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MECHANISMS AND PATHWAYS FOR CLIMATE-SENSITIVE TRANSFORMATIONAL CHANGE OF SMALLHOLDER AGRICULTURE IN GHANA

BY

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DECLARATION

I hereby declare that except for references to other people's work, which have been duly acknowledged, this thesis is the result of my own research. It has neither been presented, in part or in whole, to another academic institution for a degree.

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ABSTRACT

Efforts to transform smallholder agriculture and improve productivity have yielded some positive results. Yet, smallholder productivity in Africa remains low relative to America, Asia, and elsewhere, threatening food security and livelihoods. A major reason is the slow pace of transformation in the agricultural production, research and development processes, and the effects of climate change impacts. This thesis examined smallholder transformational change processes using the Transtheoretical (Stages of Behaviour Change) theory in a mixed-methods survey conducted in the Keta Anglo area, in the Coastal Savannah agro-ecological zone of Ghana with over 400 smallholder vegetable farmers.

The study found that over 91% of smallholders were aware of the climate change phenomenon. However, awareness did not automatically translate into a high level of climate-sensitive practices. Status as head of household, membership in a Farmer Based Organisation and access to Extension services had significant relationships with smallholder perceptions of climate change impacts. Access to Extension services and land ownership were significant factors that affected smallholder stage of transformation. Smallholder perception variables measured as awareness, recall and beliefs were all significant predictors of smallholder stage of transformational change.

The thesis concluded that the “one-size-fits-all” approach that is characteristic of most current Extension methods undermines efforts to transform smallholder agriculture in order to increase productivity. It is therefore recommended that Extension methods should aim at addressing farmer needs by disaggregating their perceptions and stage of transformational change specifically. Land tenure and ownership issues should also be addressed to enhance available mechanisms for transformation.

DEDICATION

I dedicate this thesis my father Mr. Cornelius Kodjo Yakah, to the late Prof. Owuraku Sakyi-Dawson, to the hardworking farmers of Ghana, to all those dedicated to mentoring the youth to seek opportunities in the agricultural sector, and to all those rehabilitating degraded lands or alleviating the effects of global environmental change. The good book says "*And we know that all things work together for good to those who love God, to those who are the called according to His purpose*" (Romans 8:28, NKJV). All shall pass but the word of God shall never pass. It is a strong tower and those who run to it will be saved. To God be the glory.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

AEA: Agricultural Extension Agent

AIS: Agricultural Innovation System

CAADP: Comprehensive Africa Agriculture Development Programme

COP: Conference of the Parties

CDM: Clean Development Mechanism

CSIR: Council for Scientific and Industrial Research

ENSO: El Nino Southern Oscillation

EPA: Environmental Protection Agency

EU: European Union

FAO: Food and Agriculture Organization

FBO: Farmer Based Organization

FASDEP: Food and Agriculture Development Policy

GES: Ghana Education Service

GDP: Gross Domestic Product

GHG: Green House Gases

HYV: High Yielding Variety

ICT: Information Communication Technology

IP: Innovation Platform

IPCC: Intergovernmental Panel on Climate Change

ITCZ: Inter Tropical Convergence Zone

METASIP: Medium-Term Agriculture Sector Investment Plan

MOFA: Ministry of Food and Agriculture

NADMO: National Disaster Management Organization

NAMA: Nationally Appropriate Mitigation Action

NCCAS: National Climate Change Adaptation Strategy

NCCC: National Climate Change Committee

NCCP:	National Climate Change Policy
NDPC:	National Development Planning Commission
NEPAD	The New Partnership for Africa's Development, by the African Union
OECD:	Organization of Economic Community Development
PRA:	Participatory Rural Appraisal
REDD:	Reducing Emissions from Deforestation and Forest Degradation
REDD+:	Reducing Emissions from Deforestation and Forest Degradation in Developing Countries
SDG:	Sustainable Development Goals
SREX:	AR5 SREX Fifth Assessment Report of the IPCC, Special Report on Extreme Events
SSA	Sub-Saharan Africa
TAR:	Third Assessment Report of the IPCC
TTM:	Transtheoretical Model
UNEP:	United Nations Environmental Programme
UNFCCC:	United Nations Framework Convention on Climate Change
VRA:	Volta River Authority
WMO:	World Meteorological Organization

CHAPTER ONE: INTRODUCTION

1.1 Background

In the 19th and 20th centuries, improvements in agricultural productivity propelled economic development and food production in most of the developed world (Swanson, Kobayashi, & Tewfik, 1998). However, in Africa, persistent low agricultural productivity has perpetuated food insecurity, malnutrition and loss of livelihoods especially among smallholder farmers who own over 90% of the farms in Africa (FAO, 2013; Seini, Musah, & Bonsu, 2014). In this thesis, a 'smallholder' refers to individual farmers who typically have landholdings of about 1 hectare and may be working the land alone or with family members (FAO, 2014). Based on agro-ecology, income from these farms are at times unable to support smallholders and their families, forcing them to expand their cultivation unto other lands, intensify production to increase or maintain productivity, and include non-farm income generating activities to augment their livelihoods (Uphoff, Kassam, & Harwood., 201l; FAO, 2014).

Since the 1960s, there has been a transition from reliance on expansion of cultivated land as a primary method to boost agricultural productivity to improving yields per hectare or acre (Ruttan, 2002). In addition, a myriad of interventions were used to address low productivity through the provision of inputs, transfer of technical expertise and innovation at the farm level (Davis, 2008; Ruttan, 2002). These interventions produced extraordinary yields that revolutionized land and labor productivity in certain parts of the world, especially Asia, Europe and America (Ruttan, 2002). This system of intense productivity, termed the Green Revolution, was characterized by a shift from a peasant - human and animal labor based system of production, to mechanized systems like the use of ploughs, mechanical threshers, irrigation, fertilizers, pesticides, pumps, high-yielding varieties (HYVs) of seeds, as well as credit facilities (Parayil, 1992). Attempts were made by the World Bank, donor partners, governments and members of the agricultural research and development community to introduce the Green Revolution to Africa with HYVs, pest management systems and other modern agricultural practices (Parayil, 1992; Davis, 2008). At the dawn of the 21st century, attempts to improve productivity are still being made (FAO, 2014).

Despite these efforts, agricultural productivity is only about one tonne per hectare in Africa compared to 25 tonnes per hectare in Asia (Adjei-Nsiah *et al*., 2013; FAO, 2013). Unfortunately, climate change has emerged as a new and critical magnifier to the existing threats to food security, livelihoods and the wellbeing of the earth system (Beddington *et al.*, 2012). Smallholder farmers and coastal dwellers at the bottom of the economic pyramid are most vulnerable to climate change impacts due to poverty and low adaptive capacity (IPCC, 2007; 2012).

While agricultural production is known to be a major contributor to climate change by way of Green House Gas (GHG) emissions, climate change impacts are also a major factor in agricultural production (Wollenberg, Nihart, Tapio-Bistrom, & Grieg-Gran, 2012). Consequently, the Intergovernmental Panel on Climate Change (IPCC) forecasts that by 2050 about 250 million Africans especially smallholder farmers, women, children and coastal dwellers, would be most vulnerable to climate impacts such as droughts and floods due to poverty and low adaptive capacity (IPCC, 2007). There is a call to transform agricultural research and development to address the looming climate threats (Wollenberg *et al.*, 2012). Yet, there is no consensus in the literature about how to achieve transformation (O'Brien, 2012). Consequently, how to curb climate change emissions and ensure transformation of smallholder practices at the farm level remains challenging (Wollenberg *et al.*, 2012). Further research is needed to unravel how transformation occurs amongst smallholders in Africa to support increased agricultural productivity.

It is widely recognized that besides innovation at the farm level, a different kind of innovation that is transformational in nature is needed to build the capacity of smallholders and provide access to actors, networks, and mechanisms to transform agricultural systems and create institutions that alleviate the 'pervasive bias' against smallholders to ensure food security and improved livelihoods (Djurfeldt, Holmes, Jirström, & Larsson, 2005; Hall *et al.*, 2006; Hounkonnu *et al*, 2012; Scoones *et al.*, 2008). The FAO (2014) describes the needed innovation to bring about transformation as a three-part process of (1) developing the capacities of farmers to improve production levels, (2) enhancing farm management practices and (3) improving their abilities to work within innovation systems that link various actors above the farm level together.

From a traditional Agricultural Extension perspective, developing capacity involves improving the Knowledge, Attitudes, Skills and Practices (KAPS) of smallholder farmers (Dunsberry, 1966; Swanson & Claar, 1984). Besides developing capacity in general, Marshall *et al.* (2014) propose developing transformational capacity to help farmers to cope with climate change impacts on their farming activities and livelihoods. Many researchers (Groot, 1998; Hall, Janseen, Pehu, & Rajalahti, 2006; Jiggins & Rolling, 1997; Nederlof & Pyburn, 2012; Scoones & Thompson, 2008; Quarmine, 2012) confirm that in order to increase productivity and achieve sustainable development at the local level, the capacity to make changes at the institutional and political levels above the farm or local levels are also needed. This links the smallholder transformational change debate to the Agricultural Innovation Systems (AIS) approach which has emerged as a promising framework to tackle smallholder productivity, livelihood and food security issues based on partnerships across all hierarchical levels and scales (Hall *et al*., 2006; Scoones *et al.*, 2008).

1.2 Research Problem

Man has been on a quest to improve agriculture since time immemorial. Governments, aid agencies, researchers, extensionists and others have made significant investments into various ideological pathways to improve agricultural development over the last half century. This promoted a multitude of extension approaches, methods, and mechanisms. A review of the agricultural extension literature shows a transition in the different mechanisms used in improving agricultural development over time. Hall *et al*. (2006) classify the paradigms, approaches and underlying mechanisms used to bring about innovation and thereby transformation in the agricultural sector as "Transfer of Technology" in the 1950s, 60s and 70s and "Interactive Learning" from the 1980s until the present era of Agricultural Innovation Systems (AIS).

In spite of these efforts, agricultural productivity in Africa has remained low relative to other parts of the world like Nebraska in the United States, Latin America and Southeast Asia (Dormon., Van Huis, Leeuwis, Obeng-Ofori, & Sakyi-Dawson., 2004; FAO, 2014; Lobell, Cassman & Field, 2009). Table 1.1 for instance shows the productivity levels for maize across various global regions which highlight the low average yields, and yield potentials for sub-Saharan Africa (Lobell *et al.*, 2009).

