approach at developing them. This accounts for the maladaptive nature of some of the measures peasants use in soothing their vulnerability.

The African continent, apart from producing some of the advanced technological works in the field of architecture and construction (such as the pyramids of Giza), metallurgy and stone sculpture which rival modern technologies also transferred agricultural crops and the technology of their production (such as rice and sugarcane) to the western world (Lovejoy, 2004). It is surprising that such technologies which were very common in the past are difficult to replicate today. This could be attributed to poor technology management over the year in the SSA region. Technologies especially in the area of cultivar or breeds are not very deficient in the region (Iddrisu & Peker, 2018). The problem mostly has to do with complexity and accessibility. It is thus, necessary that technologies that could improve the agricultural activities of the peasants in the SSA region should be tailored in a form accessible and usable to the farmers.

White & Bruton, (2011) identified five main importance to technology management as follows:

i. It affords human systems a cross-discipline approach to economic development

ii. It enable producers meet the sophisticated demand of modern consumers
iii. It reduces the technology development time thereby giving the implementers a lead advantage
iv. It improves the competitiveness of a locally established entity internationally
v. It direct the development of new management tools to tackle modern system

The five points stipulated above demonstrate the reasons why the SSA agriculture, apart from a few commodities such as cocoa, remains backwards. For cocoa and the other agricultural export of the region, geographical advantage afforded the region the lead to their production. Technology tailoring and management are more important today than any other time in modern history of the Sub-Saharan African region due to the vulnerability to the changing climate coupled with the increasing population of the region. Technologies that have been developed to tackle the impact of climate change are by far the most important for the farmers of the Sub-Saharan African farmers (Iddrisu & Peker, 2018). These technologies should span from land preparation, improved planting materials, sources of farm energy, irrigation, tailored farm machines, postharvest technologies and access to farm credits and improved markets.

1.3. Statement of Problem

In 2015 the world met and decided on improving the Millennium Development Goals to Sustainable Development Goals. This process came out with a 17 goals; an improvement and encompassing step from the 8 goals of the MDGs. The SDGs thus, with a 169 targets and indicators, upholds the fact that development should be achieved in complete harmony with management of the environment (Woodbridge, 2015). Hunger and sustainable environment have for some time been an issue in the SSA region for which Ghana is not an exception. The Ghana Statistical Service (GSS), (2018) estimates that about 2.4 million people in Ghana live under extreme poverty (people who are unable to meet their daily calories requirements even if they dedicate their entire resource on feeding) with 2.2 million in the rural areas (rural savannah alone contributing about 36.1 % of the total figure). Among other factors, Bird, (2019) identified agro-ecology and physical isolation and inadequate infrastructure as the factors that lead to the situation of extreme poverty. Adjasi & Osei, (2007) further added that, low level of education (which is the situation in rural communities; especially rural savannah) also lead to extreme poverty. Though the populace of rural Ghana are aware of desertification and land degradation as having both a climatic and life style causative (Fuseini, 2014), rural savannah is particularly predisposed to the effect of the changing climate (Environmental Protection Agency, 2002). This is in line with the description of the region by (Ibrahim et al., 2015).

Another factor that poses as a problem in the region is the trend in population growth (World Population Review, 2019) which is expected to be home to half of the world's dependent population (United Nations, 2019c). Feeding this growing population will be the burden of the populace which currently is facing malnutrition problems. Crowning the issues facing the region, climate change posing as a serious problem to the world and especially to the SSA region, is not a factor to be undermined. Amidst poor climate change adaptation strategies currently in the region (Antwi-Agyei et al., 2018) and low technological advancement in the agricultural sector, it has become so important to look at the subject of this study now than any other time in recent times.

Furthermore, the issue of climate change and population growth rate may put a lot of young people into the quagmire of unemployment owning to the fact that a great number of rural populace in the region are employed mostly directly by agriculture. This has been captured in the TNA report of Ghana (Essegbey et al., 2012).

1.4. Objective of the Study

The main objective of this research is: to determine the level of vulnerability and identify the kind of new technologies and management techniques needed to close the gap in terms of climate change adaptive capacity in Africa's agriculture. The specific objectives are:

1. To assess and describe the climate vulnerability situation of the resource-poor farmers
2. To assess the trend in the climatic system of the study areas
3. To identify the technology gaps that will increase climate change adaptive capacity
4. To assemble and tailor technologies that will increase productivity and satisfy specific objective number 2
5. To design technology management techniques to manage the proposed Agricultural Machinery Park

1.5. Research Questions

The research question that arise from this study are:

1. How vulnerable are the peasant farmers in Ghana to Climate Change impacts?
2. How is the trend of the climate within this decade?
3. What is the technological gap in terms of climate change adaptation between the peasants and the world standard with regard to agriculture?
4. What are the technologies and introduction methods if assembled will help improve the productivity of the Peasant farmers of the region?
5. What are the management strategies for keeping a Technology Park suitable for the study areas?

1.6. Significance of the Study

The Aim of this research is to build adaptive capacity to climate change in agriculture capable of eradicating current and future hunger and poverty situations whilst sustaining the integrity of the environment of the SSA region. It is thus expected that the following will be achieve after the completion of the program:

1. New and tailored technologies for resource-poor farmers
2. Technology management techniques adoptable by resource-poor farmers
3. Layout of effective technology introduction procedure
4. Establish a model Agricultural Machinery Park
5. Journal article publications

1.7. Scope

This research work is a case study two districts within two different regions of Ghana in West Africa; one of the regions within SSA. The first district being the Wa West district within the Upper West region of Ghana and the second being the Pru East district within the Bono East region. Small scale farmers (referred to as peasants in this study) are the part of the population considered during the study. These farmers mostly live in the suburbs of the district capitals (as in the case of the Pru East district) or small villages and farming hamlets (as in the case of the Wa West district).

Farmers considered within this study forms the majority of food producers not only within the study area but worldwide as recorded by Lowder et al., (2016) when they stated that about 87 % of the world’s agricultural lands are operated by smallholders and families for which the total farm size is mostly less than 13 acres. A lot of these families consider agriculture as the main source of family income and food source though some amount of the yield is sold to the market to purchase other family needs. Farmers within the scope of this study practice mixed cropping; implying that farmers cultivate at least two crops on the same piece of land (this system is not necessarily an inter-cropping crop system).

This study did not consider commercial farmers or contract farmers due to the large scale of their operations, resourcefulness and objective of production. All farmers are just within the selected districts. Meteorological data collected for this study are also limited to only rainfall and temperatures of the study areas or their immediate surroundings.

1.8. Limitation

The study faced two major limitations:

i. Limited access to meteorological data in some of the study areas as such the data of a close community with a similar climatic characteristics is used
ii. Inability of the researcher to exhaust the entire farming hamlets within the study areas

These two limitation however are not considered to significantly reduce the validity of the study in as much as the climate conditions of the area are much similar and the farming systems are generally the same.

1.9. Hypothesis

This study was conducted based on the deductive premises that the Sub-Saharan region is most vulnerable to climate change impact amidst a growing population and a less productive agricultural system due to limited technological inputs. This line of reasoning was supported with a inductive argument that since other communities with similar climatic, geographic and demographic characteristics have been found to be highly vulnerable, it implies that the study communities will also record high vulnerability and a limited agricultural technology input system.

CHAPTER TWO

2. LITERATURE REVIEW

2.1. Overview

In this chapter, relevant literatures were reviewed to make clear the concept of agricultural technology management in the context of climate change in Ghana. Hence, the chapter starts with a review on agricultural technology, followed by technology management. The topics which followed are climate change in Ghana and West Africa, adaptation of peasants to climate change in Ghana and Africa, technology park management, conceptual review and finally, conclusion.

2.2. Agricultural Technology

Whether the source of agriculture stemmed out of some religious mythology, the dump heap hypothesis (Jack, 1992) or nutritional features of crops and cultural forces (Abbo et al., 2005), the surety is that agriculture started with the usage of crude tools and equipment. Today, due to our advancement in identifying sources of energy and the science of molecular genetics, agriculture is heading towards the peak of precision. The discourse today has moved from merely increasing farm yields to improving agricultural productivity as stated in the report to the 64th assembly of the United Nations (O'Connor, 2009). Seed, being the most important input of the agricultural system has received significant attention both by governments and research institutions (Atilaw & Korbu, 2011). In Ghana, the leading research organisation on agriculture, the CSIR, can boast of not less than one hundred released and registered varieties (CSIR-Ghana, 2016). Similar programs can be boasted of in other parts of Africa like the IITA in Nigeria and far East in Ethiopia (Atilaw & Korbu, 2011). Notwithstanding this, researchers are still on their toes trying to release varieties that are better adaptable to the gradually changing climate. With the advancement in the development of seeds, access by smallholder farmers is mostly challenging in the rural part of Ghana (Ayamga, 2018). With those who have access, annual purchase is a norm which may lead to loss of local genetic resources (Petersen, 2014). The seed economy is operated by the leading seed companies (Zhang, 2018) which ran solely on profit making. El Khoury & Delve, (2018) recommend that different systems should be developed to take care of smallholder farmers who are by far the most important producers of arable crops in the world. It is true that technological developments in recent times are in the exponential ascension mostly driven by the competition between the leaders in the sector (Zhang, 2018). Mcguire & Sperling, (2016) identified two types of seed producing institutions; the formal and informal systems; emphasizing that most of the attention of governments and support institutions are directed towards the formal sector. Most farmers according to this publication get their seeds in the informal sector which has so far run on inefficiency. Following the establishment of private seed companies in the Sub-Saharan African region of Ghana and her surrounding, it is expected that access to seeds will increase even in rural Ghana thereby improving agriculture (Diallo, 2018). Improved seeds are best cultivated with improved technological implement and procedure. A field that has received much attention since the discovery of petroleum engines.

Mechanisation of agriculture started from the use of animals until recent past when diesel engines were introduced. These form of technologies were used for land tillage, distribution of fertilisers, watering of crops, harvesting and transportation of inputs and produce of the farm (Aguilera et al., 2019). The use of machines in the fight for sustainability of production is becoming unpopular due to its effect on soil condition (Lovarelli et al., 2017). Furthermore, without any regards to the method used, mechanisation of agriculture and agricultural process by themselves have contributed to the levels of greenhouse gases (Aguilera et al., 2019). For that reason researchers are into finding a way to increase the precisions of the machines used on the farm to as to reduces wastage and negative effect to the environment (Singh & Singh, 2011). This thus warrant the use of computers and computer managed machine in farming systems. In Sub-Saharan Africa however, the adoption of agricultural mechanisation in the intensive form is very limited due to among other reasons economic, religion and perceived consequences (Adekunle et al., 2016). The FAO quoted that whilst there exist a rate of 28 tractors per 1000 ha in Africa, the rest of the world had an average of 241 tractors per 1000 ha; a situation driven mainly by economic factors (Houmy et al., 2013). This observation is partly also shared by (Kirui & Braun, 2018). This was observed notwithstanding the increment in productivity due to the adoption of mechanisation recorded in some part of the continent (Houmy et al., 2013; Kirui & Braun, 2018). In Ghana, the situation is not different even though the government has since 2007 tried to introduce traction system in the country (Houssou et al., 2013). Fonteh, (2010), working for the FAO, stated that apart from the economic factors (cost of mechanisation and poor market of agricultural products), lack of access is one of the major factors that limited the usage of tractors in the country; a situation the government aimed at eliminating. The governmental program so far has not been effective in reaching resource-poor farmer as a result of low resourcefulness of the institutions (Diao et al., 2018). In the event of access, the farmers mostly underutilise the services, limiting their demand mostly on only land preparations especially ploughing of the land (Houssou et al., 2013) which demand only smaller tractors due to the small subsistent form of cultivation. This is in line with the recommendation of (Diao, Silver, & Takeshima, 2016) for African farmers to adopt two-wheeled power tillers in their farming process. With the current advancement in agricultural technology, almost all the cultural practices on the farm can be mechanised and in more advanced situations automated.

With the introduction of greenhouses in the agricultural system, farmers have assume the control of all factors that affect the growth of plants especially the micro-climate of the plant (Kittas et al., 2013). The greenhouse technology is gaining grounds in Ghana currently especially among vegetable producers in the major cities around the country (Coleguwor, 2018). Elings et al., (2015) also reported to that effect, adding that, factors impeding fast adoption included limited access and cost of establishment. This has led to an increasing research into ways to fine-tune the technologies that build up the system in order to reduce the cost of establishment (Kittas et al., 2013; Kurpaska & Latala, 2010; Tohidyan Far et al., 2017). Precision agriculture has thus become a new field in agriculture that operates in all aspects of the farming process (Jha et al., 2019). With the increasing understanding of communication between things (Internet of Things, IoT) agricultural automation and precision is something well with the reach of researchers (Khanna & Kaur, 2019). The situation in Ghana and Africa for that matter is different when it comes to research and adoption of these new technologies (Adekunle et al., 2016). This is the case with regards to the fact that the population is increasing at a fast rate in a climate vulnerable environment; and here is a technology which can help farmers do more, from crop planting to disease detection, with very less (Dharmaraj & Vijayanand, 2018). Artificial technology thus afford farmers an effective way of managing technology on farm.

2.3. Technology Management

Technological superiorities have underlined the progress that the developed countries use as comparative advantage over the developing and the underdeveloped countries (Çalışkan, 2015). This does not mean that the other countries have no local technologies different from that of the developed countries but the underlining factor is the effectiveness of managing those technologies. New technology development is rapidly growing in recent times partly driven by demand, necessity and advancement in the understanding of engineering technology (United Nations, 2019b). The rapid developments do come with both pros and cons to the sustainable development of the world. Among the advantages, especially for agriculture in a climate variable world, include; improving food security, nutrition and increasing agricultural development propelled by advancement in precision agriculture (United Nations, 2019b). Among the threats posed by the rapid development in technologies include those related to employment, socioeconomic divide and normative consideration. These are fundamentally important issues that researchers are interested in. for these reasons, management of technology, be it in agriculture or otherwise, is globally important.

Technology management is a multidiscipline field that eliminates the gap between engineering and business (Zaidi & Othman, 2011). Phaal et al., (2004) defined Technology management as a process including planning, directing, controlling and coordinating development and implementation of technological capabilities to shape and accomplish the strategic and operational objective of an organisation. This definition was further expounded upon by (Jin & Zedtwitz, 2008) when they explained that technology management is as a capability to make effective use of technical knowledge and skills, that is not limited to only improving or developing products and processes, but extended to the level of improving existing technology and to generate new knowledge and skills in response to the keen competition in the business world. From these definitions, we realise that technology management is not only a process but a capability, in essence, a capacity to continuously protect existing and develop new technologies so as to stay in business. For the agricultural world, we will say that, management of technology in a variable climate, will be to build capacity to sustain food security nationally and internationally. Countries which are incapable of managing their technology are found constantly unable to develop new technologies and are thus trap in the net of technology importation (United Nations, 2019b). Technology management by operation has six main routine namely; identification, selection, acquisition, exploitation, protection and learning (Cetindamara et al., 2018). Rush et al., (2007) explained identification to mean awareness and search for technological options. In this context, technology managers should be aware of the broad field of their technological demand, the competitive advantages that technology is likely to generate, the internal resources that will augment the new technology. This view was agreed with by (Gudanowska, 2017) when he stated that identification implies discovering technologies that possess absolute importance to the organisation, as a result of searching, controlling, gathering information and processing of the technology. With selection, Dogson, (2000) explained that selection as part of the technology management process entails building strategy. According to Cetindamar et al., (2016), selection involves taking account of company-level strategic issues such as objectives and priorities of the organisation. Both researchers thus agree that selection as an aspect of technology management requires the recognition of the organisational level strategies. Once a technology has been selected based on the organisation's strategies, the next activity of technology management is the acquisition of the technology. According to Rush et al., (2007), acquisition of technology can be achieved through an internal R&D, liaising with other organisation or getting it off the shelve. This view was agreed with by (Cetindamar et al., 2016) as they explained that technology acquisition can be internal, in collaboration or acquired from external developers.

After identification, selection and acquisition of technology, the next series of events include exploitation, protection and learning to realise the strategic advantage, maintain it and advance the continuous process of the technology management (Gudanowska, 2017). This is a view previously shared by (Rush et al., 2007). With regards to agriculture, technology management will require country level assessment for technologies. After building a broad view of the options available, policy maker will consider the strategic developmental framework of the region and the usability of the technology before making any selection and subsequent acquisition. There should, by this classification, a constant monitoring and a systemic learning coupled with protection of the technology to keep the country economically sound (Çalışkan, 2015). With the changing climate and the forecasted significant increment in population, this process of technology management has become very significant for nations as we are operating in a knowledge economy.

2.4. Climate Change in Ghana and West Africa

Climate change reality is not a topic for discussion in the West African region and Ghana for that matter as citizens who have lived in that of African have fully experienced the primary impacts of the phenomenon. In the mid twentieth century, the knowledge of climate change was very popular among scholars irrespective of their field of learning. It has been reported in the compilation of (Al-Yarwawi, 1970) of one of the prominent scholars of the mid-twentieth century (Alhaj Ibrahim bin Alhaj Abdullah Inyass) wrote a letter to his students, followers and leaders of the Senegambia region detailing the effect climate change after citing some factors that led to that including deforestation. The letter was so detailed and due to the charismatic nature of the scholar, the message would have effectively sunk well with his readers. Also, the belief system and tradition of the Sub-Saharan African people encourages the preservation of nature. It is a common occurrence to label an entire forest, particular trees and animals, or some determined activities as sacred and inhabitants should not venture near them (Daniel et al., 2016). The proliferation of Islam and Christianity has debunked those claims in recent times. With the increasing advent of industrialisation, some of these sacred bodies or activities have been flaunted. The African is a religious person and mostly effectively controlled by spirituality (Adekunle et al., 2016). All these explain the fact that the African traditional leadership was very conscious of nature and took effective steps to maintain it. Capstick et al., (2015) explained otherwise, claiming that there is not much public understanding of climate change in Sub-Saharan Africa and that the populace there do not consider climate change to be a threat to their lives. This perception by (Capstick et al., 2015) is debatable considering the barrage of evidence presented in the publications of the IPCC detailing the trends of the climate variability. A more recent publication by (Barber & Israel, 2017) support the stand of the IPCC as it shows that in Nigeria alone, more than 80 % know that he climate is changing and most are of the opinion that the change is due to human activities.

From it first publication in 1990 up till the latest one in 2018, the IPCC report has maintain its stand on climate variability. Temperatures, both minimum and maximum across the world and in Sub-Saharan Africa for that matter have increased with a concurrent variability in precipitation (rainfall) (Hoegh-Guldberg et al., 2018). (Srivastava et al., 2018; Tachie-Obeng et al., 2013; Serdeczny et al., 2016) all agreed with the trend in the variability of the climate.

In Ghana, the government, haven't understood the changing trend in the climatic system, got sponsorship to carry out a nationwide adaptation strategy development (UNEP/UNDP, 2013). Prior to that the National Technology Need Assessment report further confirmed the observed impact of climate variability especially in agriculture considering the type of technologies the report is proposing (Essegbey et al., 2012). This claim is further substantiated by the work of the national research institute on agriculture, the CSIR, as its work is mostly directed towards releasing varieties that are high yield and climate variability tolerant (CSIR-Ghana, 2016).

The forecast for the future are not very certain due to disagreement with climate models that look at the region's trend (Niang et al., 2014). This may be attributed to the insufficient data from the region's meteorological stations (Hoegh-Guldberg et al., 2018). Lack of meteorological data in West Africa and Ghana in particular can be attributed to the low level of resources attributed to the meteorological sector, the low expertise and demand for their services, and to some extent poor attitude towards work.

2.5. Peasants Adaptation to Climate Change

Stupak et al., (2019) explained that farmers have to some extent understanding of nature and they mostly put that understanding to use in their effort to improve their farming business. Adaptation to climate change as define by the IPCC is "the adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities" (IPCC, 2007). Effort by farmers to adjust to what they believe is a change in their knowledge of the trend of the climate indicates that they understood the concept if climate change.

According to Tambo, (2016), farmers in Northern Ghana have adopted several micro-measures to evade the impact of the changing climate on agriculture. These measures include alteration of planting time, use of drought tolerant and early maturing crops, and in some instants, changing the crop cultivated. Other farmers in the same region have resorted to agroforestry basing their reason for the switch on the potential for the system to ease the impact of climate variability (Apuri et al., 2018). Just as identified through the activities of smallholder farmers, governments in the Sub-Saharan region have advanced policies to help in building adaptive capacity in the region (Kabasa & Sage, 2009).