Unfortunately, climate variability and change has emerged as a critical magnifier that could exacerbate already low productivity levels (Wollenberg *et al.*, 2012; IPCC, 2007). Indeed, according to the IPCC (2007, 2012), the emerging climate change phenomenon will worsen agricultural productivity even more than ever (Beddington *et al.*, 2012). Stakeholders in the agricultural research and development arena see value in transforming the agricultural sector. However, how to achieve transformation remains a challenge (O'Brien, 2011; 2012).

Table 1.1 Productivity of maize across various regions of the world.

Location of Maize production	Average Yield*	Yield Potential	Yield Gap	Average Potential (%)
Nebraska, United States (irrigated)	10.0	18	8	56
Nebraska, United States (rain-fed)	6.0	15	9	40
Highland/transitional Latin America	4.0	10	6	40
Midlatitude/subtropical East and Southeast Asia	3.0	8	5	38
Midlatitude/subtropical sub-Saharan Africa	2.5	7	4.5	36
Tropical lowland East and Southeast Asia	2.2	5.5	3.3	40
Western Kenya	1.7	3.7	2	46
Tropical lowland Latin America	1.5	5	3.5	30
Tropical lowland South Asia	1.4	4.5	3.1	31
Midlatitude/subtropical Latin America	1.1	6	4.9	18
Tropical lowland sub-Saharan Africa	0.7	4.5	3.8	16

Source: Adapted from Lobell et al. (2009). *Yield is reported in units of Mg ha–1.

Andeweg and van Latesteijn (2010), authors of the TransForum model suggest that profound system wide change in the innovation process and mindsets of people are needed for achieving environmentally sustainable development. While transformational change addresses fundamental changes in system attributes and human learning, incremental steps are also needed to augment the proper functioning of existing technological, governance, psychological and value systems (IPCC, 2012, p. 439).

At the global and national levels, significant efforts have been made to transform society through adaptation of practices to minimize our anthrogenic footprints and modify our ability adapt to climate change impacts on eco-systems (Kates, Travis and Wilbanks, 2012). The United Nations Environmental Programme's (UNEP) Global Programme for Research on Climate Change (PROVIA) established guidelines for the use of the Ecosystem-based Adaptation (EbA) approach to rehabilitate the natural environment. Based on these guidelines it can be concluded that there are different kinds of transformations in response to various climate change adaptation situations at the individual or collective levels (PROVIA, 2013). Adger et al. (2004) describe difference in "soft" and "hard" engineering adaptation options that societies can adapt in the quest to transform. Examples of these adaptation measures in cluded: building dikes, building sea defense structures as part of the hard engineering approaches that could be adopted for transformation or re-zoning coastal lands and restoration of mangroves and other wet lands as part of the soft adaptation structures PROVIA (2013). The United States National Research Council panel on climate change adaptation identified 314 transformational adaptation initiatives. Despite these efforts, research has found that most so-called transformational change initiatives that aimed at helping people adapt to climate change impacts were not sufficiently transformational in nature but rather incremental (Kates et al., 2012). An emerging strand of research suggests that social and individual characteristics shape actions, practices and decisions people take in adapting to climate change which may hinder transformational change (IPCC, 2012).

Adger *et al.* (2009, p.344) reveal that deep-seated individual characteristics such as beliefs, preferences and perceptions borne out of knowledge, experiences, habits, cultural norms and values affect how individuals and societies adapt to climate change. Even where solutions such as weather forecasts are available and disseminated to assist potential victims, individual barriers such as level of awareness, social capital, language and terminology used sometimes distort or diminish the value of the solution (IPCC, 2012). Smallholders and development agencies alike who are ignorant or lack knowledge and awareness, who cannot use available information efficiently, delay in the effective use of available information; or mismatch knowledge, resources, urgent needs and social characteristics (White *et al*. 2011), all of which pose potential barriers to achieving transformation at the local or individual level. Therefore, understanding social differentiation based on perceptions and specifically awareness, recall and beliefs is important to curb maladaptation and ensure effective management of the effects of climate change impacts on agricultural productivity (IPCC, 2012). In all this, there is a lack of appreciation of the role of Agricultural Extension services play in assisting smallholders to achieve transformational change (Christoplos, 2010).

Based on the available literature it can be concluded that there are inconsistencies between the theories that support agricultural Extension approaches and the practice of Extension on the ground which may hinder the transformation process. This thesis proposes three possible explanations for this inconsistency:

(1) A deficiency in the theoretical or ideological framework or paradigms used to guide the transformation process in Extension (Leeuwis & Van den Ban, 2004; Rivera, 2006; Davis, 2008, Feldman, 2007),

(2) The perceptions of smallholders themselves due to their socio-economic characteristics and psychological or cognitive barriers (Adger *et al.*, 2009; He *et al.*, 2010; IPCC, 2012; Niles *et al.*, 2015); such as, level of awareness, recall and beliefs that hinder their ability to transform, and

(3) The limited use of available mechanisms and pathways and a gap in knowledge about how to optimize them to increase innovation and thereby transformation (Hailu & Campbell, 2014).

Koutsouris (2012) describes this knowledge gap as the difference between the knowledge of lay, non-research, indigenous or local people such as smallholder farmers on the one hand, and knowledge possessed by experts or custodians of scientific or research knowledge on the other. The nature of this gap is a source of controversy among researchers and lay people alike. Traditionally, development theorists held the view that certain external scientific or technical knowledge, attitudes, practices and skills enhanced development (Agrawal, 1995); yet, evidence on the ground suggests people undergo certain devastating climate related experiences which shape and transform their perceptions and actions (McNamara & Westboy, 2011). Indigenous beliefs, local, tacit and non-science knowledge derived from experiences, values, location specific factors, risk management and deep seated cultural issues enhance or hinder adaptive capacity and the transformation process (Mudege, 2007, Adger, 2009; Moser & Ekstrom, 2010; Marshall *et al.*, 2014).

Whether humanly induced or by nature, the issue of experiences, perceptions and recall of climate impacts cannot be ignored when dealing with transformation. There are many different definition of transformation. The Cambridge Advanced Learner's Dictionary (McIntosh, 2013) defines transformation as "a complete change in the appearance or character of something or someone, especially so that they are improved" (p.1671). Indeed, how to enhance the transformational change of smallholders and their practices in the agricultural sector is not well understood (Wollenberg *et al.*, 2012; O'Brien *et al.*, 2011; O'Brien, 2012). Further research is needed to ascertain the nature and composition of knowledge needed to bridge the gap in knowledge about smallholder perceptions such as their level of awareness, recall and beliefs and the transformational change process.

There are various sources of knowledge in Extension work. Most interventions and approaches rely on established methods, methodologies, tools and techniques. Leeuwis & Van den Ban (2004) provide a thorough explanation about the differences between approaches, methodologies, methods, tools and techniques. Methodologies are described as "*pre-defined series of steps, procedures, and activities, with each step involving the use of one or several methods*" (Leeuwis & Van den Ban, 2004, p. 210).

Examples of methodologies used in Extension interventions include Farmer Field Schools (FFS), Participatory Rural Appraisal (PRA), Participatory Technology Development (PTD), and Rapid Appraisal of Agricultural Knowledge Systems (RAAKS). Methods are said to constitute the various components or elements of a methodology although some methods may stand alone. Examples of Extension methods include farm visits, workshops, and group discussions. Tools and techniques are said to be the ways of executing or operating the methods. The Random House Dictionary (2016) defines a mechanism as "*an assembly of moving parts performing a complete functional motion, often being part of a large machine*". *Similarly, a pathway can be defined as a set direction or track which can be taken by a person; a deliberate set of actions that can be taken* (McIntosh, 2013, p.1124). All of the available Extension approaches, methods, tools and techniques therefore constitute available mechanisms that can be used to forge pathways to a transformed agricultural sector. This thesis, proposes that instead of a single method or methodology that can be used randomly in an intervention, theory based mechanisms are needed to unify Extension approaches, methods, tools and techniques to ensure smallholder transformation of the agricultural sector.

The study sought to identify factors that hinder the effectiveness of mechanisms and pathways in arid and coastal regions, where the effects of climate impacts such as low precipitation, droughts, salt water intrusion, coastal erosion and high temperatures are affecting agricultural productivity the most. It is expected that this analysis would help unravel the puzzle of how to ensure smallholder transformation and provide new insights about mechanisms and pathways to improve agricultural productivity.

1.3 Research Questions

The research was guided by the following three research questions:

1. How do smallholder perceptions of climate change impacts influence their agricultural transformation process?
2. To what extent are smallholder stages of agricultural transformational change related to their socio-economic characteristics?
3. To what extent are the actions of smallholder farmers, in adopting clime-sensitive practices, as indicated by their stage in the transformational change process explained by their socio-economic characteristics and perceptions?

1.4 General objective

The general objective is to establish a possible link between smallholder perceptions and the transformational change process as a way of improving agricultural productivity in light of climate variability and change.

1.5 Specific objectives

The specific objectives are designed to address each of the three research questions. Research question one has one specific objective, 1. Research question two has two specific objectives, 2 and 3. Research question three has two specific objectives, 4 and 5. All the specific objectives are listed as follows:

1. Determine the relationship between smallholder farmer perceptions about climate change impacts and their transformational change process.
2. Analyze the effects of smallholder socio-economic characteristics on perceptions of climate change.
3. Determine the effects of smallholders' socio-economic characteristics on their stage of transformational change.

4. Analyze the effects of smallholder socio-economic characteristics and perceptions of climate change on their stage of transformational change.

The following diagram outlines how the three main constructs (I, II, II) investigated in the thesis, captured in the research questions and specific objectives are linked together in a straight step-wise format (Do I, II, or I & II together explain III?).

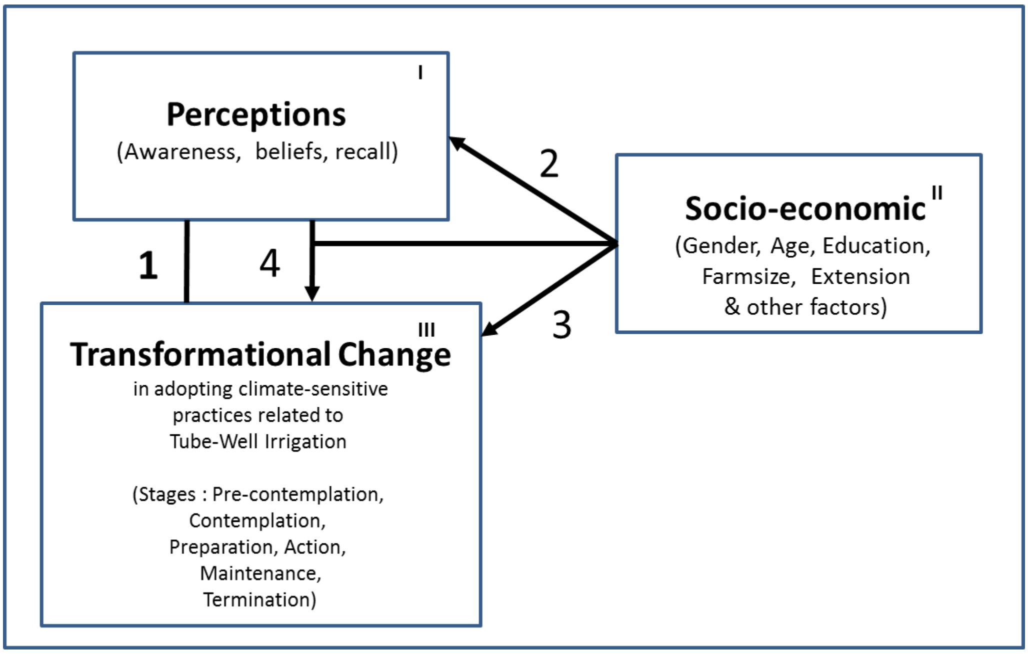


Figure 1: Conceptualisation of research objectives (Author's creation)

1.6 Hypotheses

1. H_0: Smallholder farmers' perceptions of climate change and variability do not determine their stage of transformational change.