The efforts of the farming households to adapt to the changing climate is in the right direction but with a minimal effect. Research has indicated that farmers in the Northern part of Ghana are much more vulnerable to climate change (Adu et al., 2018). Recommendations have been put forward to governments and support organisations to facilitate an organised adaptation policy and programs (Tachie-Obeng et al., 2013). The reason being that, apart from the fact that farmers effort are not efficient in reducing vulnerability, some of the measures farmers undertake are by themselves maladaptive to climate change (Antwi-Agyei et al., 2018). This notion is shared by (Williams et al., 2019) when they recommended that governmental and institutional supports are needed to improve household decision making on climate change and adaptation to its impacts. It can be understood from this point that farmers in Ghana and West African have observed the trend in climate variability and have put forward measures to adapt to its impact. These measures need augmentation from government and support institutions to be effective in reducing vulnerability.

2.6. Technology Parks

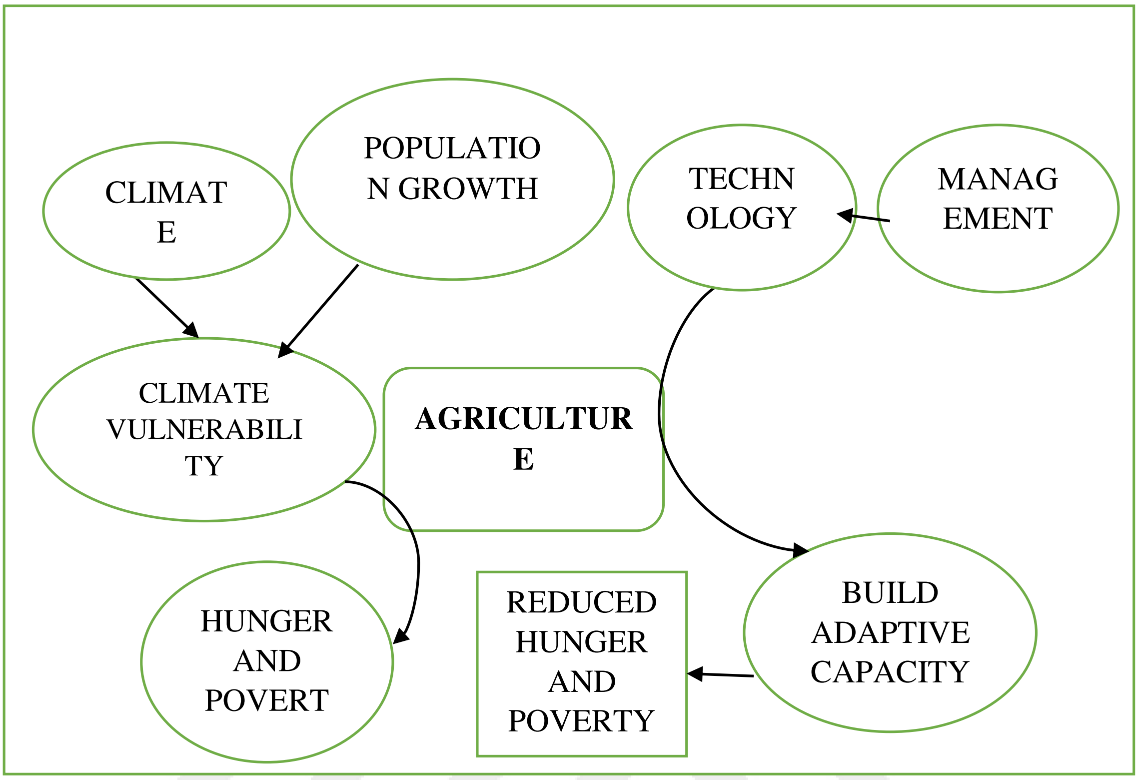
Phillimore & Joseph, (2003) explained a technology park, in broad terms, to mean a collection of high technology industrial companies concerned with both research and manufacturing, and strategically located near a research institution. According to the IASP, (2019), a technology park can be defined as "an organisation managed by specialised professionals, whose main aim is to increase the wealth of its community by promoting the culture of innovation and the competitiveness of its associated businesses and knowledge-based institutions. To enable these goals to be met, a Science Park stimulates and manages the flow of knowledge and technology amongst universities, R&D institutions, companies and markets; it facilitates the creation and growth of innovation-based companies through incubation and spin-off processes; and provides other value-added services together with high quality space and facilities." From these definitions, it can be derived that technology parks have the potential to draw together the very best of each sector that will foster the development of new technologies relevant to the development of the community it stands for (Bellini, Teräs, & Ylinenpää, 2012). Thus, a technology park has three main aspects according to (Phillimore & Joseph, 2003). These aspects include;

i. A formal link with one or more universities, research institutions or other institution of higher learning
ii. A learning centre that ensures the growth of knowledge-based industries and other organisations
iii. A managerial centre responsible for transfer of technology and business skills to stakeholders

Machado et al., (2018), agrees that technology parks are good at achieving their primary goal of reducing costs, improving management of knowledge development and establishment of synergy in the operation of stakeholders. This view is contrary to what (Malairaja & Zawdie, 2008) deduced from their work in Malaysian technology parks. There is however a middle view by the (United Nations, 2019b) in its report for the establishment of technology parks in Asia and the Pacific. Factors that determine the viability of a technology park thus fall on the effectiveness of its management from the time of establishment and during its life time.

In Ghana, the government with the interest to establish something of similar significance as the technology park for agriculture introduced the Agricultural Mechanization Service Enterprise Centre (AMSEC) (Diao et al., 2018). Most of the AMSEC projects did not serve their initial purpose and have thus been unable to pay back the cost of establishment (Houssou et al., 2013). The reasons for the failure of the system was attributed to the quality of the machines procured for the projects (Diao et al., 2018). The result of this mini-project agrees with the observation of the United Nations report on establishment of technology parks that, success depends on management and the calibre of resources and stakeholder interests at the beginning of the establishment. Due to the one-sided nature of the project, we can attribute some of the failure in that direction. There is little literature to the effect of running a technology park with the sole mandate of improving agriculture in Ghana and West Africa. Following the successes technology parks have achieved so far, it is prudent to say that such can be replicated in agriculture.

2.7. Conceptual Framework



Source: Researcher's own construct, (2019)

Figure 1. Conceptual Framework on the Relationship between Agriculture, Climate Change, Technology Management, Vulnerability to Climate Variability and Adaptation

2.8. Conclusion

From the review of the literature relevant to the scope of this study, it can be said that the climatic system of Ghana is changing along the trends predicted by the IPCC reports. Though there are significant shortage of technologies accessible to the peasant farmers, the country has shortage of technology. The real problem is with management and resourcefulness. The situation hence developed into a case of vulnerability. Farmers have also been observed to employ certain measures to adapt to the variability. Their measures are most of the time recorded to be either ineffective or maladaptive. Hence efforts are needed on the governmental front and support groups to build adaptive capacity in the study areas and Ghana at large.

CHAPTER THREE

3. METHODOLOGY

3.1. Overview

Chapter two outlines the methods used in this research. Starting from research design through to data analysis and interpretation. The research design describes the models used for testing the assumptions in the introduction. This chapter also describes the characteristics of the target population and the sampling technique. The data analysis part stipulates the tools used in the analysis of the data taken from the field. Ethical issues about the data collected are also discussed and the conclusion of the chapter follows.
This study is basically in three parts: Livelihood Vulnerability Index (LVI), Technology Need Assessment (TNA) and Technology Park Management (TPM).

3.2. Characteristics of the Research Areas

Vulnerability to climate change due to poor adaptive capacity has been found in SSA (Boko et al., 2008; Niang et al., 2014) and specifically in the Northern part of Ghana (Antwi-agyei et al., 2012). It is thus, not uncommon to witness climatic events which mostly had adverse effect on the livelihood of the populace of the inhabitants of the Northern part of Ghana (Antwi-agyei et al., 2012). Most of the inhabitants of these areas are farmers; an area recognised as the food basket of the country. The two areas are somehow different in terms of their population dynamics, farming systems and ethnicity. They are however similar in terms of their agro-ecological setting and level of agricultural technology usage. The Pru district however has a market advantage in the town of Yeji compared to the Wa West district.

Wa West District

Carved out of the Wa Municipality in the 2004, the Wa West is located west of the Wa Municipal, approximately within longitudes 9°40′N and 10°10′N, and latitudes 2°20′W and 2°50′W. The projected population of the district is 85,497 as at 2014 (representing 48.5 % males and 51.5 % females) (Wa West District, 2016) with a 11,486 number of households (with a household size of 7) and a population density of 38 (people per sq km.) (Ghana Statistical Service (GSS), 2012). The rainfall pattern in the area is

Unimodal (Friesen, 2002) with very few irrigation facilities and the use of rudimentary methods in the agricultural cultivation process. Agriculture is the main employer in the district, contributing up to 80 % to the economic output (Wa West District, 2016).

In consultation with a private field officer, the communities including Vieri through to the border town of Ga (Northern region of Ghana) all within the Guinea Savannah agro-ecological zone of the country (Antwi-agyei et al., 2012) were selected for this study in the Wa West district. He identified that the communities are very deprived and due to the sparse nature of their settlement, not much aid and extension services reach them entirely. The area is a conducive place for the cultivation of cowpea and groundnut though other crops such as maize, millet and tree crops such as cashew and mango do well in the area too (Wa West District, 2016). Underdevelopment characterised by poor infrastructural development especially the road network is a reality in the area and the communities that surround it (Ghana Statistical Service (GSS), 2012). This and the fact that not much research relating to climate change, contributed to the selection of the area for this study. Figure 2 shows the map of the Wa West.

Pru District

The Pru district is situated on the brink of the Guinea Savannah agro-ecological zone (classified as the transitional zone) of Ghana; between longitudes 0°30″W and 1°26″W, and latitudes 7°50″N and 8°22″N. The population of the district per the 2014 estimates stood at 145,469 (most of which are females and children; with a high working population), 22,579 number of household (with a household size of 5.6) and a population density of 45 people per sq. km (Pru District Assembly, 2015). Annual rainfall averages between 800 mm and 1400 mm which is also a pseudo-bimodal (Friesen, 2002). The district is also endowed with natural water sources such as the Volta Lake and the Pru River.

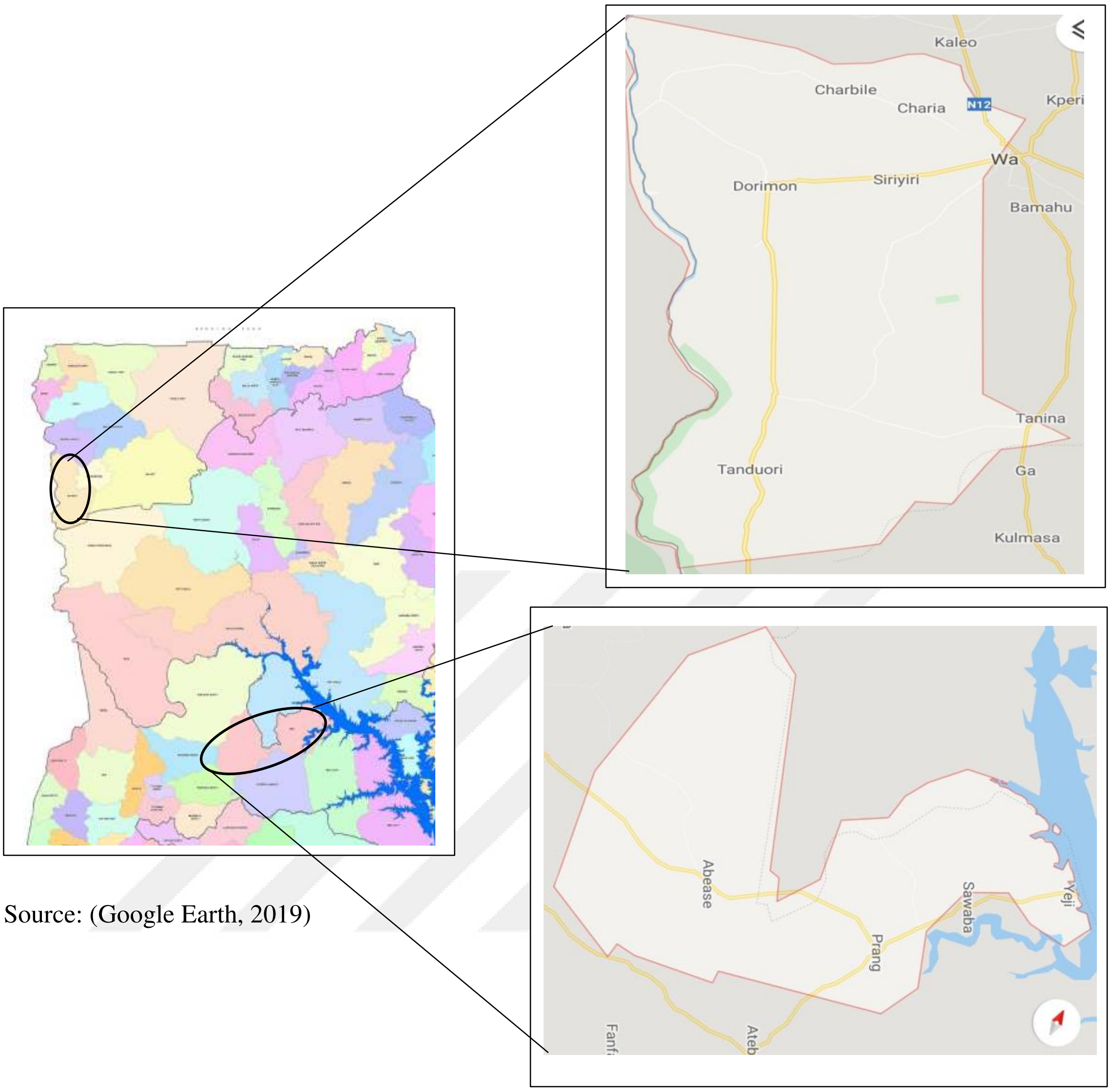
Agriculture employs more than 65 % of the population with majority of the crops being produce being Yam, Cassava, Maize, Rice and other tree crops including Shea nut, Cashew and Mango. Farmers still employ less productive, low technological and practices with a great potency to cause maladaptation to climate change in the district (Pru District Assembly, 2015). Some of these practices include slash and burn for land preparation, cutting down trees for household energy and overuse of herbicides in the control of weeds. In consultation with a government extension officer, the communities from Kojobofour to Parambo were selected for this study. Though the major communities of the study area are within reach from the main street, the small communities are difficult to reach due to poor road network (Pru District Assembly, 2015). Extension services to educate farmers in this communities faces major problem due to the poor infrastructural development. The district however has as part of its developmental plans to address the issue of low technological practices in agriculture (Pru District Assembly, 2015). Figure 2 shows the map of the study area.

3.3. Research Method

This study comes in three face:

i. The Livelihood Vulnerability to Climate Change Assessment
ii. Technology Need Assessment
iii. Technology Park Management Method

The Livelihood Vulnerability Index was used to assess face one, Household farmer needs data was used to complete face two and literature on technology management was used to develop the aspects on face three.



Source: (Google Earth, 2019)

Figure 2. Maps of the Study areas

3.3.1. Sample and Sampling technique

For the Pru district, respondents were sampled randomly from ten different communities within the study area. In the Wa West district however, seven samples were taken randomly from eleven communities with the eleventh one being only four samples due to the low populated nature of the last community. Data was collected from the household heads only (without any regards to the gender of the household head). Meteorological data were taken from the various district meteorological data centres. Management information were also organised from classical and modern publications including websites of agricultural technology designers and developers.

3.3.2. Data Collection Instruments

Mixed method was used in collecting the data for this study. Household data was taken from the study communities, meteorological data from the various district offices and technology management information from various journals, books and other publications and websites. The main instrument for collecting the data was the questionnaire administered to the households of the study communities. Household as defined by (Yaro et al., 2014) refers to a group of people with the common ownership of a productive resource who are supposed to be feeding from the same source (pot).

The questionnaire for the LVI was developed based on the balanced weighted average approached developed by (Hahn et al., 2009) for Mozambique and applied by (Adu et al., 2018) in the Brong-Ahafo region of the republic of Ghana. The framework for assessing vulnerability to the changing climate as explained by (Adu et al., 2018) aids the understanding of vulnerability as it establishes a framework for analysing the key components of livelihood as well as providing assessing the factors that are relevant in the context of a specific community. Vulnerability as defined by the IPCC (2007) is "a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, the sensitivity and adaptive capacity of that system." An earlier version of this definition was based on in the development of the LVI by (Hahn et al., 2009). According to Adu et al., (2018) the LVI is composed of seven major components which include Socio-demographic profile, Livelihood strategies, Social networks, Health, Access to food, Access to water and Natural hazards as a result of the changing climate. Each of the major components mentioned also has sub-components which are indicators for that particular component, each of which measured differently on different scale and units.

The TNA data was also collected using the same questionnaire package but with different questions. The questionnaire examined the common agricultural practices from land preparation to harvesting and postharvest technology. It then followed by enquiring on the kind of technology common at every stage of the farming process within each district. The questionnaire also tests the productivity of the farming systems of the two districts which will be compared to the national targets and the current world standard with advance technology. The TNA questionnaire ends by enquiring from the farmers aspects of the faming process they need improvements to ease the drudgery of work and to increase productivity.

3.4. Data Analysis

It was clear from the preceding data collection instrument that the data for the LVI were taken on different scales. This necessitates that each indicator be standardised into a common universal scale which in this context is the index developed using the equations below:

$$Index_{shi} = \frac{S_h - S_{min}}{S_{max} - S_{min}} \quad (1)$$

$$Index_{shi} = \frac{S_{max} - S_h}{S_{max} - S_{min}} \quad (2)$$

The choice of which equation to use depends on the relation of the indicator to vulnerability. Whereas (1) was employed with positive relation, (2) was employed with negative relation to vulnerability. From the equation, S_h is the observed sub-component, S_{min} and $Smax$ are the minimum and maximum values respectively for the entire households as explained by (Adu et al., 2018). The indices for each sub-component are then summed and averaged to obtain the index of each main component, M_h. This relation is represented by equation (3) below:

$$M_h = \frac{\sum_{i-1}^{n} Index_{shi}}{n} \quad (3)$$

The indices for all the major components are calculated using (3) where Socio-demographic profile (SDP), Livelihood strategies (LS), Social networks (SN), Health (H), Access to food (F), Access to water (W) and Natural hazards as a result of the changing climate (NDCV) are the major components for the household h, $Index_{shi}$ representing the sub-components indexed by i and n being the number of sub-components per major component. The household livelihood vulnerability index, LVI_h, is the calculated employing equation (4) using the indices and the weights, w_{Mi} (the weights are the number of sub-components of the various major components) of the major components. The LVI equation is as represented by the relation below:

$$LVI_h = \frac{w_{SDP}SDP_h + w_{LS}LS_h + w_H H_h + w_{SN}SN_h + w_F F_h + w_W W_h + w_{NDC}NDC_h}{w_{SDP} + w_{LS} + w_H + w_{SN} + w_F + w_W + w_{NDC}} \quad (4)$$

The LVI was expressed on a scale between 0 and 0.6 where 0 is low vulnerability and 0.6 being high vulnerability (Adu et al., 2018). This study adopted from (Hahn et al., 2009) the model for calculating the LVI but significantly modified it to suit the data availability and the capacity of the research.

On the technology need assessment, a method similar to that employed by (Essegbey et al., 2012) was used. Instead of taking the opinions of agricultural experts, this study make the use of the opinion of farmers within the research communities. Their opinions were graded on percentage bases and decisions were made in that direction. Microsoft Excel was used to present basic descriptive statistics of the farming practices of the two districts along with their proposed technology needs and methods of technology presentation. Correlation and regression analysis was used to assess the difference in productivity between local farmers and the national yield. Data was also presented on the national potential yield to put in perspective the deficit in productivity of agriculture in the country.

3.5. Ethical Issues

Due to sensitivity of the data collected from household and their probing nature, anonymity was maintained and information that can possibly lead to determining the respondent such as names and addresses were not included in the questionnaire. The researcher has also taken upon themselves to protect the information gathered such that the raw data is not published. Additionally, the consent of the household heads were sought before taking the household data.

3.6. Conclusion

This chapter has detailed the step by step methodology that was used to sample the study community and respondents, design the data collection instrument, collect data, analyse data and present the result of the analysis. The chapter also focused on the phases of this study including the Livelihood Vulnerability, Agricultural Technology Needs and technology Park Management.

CHAPTER FOUR

4. RESULT AND DISCUSSIONS

4.1. Overview

This section of the study presents all the results of the analysis in the previous chapter relevant to draw an intellectual conclusion on the assumptions presented in the first chapter. It will also aid in answering the research questions raised in the first chapter and fulfil the objectives of the study. Demographic information was presented describing the responding population, followed by the results on the LVI and concluding with the technology need assessment results. The chapter is presented with tables and figures followed by brief explanation of their content.

4.2. Demographic Description of the Sample Population

Out of the estimated two hundred respondents to be sampled, one hundred and seventy four were interviewed representing 87 %. This was due to the sparse nature of the Wa West district where seventy four respondent were interviewed out of the estimated one hundred. Both male and female household heads of different age groups, farm sizes, household sizes and crop (s) specialty were interviewed. Table 1 shows the brief household characteristics, highlighting the age groups, farm sizes, household size and average crop cultivated by both Wa West and Pru districts.

Table 1. Household Characteristics

			STUDY DISTRICTS			
HOUSEHOLD CHARACTERISTICS			WA WEST		PRU	
Average Age	20-30 (1)	(%)	5	3 (41-50)	34	2 (31-40)
	31-40 (2)		22		33	
	41-50 (3)		35		21	
	51-60 (4)		35		7	
	Above 60 (5)		3		5	
Average Farm Size (acres)			4		8	
Average number of crops cultivated by Household (crops/acre)			3		2	
Average number of People in Household (persons/household)			9		6	

It can be seen from Table 1 that the average age of the household head interviewed in the Wa West district was between 41 and 50 whilst that of the Pru district was between 31 and 40. This implies that the Wa West district has an older household head compared to the Pru district. With regards to farm size, it has been observed that the Pru district respondents have higher farm sizes (8 acres) on average compared to the Wa West respondents (4). The higher average number of crops cultivated by the respondents in Wa West (3 crops) compared to the Pru district (2 crops) indicates that Wa West farmers are more small holder with more mixed cropping farming system than the respondents in the Pru district. The higher household size of Wa West (9 on average) can be explained by the fact that household heads have a higher average age implying that most people live with their families longer than the Pru district (6 on average).

From figure 43, it can be observed that whereas the Wa West district respondents are almost equal with regards to gender differences (49 % females and 51 % males), the Pru district recorded a higher percentage of male respondents (65 %). This might be due to a higher level of polygamy in the Wa West district where a woman and her offspring are viewed as a household since they fit the definition presented above in the previous chapter. Most women serving as wives work with their husbands on the farm in the Pru district where they are able to cultivate larger farm sizes as observed from Table 1.

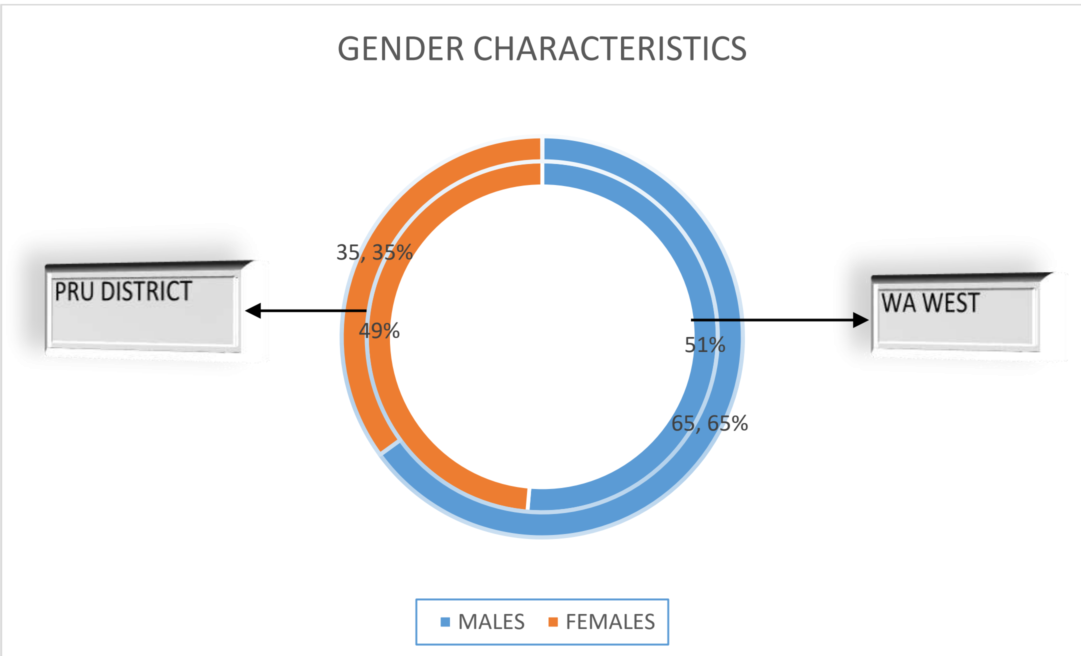


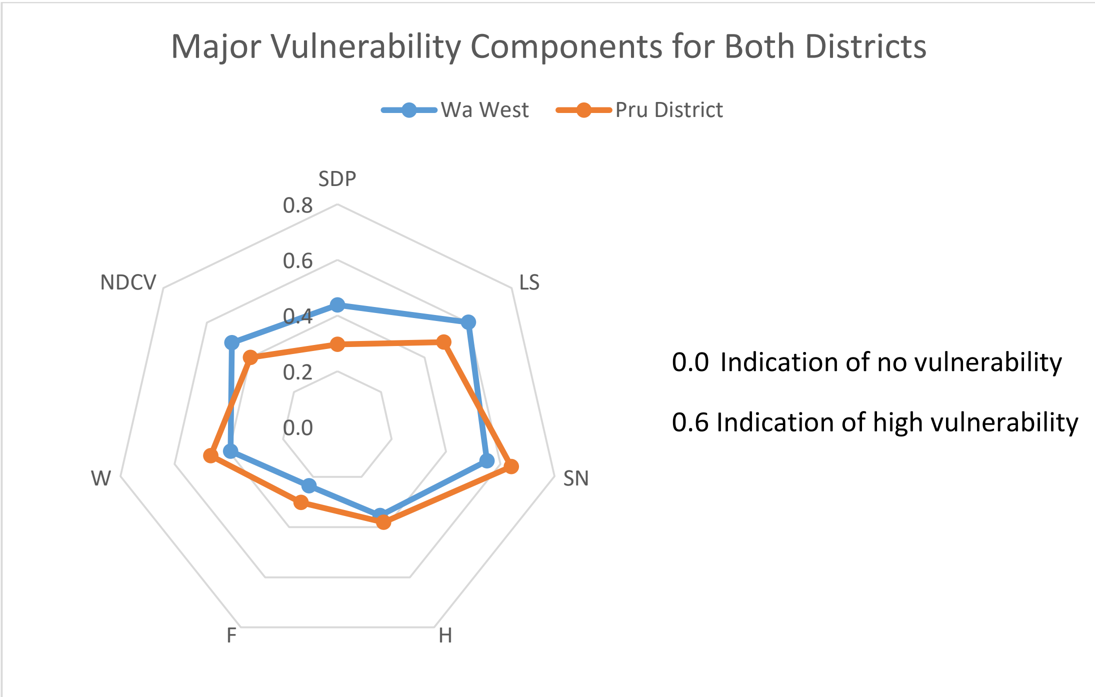
Figure 3. Gender Characteristics of the Sample Population

4.3. Livelihood Vulnerability Index

Figure 4 shows the comparative distribution of vulnerability based on the major components. Based on the Socio-demographic Profile, it has been observed that the Pru district is averagely vulnerable (0.3) whereas the Wa West district recorded a slightly higher vulnerability (0.4). This can be attributed to the lower level of education and the higher dependence ratio in the Wa West district. On livelihood Strategy, both districts recorded very high vulnerability with Wa West recording the highest (0.6). This is so because most of the respondents have farming as their main occupation and the fact that not much income is generated outside the farming business to help the household. With regards to Social Network as a major component of vulnerability, it has been observed that both districts are equally extremely vulnerable (0.6). Poor support systems financially or otherwise, between farmers or relief organisations can be the reason for this observation. Most of the respondents indicated that they did not receive or give support to others and the ratio of loan reception in both districts is very low. This might be due to the lower number of financial institutions in the areas and the fact that loans attract high interests and the need of collateral to be granted a loan.

Similar to the Social Network, both districts also recorded similar vulnerability on Health as a major component of vulnerability (0.4). The observed vulnerability is slightly above average which calls for concern. Both locations, especially Wa West district has lower number of health facilities coupled with a lower number of strategies to combat the major disease in the Sub-Saharan African region (Malaria). These are the factors the study attributed to the observed vulnerability to Health in Figure 4 below. Food component is the area in which Wa West district recorded a relatively lower vulnerability (0.2) as a result of the mixed cropping system and the fact that most of household food comes from the family farm. Pru district recorded an average vulnerability (0.3) as shown in Figure 4 below owing to the fact that there is an observed lower mixed cropping and most respondents buy foods outside the farm produce.

Notwithstanding that there exist the Pru River and the course of the Volta Lake in the Pru district, a lot of households depend on dug wells and mechanical boreholes for their household water needs. These water sources were observed not to be sustainable especially the dug wells as observed in Figure 5 below (a dug well with very low water level I the Pru district). Most of the responding households also live away from the river and lake making access difficult. For these reasons, the Pru district recorded a high vulnerability (0.5) than the Wa West district where slightly higher than average vulnerability was observed (0.4). In both districts however, there is an observed close to no availability of pipe borne water causing almost all the respondents to store water for household use. With regards to Natural Hazards as a result of Climate Change, as expected, high vulnerability was observed especially in the Wa West district (0.5) which is located in the dryer region of the savannah. Droughts and floods with accompanying unstable rainfall patterns and increasing temperatures have been observed to drive the vulnerability of both districts. These observations can be seen as represented in Figure 4 below.



Socio-demographic profile (SDP), Livelihood strategies (LS), Social networks (SN), Health (H), Access to food (F), Access to water (W) and Natural hazards as a result of the changing climate (NDCV)

Figure 4. Spider Graph of LVI Major Components for Both Districts

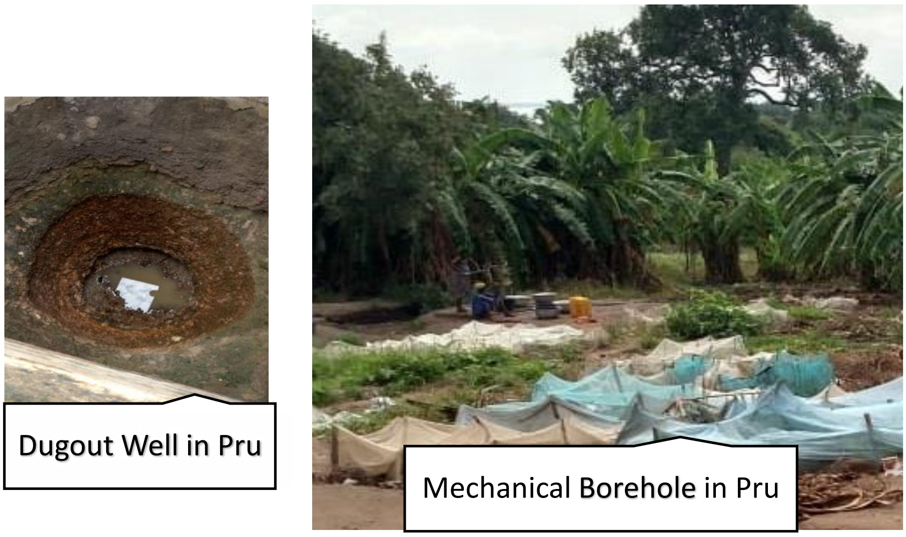


Figure 5. Dugout Well and a Mechanical Borehole in Pru Districts

Form Table 2 below, it can be observed that both Wa West and Pru districts are equally vulnerable to the changing climate. A 0.5 index shows that both districts are close to extreme vulnerability. It is clear from Table 2 and Figure 4 that both Wa West district and Pru district are vulnerable on all the major components to vulnerability except in the food component where lower vulnerability was observed. This observation is similar to that reported by Adu et al., (2018) on Wenchi and Techiman (both towns recorded 0.25). Similarly, the Social Network components also recorded high indices of 0.57 and 0.51 for Wenchi and Techiman respectively. The overall Livelihood Vulnerability Indices however are differently lower on two points in both Wenchi and Techiman compared to the 0.5 recorded for both Wa West and Pru districts (Adu et al., 2018).

Table 2. Overall Livelihood Vulnerability Index of Both Districts

	WA WEST DISTRICT		**PRU DISTRICT**	
MAJOR COMPONENTS	COMPONENT INDEX	LVI	COMPONENT INDEX	LVI
SDP	0.44		0.30	
LS	0.60		0.49	
SN	0.55		0.64	
H	0.35	**0.5**	0.38	**0.5**
F	0.24		0.30	
W	0.39		0.47	
NCDV	0.49		0.40	

SDP – Socio-demographic Profile; LS – Livelihood Strategies; SN – Social Network; H – Health; F – Food; W – Water; NDCV – Natural Disaster and Climate Variability

4.3.1 Trend in the Climatic System

Figure 6 below shows the monthly maximum temperature trend in the Pru district over the period from 2012 to 2018. The monthly trends from 2012 to 2018 shows a gradual increase in the maximum temperatures. The least increment in the trend is in December over the period. A similar trend can be observed in Figure 6 below for the minimum environmental temperatures for the Pru district. The month with relatively stable minimum temperatures was observed to be the month of October.

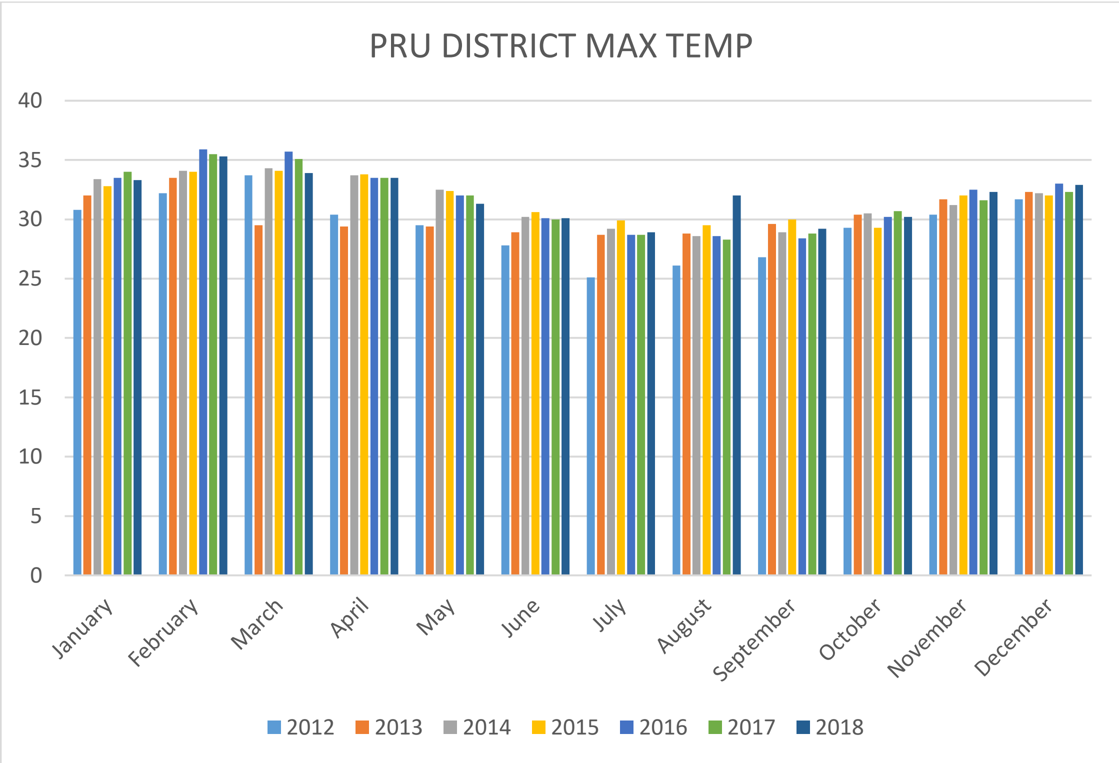


Figure 6. Chart of Monthly Maximum Temperatures for Pru District from 2012 to 2018

Average annual temperatures for the district have been observed to be increasing over the years from 2012 to 2018. Almost 3 °C temperature increment was observed from 2012 to 2016 with a slight decrement of about 0.6 from 2016 to 2018 as shown in Figure 7 below. Temperatures over the period of study were actually increasing on both the maximum and minimum points. The maximum temperatures in the Pru district however showed a clearer trend in the temperature increment of the district. This goes further to confirm the publication of the IPCC that temperatures of most part of Africa where data is available indicated an increasing trend (Niang et al., 2014). The Pru district data however goes contrary to that report on the point that minimum temperatures are increasing higher than maximum temperatures. This can be attributed to regional difference of the study sights. Generally however, it can be appreciated that the temperatures of the Sub-Saharan African region of Northern Ghana are increasing over the years.

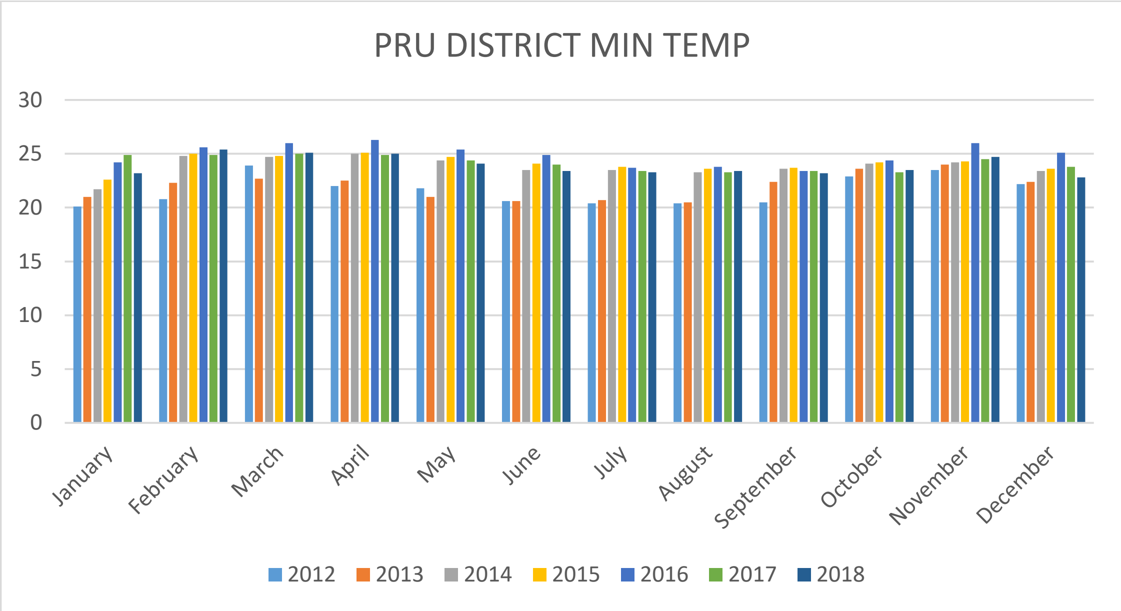


Figure 7. Chart of Monthly Minimum Temperatures for Pru District from 2012 to 2018

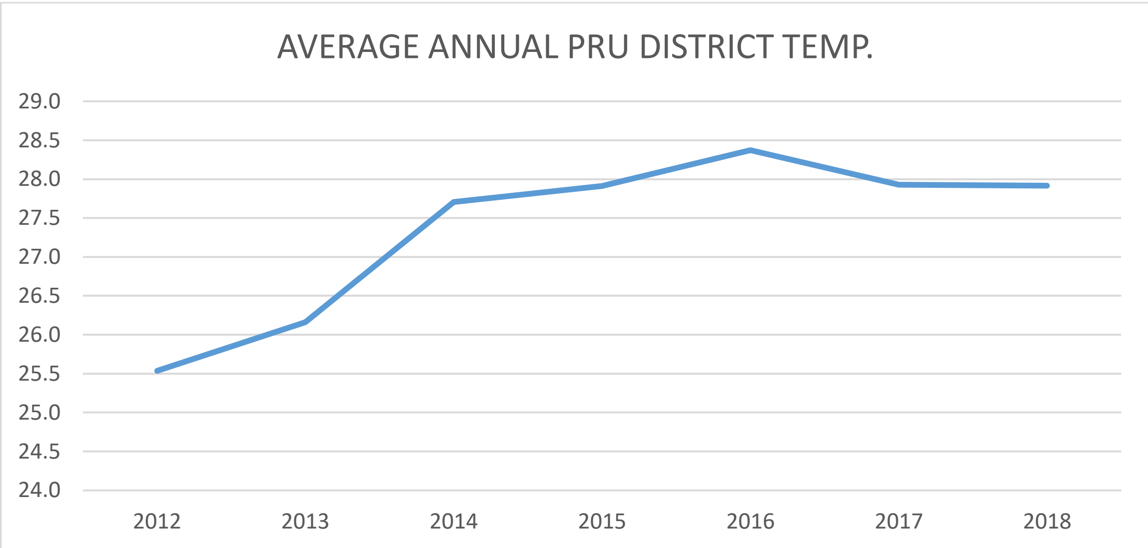


Figure 8. Graph of Average Annual Temperature of Pru District from 2012 to 2018

Unlike the Pru district, there has not been any significant increasing trend in terms of average monthly maximum temperatures for the Wa West district. Some changes were however observed occasionally as in 2014 and 2015 as shown in Figure 8 below. Minimum temperatures unlike the maximum temperatures have shown an observable incremental trend but not to the levels observed in the Pru district. This agrees with the IPCC observations on Africa that minimum temperatures are increasing faster than the maximum temperatures (Niang et al., 2014). Figure 9 below showed an unusual trend in 2014 for the annual average temperatures as it recorded significantly lower average compared to the other years. There is however an observed increment of about 0.8 °C from 2012 up to 2016, thereafter, a decrement of about 0.3 °C coming to 2018. In general, it has also been observed that there is an observed increase in maximum, minimum and average annual temperatures in the Wa West district.