   H_1: Smallholder farmers' perceptions of climate change and variability determine their stage of transformational change.

2. H_0: Perceptions of climate change impacts are not socially differentiated.

   H_1: Perceptions of climate change impacts are socially differentiated.

1.7 Relevance of the study

Dwindling of arable land, water and other resources are a major constraint for agricultural productivity in Africa. Over 60% of Africa's population is rural, depending on less than 10% of arable land for subsistence farming to ensure access and availability of sufficient and nutritious food for a healthy lifestyle and sustainable livelihoods (Barrett, 2010). World Bank and IMF reports show that over half of Africans in Sub-Saharan Africa (SSA) are classified as extremely poor people living on less than US$1.25 per day (Yumkella *et. al.*, 2011). According to the FAO (2009) food production would have to increase by over 70% in the coming decades to feed future populations. However, climate change has emerged as a threat to agricultural productivity (Dormon *et al.*, 2004). Smallholder farmers are most vulnerable to these issues of declining productivity, population rise and poverty and therefore require greater and more effective policies and social protection (IPCC, 2012). Findings from this research aim at contributing to planning effective adaptation interventions, extension programmes, risk management and livelihood strategies for smallholder farmers in the study area, and in other coastal and arid farming systems.

It is well recognized that increasing and changing the levels, quality and types of investment in agriculture to build institutions, human capacity and to help smallholder farmers accumulate physical capital is vital to promoting agricultural productivity, reducing poverty and promoting environmental sustainability (FAO, 2012). The New Partnership for Africa's Development (NEPAD) has committed leaders of African states to the Comprehensive Africa Agriculture Development Programme (CAADP) with the aim of increasing agricultural productivity by 6% per annum with a minimum of 10% of annual budgets invested in agriculture (Yumkella *et* *al.*, 2011). Investments will directly influence the nature and types of mechanisms available to smallholder farmers in the agricultural sector.

However, history shows that more investments and participatory approaches do not automatically translate into improved productivity if practices, policies and other institutions remain the same (Mytelka & Farinelli, 2000; Hall *et al.*, 2006, Dethier & Effenberger, 2012). Changes needed to increase adaptation to climate change and increase productivity have been identified as incremental and transformative change (Marshall *et al.*, 2014).

Climate models show that by 2020, rain-fed agricultural production, access to food, size of cropping areas, and yields could decline by as much as 50% in many countries across Africa due to declining rainfall patterns (Agoumi, 2003; also, cited in IPCC, 2007, p. 448). According to the Stern Review (2006), failure to curb climate change impacts significantly by 2030 could result in costs of about 5 to 20% of global GDP per annum. New climate-sensitive practices are therefore needed to curb the negative impacts and improve agricultural productivity (Smith & Wollenberg, 2012).

Leeuwis and Van den Ban (2004, p. 61) describe "practices" as recurrent patterns of human behaviour or actions over a period of time. Although smallholder transformation may be a latent phenomenon, transformation of their current practices into new patterns of behaviour and actions are observable and can in principle be measured to track productivity.

This thesis reviewed various eras of extension that have emerged in response to increasing productivity in the agricultural sector and attempted to analyse the dominant theories, methods, mechanisms, and other factors that influenced the transformational change process during those eras. Indeed, research has identified inadequate coordination between actors as a barrier to accelerated climate adaptation (IPCC 2012,

p. 323). There are several streams of literature on the types of mechanisms and pathways that are needed to overcome these barriers. O'Brien *et al.,* (2011) propose that to achieve transformation, the goal of the climate change adaptation process should be focused on creating partnerships and increasing resilience over a time continuum.

This thesis supports the view of O'Brien *et al.* (2011) but also argues that analyzing smallholder perceptions of climate change and mechanisms are a precondition for achieving transformational change. This is because even if mechanisms and partnership opportunities exist above the farm level to increase productivity, and address institutional constraints, smallholders cannot benefit from them if they are unaware of them, if they do not perceive the climate change phenomenon or if they do not believe that they can benefit from available and emerging mechanisms due to their explicit and tacit knowledge, beliefs, cognitive and psychological disposition. There is a need to understand smallholder perceptions and the relationship between their perceptions and how they undergo transformation, to better target limited resources to enhance the effectiveness of mechanisms. This research aims at providing insights about smallholder perceptions of climate change and how to incorporate them in theory and practice of transformation to improve smallholder agricultural productivity and livelihood outcomes.

This thesis proceeds from the point of inadequate research on understanding the link between smallholder perceptions and behavioural change where the subject or unit of analysis is the smallholder farmers' process of systematically changing behaviour by transforming perceptions into desired climate-sensitive agricultural practices. Adoption studies suggest that individuals are not easily convinced by innovation messages they are exposed to, be it expert/ scientific knowledge or otherwise, unless the innovations involved are perceived to be relevant and fit with the individual's needs, attitudes and beliefs (Rogers, 2003). Thus, individual perceptions are critical in the innovation and transformation process (Marshall *et al.*, 2014). Koutsouris (2012) proposes that the nature and lack of social differentiation or stratification of perceptions about transformation creates constraints that could be overcome in the intermediation process if these constraints are identified and made explicit.

The Agricultural Innovation Systems (AIS) approach is an emerging extension mechanism to help overcome this barrier by fostering multi-stakeholder learning processes and partnerships. However, the AIS approach is founded on action research methodology (Lewin, 1952, Rapoport, 1970; Lincoln & Guba, 1985, 2000; Greenwood & Levin, 2007) which emphasises constructivist world views on the establishment, facilitation and efficiency of AIS and innovation platforms (IPs) as a way of bringing people together to solve societal problems and alleviate institutional barriers (Scoones *et al.*, 2008; Hounkonnu *et al.*, 2012).

While the action research process offers meaningful insights as a qualitative research method, it is not without criticism (Feldman, 2007; Vellema, 2012). Current AIS literature regarding smallholder transformation overlooks the actual process by which individual smallholder farmers transform at the cognitive and psychological levels to participate effectively within the AIS. This is evidenced by the fact that despite increasing numbers of studies exploring innovation and the role, interactions and challenges of smallholders within the AIS framework (Scoones et al., 2008; Nederlof & Pyburn, 2012; Quarmine, 2012); few studies explicitly investigate how smallholder farmers undergo the transformation process over time to achieve “transformational change”.

The current AIS and Agricultural Extension literature attempt to describe, interpret and understand smallholder transformation through qualitative communicative innovation and social learning based on action research (Leeuwis & van den Ban, 2004; Jiggins, 2012; Hounkonnu *et al*., 2012) but do not measure, track or quantify the extent of transformation or behavioural change per se (Feldman, 2007, p. 22). According Vellema (2012), an "approach" usually refers to a system based on a clear intervention theory. However, the current "innovation systems approach" lacks a clear theoretical foundation to detect and explain *"why certain interventions lead to observed outcomes… [as such] there is a danger of hopping from one fashionable best practice, or approach to the next, without considering what the real processes are that generate or obstruct outcomes"* (Vellema, 2012, p.121). Deeper, more comprehensive and holistic analyses are needed at the individual level to establish and explain the underlying relationships that exist and lead to certain outcomes. This study attempts to understand the relationship and quantify the extent of behavioural change that can be attributed to various factors at the individual level. The study and to determine how findings can be generalised across communities, regions and industry sectors for sufficient, appropriate and timely intervention mechanisms to be deployed (Marshall *et al.*, 2014).

The thesis maintains that although smallholders need an enabling environment, as proposed by the AIS paradigm, much also rests on the individual smallholder's ability to take advantage of emerging opportunities and to participate effectively within an innovation system. Not all smallholders have the same level of readiness, willingness, capacity and ability to change (He, *et al.* 2010). Similarly, not all agricultural extension methods are suitable for promoting transformational change (Davis, 2008). While the phenomenon of smallholder behavioural change can be studied across many different contexts, this thesis specifically deals with smallholder behavioural change within the context of climate change adaptation and based on theories of transformational change.

Against this backdrop, the thesis aims at making three contributions to existing knowledge as follows: (1) Extending the agricultural extension literature on socially differentiated transformational change; (2) Testing the applicability of incorporating new perception variables into the Transtheoretical or Stages of behavioural change Model as a way of extending Rogers' diffusion of innovations theory for greater effectiveness and use in agricultural development; and (3) Offering the Transtheoretical Model as a tool for disaggregating smallholder perceptions about climate change to improve the measurement, monitoring and documentation of changes in behaviour and serve as a catalyst for improving communications and muting barriers to the adaptation process and thereby increasing agricultural productivity.

Consequently, the thesis is highly relevant to understanding the process for smallholder transformation at the individual level as a precondition for improving agricultural productivity in Africa when faced with climate variability and change (Marshall *et al.*, 2014). This is because the climate change phenomenon is a time sensitive phenomenon that requires that smallholders change their behaviour rapidly and adopt climate sensitive practices in order to mitigate harmful impacts and extreme climate events (Smith & Wollenberg, 2012; Wollenberg *et al*., 2012; IPCC, 2012). This research provides a framework for understanding and quantifying the nature of relationships and changes that occur along the transformational change process.

1.8 Structure of the thesis

The study investigates mechanisms and pathways for achieving transformational change for climate-sensitive agricultural practices among smallholder farmers. First is an analysis of the evolution of agricultural extension to identify the underlying paradigms and associated mechanisms that have been deployed over time to improve productivity. Next the thesis examines two alternative conceptual and theoretical perspectives highlighting how these frameworks contribute to the transformational change process which has emerged as a dominant theme for increasing productivity among smallholder farmers in the face of climate change. Finally, the thesis presents an empirical analysis of the concept of transformational change followed by discussions about its applicability for solving the problem of low productivity among smallholder farmers faced with climate change impacts.