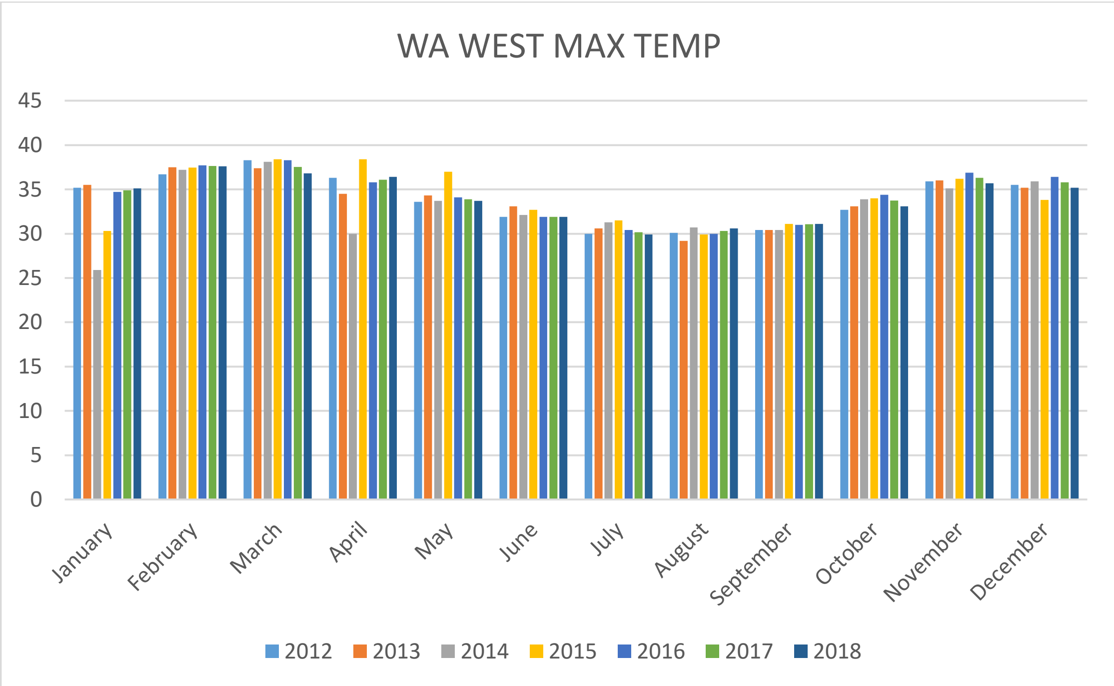


Figure 9. Chart of Monthly Maximum Temperatures for Wa West From 2012 to 2018

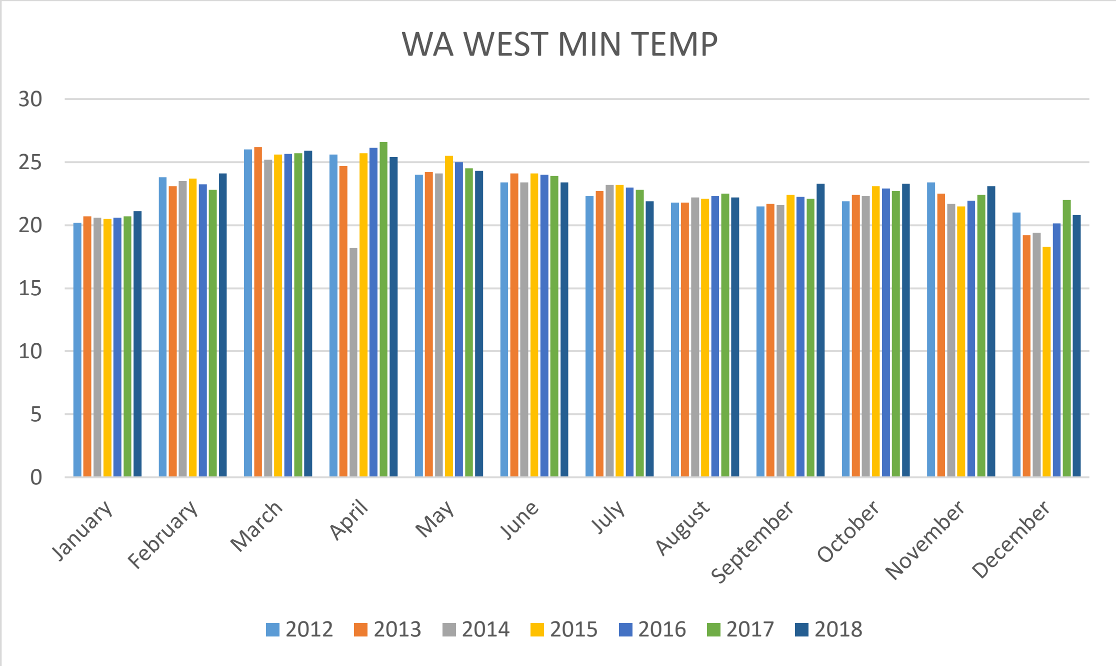


Figure 10. Chart of Monthly Minimum Temperatures for Wa West From 2012 to 2018

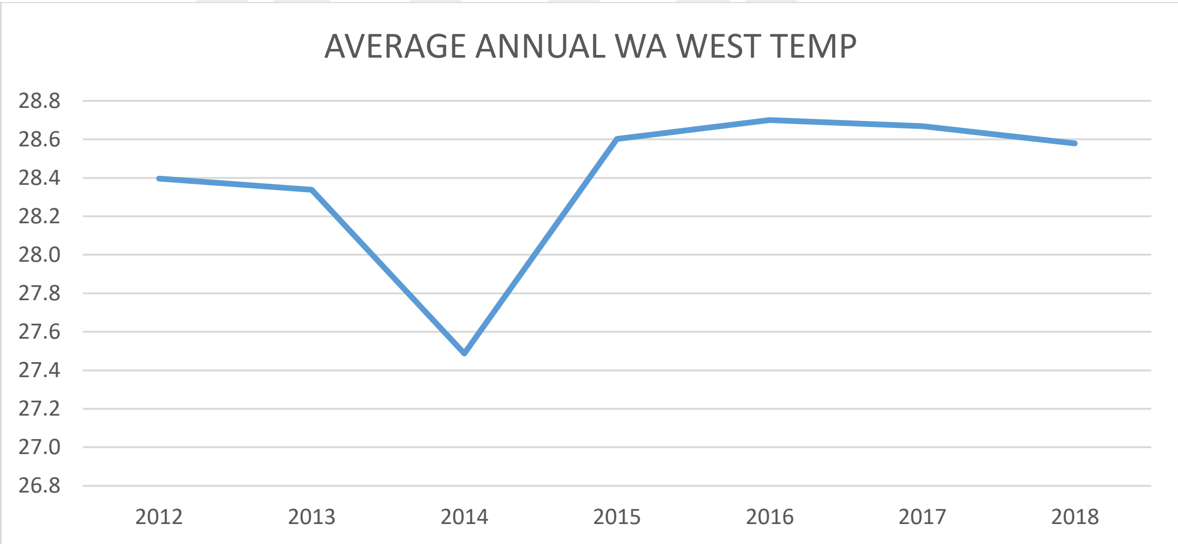


Figure 11. Graph of Average Annual Temperature of Wa West District From 2012 to 2018

Rainfall patterns in both Pru and Wa West districts have been erratic as shown in Figures 12 and 13 below. This is further confirmed by the changing trends in the annual rainfall averages for both districts as shown in Figure 14 below. In 2014, whereas there was an increase in the amount of rainfall in the Pru districts of more than 250 mm, the Wa West district recorded a slight decrease in the same year with about 120 mm as shown in Figure 14 below. From 2014, there has been an observed general decreasing trend of the annual rainfall pattern of both districts. Due to the erratic nature of the rainfall pattern of both study areas, there has been an observed increment in the amount of rainfall for both districts in 2018.

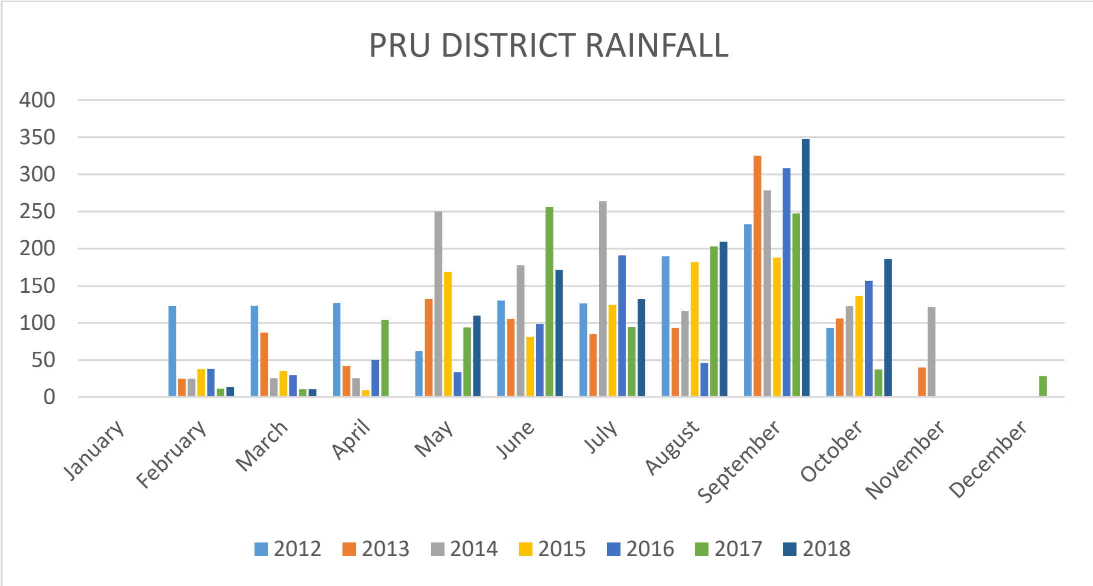


Figure 12. Chart of Monthly Rainfall of Pru District from 2012 to 2018

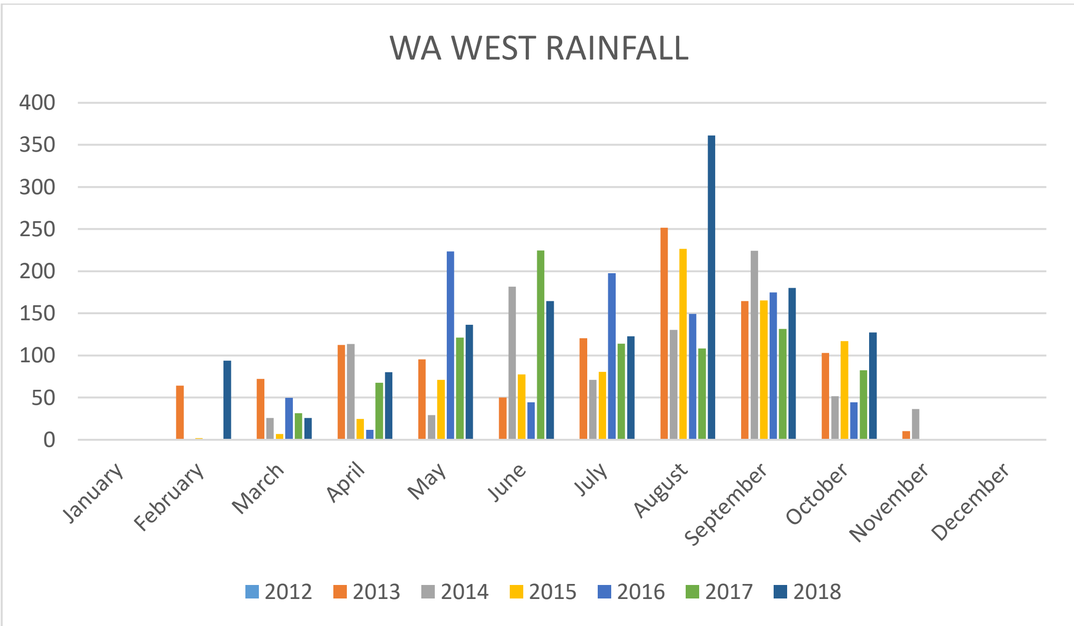


Figure 13. Chart of Monthly Rainfall of Wa West District From 2012 to 2018

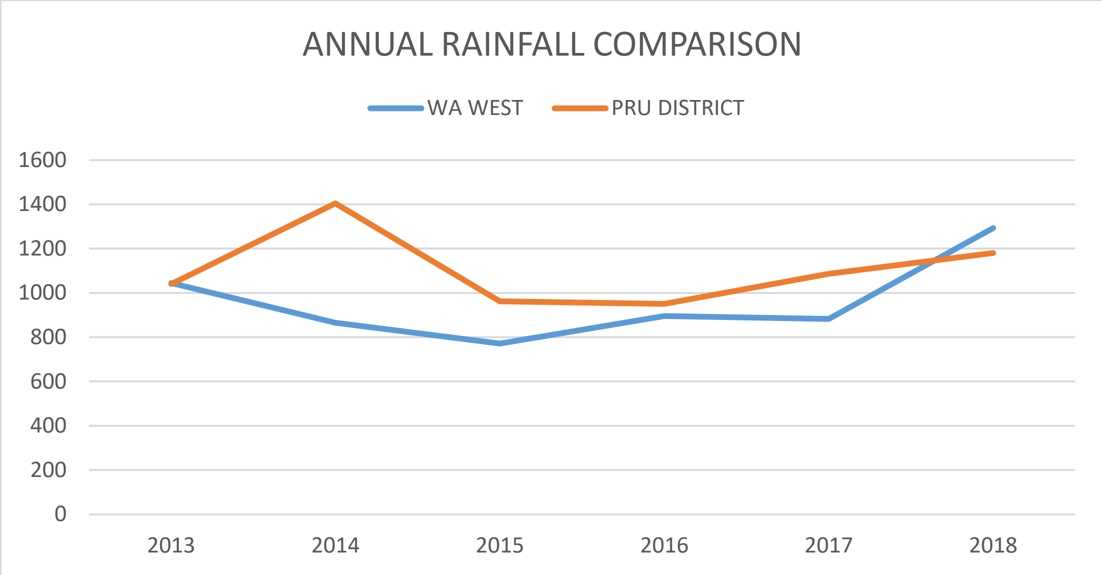


Figure 14. Graph of Annual Rainfall of Both Districts from 2013 to 2018

When quizzed on whether the climate is changing, respondent in both Pru and Wa West districts responded with a 93 % in the affirmative. In Wa West, the remaining 7 % were uncertain as to whether the climate is changing whereas 4 % in the Pru district responded in the uncertainty. 3 % of respondents in the Pru district think the climate is not changing as shown in Table 3 below. Majority of the respondents in both districts gave only a reason to buttress their claim that the climate is changing (51 and 64 for Wa West and Pru districts respectively. As shown in Table 3 below, 11 % and 7 % of the respondents in affirmative on climate change in Wa West and Pru districts respectively gave no reason for their agreement with the notion that the climate in changing.

Table 3. Opinion of Respondents on Climate Change

		WA WEST DISTRICT (%)	PRU DISTRICT (%)
IS THE CLIMATE CHANGING?	Yes	93	93
	No	7	3
	Uncertain	0	4
NUMBER OF REASONS GIVEN	Just 1	51	64
	Two Or More	38	29
	None	11	7

4.4. Technology Need Assessment

The questionnaire administered to the responding farmers seeks to identify the common farm practices among all the farmers. It was observed that the agricultural practices of the responding farmers have not differed from the general practices i.e. land preparation, nursery practices, planting of crops, weed and pest management, fertilization and irrigation, harvesting and postharvest treatment, and storage. Each of these stages and activities need certain amount of technological advancement in order to optimise agricultural productivity so as to achieve the United Nations goal of eliminating hunger and starvation around the world. Among the important inputs of the farming process is the seed. Seed quality is very important as it determines to a greater extent the nature of the yield of the farming process all other things been equal. The best seeds in Ghana are mostly from the Ministry of Agriculture or those from government funded research institutions such as the Crop Research Institute (CRI-Kumasi). Farmer saved seeds, especially for hybrid varieties, are the lowest in terms of seed quality. From Table 4 below, it can be observed that most of the respondents in the Pru district (74 %) save their own seeds or planting materials compared to the response from Wa West district where up to 38 % respondents reuse their stored planting materials. 20 % of respondents to the questionnaire acquire planting materials from the Ministry of Agriculture agents in Wa West whereas only 5 % responded that their planting materials come from the Ministries in the Pru district as can be observed in Table 4 below. Most of the respondents in the Wa West district (42 %) use planting materials from input dealers in the district as compared to only 21 % in the Pru district.

Table 4. Characteristics of Respondents Farming Practice

		WA WEST DISTRICT (%)	PRU DISTRICT (%)
PLANTING MATERIALS	Farmer Saved Seeds	38	74
	Seeds From Input Dealers	42	21
	Seeds From Ministry of Agriculture	20	5
TILLAGE METHOD	Use of Tractor	78	68
	Manual Labour	18	19
	Zero-Tillage	4	13
WEED CONTROL	Use of Weedicide	59	64
	Manual Control	41	36
	Cultural Method	0	0
MACHINERY USAGE	Tractors	73	66
	Cultivators/motorised machines	5	31
	None/Non-motorised	22	3

The healthy growth of a plant depends to a large extent on the soil on which it is cultivated. Tillage practices have been identified to influence crop growth and in the same breath the sustainability of the land on which the farming process is being practiced. For sustainability purposes, zero and minimum tillage are being promoted. It can be observed from Table 4 above that only 4 % and 18 % of respondents are into zero and minimum tillage respectively in the Wa West district compared to 13 % and 19 % zero and minimum tillage in the Pru district. A significantly higher number from both districts (78 % in Wa West; 68 % in Pru district) use tractors in their tillage process. This study observed that most of the respondents only use the tractor for ploughing of the land or creation of ridges for upland cultivation.

With a good seed and a well prepared bed, the impediment for the healthy growth of the crop will be the incidence of competitors (weeds) and pests. This study only considers weed management. From Table 4 above it can be observed that most of the respondents use chemical herbicides to control farm weeds. 59 % and 64 % respectively for Wa West and Pru districts are the frequency of chemical herbicide users for weed control. It has been observed that in both districts, respondents do not consider cultural practices when it comes to weed control. From Table 4 above, it can also be observed that 41 % and 36 % in Wa West and Pru district respectively control weeds manually using hoe and cutlass. This is a common practice among poor households and for secondary weed control.

Apart from the tillage process, farmers also use machines in keeping their crops such as during weed control, fertilizer application, harvesting and irrigation. 73 % and 66 % of respondents in Wa West and Pru districts respectively use tractors again for at least harvesting of their farm produce as shown in Table 4 above. 31 % of respondents in the Pru district use small motorised machines and cultivators in their farming process compared to only 5 % in the Wa West district as can be observed in Table 4 above. 22 % of the respondents I the Wa West district either use a non-motorised machine such as the mechanical knapsack sprayer or use no other machine in the cultivation process.

Table 5. Farmer's Opinion on Technology Needs and Introduction Methods

		WA WEST DISTRICT (%)	PRU DISTRICT (%)
Technological Needs	Seed	45	4
	Traction	18	14
	Cultural Practices	24	6
	Services	14	30
	Extension Service	0	46
Method of Introduction	Individual	36.5	34
	Group Meeting	59.5	55
	Field trips	0	3
	Electronic Media	4	8

When questioned on the kind of technologies respondents deemed fit to be introduced in the district to improve agriculture, 45 %, which is the highest in Wa West demanded that more improved seeds and planting materials should be introduced as shown in Table 5 above and Figure 16 below. Response in the Pru district for planting materials was however very low (only 4 %). 46 % of the respondents in the Pru district demanded the improvement in the Extension services in the district. Comparatively, there was no positive response for Extension service in the Wa West district. Among the respondents, 18 % and 14 % in Wa West and Pru district respectively, demanded that more tractors should be supplied to reduce the drudgery on the farm.

Form Figure 16 below, it can be observed that most of the respondents preferred the Group Meeting where the technology will be introduced (59 % and 55 % for Wa West and Pru districts respectively). The second most preferred method by the respondents was individual methods where the farmer will be visited alone and the technology be introduced to them (36 % and 34 % for Wa West and Pru district respectively). 4 % and 8 % of respondents in Wa West and Pru district respectively preferred technology introductions be made through the media as shown in Table 5 above.

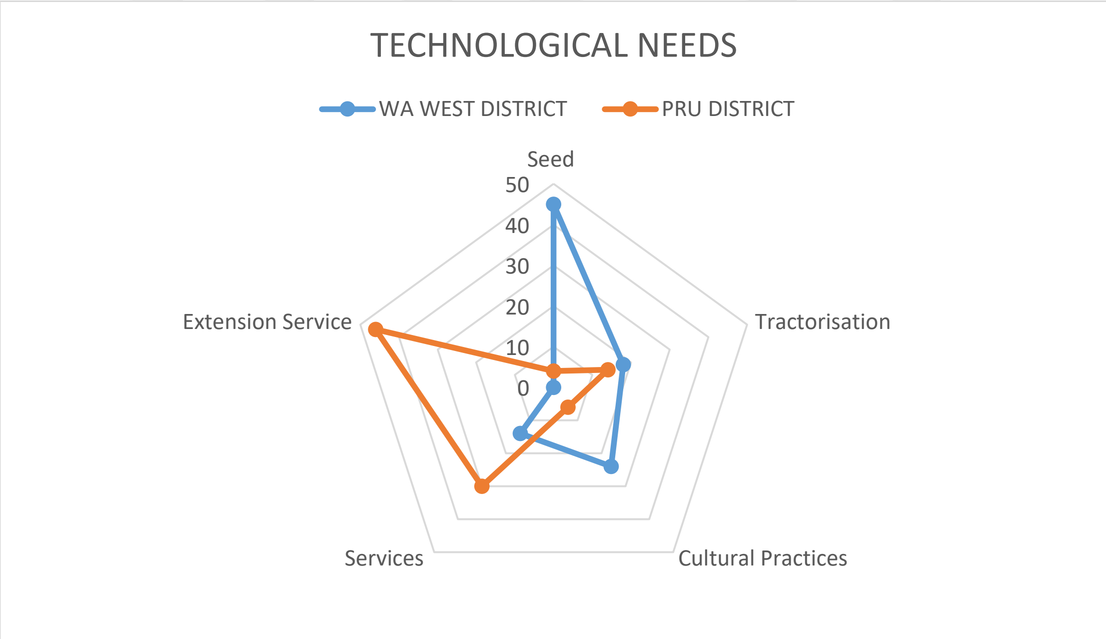


Figure 15. Farmers Opinion on Technology Needs in Both Districts

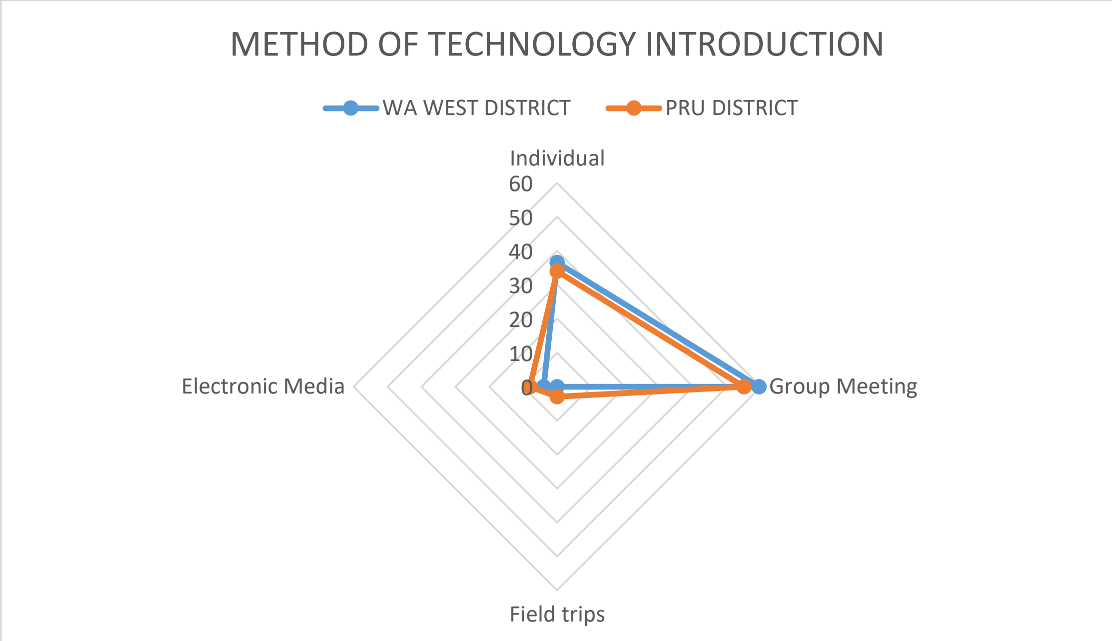


Figure 16. Technology Introduction Method Preference in Both Districts

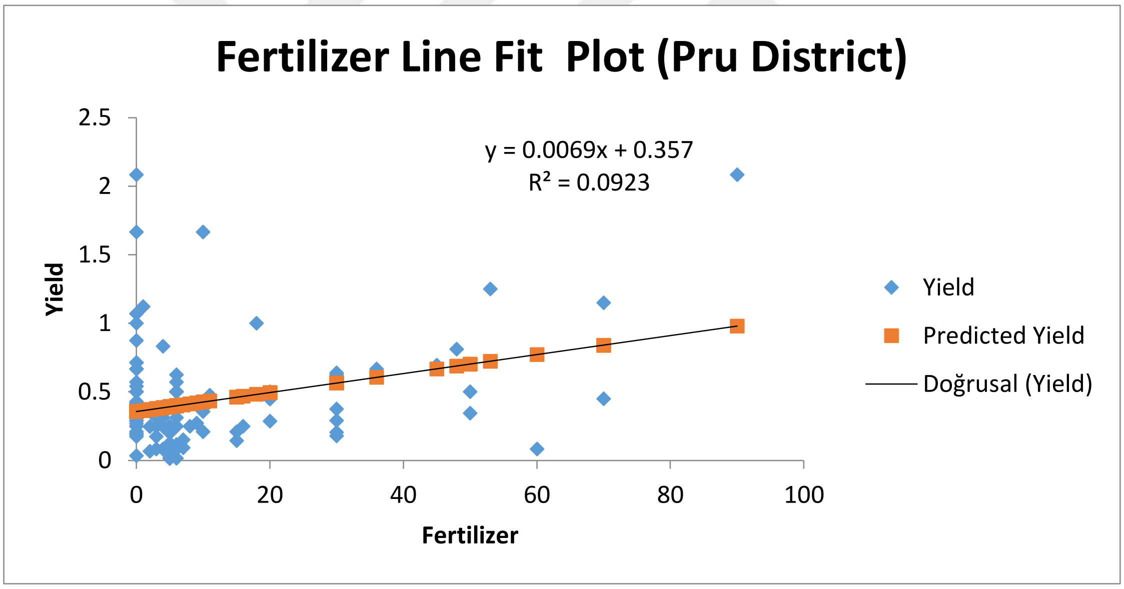


Figure 17. Regression Analysis of Yield against Fertilizer Usage in Pru District

Figure 17 above shows the regression analysis and line fit of yield against fertilizer application for the Pru district. The equation of the lines has a gradient of 0.0069 and an intercept of 0.357 as shown in Figure 17 above. This implies that a unit (50 kg) increase in fertilizer application will lead to only 0.0069 metric tonnes of yield increment. This is woefully inadequate for the amount of fertilizer applied. The R-Square value is also very low indicating that the model is very weak in predicting the outcome of a fertilizer application. This could be attributed to the low usage of fertilizers by respondents implying that there was little information to help develop the model. This, as shown in Figure 4.4.3 above, can be seen from the cluster of points around the origin of the regression line.

Similar to the data in the Pru district, an R-Square value of 0.0641 can be seen for the Wa West district regression analysis from Figure 18 below. This also mean that the model is very weak in predicting the yield per unit fertilizer applied. This is evident from the negative slope (-0.0037) and an intercept of 0.4187. Implying that, a unit increase in fertilizer application results in a reduction of yield by 0.0037 metric tonnes. This calls for concern as fertilizers are expected to increase yield and not the other way round. It is however evident from Figure 18 below that not much fertilizers are being used in the district agricultural activities and the knowledge of fertilizer application of the respondents can be questionable.

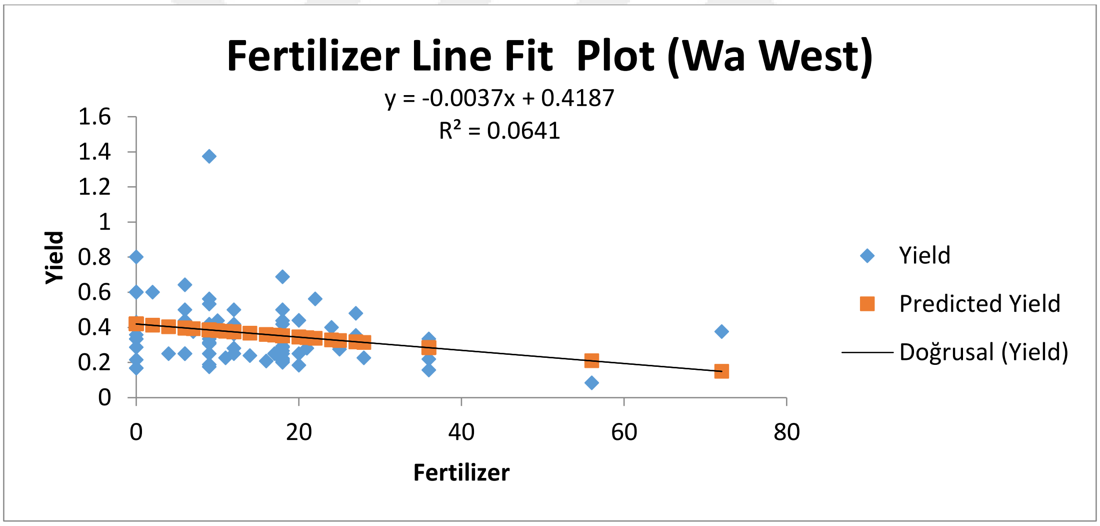


Figure 18. Regression Analysis of Yield against Fertilizer Usage in Wa West District

Table 6. Irrigation, Extension and Farm Produce Storage in both Districts

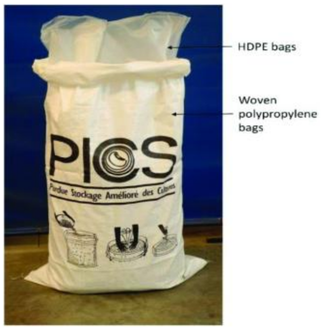
		WA WEST DISTRICT (%)	PRU DISTRICT (%)
Use of Irrigation	Yes	3	2
	No	97	98
Extension Service Training And Visit	None	35	28
	Once a year	42	57
	Twice a year	19	5
	Regularly	4	10
Method of Product Storage	Jute sack	82	5
	Triple Sack	0	1
	Barn	18	94

From Table 6 above, it can be observed that a lot of the respondents in the two districts have no access to irrigation facilities. 97 % and 98 % in Wa West and Pru districts responded as such. Considering the erratic nature of the rainfall systems in the two districts, it is expected that irrigation will significantly aid in optimising yield. On the frequency of extension visit and training respondents receive annually, it has been observed as shown in Table 6 above that whereas 35 % responded saying they receive no extension visit or training in the Wa West district, 28 % responded in a similar manner in the Pru district. Relatively, the majority of respondents (42 % for Wa West and 57 % for Pru district) indicated that they receive just a visit annually from the extension service. 19 % and 4 % of the respondent from Wa West indicated that they receive twice and regular visits a year respectively. In the Pru district, 5 % and 10 % of the respondents indicated that they receive extension visits and training twice and regularly a year respectively.

There was an observed sharp contrast between Wa West district and Pru district when it comes to the method of agricultural produce storage. Whereas most of the respondents in the Wa West district responded saying they use Jute sacks for storage (82 %), those in the Pru district (94 %) use the silos-like Barns for storage as shown in Table 6 above. It was observed that close to no one uses the newly introduced Purdue Improved

Crop Storage (PICS) bags which has proven to be very effective in maintaining the storage quality of especially grains. Figure 19 shows images of the storage methods.

A



B

C

A= Jute Sacks (Mighty Earth, 2019); **B**= Triple PICS (Manandhar et al., 2018); **C**= Local Barn (Goodier, 2013)

Figure 19. Storage Methods by Respondents in the two districts

4.5. Discussions

The study now puts together the results and discusses it in light of the objectives of the study trying to answer the questions raised in the beginning of this work. Thus, this section will compare the results in this chapter with other studies such as that of (Adu et al., 2018; Antwi-Agyei et al., 2018; Essegbey et al., 2012; Hahn et al., 2009; Niang et al., 2014) and others that will relevantly aid in the explanation of the observation in this study.

4.5.1. Vulnerability of Smallholder Farmers to Climate Change

According to the IPCC report as quoted by (Shah et al., 2013), vulnerability is a function of adaptive capacity, sensitivity and exposure. These factors are further broken down into components as appeared in the major components of the livelihood vulnerability index. For adaptive capacity, socio-demographic profile, livelihood strategies and social network are the sub-components that influence the vulnerability of a locality. This assertion is shared by (Adu et al., 2018) and (Hahn et al., 2009). It was observed that both Wa West and Pru district being a dominantly rural community especially the study areas (Pru District Assembly, 2015; Wa West District, 2016) are bound to be much vulnerable on this function of adaptive capacity. With not less than 0.3 index on a scale of 0 to 0.6 in terms of all the three factors under adaptive capacity, it shows that the two communities especially their rural areas are much more vulnerable to climate change. This findings compared to that of (Adu et al., 2018; Hahn et al., 2009; Shah et al., 2013), further proves that Wa West and Pru district are much vulnerable. This is a situation that mostly trigger the inhabitants to indulge in livelihood diversification strategies that mostly prove to be maladaptive (Antwi-Agyei et al., 2018). Specific factors such as education and agricultural economic activities do play significant roles in communities such as Wa West and Pru district where agriculture employs 80 % and 65 % of their population respectively (Pru District Assembly, 2015; Wa West District, 2016). Education of the populace is seriously in deficit especially in the very rural communities where this study was carried on. Most of the respondents could not read or write properly even if they responded as attaining some level of education due to the poor nature of the education system in those localities. Proper education opens up new opportunities for those who are educated. This claim is agreed with by (Shah et al., 2013). Those who are educated could get employment in the white-colour system whilst engaging in their agricultural production. Most of the household in the two districts however have less in term of education making their lives a seasonal routine.

There are not much financial institutions in the districts. Pru district which is the better of the two in term of development has only one commercial bank which only operates in the district capital. The other rural banks which are of much smaller scale also operate in the two major towns of the district leaving the rural folks without any financial help to support their agricultural activities. Getting loan from the financial institutions is very difficult due to the demand for collaterals which the rural people are unable to provide (Pru District Assembly, 2015).Without financial support to get amendments in the agricultural process, low yields result, which forces the populace to indulge in tree cutting to sell as firewood or when clearing new fields for cultivation (Antwi-Agyei et al., 2018). Both have maladaptive capacities in that they create more vulnerability especially for the future generation. This future generation currently represents the dependent population and also taking a high percentage of the population. This has further aggravated the sensitivity of the two districts to climate change.

From the IPCC's definition of vulnerability index, it is understood that access to food, water, health and shelter contribute to determining the vulnerability of a community (Adu et al., 2018). With a changing climate and a resultant decrease in agricultural productivity, food is bound to be in scarcity. The two districts are however, on the scale of 0-0.6, low in food vulnerability compared to other factors (0.2 and 0.3 for Wa West and Pru districts respectively). Both districts are also averagely vulnerable in terms of access to health services. Similar results was recorded by (Adu et al., 2018) for Wenchi and Techiman in terms of food and health with the exception of health in Wench where there is a recording of 0.4. This shows a correlation in the sensitivity of two study groups to climate change. On access to water, it has been found that Wa West and Pru district are vulnerable due to the high indices recorded compare to the study by (Adu et al., 2018) but similar to a faraway community in the study of (Shah et al., 2013). Following this, it can be deduced that vulnerability to climate change driven by access to water is a common phenomenon in the Sub-Saharan African region. The report by the districts show that both communities have been affected by the changing climate resulting in erratic rainfall and high temperatures. This further causes the drying of the water bodies which the communities depend on for most of their water need. The drying water bodies especially in the Pru district also results in the increment in the incidence of diseases in the community (Pru District Assembly, 2015). With low access to health facilities and increasing disease incidence, a community will invariably be identified to be very vulnerable to the changing climate.

More to the issue of the changing climate is the disasters that the communities face. Flooding, delayed onset of season, erratic rainfall and high temperatures are common happenings in the two districts. Most of the farmers reported being affected severely by changes in the climatic system especially the erratic rainfall pattern which sometimes results in crop failure. This is evident from the 0.4 indices recorded by both districts on natural disaster and climate variability. This further exposes the communities to climate change. The issue of exposure cuts across the communities within Ghana and those of Sub-Saharan Africa (Adu et al., 2018; Hahn et al., 2009; Shah et al., 2013). This further validates the report of the IPCC on the exposure of the African continent to the impact of climate change especially in the coming decades (Niang et al., 2014). Finally, the inhabitants of the two study areas are among the populace considered as dominantly poor in the country. Poverty, though not an indication of vulnerability, exposes a community to the impact of the impacts severely when they hit (Antwi-agyei et al., 2012).