The work is organized into five main chapters: (1) introduction, (2) literature review and conceptual framework, (3) methodology, (4) results and discussion and (5) conclusions and recommendations. Chapter one provides an introduction to the research by setting the scene with a brief background and presenting the research problem, relevance of the study and a list of the research questions and objectives. Chapter two presents literature on the conceptual, theoretical, and methodological considerations that undergird the study. Chapter three provides an overview of the methodology by which the research questions are systematically and scientifically addressed. It presents the sampling strategy, data collection procedures and analytical models used in ensuring objectivity and rigor in the study. Chapter four, the results and discussion section, presents the findings which are discussed briefly per research question. Chapter four also discusses all the findings relative to existing literature, implications and contributions to existing knowledge bases. Finally, chapter five offers conclusions and recommendations based on the findings.

CHAPTER TWO: CONCEPTUAL FRAMEWORK AND LITERATURE REVIEW

2.1 Introduction

This chapter presents historical and current synthesis of literature relating to the impact of climate change, climate change adaptation and the potential for smallholder transformational change in achieving agricultural productivity. This chapter explores the conceptual, theoretical, methodological and general scientific basis for the research and how it contributes to filling a knowledge gap in the field of Agricultural Extension. The research takes its point of departure from understanding the smallholder transformational change process as a pre-condition for solving the problem of low-productivity among smallholder farmers in Africa. This thesis postulates that it is inconsistent to pursue the goal of achieving transformational change by using old ideological, theoretical and methodological constructs and conceptions that cannot ensure or track transformational change at the individual or societal levels.

The literature review section is thus inspired by the style of Sumberg and Sabates-Wheeler (2011) and Hall et al. (2006) by reviewing the main paradigms underpinning models and mechanisms to improve agricultural productivity from the transfer of innovation era to the agricultural innovation systems era, and exposing weaknesses and opportunities within these models that could be enhanced to contribute to improved agricultural productivity. The review covers four areas. First an outline of literature on the evolution of agricultural extension highlighting its mandate and attempts made at resolving the problem of low agricultural productivity. Second, it presents literature from different schools of thought on how to achieve transformational change in the practices of smallholder farmers. Third, it presents views on how the climate change phenomenon, smallholder perceptions and other socially differentiated factors contribute to the transformation process. In this section, the review sheds light on the theoretical framework delineating how the transtheoretical theory or stages of behavioural change model fosters transformational change among smallholders in the context of climate change adaptation. Finally, a conceptual framework illustrates how the various theoretical constructs, variables, and key assumptions contribute to achieving transformational change.

2.2 Climate change as a mechanism for agricultural development

In 1988, the United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO) established the Intergovernmental Panel on Climate Change (IPCC) in response to increasing concerns about anthropogenic drivers of climate change particularly the emissions of greenhouse gases and how they can potentially influence the normal functioning of the earth's climate system (IPCC, 2007). According to the European Union (EU), a 2^{o}C increase in global mean temperature above pre-industrial levels (Adger *et al.*, 2009; Stafford-Smith *et. al.*, 2012) may result in water-stress, starvation, malnutrition and loss of livelihoods in many developing countries, especially those located within the southern hemisphere of the earth affected by the El Nino Southern Oscillation (ENSO) (World Bank, 2012).

Globally, there has been a push for understanding and alleviating climate impacts across various sectors of economies including the agricultural sector. This is because climate change has not only disrupted the balance of agricultural systems but also presents new opportunities for farmers and others in the global agricultural sector. All actors in the business of producing, processing, distributing, and financing of primary and secondary agricultural products, from large multi-national corporations to sole-proprietorships, stand to gain from any new opportunities that may emerge. From an institutional perspective:

> *"Once a national economic institution or a business practice is put into place, and becomes taken for granted as the most efficient way to organize a particular domain, some kind of shock is usually required to displace it. The shock typically sets off a contest among different groups, with different ideas about what the new policy or practice should look like. At this point power comes into the equation, as groups try to use rhetoric and resources to ensure that their favored solution is adopted. Networks often provide the conduits through which new practices are tested out, and through which the word is spread. As powerful agents use their networks to try to convince others of the efficacy of the economic policy or business practice they favor, a new policy or practice becomes institutionalized, often eliminating competitors in the process. Thus, begins a new cycle, in which taken-for-granted policies and practices are eventually undermined by challenges, and in which groups vie to define what will replace them,"* (Dobbin, 2005, p.46).

For centuries, it was taken for granted that agricultural systems would prioritize productivity and efficiency at the farm level in a way that guarantees high productivity, food security and respectable incomes. In many ways, the climate change phenomenon of the 21st century is akin to a shock to global agricultural and economic systems that has set off different debates on policy and best practices for agricultural transformation. It is unlikely that all stakeholders will participate equally in transformation. However, for those regions and groups that are most vulnerable to climate impacts, new policies and practices are urgently needed (Kates *et al*., 2012; Parris, 2003; Ostrom, 2010; Smith & Wollenberg, 2012; IPCC, 2012).

The rate of climate change adaptation varies across communities in Africa. Whereas climate-sensitive responses to climate change can be traced back over centuries in some communities, others are yet to realize the urgency to react (IPCC, 2012). This has implications for livelihoods and food security. Traditionally, agricultural extension agencies have had the mandate to introduce and manage communication and interventions involving farmers to enhance agricultural productivity (Jones & Garforth, 1998; Scoones *et al.*, 2008). Hence if there are to be opportunities or threats from the climate change phenomenon, the role of agricultural extension cannot be ignored. Yet, over time, the role and effectiveness of extension has been viewed with ambiguous ambivalence by farmers, researchers and others in the agricultural development sector (Christoplos, 2010). While there is a call for greater extension, there are also reports about the ineffectiveness of extension and the need for reforms (Scoones *et al.*, 2008). Extension agents, whether public or private are often tagged as "all-purpose" rural development agents, and are thus overburdened with tasks beyond their core mandates (Christoplos, 2010). The FAO recommends a 1:500 Agricultural Extension Agents (AEA) to clients' ratio (GECCPAN, 2015); however, in practice most localities that have AEAs have ratios far in excess of this recommendation due to lack of resources, out-dated organizational management structures and other problems which dilute their effectiveness (Ruttan, 2002; Christoplos, 2010).

New theoretical perspectives and methodological refinement are needed to manage the complexity of forging new pathways to agricultural and social transformation (Davis, 2008; Ostrom, 2010; Sumberg & Sabates-Wheeler, 2011; Marshall *et al.*, 2014). New theoretical perspectives are particularly important for predicting the outcomes of interventions and to interpret, organize, process and place everyday observations in a meaningful context (Keenan, 2000; Sumberg and Sabates-Wheeler, 2011). Keenan (2000) further posits that assumptions on which theories are based also influence interpretations made from theories across cultural contexts, belief systems and the particular sample population considered. According to Miller (1993), a good theory ought to fit well with empirical evidence and help understand, predict and account for changes along the different states of development. To ensure transformational change in agricultural development a good theory of transformational change is needed.

There is extensive literature on behavioural change across many disciplines (Marquart & Waddill, 2004). For decades, researchers in psychology, public, mental and other health sciences have investigated behavioural change from many cognitive and psychological angles. The Transtheoretical (Stages of Behaviour Change) Model (TTM) by Prochaska and Associates (1992) was selected to undergird this scientific inquiry. Instead of a "one-size-fits-all" approach, the transtheoretical model (TTM) assumes that individuals are at different levels or stages of readiness, willingness, and ability, to engage in transformational change based on a combination of cognitive, psychological and socially differentiated factors that shape their attitudes, beliefs and values (He *et al.* 2010).

The literature shows that humans are by and large heterogeneous with cognitive, as well as socially differentiated characteristics such as ethnicity, language, experiences and socio-economic factors that may pose barriers to transformation (IPCC, 2012). The nature of humans to organize as economic agents and as firms (Coarse, 1937) to consider alternative livelihood strategies and to seek opportunities to improve their capabilities, access to food, incomes, and assets cannot be underestimated (Chambers & Conway, 1991). Ideally, attempts to improve livelihoods should be environmentally and socially sustainable. According to Chambers and Conway (1991) a livelihood is environmentally sustainable if maintains or adds to local or global resources that support livelihoods or has net positive impacts on other livelihoods. Similarly, a livelihood is socially sustainable if it can withstand and recover the stress and shock of over exploitation, in order to fulfill the demands of current and future generations (ibid). However, in most cases many of the natural resources used in the agricultural sector such as land, water and mineral resources are neither environmentally nor socially sustainable because of human activities.

As a human activity, agriculture offers a paradox in climate change debates because it provides livelihoods and food security, yet agriculture is said to contribute about 10-12% of emissions directly related to climate change (Wollenberg *et al*., 2012). Roling (1997) argues that the biosphere cannot continue to support life if human activity continues its current trajectory, exposing society to the risks of "land degradation, erosion, loss of water retention capacity, loss of biomass, loss of biodiversity, loss of soil fertility, soil pollution, and other problems, which are all caused by human activity" (Roling, 1997, pp. 248). He calls on both agricultural and social scientists to work together to explore and analyze the fundamental drivers of human intentionality and societal dynamics.

Niles *et al.* (2015) assert that "*it is time to join together ecological and social/psychological theories and apply them to real-world data to advance work in climate change adaptation* … [moreso because] *empirical examples of joining disciplines and theories to actually link ecological contexts with decision-making to predict behaviours are scarce"* (p.184).

This thesis seeks to investigate the psychological aspects of climate change impacts by linking individual perceptions with climate-sensitive transformational behavioural change along particular pathways to safeguard ecologies, human lives and smallholder livelihoods.

Leeuwis & Aarts (2011) theorize that humans can be interpretative beings who use mental schemes to reflect their knowledge, aspirations, feelings and evaluations while interacting with others through language, or engaged in physical activity. Leeuwis & Aarts (2011) posit that these interactions and interpretations occur in a construct called a “Discursive Space” as shown in Figure 2. The discursive space consists of four main conceptual spaces: the sphere of thinking called ‘Mental Space’; the sphere of doing called ‘Inter-actional Space’; the ‘Socio-institutional Space’ which serves as a store of “legal, cultural, relational, economic or political knowledge, aspirations, feelings, evaluations, etc.”; the ‘Bio-physical Space’ which is a store of “technical, geographical, ecological, or temporal” facts and representations. The four conceptual and theoretical elements are linked together by communication.