4.5.2 Trend in the Climatic Systems of the Study Areas

As established above, this study has observed that the climatic variables of rainfall and temperature are changing. Trend in both minimum and maximum temperatures have been observed to be in the rise for both Wa West and Pru districts. This is evident not only in the study areas but also in other parts of the Sub-Saharan African region. According to the OECD/FAO (2016), there was a significant observed drought condition recorded in the East Africa over the 2015/2016 season. Though researchers agree that a small fluctuation within a short period does not account to climate change, respondents to this study have overwhelmingly confirmed that the climate is changing from what they use to know. The average age of the respondents for this research has been above 30 years; implying that most of the respondents have lived over three decades. Hence their assessment of the climate, though seemingly unscientific, carries weight in determining whether the climate is actually changing for those particular communities. This is supported by the report of the IPCC where it was indicated that there exist a disagreement on the projected rainfall amounts though recent observations are speaking for the erratic, reduced nature of the rainfall pattern in West Africa, home to the study areas. Evidence to this can further be seen in the higher standard deviations observed for monthly rainfall in the work of (Adu et al., 2018) for Techiman and Wenchi which are neighbours to The Pru district. Antwi-agyei et al., (2012) have established the extensive nature of drought occurrence in the Upper regions of Ghana. Reducing and erratic rainfall pattern will invariably lead to a high temperature experience.

As observed in the results of the study, the temperatures of the two communities are gradually in the upward movement. Observed temperature increments in those regions of Ghana has been attributed to the increasing desertification of vegetation as a result of the human activity of cutting down trees which otherwise help in maintaining a stable climate (Owusu et. al., 2013). Annual mean temperature are forecasted to increase up to 3.9 °C by the year 2080 and the trend has already started to be observed in these vulnerable communities (Antwi-agyei et al., 2012). Adu et al., (2018) recorded a higher standard deviation for both minimum and maximum temperature for Techiman and

Wenchi; an indication that the temperatures of those communities, which are neighbours to the study areas of this work, are changing in the upward trend.

Established at this point is the notion that the trend of the climate of the two study areas are as observed and predicted by the published information by the IPCC and other researchers. Rainfalls are erratic and in reducing trends for the two study areas and other communities in Ghana and other countries in the Sub-Saharan African region. Temperatures, both minimum and maximum, are on the increasing trend as observed by researchers and the respondents of this study. Some of the observed changes can be attributed to local livelihood strategies to adapt to the changing climate. These strategies have been found to be mostly maladaptive, increasing the risks of the impact of future events.

4.5.3. Technology Gaps Peculiar to the Study Areas

It is the goal of the United Nations to end hunger and poverty of all forms in the world as clearly stated in the SDGs (Woodbridge, 2015). Feeding an increasing population of the African continent with a current deficit in food production will be a very difficult task with current technological reach. According to the United Nations, (2019), the world population growth rate stands below 1.1 per year, with an estimated addition of more than 1 billion for which more than half will be from the Sub-Saharan African region. With a population growth rate of 2.5 per annum, Ghana should be putting strategies in place to cater for the additional population (Ghana Statistical Service (GSS), 2012). Table 7 shows the relationship between the average yields of some selected crops and the potential yield in the country when the right technologies and extension education are provided. It can be observed that, with the exception of pineapple, no crop has recorded average yield of up to 60 %. Pineapple, which recorded the 85.83 % is an export crop and not considered as an arable crop. Ghana now is considered a net importer of food to feed her current population. With the right technology, extension education and technology adoption and implementation, the country will be expected to be capable of feeding even the expected growth in population. The discourse has however, been raised to the next level considering the lingering impacts of the changing climate whose signs have already been felt. According to the report on the climate change adaptation strategies in Ghana by (UNEP/UNDP, 2013), the countries climate is evidently changing with increasing average temperatures, reduced rainfalls and variability across all ecological zones. This is further confirmed by the IPCC report on Africa for West Africa (Niang et al., 2014). With poor performing agriculture amidst a changing climate and an increasing population, the time has never been right to look critically into the systems and structures of a nation with potentials. The study areas, being part of Ghana and for that matter, belonging to some of the most deprived communities, are much more in need of this paradigm shift than any other locality for the mere survival of their populace now and the impending future.

This study has observed and realised deficits of technology in agricultural practices of the study areas related to;

i. Land preparation and crop establishment
ii. Weed management and soil health management
iii. Seed and propagules for annual cultivation
iv. Harvesting and postharvest technologies
v. Access to credit

Table 7. Current Average Yield and Potential Yield in Ghana for Some Selected Crops

Crop	Average Yield (Mt/h)	Potential Yield (Mt/h)	Percentage Achieved (%)
Maize	1.99	5.50	36.18
Rice	2.92	6.00	48.67
Groundnut	1.30	3.50	37.14
Yam	17.42	52.00	33.50
Cashew	0.50	1.80	27.78
Soya	1.65	3.00	55.00
Pepper	15.00	30.00	50.00
Cassava	20.25	45.00	45.00
Cowpea	1.41	2.50	56.40
Cocoa	0.50	1.00	50.00
Pineapple	61.80	72.00	85.83

Mt/h = Metric tonnes per hectare

Source: (MINISTRY OF FOOD AND AGRICULTURE, 2017)

From this study, we observed that whilst most of the farmers in the Wa West district are suggesting the introduction of superior planting materials, those in Pru district think intensifying the work of the extension service has a lot to do with increasing productivity. Cultural practices improvement and production process services were the focus of the respondents from Wa West and Pru district respectively afterwards. From the analysis, it has been observed that the demand of the farmers are to a large extent valid. Extension education is responsible for conveying new technologies to farmers who are in need of it. With a poor extension service (in terms of visits and competence), there is definitely going to be an observed low production in the country. Iddrisu & Peker, (2018) indicated that there is no significant shortage of technology in Sub-Saharan Africa; the major problem is with education, accessibility and adoption. This has been agreed with by the (MINISTRY OF FOOD AND AGRICULTURE, 2017) in its publication on the facts and figures on agricultural performance.

4.5.4. Technology Park Establishment and Management for Resource Poor Communities

Looking at the results of the study, it can be realised that the study communities are in need of a lot of technological support which are not lacking in the country. The most important factors that impede the realisation of an agricultural system abreast with the technological advancement in the country are costs, access and information (Mwangi & Kariuki, 2015). This study hence considered bringing all the technologies at a go in a sustainable manner. The possibility of establishing a mini-technology park for agriculture resident within each community. Technology parks as explained by Machado et al., (2018) is a hybrid institution that brings different players together to achieve a common goal of technological improvement.

Considering the fact that different persons demand different methods of technology introduction, establishing a park close to the farmers will really allow easy access. The park as viewed by the author of this study will involve the management of the facility, the community leadership, the government, an agricultural institution of higher learning, a credit and product buying entity, and most importantly farmer groups. With the exception of the facility management, none of the other stakeholders have to stay within the facility. With the level of improvement in the country's communication system, information can be shared on daily bases without the necessity to have a physical presence.

The role of the management will be to coordinate all affairs of the park alongside sharing information with and taking information from the farmers on new developments and new needs respectively. The government will support the park with policy in term of subsidies and initial support for establishment. The community leadership will act as board of directors for the facility so as to ensure the sustainability of the facility. The institution of higher learning will be responsible for carrying out research works annually using their students. The credit giving and product buying entity will support the continuous running of the facility. And finally, the farmers are the main users of the facility; providing direction for research and implementing the findings of the research work.

CHAPTER FIVE

5. CONCLUSION AND RECOMMENDATION

5.1. Overview

This chapter concludes and makes recommendations for this study. All data analysed and information gathered have been put together to make meaningful conclusions relevant to the objectives of the study. Recommendations which are targeted at government, non-governmental organisations, corporate players and academics also made. Implementing the recommendations of this study will go a long way to reduce the adaptation gaps in the study areas and also improve the agricultural landscape of the communities.

5.2. Summary of Findings

After studying the communities within the two districts; Wa West and Pru districts, the following are the summary of the findings:

- Most of the respondents are males (51% for Wa West and 65 % for Pru districts). This shows that males still maintain the head of family role in a household. More females were recorded in the Wa West district because some husbands were not around (either due to travelling to other towns for work or being with another household). On the household characteristics, it has also been observed that most of the respondents are between the ages of 31 and 50 years (57 % for Wa West and 54 % for Pru districts). This observation shows how active the population is due to its youthful nature. There are more people in the Wa West district household than they were in the Pru district household (9 per household in Wa West and 6 per Household in the Pru districts). On the agricultural front, it was observed that respondents in the Wa West district have fewer lands and practice more mixed cropping compared to the Pru district respondents who have more lands but practice less mixed cropping. Education is however lower in both districts especially with the older generations.
- Both responding communities have been observed to be highly vulnerable to the changing climate on all the seven major components of the vulnerability index except for food which recorded less. On a scale of 0 to 0.6, an index of

0.5 is very high. This study has observed that the vulnerability recorded in both districts were as a result of weak institutions. Though supports do come from the government or other aid organisations, the effects are not significantly felt due to the weak institutions.

- Technology gaps have been identified from land preparation to produce storage. This study found out that there is drudgery in the land preparations process of the responding farmers of both districts. This is due to the low number and high cost of tractor services. Access to inputs such as seeds and fertilizers are limited, making farmers keep their own seeds which are not high yielding, planted on marginal soils. Irrigation was close to zero with regards to access by farmers though the districts have potentials for irrigation. There is also low access to credit and financial network making it difficult for farmers to adopt new technologies that have high initial investment. By far the most important technology gap apart from irrigation and soil health management is extension service. Last but not the least is the postharvest storage of farm produce.
- The trend in the climatic systems are in support of the data and information by the IPCC. Both minimum and maximum temperatures for both Wa West and Pru districts are showing the upward trends. Rainfall patterns have changed to an erratic nature in both district. The amount of rainfall within this decade has reduced especially in the Wa West district. This study has thus found that there is variability in the climatic systems of the two district within this decade. There is also enough evidence to show that the variability started from the twentieth century. Hence enough evidence to show that the climatic systems of the country are changing.

5.3. Conclusions

By way of conclusion, this study has found out that the populations of the study areas are increasing amidst a changing climate similar to the IPCC observations. With high vulnerability to climatic impacts in a poorly performing agricultural system, the surest way to salvage these communities will be to build capacity especially in the area of agriculture which is the major employer of most of the population. This study observed that low application of technology due to poor access, high cost or lack of information are the major cause of the poor performance of the study areas' agricultural systems. Farmers are constantly trying to adapt to the changing climate by diversifying into different economic activities which are by themselves maladaptive to climate change. Hence the driving force to building the capacity that will alleviate the vulnerability is to build capacity in extension education, provide access to climate information, and create access to agricultural services such as irrigation and inputs like seeds, fertilizers and machinery. It is the conviction of the study that, with effective management of the technology system, agriculture will improve, leading to capacity building against climate change. Thus offsetting the vulnerability that has been observed.

5.4. Recommendations

The following recommendations are made based on the research findings.

1. Capacity should be built in all the seven components of the climate vulnerability index
2. Due to the erratic nature of the rainfall pattern, climate monitoring systems should be put in place to reduce the incidence of crop loss and climate casualty
3. New and access to current agricultural technologies should be created to improve the farming systems of the study areas by government, NGOs or any corporate body
4. A technology park should be operationalized and studied on its ability to close the technology gaps existing in the study areas

This study thus reduces the technological demand of the farmers of the two study communities into three aspects:

i. Education and access to information
ii. Services and input needs
iii. Credits and financial network

This classification agrees with report of the Ghana National Technology Need Assessment on Agriculture (Essegbey et al., 2012). From the report, extension service technology received the first rank among all other needs. This was followed by irrigation service to minimise the effect of the erratic rainfall pattern and to support all-year round production. Climate monitoring and early warning systems, soil health management and crop genetic resource management were the next to follow. Credit and financial network was not mentioned in the report. Instead, climate insurance was mentioned which was also given a very low priority. This study considers access to credit and financial support as an important factor for adoption of technologies by resource poor farmers, hence include it as a need in the effort to improve the agricultural climate of the study area. This assertion is agreed with by Yigezu et al., (2018) on their work on resource poor barley and wheat farmers. Since most support to the farmer do not come for free and in case of subsidies, poor administrative structures are feared to limit the access of the farmers to the introduce support.

Farmer education and access to information entails extension service field visits and training on new good agricultural practice and sustainable agriculture. It also include direct communication, mobile communication or communications through electronic and social media on the updates on climate variability and the yearly and monthly forecasts along with technical suggestion on the best practices of that time.

Soils on which the farming process takes place have been recorded to be marginal due to over cropping and the effect of climate and human activities. This thus demand amendment in the form of synthetic and natural fertilization, and amendment to maintain soil quality for a given crop. The service and input needs aspect of this study will detail the demand in this areas. Supply of planting material will be captured under this aspect along with the provision of mechanisation services and storage facilities are included under service needs. Probably the most important need of this aspect is the provision of irrigation facilities for farmers to minimise the shock of erratic rainfall and to enable all-year round production. This aspect also entails the provision of other agricultural inputs in the form of weedicides and pesticides both synthetic and biologically based.

As established above, access to credit is very important to adoption of new technology. Also important is access to market for commercial and export crops. The credit and financial network aspect entails creating a network where farmers can receive credit support to help sponsor their demand for new technology alongside a ready market to consume their excess production and crops produced just for the market. Also, strengthening and building farmer-based support groups will also fall under this aspect.

This study has therefore identified production and climate change adaptation gaps in the form of education and information needs, services and input needs, and credit and financial network need. The conclusions are also in agreement with the work of the

National Technology Needs Assessment report on Agriculture (Essegbey et al., 2012) and the work of (Yigezu et al., 2018).

Technology Proposals to Reduce yield Gaps in Agricultural systems of the study areas

Technologies outlined here will follow an organised form as is the routine in the farming process: land preparation, nursery and planting, weed and pest management, soil amendments, cultural practices, harvesting, postharvest management and marketing. Extension training will be treated as a separate component as it is seen as a conveyer of new knowledge and information. Finally, the credit and financial model will be spell out to establish the technological gap-filling standards so as to achieve the general objective of this study.

i. Proposed Soil Health and Land Preparation Technologies

Below is the list of some of the technologies proposed for land preparation and maintaining soil health relevant to the study areas and for that matter, the other districts within the same ecological zones of the study areas.

Table 8. Soil management and Land Preparation Technologies

Technology	Principles	Advantages	Reference
Conservation Tillage	• Minimum soil disturbance • Maximum soil cover • Crop associations and rotations	• Enhances soil structure and improves soil fertility • Improves water infiltration • Reduces weed and pest insurgence • Reduces soil erosion	(World Agroforestry Centre, 2013)
Fenlong Activated Resources	• Deep cultivation and tillage • Smooth and uniform seed bed • Loose soil	• Facilitates the usage of leached resources • Improves aeration and biological activities • Loosen marginal soils	(WEI, 2017)
Mechanical Strip-Tillage	• Minimum disturbance • Minimum machinery movement • Reduced water movement	• Low cost • Improve water retention • Reduced soil erosion and runoff	(Islam et al., 2014)
Grass waterway	• Maximum cover • Water conservation • Soil improvement	• Reduce soil erosion • Maintain soil structure • Soil water conservation	(UNFCCC, 2006)
Fertilizer Application	• Nutrient refurbishment • Water use efficiency • Soil improvement	• Improves soil fertility • Improves soil water holding capacity • Improves crop health	(Dinesh & Vermeulen, 2016)
Compost application	• Soil amendment • Sustainability • Resource utilization	• Improves soil fertility • Makes use of on-farm residue • Sustainable production	(Seyedbagheri, 2010)
Use of Power Tillers	• Small-Scale mechanisation • Minimum Tillage • Efficiency	• Low cost of adoption • Easily adoptable • Less impact on the soil health	(Cherian et al., 2016)

The above mentioned technologies are not in any way exhaustive of the numerous technologies used in the world today to manage soil health or prepare the soil for cultivation. Due to the marginal nature of the soils in the study areas, it is imperative to start the technological improvements on the soil. This study has therefore looked for technologies that address the soil structure and water management, soil nutrition and plant bed management to support the healthy growth of crops grown on the prepared soil and to increase the sustainability of the farming systems.

i. Proposed Planting Materials

Studies by (Iddrisu & Peker, 2018) identified that there is no shortage of good cultivars in the Sub-Saharan African region and for that matter Ghana. This claim is true for such crops as maize, cowpea, cassava, yam, millet and cocoa for which the Crop Research Institute of Ghana has a lot of improved cultivars for increasing productivity in the farming system. Below are some of the varieties released by the Crop Research Institute of Ghana and other cultivar development institutions that will be important to the improvement in the agricultural process of the study areas and the country at large.

Table 9. Planting Material Technologies

Technology	Principle	Advantages	Reference
Locally Improved Varieties (maize, cowpea, cassava, groundnut, rice, sorghum, soya, yam, sweet potatoes and pepper)	• Malnutrition • Climate change adaptation • Increasing productivity • Technology management	• Early maturing • High yielding • Drought tolerance • Highly nutritious • Adapt to local climate and soils	(CSIR-Ghana, 2016)
Climate Resilient Crops	• Climate change adaptation and resilience • Different biotic environment adaptation	• Drought tolerant • Heat stress tolerant • Flood tolerant • Salinity stress tolerant	(Maheswari et al., 2015)
Food Security Cultivars	• Climate sensitivity • Hunger elevation • Agricultural development	• Climate stress tolerant • Soil stress tolerant • Gene maintenance	(Dhankher & Foyer, 2018)

ii. Proposed Nursery Practise, Planting Technique and Weed Control technologies

From the information gathered in this study during the questionnaire administration, it has been observed that most farmers keep their seeds and propagules for future cultivation. This method if not well managed has an effect on the subsequent plant that will be generated from such planting materials (Atilaw & Korbu, 2011). Notwithstanding, a good seed will also require a good management practice during the seedling stage in order to develop into a healthy plant. Nursery technologies, following this, have been advanced from all aspects including planting medium and micro-climate management (SALAŠ, 2002). Though most of the crops cultivated by the study areas will require no nursing, this study is proposing an improvement in the nursery practices for the vegetable and tree crops to meet world standard using local materials such as in the works of (Roshetko et al., 2010; SALAŠ, 2002). The current system of nursery is so poor thereby wasting a lot of seed.

This study observed through the field trip that farmers of cereal crops plant their crops in rolls. This they achieve using hoe, cutlasses and dibbers. The process is effective but cumbersome. An introduction of a tractor mounted planter will reduce the drudgery and also increase the effectiveness and efficiency of the planting process.

Manual weed control method is second to the use of synthetic herbicides in the study areas. The use of synthetic chemicals in weed and best control has been found to pose environmental hazards as well as health hazards to the users (Sande et al, 2011). There is also drudgery in the manual method of weed control as well. This research is thus, proposing mechanised, biological and most importantly cultural systems of weed control as proposed by (Chappell et al., 2012; PAN Europe, 2017).

iii. Harvesting and Postharvest Management Technologies

There is poor use of tractor power in the study areas hence farmers have to mostly harvest their crops, especially cereals, manually. Threshing of harvested crops is also achieved through a manual means by resource poor farmers. Finally, storage is poorly done considering the method of produce storage in the study areas. This study thus proposes that, mini-harvesters should be used, threshing can be done with tractor mounted implements and storage of especially cereals and root tubers should be done using improved silos and the PICS triple bags. Maintenance of the storage structure should be part of the farming routine. Achieving these, this study, concludes that, reduction of postharvest losses will be realised.

iv. Proposed Irrigation and Water Management Technologies

There are lots of irrigation facilities that will be suitable and adoptable to the resource-poor farmer. Following the erratic and low levels of rainfall in the country, adopting simple mini-irrigation project will go a long way to support the agricultural system of communities within the country. The main challenge however will be the high cost of initial installation. This could be directed to the government, NGOs or corporate bodies who are interested in investing into the major crops or potentials of these communities. Below are some of the proposed irrigation facilities which can be implement in the study areas and the country at large:

Table 10. Irrigation Technologies

Technology	Principle	Advantages	Reference
Micro-irrigation	• Affordability • Climate smart • Agricultural improvement	• Low initial costs • Higher yield relative to conventional irrigation • All year round production	(Varma et al., 2006)
Underground water irrigation	• Available potentials • Climate smart • Agricultural improvement	• All-year round availability • Improvement in land productivity • Ease of access • Lower cost	(Nazoumou et al., 2016)
Personal irrigation facility	• Small-scale • Climate smart • Local potential	• Low initial and maintenance costs • Available potential and resources • All-year round production	(Smith et al., 2014)
Integrated water management	•	•	

v. Proposed Extension Service Education and Information Distribution

The education and information aspect of the technology proposals is probably the most important aspect as it links all other aspects together. Its effective operationalization is as good as the effective establishment of all the other technology proposals. This aspect will bring information to the farmer and from the farmer to the research and technology management centre. Being the link between the two entities, it stands to be the most important as any communication bridges will lead to ineffectiveness of the entire technology project. The system will however be designed in such a way that will allow a substantial amount of time before any negative effect will felt.

Farmers on their own do have a certain superior understanding of their farming process. This ranges from cultivar selection, weather prediction, alteration in management practices and produce storage and marketing. The problem which has arisen in recent times is the effect of the changing climate; resulting in a thwarted understanding and decision making ability. More to the point, lack of effective transfer of indigenous knowledge to the younger generation and the ineffective management of the knowledge possessed by farmers have contributed greatly to the current observed problems in the farming sector.

The education and information program as proposed by this study will be in two aspects;

a. The human phase
b. The electronic and IT phase

The human phase will be made up of humans of same ethnicity as the end user of all the proposed technologies. They should necessarily speak the dominant language of the community fluently and have been trained in agriculture and agricultural extension. These extension agents will organised and train the farmers on new technologies and also record the challenges of farmers in their farming process. With effective understanding and belief in the technologies being introduced, an agent belonging to a community is highly likely going to convince his fellow countrymen to adopt the technology. The spirit with which the agent will work is not that of spreading information but that of helping their community to alleviate their suffering and drudgery. It is thus expected that, the agents will be occasionally trained at a centre in a trainers' training program which will be followed by them training the farmers. The agents will also keep a demonstration field where local farmers can visit to have a first-hand experience on the new technology. This is so because some farmers according to this study deemed it the best to have individual training. Another problem observed by this study during the field was that, the low extension visitation and training are as result of poor logistics and low number of agents.

Thus, having agents who are indigenes will reduce the incidence of low logistics as they do not have to always travel to disseminate the information.

With regards to the electronic and IT phase, it is the understanding of this study that the respondents have little to no access to information on weather forecasts as they are mostly done only on television station. This has resulted in farmers depending on their own knowledge of the weather to determine the crop to produce and when to start land preparations. Iddrisu & Peker, (2018) have identified that there is a proliferation of the usage of mobile phones in the Sub-Saharan African region. Reading text messages might be very difficult for an ordinary local farmer. But if that message were to be received by the community extension agent, that message will be useful to the entire community. To achieve this, there is bound to be the existence of a climate early warning system in place either for the district or the nation at large (Niang et al., 2014). Software can be designed to aid farmers using android phones to manage their farming process. A software can take information from the farmers' field and the climate monitoring device so as to predict the cultural practices that are necessary for any give period. Since a lot of farmers in the deprived communities listen to the local radio stations in their own language, distributing information on the weather development will aid in making the best farming decisions. These broadcast should be as reliable as possible to keep trust of the farmers.

vi. Proposed Credit and Financial Network Technologies

There has been the operationalization and success of a credit policy elsewhere in Ghana. This system is the case where an investor supplies farmers with all needed farm inputs, determine the type and quality of crop to be produced, and receive payments in the form of farmer's yield. This system if well monitored with any intent to stress the farmer, will help adopters immensely. Farmers who will enrol into this system will have access to inputs as well as extension education from the corporate body or any institution that is responsible for the running of the system. Another important advantage is the access to ready market for cash crops and excess production. By this, farmers will have the opportunity to expand their farming fields to increase their production capacity.

REFERENCE

Abbo, S., Gopher, A., Rubin, B., & Lev-yadun, S. (2005). On the Origin of Near Eastern Founder Crops and the ‘ Dump-heap Hypothesis .’ *Genetic Resources and Crop Evolution*, *52*(2005), 491–495. https://doi.org/10.1007/s10722-004-7069-x

Abdul-Razak, M., & Kruse, S. (2017). The adaptive capacity of smallholder farmers to climate change in the Northern Region of Ghana. *Climate Risk Management*, *17*, 104–122. https://doi.org/10.1016/j.crm.2017.06.001

Adekunle, A., Osazuwa, P., & Raghavan, V. (2016). Socio-economic determinants of agricultural mechanisation in Africa: A research note based on cassava cultivation mechanisation. *Technological Forecasting & Social Change*, *112*, 313–319. https://doi.org/10.1016/j.techfore.2016.09.003

Adjasi, C. K. D., & Osei, K. A. (2007). Poverty profile and correlates of poverty in Ghana. *International Journal of Social Economics*, *34*(7), 449–471. https://doi.org/10.1108/03068290710760236

Adu, D. T., Kuwornu, J. K. M., Anim-Somuah, H., & Sasaki, N. (2018). Application of livelihood vulnerability index in assessing smallholder maize farming households’ vulnerability to climate change in Brong-Ahafo region of Ghana. *Kasetsart Journal of Social Sciences*, *39*(1), 22–32. https://doi.org/10.1016/j.kjss.2017.06.009

Aguilera, E., Guzman, G. I., Molina, M. G. de, Soto, D., & Infante-Amate, J. (2019). From animals to machines . The impact of mechanization on the carbon footprint of traction in Spanish agriculture : 1900 - 2014. *Journal of Cleaner Production*, *221*, 295–305. https://doi.org/10.1016/j.jclepro.2019.02.247

Al-Yarwawi, A. A. (1989). *Jawahir Ar-rasa’il*. Dar Alfikr Publishing.

Anthony, D., You, D., Hug, L., Beise, J., Choi, Y., Lee, S., & Mshvidobadze, A. (2017). *Generation 2030 Africa 2.0: Prioritizing Investments in Children to Reap the Demographic Dividend*. Retrieved from https://www.unicef.org/publications/files/Generation_2030_Africa_2.0.pdf

Antwi-Agyei, P., Dougill, A. J., Stringer, L. C., & Codjoe, S. N. A. (2018). Adaptation opportunities and maladaptive outcomes in climate vulnerability hotspots of northern Ghana. *Climate Risk Management*, *19*(November 2017), 83–93.

https://doi.org/10.1016/j.crm.2017.11.003

Antwi-agyei, P., Fraser, E. D. G., Dougill, A. J., Stringer, L. C., & Simelton, E. (2012). Mapping the vulnerability of crop production to drought in Ghana using rainfall , yield and socioeconomic data. *Applied Geography*, *32*, 324–334. https://doi.org/10.1016/j.apgeog.2011.06.010

Apuri, I., Peprah, K., & Achana, G. T. W. (2018). Climate change adaptation through agroforestry: The case of Kassena Nankana West District, Ghana. *Environmental Development*, *28*(August), 32–41. https://doi.org/10.1016/j.envdev.2018.09.002

Atilaw, A., & Korbu, L. (2011). Recent Development in Seed Systems of Ethiopia. In D. Alemu, S. Kiyoshi, & A. Kirub (Eds.), *Improving Farmers' Access to Seed* (pp. 13–30). Addis Ababa, Ethiopia.

Ayamga, M. B. (2018). *Access to Hybrid Seeds in Ghana : A case of Smallholder Farmers in Tamale*. International Institute of Social Studies.

Barber, L., & Israel, R. (2017). *RESULTS FROM CLIMATE CHANGE PUBLIC OPINION SURVEYS IN COUNTRIES AROUND THE WORLD*. Retrieved from https://www.climatescorecard.org/wp-content/uploads/2018/02/ClimateScorecardReport15.pdf

Bellini, N., Teräs, J., & Ylinenpää, H. (2012). Science and Technology Parks in the Age of Open Innovation . The Finnish Case. *SYMPHONYA Emerging Issues in Management*, *1*, 25–44.

Bird, K. (2019). Addressing Spatial Poverty Traps. *Paper Prepared for the Expert Group Meeting: "Eradicating Rural Poverty to Implement the 2030 Agenda for Sustainable Development" 27 February to 1 March 2019, Hosted by the Division for Inclusive Social Development, United Nations Department of Economic A*, (February), 1–17. Chronic Poverty Advisory Network.

Bizimana, J., & Richardson, J. W. (2019). Agricultural technology assessment for smallholder farms : An analysis using a farm simulation model (FARMSIM). *Computers and Electronics in Agriculture*, *156*(October 2018), 406–425. https://doi.org/10.1016/j.compag.2018.11.038

Boko, M., Niang, I., Nyong, A., Vogel, C., Githeko, A., Medany, M., … Yanda, P. (2008).

Africa ,Climate change 2007: Impacts, adaptation and vulnerability. In P. J. van der L. and C. E. H. M.L. Parry, O.F. Canziani, J.P. Palutikof (Ed.), *Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* (pp. 433–467). https://doi.org/10.2134/jeq2008.0015br

Brummer, C. E., Barber, W. T., Collier, S. M., Cox, T. S., Johnson, R., Murray, S. C., … Thro, A. M. (2011). Plant breeding for harmony between agriculture and the environment. *Frontiers in Ecology and the Environment*, *9*(10), 561–568. https://doi.org/10.1890/100225

Çalışkan, H. K. (2015). Technological Change and Economic Growth. *Social and Behavioral Sciences*, *195*, 649–654. https://doi.org/10.1016/j.sbspro.2015.06.174

Capstick, S., Whitmarsh, L., Poortinga, W., Pidgeon, N., & Upham, P. (2015). International trends in public perceptions of climate change over the past quarter century. *WIREs ClimateChange*, *6*(2), 35–61. https://doi.org/10.1002/wcc.321

Cetindamar, D., Phaal, R., & Probert, D. R. (2016). Technology management as a profession and the challenges ahead. *Journal of Engineering and Technology Management - JET-M*, *41*(June 2011), 1–13. https://doi.org/10.1016/j.jengtecman.2016.05.001

Cetindamara, D., Phaalb, R., & Probert, D. (2018). Understanding technology management as a dynamic capability : A framework for technology management activities. *Technovation*, *29*(April), 237–246. https://doi.org/10.1016/j.technovation.2008.10.004

Chappell, M., Knox, G., & Stamps, R. H. (2012). *Alternatives to Synthetic Herbicides for Weed Management in Container Nurseries* (pp. 1–7). pp. 1–7. Retrieved from https://secure.caes.uga.edu/extension/publications/files/pdf/B 1410_1.PDF

Cherian, A., Punnan, J. S., & Varghese, A. (2016). A Review on Power Tiller Attachments. *KETCON-2016 Technology for Sustainability*, (May). https://doi.org/10.13140/RG.2.1.4843.3528

Coleguwor, D. M. (2018). *ASSESSING THE CURRENT STATUS OF GREENHOUSE INDUSTRY IN SELECTED REGIONS IN GHANA*. University of Ghan.

CSIR-Ghana. (2016). *CSIR CROP VARIETIES RELEASED AND REGISTERED IN*

GHANA. Retrieved from https://www.csir.org.gh/images/Doc/NewsLetter/CROP VARIETIES RELEASED AND REGISTERED IN GHANA.pdf

Daniel, K., Udeagha, A. U., & Jacob, D. E. (2016). Socio-Cultural Importance of Sacred Forests Conservation in South Southern Nigeria. *African Journal of Sustainable Development*, *6*(2), 251–268.

Dhankher, O. P., & Foyer, C. H. (2018). Climate resilient crops for improving global food security and safety. *Plant, Cell & Environment*, *41*(March), 877–884. https://doi.org/10.1111/pce.13207

Dharmaraj, V., & Vijayanand, C. (2018). Artificial Intelligence (AI) in Agriculture. *International Journal of Current Microbiology and Applied Sciences*, *7*(December), 2122–2128. https://doi.org/10.20546/ijcmas.2018.712.241

Diallo, Y. (2018). *Identifying Leading Seed Companies in Western and Central Africa*.

Diao, X., Agandin, J., Fang, P., Justice, S. E., Kufoalor, D., & Takeshima, H. (2018). *Agricultural Mechanization in Ghana: Insights from a Recent Field Study* (No. 01729).

Diao, X., Silver, J., & Takeshima, H. (2016). *Agricultural Mechanization and Agricultural Transformation*. Retrieved from https://www.jica.go.jp/jica-ri/publication/booksandreports/l75nbg0000004aet-att/l75nbg0000004aik.pdf

Dinesh, D., & Vermeulen, S. (2016). *Climate change adaptation in agriculture: practices and technologies - Opportunities for climate action in agricultural systems* (pp. 1–7). pp. 1–7. https://doi.org/10.13140/RG.2.1.4269.0321

Dogson, M. (2000). *The Management of Technological Innovation*. Oxford University Press, Oxford.

El Khoury, W., & Delve, R. (2018). *Lessons learned: Supporting Smallholder Seed Systems*. Retrieved from https://www.ifad.org/documents/38714170/41211727/Seeds_LL.pdf/dd9f46b3-4f26-48a3-9f94-3f09cd126cb9

Elings, A., Saavedra, Y., & Nkansah, G. O. (2015). *GhanaVeg Sector Reports Strategies to support the greenhouse horticulture sector in Ghana*. Retrieved from https://library.wur.nl/WebQuery/wurpubs/fulltext/342456

Environmental Protection Agency. (2002). *National Action Programme To Combat Drought and Desertification*.

Essegbey, G. O., Amisigo, B., Nutsukpo, D., Oppong-Boadi, K. Y., & Benefo, D. (2012). *Technology Needs Assessment Report*. Retrieved from http://goo.gl/RyfSAH

Fonteh, M. F. (2010). *Agricultural mechanization in Mali and Ghana: strategies, experiences and lessons for sustained impacts* (No. 8). Retrieved from http://www.fao.org/fileadmin/user_upload/ags/publications/K7325e.pdf

Friesen, J. (2002). *Spatio-temporal Rainfall Patterns in Northern Ghana*. Rheinischen Friedrich-Wilhelms-Universität Bonn Spatio-temporal.

Fuseini, O. (2014). *Land Restoration Training Programme Keldnaholt, 112 Reykjavik, Iceland Final project 2014*. United Nations University.

Gatto, P., Mozzato, D., & Defrancesco, E. (2019). Analysing the role of factors affecting farmers' decisions to continue with agri-environmental schemes from a temporal perspective. *Environmental Science and Policy*, *92*(September 2018), 237–244. https://doi.org/10.1016/j.envsci.2018.12.001

Ghana Statistical Service (GSS). (2012). *2010 POPULATION & HOUSING CENSUS: Summary Report of Final Reports*. Accra.

Ghana Statistical Service (GSS). (2018). *Ghana Living Standards Survey Round 7 (GLSS 7): Poverty Trends in Ghana 2005 - 2017* (pp. 1–122). pp. 1–122. Retrieved from https://www.mendeley.com/viewer/?fileId=119e91a4-c2d9-c5a1-7b36-927ea11b6df6&documentId=87f63a8d-72e2-31e5-a8bf-5621276a664f

Goodier, R. (2013). Engineering for Change.

Gudanowska, A. E. (2017). Modern Research Trends within Technology Management in the Light of Selected Publications. *Procedia Engineering*, *182*, 247–254. https://doi.org/10.1016/j.proeng.2017.03.185

Hahn, M. B., Riederer, A. M., & Foster, S. O. (2009). The Livelihood Vulnerability Index : A pragmatic approach to assessing risks from climate variability and change — A case study in Mozambique. *Global Environmental Change*, *19*, 74–88. https://doi.org/10.1016/j.gloenvcha.2008.11.002

Hoegh-Guldberg, O., Jacob, D., Taylor, M., Bindi, M., Brown, S., Camilloni, I., … Zhou,

G. (2018). 1.5º C global warming on natural and human systems. In V. [Masson-Delmotte, P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P. R. Shukla, … T. Waterfield (Eds.), *Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change,* (pp. 175–311). https://doi.org/10.1002/ejoc.201200111

Horrocks, I., & Walker, S. (2019). *Technology, Innovation and Management*. Retrieved from https://learn2.open.ac.uk/mod/oucontent/view.php?id=305248

Houmy, K., Clarke, L. J., Ashburner, J. E., & Kienzle, J. (2013). *Agricultural Mechanization in Sub Saharan Africa : Guidelines for preparing a strategy* (Vol. 22). Rome, Italy: PLANT PRODUCTION AND PROTECTION DIVISION FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS.

Houssou, N., Diao, X., Cossar, F., Kolavalli, S., Jimah, K., & Aboagye, P. (2013). *Agricultural Mechanization in Ghana: Is Specialization in Agricultural Mechanization a Viable Business Model?* (No. 30). Retrieved from http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.278.5995&rep=rep1&type=pdf

IASP. (2019). Definitions. Retrieved from International Association of Science Parks and Areas of Innovation website: https://www.iasp.ws/our-industry/definitions

Ibrahim, Y. Z., Balzter, H., Kaduk, J., & Tucker, C. J. (2015). Land degradation assessment using residual trend analysis of GIMMS NDVI3g, soil moisture and rainfall in Sub-Saharan West Africa from 1982 to 2012. *Remote Sensing*, *7*(5), 5471–5494. https://doi.org/10.3390/rs70505471

Iddrisu, A. M., & Peker, K. (2018). ASSESSMENT OF TECHNOLOGY FOR CLIMATE CHANGE ADAPTATION IN SUB-SAHARAN AFRICA. *Journal of Global Innovation in Agricuture and Social Science*, *6*(4), 101–114.

IPCC. (2007). Climate Change 2007: impacts, adaptation and vulnerability. In M. L. Parry, O. F. Canziani, J. P. Palutikof, P. J. van der Linden, & C. E. Hanson (Eds.), *contribution of Working Group II to the fourth assessment report of the Intergovernmental Panel on Climate Change*. https://doi.org/10.1256/004316502320517344

IPCC. (2014). *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* (V. R. Barros, C. B. Field, D. J. Dokken, M. D. Mastrandrea, K. J. Mach, T. E. Bilir, … L. L. White, Eds.). United Kingdom and New York, NY, USA: Cambridge University Press, Cambridge.

IPCC. (2018). Summary for Policymakers. In [V. Masson-Delmotte, P. Zhai, H. O. Pörtner, J. S. D. Roberts, P. R. Shukla, A. Pirani, … T. Waterfield (Eds.), *Global warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change,* (p. 32). Geneva, Switzerland: World Meteorological Organization.

Islam, S., Gosh, A. K., Hossain, K., Rahmand, M., Khayer, A., Hassana, M. K., … Gathala, M. K. (2014). Performance of Maize Hybrid under Conventional and Strip-Tillage Systems in Three Districts of Bangladesh. *International CA Conference for Smallholders in Asia and Africa*, *7*(11), 7–8.

Jack, R. H. (1992). *Views on Agricultural Origins* (pp. 1–21). pp. 1–21.

Jha, K., Doshi, A., Patel, P., & Shah, M. (2019). A comprehensive review on automation in agriculture using arti fi cial intelligence. *Artificial Intelligence in Agriculture*, *2*, 1–12. https://doi.org/10.1016/j.aiia.2019.05.004

Jin, J., & Zedtwitz, M. von. (2008). Technological capability development in China's mobile phone industry. *Technovation*, *28*, 327–334.

Kabasa, J. D., & Sage, I. (2009). Climate Change and Food Security in Africa. In H. Besada & N. Sewankambo (Eds.), *Climate Change in Africa: Adaptation, Mitigation and Governance Challenges*. https://doi.org/10.3726/b13085

Kapur, R. (2018). Usage of Technology in the Agricultural Sector. *Acta Scientific Agriculture*, *2*(6), 78–84. Retrieved from https://actascientific.com/ASAG/pdf/ASAG-02-0103.pdf

Katengeza, S. P., Holden, S. T., & Fisher, M. (2019). Use of Integrated Soil Fertility Management Technologies in Malawi: Impact of Dry Spells Exposure. *Ecological Economics*, *156*(September 2018), 134–152. https://doi.org/10.1016/j.ecolecon.2018.09.018

Kebebe, E. (2018). Bridging technology adoption gaps in livestock sector in Ethiopia: A innovation system perspective. *Technology in Society*, (December), 1–8. https://doi.org/10.1016/j.techsoc.2018.12.002

Khanna, A., & Kaur, S. (2019). Evolution of Internet of Things (IoT) and its signi fi cant impact in the fi eld of Precision Agriculture. *Computers and Electronics in Agriculture*, *157*(December 2018), 218–231. https://doi.org/10.1016/j.compag.2018.12.039

Kirui, O. K., & Braun, J. Von. (2018). *Mechanization in African Agriculture A Continental Overview on Patterns and Dynamics* (No. 169). Retrieved from https://www.zef.de/uploads/tx_zefnews/ZEF_WP_169_web.pdf

Kittas, C., Katsoulas, N., Bartzanas, T., & Bakker, S. (2013). Greenhouse climate control and energy use. In *Good Agricultural Practices for greenhouse vegetable crops: Principles for Mediterranean climate areas* (217th ed., pp. 64–95). FAO.