Leeuwis and Aarts (2011) posit that the ‘sphere of thinking’ and ‘sphere of doing’ cannot be separated physically but only analytically. This highlights an intrinsic link between thought and action that is consistent with most theories of change (Bandura, 1977; Flood & Romm, 1996; Pelling *et al.*, 2008). Based on this principle, this thesis argues that prior to engaging with others in reflective social learning, individuals engage themselves, they ponder over issues critically based on whatever knowledge they may have based on perceptions, recall or beliefs. They may then decide who to contact within their social network for additional information or support, which begins the social learning process for transformational change.

Researchers, agricultural Extension agents and others in the agricultural knowledge system can engage with smallholder farmers to share useful information and create “space for innovation” (Leeuwis & van Den Ban, 2004) not by offering a one-way linear transfer of technology, prescriptive diagnosis, but by engaging with their various “spaces” to build on perceptions, to co-generate comprehensive adaptive, farmer-centered solutions (Collinson, 2001; Leeuwis, 2004; Leeuwis & Aarts, 2011; Andeweg and van Latesteijn, 2010).

This is the communicative innovation (Leeuwis, 2004; Leeuwis & Aarts, 2011) that the agricultural innovation systems approach encourages except that the available literature does not show that the AIS approach probes deep enough to achieve transformational change based on any underlining theories of transformational change per se. This thesis argues that for greater effectiveness, the discursive space for innovation should be explored and used based on the theories of transformational change such as the transtheoretical model to support rapid and measurable smallholder transformation.

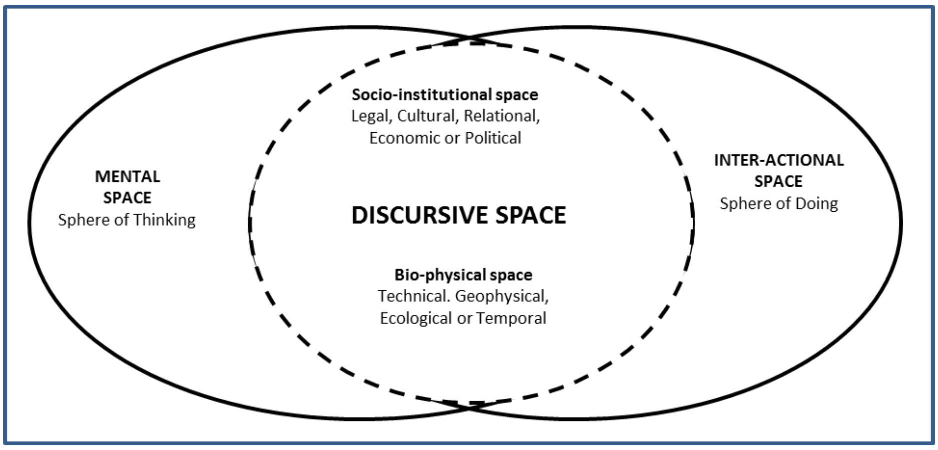


Figure 2: Different spaces within the discursive space (Leeuwis & Aarts, 2011)

In other words, this thesis sought to explore the basis for the creation of a ”discursive space” for transformational change based on theories of transformational change and also incorporating awareness knowledge, recall and beliefs is a key mechanism for facilitating behavioural change. Roling (1997) argues that agricultural production can be enhanced through the sustainable management of land and human practices by:

“continuous exploratory probing, monitoring, and adaptation of our interventions, redefining sustainability as learned, negotiated and agreed upon, …an outcome of human activity grounded in institutions, policies, culture and power; [and as] an interface between human ability to learn and the biosphere of which we form part”.

(Roling, 1997, p. 248),

The survival of humans depends on widespread society-wide adaptive learning at various levels and "*collective action at the household, community, national and global scales*" (Roling, 1997, p. 249). This underscores the importance of creating space for multi-stakeholder interactions amongst farmers, extension agents, and other actors in achieving transformational change to climate and human induced problems including low productivity that leads to food insecurity and malnutrition (Dormon *et al.*, 2007). Therefore, attempts to scientifically investigate the mechanisms and pathways by which smallholder crop farmers achieve transformational change remains a key research priority in agricultural development.

Over the decades, the role and importance of individual perceptions, values and social institutions towards building resilience and capacity in the climate change adaptation process has been well examined across many fields. However, little is written about how individuals - and in this case, smallholders specifically - achieve transformational change when faced with climate change impacts, extreme weather events and disasters that often inflict some level of psychological distress. This thesis joins Mezirow (1996, 1997, and 2000) and others (O'Brien *et al.*, 2011; Marshall *et al.*, 2014) who propose that "*individual transformation can spur larger, societal movements and transformations*" (Moore, 2005, p. 395). Yet, a large scale social movement of hype and rhetoric cannot ensure individual transformation. At best, it may create awareness but may not necessarily lead to "transformational change".

Major architects of climate-smart solutions and others concerned about the effects of the climate change phenomenon on agriculture (Beddington *et al.*, 2012; IPCC, 2012; FAO, 2014; Hailu & Campbell, 2014, Smith & Wollenberg, 2012) hope to enable agricultural productivity increases in Africa similar to the tremendous growth rates that propelled Asia from the brinks of famine in the late 1960s to their current status as net food exporters. To achieve this target, resources have been mobilized at the geopolitical and local scales to support the UNFCCC conference of the parties (COP) in various initiatives and to set aside funds for climate change adaptation and mitigation. Mechanisms such as the clean development mechanism (CDM), payment for environmental services (PES), the participatory governance assessment (PGA) and other global compensation schemes and initiatives have emerged (IPCC, 2007; 2012; Hailu & Campbell, 2014).

A synthesis of various mechanisms in the climate change literature reveals a number of pathways for transformational change, summarized in Table 2.1. In this thesis, a pathway consists of a sequence of mechanisms that are engaged to bring about a desired outcome whereas a mechanism is a specific intervention, activity or policy instrument which must be used in concert with other mechanisms, tools, approaches or interventions, within a particular system, context, configuration, institutional framework or conditions to achieve a desired outcome (Geels and Schot, 2007).

To achieve transformation in the agricultural sector, it is clear that a number of mechanisms and pathways must be utilized in concert. The implementation of climate-smart solutions and policies through governments and their incorporation into national development policies have dominated climate debates and the development space in recent years. Yet it is not clear how these activities will lead to transformational change in Africa if some of the theory based principles and factors that ensured success in transforming agriculture in Asia - such a focus on smallholder farmers at the individual level, market mediated solutions and context specific interventions (Djurfeldt *et al.*, 2005) including appropriate socially differentiated extension delivery methods - are not explored.

Table 2. 1 Emerging Pathways for Addressing Climate Change Impacts

Emerging Pathway	Transformation Mechanisms	Some Authors
Policy Push/ Thematic Pathways	WMO, UNEP, IPCC, Strategic themes: Sustainability, Vulnerability, Mitigation, Adaptation, Early Warming/Disaster Risk Management, Climate-Smart Agriculture, MDG, HDI, Transformation, SDGs	IPCC, 2007, 2012; Scoones *et al.*, 2008 ; O'Brien 2012 ; Adger *et al.*, 2009 ; Roling 1997
Parametric Modeling Pathways	Assessing parameters and risks: Projections, Thresholds, Mapping, Yield Gaps, Climate Scenarios, Emissions Trajectories, Land cover land use (LCLU), Geographical Information Systems,	Mendelsohn *et al.*, 2000; World Bank; O'Neill, 2014
Negotiation Pathways	UNFCCC, COP (Kyoto, Rio, Copenhagen, Paris, etc.), UNEP, UNDP, FAO, WTO, NEPAD, OECD	IPCC, 2007, 2012; Yumkella *et al*. 2011;
Compensation, Trade-offs, Incentives or Agency based Pathways	CDM, PES/Transfer mechanisms, REDD, REDD+, Carbon intensity, Risk pooling, Insurance, Stewardship, Land-use, Resource dependency	Ferraro & Kiss, 2002; Derissen & Latacz-Lohmann, 2013; Mahanty *et al.*, 2013
Disciplinary/ Theoretical / Transitions Pathways	Disciplinary and Industry Focused Research, Structural, Infrastructural, Engineering, Agricultural Scetor Interventions, Socio-technical transitions, Practical, Methodological and Theoretical advancement in various fields and sectors	Geels & Schot, 2007; PROVIA, 2013
Integration / Institutionalization Pathways	Collective Action, Coordination, Institutionalization, Convergence, Complementarities, NGO, CSO, Advocacy, Mainstreaming, Boundary focused research	Ostrom, 1999, 2010; IPCC, 2012; Beddington *et al.*, 2012; Hailu & Campbell, 2014; Hounkonou et al., 2012
Socio-economic Pathways	Socio-economic indicators, Indices, Equity, Governance, Globalization, Markets, Value Creation	Sachs, 2004; O'Neill *et al.*, 2014, 2015; Rosenbloom, 2017
Social Transformation Pathways	Adaptive capacity, Social/ Psychological/ Cognitive limits, Self-efficacy; Stages of change, Transformation capacity, Identity, Translocation, Embedded and Interactive Spheres, Individual level change	Yohe & Tol, 2002; Adger *et al.*, 2009; Ostrom, 2010; Moser & Ekstrom 2010; O'Brien, 2012; Kates, *et al.*, 2012, O'Brien & Sygna, 2013; Marshall *et al.*, 2014

Source: Compiled by author

The expiration of the Millenium Development Goals (MDGs) and creation of the Sustainable Development Goals (SDGs) have helped many to regonize and embrace the importance of setting goals to track the achievement of environmental sustainability goals at both the global and local scales. According to Lu et al. (2015), in order to achieve the Sustainable Development Goals (SDGs), including goal thirteen – climate action, governments, natural and social scientists alike must establish mechanisms to measure, collect and monitor important and relevant data not only of traditional scientific indicators but also behaviour, values and beliefs that drive the attainment of the shared principles.

2.3 Evolution and change in Agricultural Extension

There are many dimensions of change. On a temporal scale, change can be short-term or temporary in nature. It can also be medium-term, neither temporary nor permanent, and it can be long-term, permanent or irreversible. Transformational change as discussed in this thesis refers to long-term change. Agricultural Extension is concerned with bringing about long-term, permanent and complete change in the knowledge, attitudes, skills and practices of individuals and communities (Swanson & Claar, 1984, p. 1). Jones and Garforth (1998) describe the goal of Agricultural Extension as seeking to broaden and enhance the abilities of farmers to adopt new and appropriate practices for changing societal conditions and needs. Agricultural Extension researchers, practitioners and others in the agricultural development and research nexus have relied on various theories, methods and approaches to disseminate useful information and bring about change (Everson, R., 1998).

2.3.1 The role of Agricultural Extension over time

Agricultural Extension has been a pivotal agency with the mandate and potential to assist farmers. Agricultural Extension Agents (AEAs) specialize in linking farmers with researchers and the development community to facilitate innovation and transform rural and marginalized populations. Dunsenberry (1961) defines Agricultural Extension as:

"Education, social and cultural development of people outside regularly organized schools or classes. It uses information obtained and assembled from research studies from all over the world, from experience and from results of demonstrations performed for the purpose of extending knowledge. Extension is as broad and varied in its meaning as the interests of the people it serves. It is an educational programme for the people, based on their needs and problems and designed to meet these needs and solve these problems on a self-help basis. Where aid in solving rural problems is available from governmental or non-governmental agencies, extension provides information in the use of such assistance" (p.851).

Dunsenberry (1966) further posits that Extension is a teaching and learning process. *An out-of-school education that seeks to produce changes in human behaviour by way of changes in knowledge or things known, changes in skills or things done and changes in attitudes or things felt* (p. 853). This basic assumption and emphasis on changing knowledge, skills and attitudes is one of the central tenets of Extension that continues to guide the contemporary practice of Extension today. Although there are slight variations in the definitions and mandate of Extension over time, one of the central tenets of Extension which also grounds this research is that, to be successful, Extension practitioners and researchers must continue to engage clients and stakeholders based on their location specific needs, drawing on their past experiences, both explicit and tacit knowledge, attitudes and perceptions.

Maunder (1973) defines Extension as "a service or system which assists farm people, through educational procedures, in improving farming methods and techniques, increasing production efficiency and income, bettering their levels of living, and lifting social and educational standards.' Van Gent & Katus (1980) posit that "*Extension is a deliberate and systematic attempt – by means of the transfer of knowledge and insight*

– to help and/or develop someone in such a way that the person is able to take decisions in a specific situation with a maximum level of independence, consciousness, and conformity with his own interest and wellbeing". According to Adams (1982) Agricultural extension is "*assistance to farmers to help them to identify and analyse their production problems and to become aware of the opportunities for improvement"*. Roling (1988) defines Extension as "*a professional communication intervention deployed by an institution to induce change in a voluntary behaviour with a presumed public or collective utility*". Van den Ban (1974) and Van den Ban & Hawkins (1996) define Extension as involving "*the conscious use of communication of information to help people form sound opinions and make good decisions*".

It is striking that all of these definitions emphasize assistance to farmers in a way that transforms their production by changing their perceptions and behaviour to make them aware of opportunities. The definitions also identify the role of Extension as an agency charged with assisting and bringing about these changes among farm or rural people. If, after all these decades, agricultural productivity is still lagging in Africa, then what has gone wrong in the Extension establishment in bringing about change? There are a multiplicity of explanations and clues.

2.3.2 Mechanisms to improve agricultural productivity

Methods to improve agricultural productivity and Agricultural Extension can be traced back to as early as A.D. 60 when the Romans disseminated educational materials with best practices in husbandry, timing of agricultural operations, and use of methods based on soil type (Kellogg, 1957). With the emergence of science in the 16th century, scientists, chemists, geologists, agricultural scientists and others sought scientific explanations to ascertain linkages between soil fertility, plant nutrition and growth (Kellogg, 1957). This launched an era of scientific research in agriculture with experimentation in fields, laboratories and experimental stations as we know it today (Swanson et al, 1998). For decades, this perpetuated a natural science, agricultural productivity bias as the limiting constraint to smallholder success at the farm level (Kellogg, 1957). Globally, science-based research and development has led to increases in agricultural productivity (yield per hectare). However, despite significant efforts by African governments through their ministries of agriculture, donor agencies, UN organizations, and the Consultative Group for International Agricultural Research (CGIAR) to foster a Green Revolution in Africa (Swanson *et al.*, 1998; Hounkonnu *et. al*., 2012), agricultural development has failed to transform agricultural practices to ensure food security and poverty alleviation in Africa (Pretty *et al.*, 2011). This failure calls for new radical and farmer-centered approaches for investigating and promoting productivity in Africa (Scoones *et al.*, 2008).

A number of extension approaches have emerged over the years for use in interventions to increase agricultural productivity. An approach is defined as a basic planning philosophy for carrying out a development intervention which can in theory be either prescriptive and instrumental or interactive and participatory in nature (Leeuwis & Van den Ban, 2004). According to and the Ministry of Food and Agriculture's Directorate of Agricultural Extension Services (MoFA DAES), as cited in the findings of the Ghana Environment and Climate Change Policy Action Node (GECCPAN, 2015), there are a number of extension approaches that have been used in Ghana over the years. These include:

1) The General Agricultural Extension Approach,

2) Training and Visit Extension Approach,

3) Commodity Specified Extension Approach,

4) Farming Systems Research / Extension Approach,

5) Cost Sharing Extension Approach,

6) Participatory Extension Approach,

7) Educational Institution Extension Approach,

8) Project Extension Approach,

9) Electronic Extension Approach (e-Extension),

10) Mass Communication Approaches, and

11) Advanced Participatory Extension Approach also known as The Saemaul Udong Approach. However, only four main approaches are currently being used. They are: 1) The Farmer Field School/ IPM Approach, 2) The Training and Visit Extension Approach, also known as the Technology Transfer Approach, 3) Participatory Approach, and 4) Commodity Specified Extension Approach (See Appendix IV).

While the approaches have, distinct theoretical underpinnings rooted in rural sociology, anthropology, psychology, economics, adult education, and learning theory, in practice the approaches are no longer strictly theory-based. Davis (2008) provides an overview of four typologies of Extension approaches by various scholars which can be used to categorise Extension approaches in practice. They are: Top down, participatory, contract farming, and rural development as shown in Table 2.2. Based on this classification, Farmer Field School/ IPM approach, Farming Systems Research and Extension (FSR/E), the Training and Visit Extension (T&V) Approach, also known as the Technology Transfer (ToT) Approach, and Commodity Specified Extension approaches are all classified as top-down Extension approaches even though by design Farmer Field School (FFS)/ IPM approach and Farming Systems Research and Extension (FSR/E) approaches were initially participatory approaches.

Table 2. 2 Typologies of Agricultural Extension by various scholars

Type		Rivera (1988)	Axinn (1998)	Gêmo (2005)
Top-down	1	2. Conventional 3. Training and visit (T&V) 4. University 5. Technical innovation 6. Integrated agricultural development program	1. General agriculture 2. Commodity 3. T&V 4. Agricultural participatory approach 5. Farming systems research and extension (FSR/E) 6. Cost sharing 7. Educational institute approach	1. Public 2. Commodity 3. T&V 4. Private sector 5. Farmer field schools (FFS)
Participatory	1.	2. Farmer information dissemination system 3. Farming system research-extension		
Contract farming	1.	2. Community development 3. Commodity focused		
Rural development	1	2. Community development 3. Integrated rural development programs 4. Animation rurale		

Source: Adapted from Davis (2008)

The Top-down approaches are largely guided by the *Diffusion of Innovations theory* (Rogers, 1962, 1995, 2003) which takes its roots from rural sociology and psychology. The theory institutionalised the "Transfer of Technology" (ToT) paradigm by identifying different adopter categories, attributes of innovations that enhance their adoption and barriers that hinder the adoption or diffusion process through a social system. The theory supports individual level transformation that leads to societal transformation through linear teaching methods. It has been the dominant paradigm in agricultural development over the last half century (Nagel, 1998; Ruttan, 2002; Davis, 2008, Adjei-Nsiah *et al.*, 2013). In contrast, Farmer Field Schools (FFS) as an Extension approach was first developed based on experiential learning theory (Kolb, 1984) to empower farmers by helping them learn through experience by doing and experimenting in an informal setting (Leeuwis & Pyburn, 2001).

Leeuwis and Van den Ban (2004) present Farmer Field Schools as an experiential learning methodology which is theoretically distinct from the ToT approach. Yet in practice, the top-down ToT approach has now been infused into almost all the Extension methods as shown in Table 1.2. Similarly, Appendix IV provides a summary of the four main Extension approaches practiced in Ghana which again shows how in practice participatory approaches are infused with the ToT approach thus blurring their theoretical uniqueness and reducing their effectiveness. If the goal is to achieve transformation of the agricultural sector through the use of these Extension approaches, then any inconsistencies between the theory and practice of Extension approaches constitute gaps in our understanding of the transformation process.

Some potential explanations why the gaps exist can be traced to current practices. For example, Agricultural Extension Agents (AEAs) and researchers are expected to conduct needs assessment to determine farmers' needs for new technologies such as improved seed varieties or inputs and understand their prior conditions before the adoption process (Rogers, 2003). In theory, researchers and Extension personnel are expected to use appropriate theory based methods and mechanisms to solve problems and empower clients (Scoones, *et al.* 2008; GECCPAN, 2015). Traditionally, the General Agricultural Extension approach, T&V approach, Commodity focused Extension approach, Farming systems research and extension (FSR/E) approach, Cost sharing approach, Educational institute approach and others have been linked to the Diffusion of Innovations Theory and ToT approach. The theory describes five stages in the individual innovation decision process: Knowledge, Persuasion, Decision, Implementation, and Confirmation to promote the dissemination of information from a source of knowledge to persons who may not have that knowledge. It is assumed that Extension personnel would facilitate innovation processes that meet the needs of their clients (Leeuwis & Van den Ban, 2004). However, in practice the Diffusion of Innovations theory or ToT approach has been criticized as being prescriptive and linear and not adaptive to farmer needs (Hall *et al.,* 2006; Scoones *et al.,* 2008). If Extension services do not meet farmers' needs, this is a problem because farmers often invest their hard-earned resources into farming as a livelihood strategy and to augment food security. Therefore, if the agencies tasked to assist them are using inappropriate approaches then it puts farmers' livelihoods and food security in danger (Smith & Wollenberg, 2012; IPCC, 2012, FAO, 2014).

Research and Development agencies often come up with High Yielding maize and other crop varieties that are intended to transform the agricultural sector. However, the right approach is not about the high yields alone but also about other factors that constitute a mechanism to address the needs of farmers holistically. For example, interventions such as the Sasakawa Global 2000 where the ToT approach was effectively used to transfer High Yielding maize varieties from R&D to farmers, although farmers realized very high yields on their experimental plots, the cost of inputs was also dramatically high causing farmers to become stressed as they lost both economically and socially and eventually abandoned the intervention (Howard Crawford, Kelly, Demeke & Jeje, 2003). This goes to show that to achieve transformation, appropriate mechanisms and pathways that consider the individual farmer's ability and characteristics, perceptions, recall of adverse incidents or prior conditions are needed (Rogers, 2003, Adger *et al.*, 2009; Marshall *et al.,* 2014).