Kurpaska, S., & Latala, H. (2010). Energy analysis of heat surplus storage systems in plastic tunnels. *Renewable Energy*, *35*(12), 2656–2665. https://doi.org/10.1016/j.renene.2010.04.011

Lovarelli, D., Bacenetti, J., & Fiala, M. (2017). Effect of local conditions and machinery characteristics on the environmental impacts of primary soil tillage. *Journal of Cleaner Production*, *140*, 479–491. https://doi.org/10.1016/j.jclepro.2016.02.011

Lovejoy, P. E. (2004). Collective Volume. *The UNESCO Slave Trade Project*, pp. 1–38.

Lowder, S. K., Skoet, J., & Raney, T. (2016). The Number, Size, and Distribution of Farms, Smallholder Farms, and Family Farms Worldwide. *World Development*, *87*, 16–29. https://doi.org/10.1016/j.worlddev.2015.10.041

Machado, H. V., Lazzarotti, F., & Bencke, F. F. (2018). Innovation models and technological parks : interaction between parks and innovation agents. *Journal of Technology Management & Innovation*, *13*(2), 104–114.

Maheswari, M., Sarkar, B., Vanaja, M., Rao, M. S., Rao, C. S., Venkateswarlu, B., & Sikka, A. (2015). *Climate Resilient Crop Varieties for Sustainable Food Production under Aberrant Weather Conditions* (p. 47). p. 47. Central Research Institute for Dryland Agriculture (ICAR), Hyderabad.

Malairaja, C., & Zawdie, G. (2008). Science parks and university – industry collaboration in Malaysia. *Technology Analysis & Strategic Management*, *20*(6), 727–739.

Manandhar, A., Milindi, P., & Shah, A. (2018). An Overview of the Post-Harvest Grain Storage Practices of Smallholder Farmers in Developing Countries. *Agriculture*, *8*, 13–20. https://doi.org/10.3390/agriculture8040057

Mango, N., Makate, C., Tamene, L., Mponela, P., & Ndengu, G. (2018). Adoption of small-scale irrigation farming as a climate-smart agriculture practice and its influence on household income in the Chinyanja Triangle, Southern Africa. *Land*, *7*(2), 1–19. https://doi.org/10.3390/land7020049

Mcguire, S., & Sperling, L. (2016). Seed systems smallholder farmers use. *Food Security*, *8*, 179–195. https://doi.org/10.1007/s12571-015-0528-8

Mighty Earth. (2019). Companies Support Higher Cocoa Prices for Farmers. Retrieved from Forestry website: http://www.mightyearth.org/companies-support-higher-cocoa-prices-for-farmers/

MINISTRY OF FOOD AND AGRICULTURE. (2017). AGRICULTURE IN GHANA: Facts and Figures (2016). *Statistics, Research and Information Directorate (SRID)*, p. 113. https://doi.org/10.1126/science.35.911.927-a

Mwangi, M., & Kariuki, S. (2015). Factors Determining Adoption of New Agricultural Technology by Smallholder Farmers in Developing Countries. *Journal of Economics and Sustainable Development ISSN*, *6*(5), 208–216. Retrieved from https://actascientific.com/ASAG/pdf/ASAG-02-0103.pdf

Nazoumou, Y., Favreau, G., Moustapha, M., & Maïnassara, I. (2016). La petite irrigation par les eaux souterraines, une solution durable contre la pauvreté et les crises alimentaires au Niger? *Cahiers Agricultures*, *25*(April), 10. https://doi.org/10.1051/cagri/2016005

Niang, I., Ruppel, O. C., Abdrabo, M. A., Essel, A., Lennard, C., Padgham, J., & Urquhart, P. (2014). Africa. In V. R. Barros, C. B. Field, D. J. Dokken, M. D. Mastrandrea, K. J. Mach, T. E. Bilir, … L. L. White (Eds.), *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* (pp. 1199–1265). Retrieved from https://www.ipcc.ch/site/assets/uploads/2018/02/WGIIAR5-Chap22_FINAL.pdf

O'Connor, D. (2009). *Agricultural Technology for Development: Old Issue , New Context*. Retrieved from https://sustainabledevelopment.un.org/content/documents/Agrtechdev-v6.pdf

OECD/FAO. (2016). Agriculture in Sub-Saharan Africa : Prospects and challenges for the next decade. In *OECD-FAO Agricultural Outlook 2016-2025* (Vol. 181, pp. 59–95). https://doi.org/http://dx.doi.org/10.1787/agr_outlook-2016-5-en

Ohadike, P. O. (1996). The African population growth and development conundrum. *Health Transition Review*, *6*, 325–344. Retrieved from http://htc.anu.edu.au/pdfs/Ohadike1.pdf

Owusu, A. B., Cervone, G., & Luzzadder-Beach, S. (2013). Analysis of desertification in the Upper East Region (UER) of Ghana using remote sensing, field study, and local knowledge. *Cartographica*, *48*(1), 22–37. https://doi.org/10.3138/carto.48.1.1065

PAN Europe. (2017). *Alternative Methods in Weed Management to the Use of Glyphosate and Other Herbicides*. Retrieved from https://www.pan-europe.info/sites/pan-europe.info/files/public/resources/reports/Alternative methods in weed managment to glyphosate_PAN Europe_III.pdf

Petersen, M. E. (2014). *SEED SOVEREIGNTY: How can organic agriculture contribute to the* (p. 15). p. 15.

Phaal, R., Farrukh, C. J. P., & Probert, D. R. (2004). A framework for supporting the management of technological knowledge. *International Journal of Technology Management*, *27*(1), 1–15.

Phillimore, J., & Joseph, R. (2003). Science Parks : A Triumph of Hype over Experience ? *The International Handbook on Innovation*, 2003.

Pru District Assembly. (2015). The Composite Budget of the Pru District Assembly for the 2015 Fiscal Year. *Economics of Education Review*, Vol. 20, pp. 263-278. https://doi.org/10.1901/jeab.2009.92-275

Roshetko, J. M., Tolentino, E. L., Carandang, W. M., Bertomeu, M., Tabbada, A., Manurung, G. E. S., & Yao, C. E. (2010). *TREE NURSERY SOURCEBOOK: Options in Support of Sustainable Development*. Retrieved from http://old.worldagroforestry.org/downloads/Publications/PDFS/MN16651.pdf

Rothstein, S. J. (2007). Returning to our roots: Making plant biology research relevant to future challenges in agriculture. *Plant Cell*, *19*(9), 2695–2699. https://doi.org/10.1105/tpc.107.053074

Rush, H., Bessant, J., & Hobday, M. (2007). Assessing the technological capabilities of firms : developing a policy tool. *R&D Management 37, 37*(3), 221–236. Retrieved from https://onlinelibrary.wiley.com/doi/epdf/10.1111/j.1467-9310.2007.00471.x

SALAŠ, P. (2002). New technologies and improvement of nursery stock quality. *Journal of Horticultural Science*, *29*(4), 153–160. Retrieved from https://www.agriculturejournals.cz/publicFiles/54986.pdf

Sande, D., Mullen, J., Wetzstein, M., & Houston, J. (2011). Environmental Impacts from Pesticide Use : A Case Study of Soil Fumigation in Florida Tomato Production. *International Journal of Environmental Research and Public Health*, *8*(12), 4649–4661. https://doi.org/10.3390/ijerph8124649

Serdeczny, O., Adams, S., Baarsch, F., Coumou, D., Robinson, A., Hare, W., … Reinhardt, J. (2016). Climate change impacts in Sub-Saharan Africa: from physical changes to their social repercussions. *Regional Environmental Change*, *15*(JANUARY). https://doi.org/10.1007/s10113-015-0910-2

Seyedbagheri, M.-M. (2010). Compost: Production, Quality, and Use in Commercial Agriculture. *University of Idaho: College of Agricultural and Life Sciences*, p. 7.

Shah, K. U., Bansha, H., Johnson, C., & Baptiste, A. (2013). Geoforum Understanding livelihood vulnerability to climate change : Applying the livelihood vulnerability index in Trinidad and Tobago. *Geoforum*, *47*, 125–137. https://doi.org/10.1016/j.geoforum.2013.04.004

Sims, B., Hilmi, M., & Kienzle, J. (2016). Agricultural Mechanization: A key input for sub-Saharan African smallholders. In *Integrated Crop Management* (Vol. 23). https://doi.org/10.1016/B978-0-444-52512-3.00236-9

Singh, C. D., & Singh, R. C. (2011). Computerized instrumentation system for monitoring the tractor performance in the field. *Journal of Terramechanics*, *48*(5), 333–338. https://doi.org/10.1016/j.jterra.2011.06.007

Smith, M., Muñoz, G., & Alvarez, J. S. (2014). *Irrigation Techniques for Small-scale Farmers*.

Srivastava, A. K., Mboh, C. M., Zhao, G., Gaiser, T., & Ewert, F. (2018). Climate change impact under alternate realizations of climate scenarios on maize yield and biomass in Ghana. *Agricultural Systems*, *159*(September 2016), 157–174. https://doi.org/10.1016/j.agsy.2017.03.011

Stupak, N., Sanders, J., & Heinrich, B. (2019). The Role of Farmers' Understanding of Nature in Shaping their Uptake of Nature Protection Measures. *Ecological Economics*, *157*(March 2018), 301–311. https://doi.org/10.1016/j.ecolecon.2018.11.022

Tachie-Obeng, E., Akponikp, P. B. I., & Adiku, S. (2013). Considering effective adaptation options to impacts of climate change for maize production in Ghana. *Environmental Development*, *5*, 131–145. https://doi.org/10.1016/j.envdev.2012.11.008

Tachie-Obeng, E., Akponikpè, P. B. I., & Adiku, S. (2013). Considering effective adaptation options to impacts of climate change for maize production in Ghana. *Environmental Development*, *5*(1), 131–145. https://doi.org/10.1016/j.envdev.2012.11.008

Tambo, J. A. (2016). Adaptation and resilience to climate change and variability in north-east Ghana. *International Journal of Disaster Risk Reduction*, *17*, 85–94. https://doi.org/10.1016/j.ijdrr.2016.04.005

Tohidyan Far, S., & Rezaei-Moghaddam, K. (2017). Determinants of Iranian agricultural consultants' intentions toward precision agriculture: Integrating innovativeness to the technology acceptance model. *Journal of the Saudi Society of Agricultural Sciences*, *16*(3), 280–286. https://doi.org/10.1016/j.jssas.2015.09.003

UNEP/UNDP. (2013). National Climate Change Adaptation Strategy. In *Global Environmental Change* (Vol. 5). https://doi.org/10.1007/978-3-319-31499-0

UNFCCC. (2006). Technologies For Adaptation To Climate Change. In *Climate and Development*. https://doi.org/10.1136/ip.2009.025056

United Nations. (2019a). *Establishing Science and Technology Parks : A Reference*

Guidebook for Policymakers in Asia and the Pacific. Retrieved from https://www.unescap.org/sites/default/files/Guidebook_Final_0.pdf

United Nations. (2019b). *The impact of rapid technological change on sustainable development: Report of the Secretary-General* (Vol. 03558).

United Nations. (2019c). World population prospects 2019: Highlights. In *United Nations. Department of Economic and Social Affairs. World Population Prospects 2019.* Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/12283219

Varma, S., Verma, S., & Namara, R. E. (2006). Promoting micro-irrigation technologies that reduce poverty. *Water Policy Briefing Series*, (23), 6.

Wa West District. (2016). *THE COMPOSITE BUDGET OF THE WA WEST DISTRICT ASSEMBLY 2016 FISCAL YEAR* (p. 68). p. 68.

WEI, B. (2017). Discussion on the Construction of Green Agriculture "3+1" Industry System Using Fenlong Activated Resources. *Agricultural Science & Technology*, *18*(2), 380–384.

White, M. A., & Bruton, G. D. (2011). *The Management of Technology and Innovation: A Strategic Approach* (2nd ed.). https://doi.org/10.1017/CBO9781107415324.004

Williams, P. A., Crespo, O., & Abu, M. (2019). Adapting to changing climate through improving adaptive capacity at the local level – The case of smallholder horticultural producers in Ghana. *Climate Risk Management*, *23*(September), 124–135. https://doi.org/10.1016/j.crm.2018.12.004

Williamsa, P. A., Crespoa, O., & Abu, M. (2018). Adapting to changing climate through improving adaptive capacity at the local level – The case of smallholder horticultural producers in Ghana. *Climate Risk Management*, (December), 1–12. https://doi.org/10.1016/j.crm.2018.12.004

Woodbridge, M. (2015). *From MDGs to SDGs: What are the Sustainable Development Goals?* (pp. 1–4). pp. 1–4. ICLEI World Secretariat.

Woodhouse, P., Veldwisch, G. J., Venot, J. P., Brockington, D., Komakech, H., & Manjichi, Â. (2017). African farmer-led irrigation development: re-framing agricultural policy and investment? *Journal of Peasant Studies*, *44*(1), 213–233. https://doi.org/10.1080/03066150.2016.1219719

World Agroforestry Centre. (2013). *Evergreen Agriculture : Conservation Agriculture in maize production in Malawi* (pp. 1–8). pp. 1–8. Retrieved from http://www.fao.org/3/CA2557EN/ca2557en.pdf

World Bank. (2018). Fertilizer Consumption. Retrieved from World Development Indicators - Google Public Data Explorer website: https://www.google.com/publicdata/explore?ds=d5bncppjof8f9_&ctype=l&met_y=agricultural_production_index#!ctype=l&strail=false&bcs=d&nselm=h&met_y=ag_con_fert_zs&scale_y=lin&ind_y=false&rdim=region&idim=region:ECS:NAC:SSF:SAS:MEA:LCN:EAS&ifdim=region&tdim=

World Population Review. (2019). Sub Saharan Africa Population 2019. Retrieved September 21, 2019, from Sub Saharan Africa website: http://worldpopulationreview.com/continents/sub-saharan-africa-population/

Yaro, J. A., Teye, J., & Bawakyillenuo, S. (2014). Local institutions and adaptive capacity to climate change/variability in the northern savannah of Ghana. *Climate Development*, 1–11.

Yigezu, Y. A., Mugera, A., El-Shater, T., Aw-Hassan, A., Piggin, C., Haddad, A., … Loss, S. (2018). Enhancing adoption of agricultural technologies requiring high initial investment among smallholders. *Technological Forecasting and Social Change*, *134*(June), 199–206. https://doi.org/10.1016/j.techfore.2018.06.006

Zaidi, M. F. A., & Othman, S. N. (2011). Exploring the Concept of Technology Management through Dynamic Capability Perspective. *International Journal of Business and Social Science*, *2*(5), 41–54.

Zhang, J. (2018). *Top 20 Global Seed Companies in 2017* (pp. 13–15). pp. 13–15.

APPENDIX

App 1. The Originality Report

SOSYAL BİLİMLER ENSTİTÜSÜ

YÜKSEK LİSANS TEZ ÇALIŞMASI ORİJİNALLİK RAPORU

ÖĞRENCİ BİLGİLERİ	
Adı-Soyadı	Abdul-Mumeen IDDRISU
Öğrenci Numarası	172216102
Enstitü Anabilim Dalı	Business . Administration
Programı	İşletme
Danışmanının Unvanı, Adı-Soyadı	Prof. Dr. Kenan PEKER
Tez Başlığı (Türkçe)	Teknoloji Yönetimi

SOSYAL BİLİMLER ENSTİTÜSÜ MÜDÜRLÜĞÜ'NE

Yukarıda başlığı belirtilen tez çalışmamın a) Kapak sayfası, b) Giriş, c) Ana bölümler ve d) Sonuç kısımlarından oluşan toplam ...76.. sayfalık kısmına ilişkin, /19/12/2019 tarihinde şahsım/tez danışmanım tarafından Turnitin adlı intihal tespit programından aşağıda belirtilen filtrelemeler uygulanarak alınmış olan orijinallik raporuna göre, tezimin benzerlik oranı %5,9.....'tür.

Uygulanan filtrelemeler:

1- Kabul/Onay ve Bildirim sayfaları hariç,
2- Kaynakça hariç
3- Alıntılar hariç/dâhil
4- 5 kelimeden daha az örtüşme içeren metin kısımları hariç

Yukarıda bilgileri verilen öğrencinin doktora tezi Sosyal Bilimler Enstitüsü Yönetim Kurulu tarafından belirlenen azami benzerlik oranlarını aşmadığını ve tez çalışmamın herhangi bir intihal içermediğini; aksinin tespit edileceği muhtemel durumda doğabilecek her türlü hukuki sorumluluğu kabul ettiğimi ve yukarıda vermiş olduğum bilgilerin doğru olduğunu beyan ederim.

Gereğini saygılarımla arz ederim.

Prof. Dr. Kenan PEKER
Danışmanın Adı-Soyadı
(İmzası)

Prof. Dr. Zahir KIZMAZ
Anabilim Dalı Başkanı
(İmzası)

Lisansüstü tezler, savunma öncesinde İntihal program raporu ile birlikte enstitüye teslim edilir.

İntihal raporu ile ilgili olarak etik kurallar dâhilindeki benzerlik oranları ilgili Enstitü Yönetim Kurulu tarafından belirlenir. (Enstitü Yönetim Kurulu tarafından tezin, intihal kapsamı dışında değerlendirilmesi için TURNİTİN'den alınan raporda "benzerlik oranı"nın, "alıntılar hariç" en fazla %10, "alıntılar dâhil" % 30'u geçmemesi şeklinde kabul edilmiştir).

App 2. Questionnaire

QUESTIONNAIRE for the Establishment of a Technology Park as Part of an Ongoing Postgraduate Studies

Department of Business Administration, Firat University, Turkey

1. Region: ___________________________
2. Gender of respondent: Male_____/Female_____
3. Age range: 20-30______ 31-40______ 41-50______ 51-60______ above 60_______
4. Size of farm: _________ acres
5. Crop (s) cultivated: _________, _________, __________, ________, _________
6. Source (s) of planting materials: ____
7. Method of land preparation: ____ ____
8. Method of weed control: ____
9. Machine (s) used in cultivation process: _____________________________________
10. Common agricultural practices undertaken by farmer: ____ ____
11. Amount of fertilizer used in total for the past three years: ____
12. Minimum yield on a piece of land for each crop: _____________________________ ____

13. Maximum yield on a piece of land for each crop: ______________________________
____

14. Usage of irrigation facility: ____

15. How often farmer gets extension service training: ______________________________

16. How farmer store farm produce: ____
____?

17. Observation on whether the climate is changing: Yes______ No_____

18. If yes, factors that shows the climate is changing:
____
____
____
____

19. Aspects of the farming process farmer wants improved:
____
____
____
____

20. Technology introduction method farmer feels it right:
____
____
____
____

	Parameter	Options/answer
1	Number of people in the household	
2	Number of people above 65 years:	number of which are
3	Number of children less than 15 years: number of which are girls:	
4	Highest educational level of household head: tertiary/high school/basic school/non	
5	Is anyone in the household in need of regular care due to age, physical or mental state? yes no	
6	Number of members of the household who go to another community for work	
7	What is the main source of income of the household?	
8	Other agricultural activities that bring income: (animal rearing, fishing, Shea nut collection, etc.)	
9	Non-agricultural sources of income:	
10	Number of support received by household within the past month:	
11	Number of support household gave to other households:	
12	Ratio of loan taken to loans given ______/_______	
13	How long does it take to get to a health centre?	
14	Is there anyone in the family who regularly get sick?	
15	Has someone missed work or school in the past two months due to illness?	
16	What does the household do to prevent malaria and diarrhoea?	
17	Is most of the household's food from the family farm?	
18	Number of crops grown by household:	
19	Does household sell some of their farm produce?	
20	Where does household collect water?	
21	How many months does the source of water lasts?	
22	Does household store water?	
23	Number of floods/droughts in the past three years	
24	Was household seriously affected in any of them?	

CIRRUCULUM VITAE

Abdul Mumeen Iddrisu was born in the city of Bawku in Ghana. He attended primary school at the Azharia Islamic School and Middle school at the St Anthony's Junior Secondary School. He had his High School education in Navrongo at the Navrongo Secondary school where he studied Agriculture. He got admission to the Kwame Nkrumah University of Science and Technology to study Agriculture in 2009 and he graduated in 2013. In 2017, he graduated with a diploma in Pedagogical Formation in the Firat University.