Secondly, the Diffusion of Innovations theory posits that individual adopters are influenced by certain attributes such as relative advantage, compatibility, trialability, and complexity of an innovation (Rogers, 2003). Therefore, it was common for development agents to attempt to deliberately "plan" innovation through persuasion and other instrumental top-down approaches (Leeuwis & Van den Ban, 2004). However, in practice researchers have found that besides transformation of agriculture through new technologies and inputs, there are other types of innovations that are social, institutional and communicative in nature which require different sets of factors for adoption for which the proposed attributes suggested by the Diffusion of Innovations theory may not apply (Leeuwis & Van den Ban, 2004; Scoones *et al.,* 2008; Hounkonnu *et al,* 2012; Nederlof & Pyburn, 2012; Quarmine *et al.,* 2012; Adjei-Nsiah *et al.,* 2013). For example, to address the climate change phenomenon, different types of transformation including incremental or radical changes in individual practices, institutional and social arrangements, interactions and negotiations above the farm level are needed which are not consistent with the technical input (HYV, seed, and fertilizer) based underpinnings of the diffusion theory (Andeweg & van Latesteijn, 2010; O'Brien, Devisscher & O'Keefe, 2011; IPCC, 2012, Marshall *et al.*, 2014).

Participatory approach, guided *by Participatory theory* is a commonly used Extension approach which proposes a bottom up, inclusive approach to the development process (Pretty, 1995). In theory, participatory approaches are designed to be the opposite of the ToT approach. Over time a number of participatory approaches have emerged including Participatory Rural Appraisal (PRA), Participatory Technology Development & Extension (PTD&E), and Participatory Rural Learning and Action Research (PLAR) which are all meant to empower farmers and give them a greater opportunity to impact the research agenda and process (Leeuwis & Van den Ban, 2004). However, in practice, researchers have acknowledged that besides a few successes, most participatory approaches have only been ineffective variations of the same approach with limited add-ons, which means that "*farmer participation has been bolted on to essentially old-style technology transfer approaches. The more* *transformative hopes of the … approach have often not been fully realised"* (Scoones *et al.*, 2008, p. 10).

Contract farming approach is another typology of Extension approaches identified by Davis (2008) which derives its theoretical support from the hard science of neoclassical economics and New Institutional Economic (NIE) theory where prediction and empirical testing are commonplace. Contract farming is grounded on the principle that higher productivity requires well established institutions (North, 1990). It is expected that rules and regulations, policies and arrangements that can guarantee rational agents like farmers and chain actors a certain level of protection for the enforcement of contracts and agreements, would promote higher productivity to transform the agricultural sector (North, 1990; Menard & Shirley, 2012). Yet in practice, contract farming as an Extension approach has not transformed smallholder agriculture (Davis, 2008).

Rural development approaches are the third typology of approaches identified by Davis (2008). They are usually community based development approaches which primarily rely on informal training supported by *Experiential learning theory* (Kolb, 1984), *Theory of reasoned action* (Ajzen & Fishbein, 2000), and *Social learning theory* (Bandura, 1977). The proponents of social learning theory (Leeuwis & Pyburn, 2001; Roling, 2002; Woodhill, 2002; Jiggins, 2012) often argue that individual learning is insufficient for promoting interdependence among stakeholders in developing social innovations. In theory, the goal of social learning theory is to act as a mechanism for creating joint, shared or collective cognition or perceptions instead of multiple cognitions (Roling, 2002). It has been noted that social learning allows farmers the opportunities to carry out collective experimentation. However, in practice, although stakeholders may develop coherent and complementary practices and cognition due to similar ideas, values and aspirations, their perceptions may not be “shared” leading to a situation where they may have different perceptions (Leeuwis & Van den Ban, 2004).

To overcome this hurdle, Leeuwis & Van den Ban (2004) suggest that in theory multi-stakeholder learning sessions that support both “distributed cognition” for collective action and “co-ordinated action” which is a collection of individual perceptions should be used. In practice, most rural development programmes use Farmer based organisations (FBOs) to create groups and establish multi-stakeholder learning environments to help smallholders benefit from social learning. However, in practice, it has been found that the over utilization of group methods especially in Ghana through the use of FBOs poses a threat to extension delivery (Oladele, 2013). This calls for reassessing Extension delivery approaches to encourage polycentric systems that incorporate individual learning for greater effectiveness.

To achieve transformational change, encouraging polycentric systems including the AIS approach with a greater emphasis on individual contributions towards change (Niles, Lubell & Brown, 2015; Ostrom, 2010) and using theories (Davis, 2008) of transformational change could prove valuable (Moore, 2005).

2.3.3 Paradigms of Agricultural Extension

The Extension literature shows several distinct eras and paradigms of change from as early as 1800 B.C. to the 19th, 20th and 21st centuries (Jones & Garforth, 1998; Scoones *et al.*, 2008). Today, at the dawn of the 21st century, Extension is focused on social innovations and communicative interventions (Leeuwis & Van den Ban, 2004). This is a shift from the linear transfer of technology era to empowering farmers to develop new patterns of co-ordination, co-dependent partnerships with other actors outside the farm to solve community, national, international and collective action problems that affect their production.

Most of the earlier paradigms were founded on the assumption that transferring technical knowledge and innovations to individual farmers would culminate in societal change (Nagel, 1998). Rogers' Diffusion of Innovations theory (Rogers, 1995; 2003) was a cardinal conceptual and analytical model for managing Agricultural Extension by governments, understanding innovation, guiding research and interpreting empirical evidence. It has played a major role in shaping agricultural research and practice. Ministries of Agriculture, National Agricultural Research Systems (NARS) and Agricultural Extension services in developing countries built Extension delivery programmes based on Rogers' transfer of technology paradigm (Nagel, 1998; Ruttan, 2002; Davis, 2008).

It is interesting to note that from the 1950s through the 1960s most African countries were self-sufficient in food production to the point of being net exporters of food in some cases. This was unlike the apocalyptic circumstances of famine and malnutrition that have now emerged after over five decades of agricultural research and development (Djurfeldt *et al.*, 2005). What general lessons can be drawn from the different eras, paradigms, theoretical and methodological conceptions of agricultural research and development since the 1950s? Hall *et al.* (2006) capture the evolution of paradigms from the 1950s' when the Green Revolution was introduced to the present era of Agricultural Innovation Systems (AIS) in Table 2.3. It describes the transition from National Agricultural Research Stations (NARS) set up by governments and donor agencies as the main sources and facilitators of change during and after the Green Revolution, to the Agricultural Knowledge Infrastructure System (AKIS) in the 1970s' to 1990s', and Agricultural Innovation Systems (AIS) from the 2000s' to present. Each paradigm seeks to improve on the preceding system which was found to be inadequate at improving productivity.

The purpose of agricultural Extension changed from planning capacity for agricultural research, technology development, and technology transfer in the 1950s to strengthening communication and knowledge delivery services of rural people in the 1970s, to strengthening the capacity to innovate throughout agricultural production and marketing system via innovation systems (Hall *et al.*, 2006) and value chains (Oladele, 2013). Research priorities changed from national, donor driven priority setting in the 1950s, to donor driven with participation from farmers in the 1970s to demand driven institutionalization and transformation in the 21st century. Yet, besides the littering of the term "transformation" across the agricultural research and development literature, there is little evidence of how transformation is being achieved and measured from the theoretical and methodological perspectives. Instead, there are many emerging approaches that rely on Rogers' diffusion of innovations theory but cloaked in "transformative" rhetoric.

According to Oladele (2013), the transfer of technology paradigm simplifies the interpretation of farmer actions with a built-in bias that promotes the transfer of knowledge and innovations from rich countries to farmers through the extension delivery services of poor countries which ignore the actual psychological and other constraints faced by farmers. "*The underlying assumptions were: i) The most modern is the best, there is a single frontier of world scientific knowledge, agricultural technology has global transferability irrespective of local ecological conditions; and poor-country farmers are traditional and must undergo a quantum transformation to be modern (Ellis, 1992). The transfer of technology model sees the farmer as a passive recipient of new technology. If a farmer adopts the technology then the farmer is progressive. Failure of adoption is attributed mainly to psychological factors such as irrationality, conservatism and traditionalism (Oladele, 2013, p. 11).*

Table 2. 3 Evolution of Agricultural Extension paradigms from 1950s' to present

Defining feature	NARS	AKIS	AIS
Purpose	Planning capacity for agricultural research, technology development, and technology transfer	Strengthening communication and knowledge delivery services to people in the rural sector	Strengthening the capacity to innovate throughout agricultural production and marketing system
Actors	National agricultural research organizations, agricultural universities or facilities of agriculture, extension services, and farmers	National agricultural research organizations, agricultural universities or facilities of agriculture, Extension services, and farmers, NGOs, entrepreneurs in rural areas.	Potentially all actors in the public and private sectors involved in the creation, diffusion, adaptation, and use of all types of knowledge relevant to agricultural production and marketing.
Outcome	Technology invention and technology transfer	Technology adoption and innovation in agricultural production	Combinations of technical and institutional innovations throughout the production, marketing, policy research, and enterprise domains.
Organizing principle	Using science to create inventions	Accessing agricultural knowledge	New uses of knowledge for social and economic change
Mechanism for innovation	Transfer of technology	Interactive learning	Interactive learning
Degree of market integration	Nil	Low	High
Role of policy	Resource allocation, priority setting	Enabling framework	Integrated component and enabling framework
Research priority	National mandate, donor driven	Donor driven, participation by farmers	Demand driven, institutionalization, transformation
Nature of capacity building	Infrastructure and human resource development	Strengthening communication between actors in rural areas	Strengthening interactions between actors, institutional development and change to support interaction, learning and innovation; creating and enabling environment

Source: Hall *et al.* (2006).

Rogers' diffusion of innovation theory was a relevant and dominant theory for many decades. It identified five main categories of adopters: Innovators, Early Adopters, Early Majority, Late Majority, and Laggards based on the speed by which people adopt new innovations within their social systems (Rogers, 1995; 2003). Most Agricultural Extension methods that emerged, such as the Training and Visit (T&V) approach and variants of it sought to train trainers or itinerant instructors, usually successful or experienced farmers, as opinion leaders who influence other community members by demonstrating approved techniques and disseminating useful information (Jones & Garforth, 1998; Nederlof & Pyburn, 2012).

Despite its success, there is also recognition of its weaknesses. These wide spread criticisms have led to intellectual advancement in Extension and the creation of new Agricultural Extension delivery approaches and methods as depicted in the paradigm changes in Table 2.3 (Hall *et al.*, 2006). It is sad to note that smallholder productivity remains low in spite of these methodological advancements. One of the key explanations for this phenomenon is that previous approaches derived from the Diffusion of Innovations theory were not well-suited or adaptive to farmers' needs, thereby giving way to bottom-up, people-centered alternative approaches such as the current AIS approach which promotes learning and the systems perspectives (Röling, 1992; Nagel, 1998; Hall *et al.*, 2006; Scoones *et al.*, 2008; Spielman *et al.*, 2009).

The Agricultural Innovation Systems (AIS) approach offers a promising framework for organizing and facilitating agricultural research, policy and development practice to enhance smallholder productivity (Hall *et al.*, 2006; Hekkert *et al.*, 2007; Hounkonnou *et al.*, 2012; Nederlof & Pyburn, 2012). Like prior extension paradigms, AIS seeks to bring about permanent changes in the lives of farmers and other rural and urban people. AIS promotes this change by embedding farmers, scientists, innovation brokers, and other public and private sector actors in an innovation platform (Klerkx *et al.*, 2009). Innovation platforms are specially designed constructs to foster cooperation among partners and value chain development to bring about lasting transformative change among smallholders and their livelihoods. Hall *et al.* (2006) describe an innovation system as:

"a network of organizations, enterprises, and individuals focused on bringing new products, new processes, and new forms of organization into economic use, together with the institutions and policies that affect their behaviour and performance. The innovation systems concept embraces not only the science suppliers but the totality and interaction of actors involved in innovation. It extends beyond the creation of knowledge to encompass the factors affecting demand for and use of knowledge in novel and useful ways" (p. 16).

2.3.4 Criticisms of the Agricultural Innovation Systems approach

While the Agricultural Innovation Systems (AIS) approach provides an alternative to approaches based on Roger's Diffusion of Innovations theory and places the smallholder within an enabling environment with other actors to facilitate change, the AIS approach lacks a clear theoretical foundation that can support and assess behavioural change over time. To start with, the AIS approach does not clearly identify the stages of change or address the issue of how smallholders transition from each iterative stage of change within the innovation process. The common view is that the AIS approach uses qualitative methods such as the action research approach (Lewin, 1952; Rapoport, 1970; Lincoln & Guba, 1985; Greenwood & Levin, 2007) and Soft-Systems Methodology (Checkland, 1981) as the main methodologies in researching and implementing behavioural change in the AIS paradigm. However, in practice, differences in stakeholder perceptions and levels are not captured or documented a priori to establish a clear baseline during the planning stages for the action research process.

Problem solving in the action research paradigm typically follows the constructivist view of allowing the problems to emerge during the course of the research or development interventions. This methodology or approach is based on variations of the steps for conducting action research recommended by Lewin (1946) as follows: (1) identify an initial idea, (2) carry out an exploratory or reconnaissance or fact finding study, (3) plan, (4) take an initial first action step towards a solution; (5) evaluate the outcome, (6) amend plan and (7) take a second or subsequent step. Later and more recent versions of this methodology emphasize reflection as a key component between each iterative action step taken during the course of the research and problem solving process (Schein, 1983, 1987; Greenwood & Levin, 2007). Even so, there is often a lack of measurement of the outcome per se based on a clear theoretical framework for behavioural change.

According to Checkland (1981) "*There must be an intellectual framework, declared in advance, in terms of which learning is to be defined. Without such a framework, action research can quickly become indistinguishable from mere action*" (Checkland, 1981, p. 400). Also, qualitative studies and methodologies often seek to describe, interpret and understand phenomena and do not focus on measuring aspects of the research per se especially where impact or change is concerned (Feldman, 2007). The IPCC confirms that to achieve long-term transformational change towards resilience to climate change, "the range and choice of actions that can be taken at the individuals or households are often event-specific and time-dependent" (IPCC, 2012, p. 319). Yet without a clear, time-bound tracking or monitoring mechanism to document the distinct incremental or radical changes that should or could occur in smallholders or other participants in the AIS, it would be challenging to ascertain progress, account for impact or attribute changes to the AIS approach over time.

Currently, the AIS does not explicitly disaggregate, distinguish, or document the progressive stages by which smallholder farmers transform their behaviour based on transformational behavioural change theories while engaged in the innovation process. Results or expected outcomes of interventions are documented ex ante but not based on behavioural change theory. Ultimately, this lack of measurement of behavioural change may render the AIS approach the same fate suffered by other T&V based extension approaches that were unable to overcome the attribution problem (Davis, 2008) or effectively account for transformative change in smallholders and their quest to improve agricultural productivity.

Finally, Rivera *et al.* (2006) argue that the current AIS approach lacks practical insights and needs further refinement to transform and operationalize it from a conceptual and analytical framework into robust, evidence and theory based approaches to strengthen mechanisms for agricultural innovation and transformational change. This thesis supports the views of researchers like Rivera *et al.* (2006), Hall *et al.* (2006) who advocate for the cross-fertilization of the AIS with other evidence based approaches and paradigms for greater applicability and effectiveness. This thesis specifically considers the cross-fertilization of the AIS and Roger's Diffusion of Innovations theory with a greater emphasis on aspects of Prochaska's transtheoretical (TTM) or stages of behavioural change theory. The thesis aims at contributing to the agricultural extension literature by extending both the Diffusion of Innovations Theory and AIS framework for greater applicability and effectiveness.

2.3.5 Transformation from the IPCC perspective

The Intergovernmental Panel on Climate Change (IPCC) has since its inception been a renowned authority on assessing, synthesizing and communicating new knowledge on all aspects of climate change including: scientific evidence of climate change, impacts and vulnerabilities to the earth system, climate change adaptation and mitigation (IPCC, 2007). In fulfilling its mandate, the IPCC examines all available sources of knowledge including published academic and grey-literature written in English and non-English and has so far synthesized new knowledge into five assessment reports published in 1990, 1996, 2001, 2007 and 2012 respectively.

IPCC assessment reports and systematic literature reviews serve as a key point of reference for this research. They reveal that farmers, researchers, governments, non-governmental organizations (NGOs), and others in the global agricultural research and development sector have made extensive contributions in response to emerging climate related challenges. Nevertheless, agricultural productivity in Africa is expected to deteriorate in the next decades, due to an unprecedented rate of change caused by anthropogenic factors (IPCC, 2007).

The IPCC recognizes transformation as a critical component for arresting the rapid rate of decline and for fostering climate change adaptation and disaster risk management approaches across the globe and in Africa in particular (IPCC, 2012). It defines transformation as: *"The altering of fundamental attributes of a system including value systems, regulatory, legislative, or bureaucratic regimes; financial institutions; and technological or biological systems" (IPCC, 2012, p. 439).*

Agricultural systems, ecosystem and human institutions are in a state of transition in response to changing climatic conditions as well as to system dynamics and feedbacks (Stafford-Smith *et. al.*, 2012). So far, responses to climate change have been focused on reducing vulnerability while improving response capacity, resilience and adaptation (IPCC, 2007, 2012). It is assumed that the greater the resilience and adaptive capacity of a system, the less vulnerable the system will be to harmful impacts.

The IPCC's 4th assessment report, AR4 published in 2007 identified adaptation as the most critical response to climate change. The report defines adaptation as "*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, p. 6). Globally the agricultural sector, and farmers in particular, have responded to climate change by changing planting dates, using better nutrient and water management systems, using irrigation, importing agricultural products, using drought or flood resistant varieties, patronizing climate insurance schemes and other risk transfer mechanisms, changing livelihoods, using off-farm income to supplement on-farm revenues, selling labour, migration, remittances from relatives, as well as using weather forecasts and predictions (IPCC, 2012, Wollenberg *et al.*, 2012). The fifth assessment report (SREX), highlights the need for transformation by exploring opportunities to improve learning, resilience, coping mechanisms, adaptive and mitigative capacity against climate impacts, and extreme events. The report presents an extensive discussion on the role of learning and education in achieving transformational change among smallholders and other vulnerable populations.

The report also emphasizes learning as a critical part of the long-term adaptation and transformational change process (IPCC, 2012, p. 50). Figure 4, adapted from O'Brien *et al*. (2011) featured in the SREX represents the current thinking on climate change adaptation. It proposes that individual learning fosters reflective social learning which culminates into social transformation. It assumes that climate change impacts and extreme events drive improvements in local capacity building and institutional change towards adaptation and resilience. Individual learning responses thus form a critical first step in social transformation after climate impacts are perceived.

This thesis postulates that there is a missing link between that first step of individual learning and societal transformation that should be interrogated further to achieve transformational change. Current debates recognize that there are cognitive and socially differentiated barriers to the individual learning process that hinder the adaptation process (Adger, 2009; Moser & Ekstrom, 2010; Marshal *et al.*, 2014). However, there is little understanding about how or when these barriers are overcome between the individual learning and societal transformation.

O'Brien *et al.* (2011) suggest that many people impacted by climate change, including smallholders, respond by using linear, top-down approaches, reflective social learning and, at best, some level of participation; although what is needed are changes that foster real, dynamic, transformational, multi-faceted partnerships among multi-stakeholders. The illustration emphasizes a difference between the current practice of adaptation and the need for alternative practices. This backdrop underscores the need to investigate how individual learning translates into individual transformational change and how this change is currently being measured and achieved in the literature to contribute to societal transformation.

2.3.6 State of the art literature on transformational change

In January, 2016, a systematic review protocol (DFID, 2012) was used to identify state of the art publications on the term "transformational change" (IPCC, 2012). A Scopus database search revealed 2,296 documents including eight patents written between 1972 and 2016 with the term "transformational change" either in the abstract, key words or title. They consisted of 1,532 articles, 270 conference papers, 242 reviews, 114 book chapters and 51 books. About eighty percent of these were published in the last decade, between 2005 and 2016 with the highest number published in 2013. The Scopus Web of Science database by Elsevier was chosen for this search to limit the findings to scholarly works rather than reports and other grey literature found in other databases that may not be theory driven or oriented. All available years were considered to obtain a comprehensive sample of all documents that have used the term “transformational change” over time.

Of all the 2296 documents that were found in the initial search, 827 or 36% were in social sciences, 487 or 21% were in business management and accounting, 352 or 15% were in medicine, 222 or 10% were in computer science, 215 or 9% in psychology and engineering respectively. There are a number of other disciplines with smaller fractions of which earth and planetary sciences had 69 or 3% and agriculture and biological sciences had only 63 or 2.7%. When the search is limited to the 63 documents in agriculture and biological sciences, it showed that one document, the earliest was published in 1981 and eight, the highest number, were in 2011, 2014 and 2015 respectively. When the search was limited to only agriculture, it showed that 23 documents published between 1972 and 2016 had both “transformational change” and “agriculture” as key terms. Of this 23, the earliest five were published in 2011, another five in 2012, two in 2013, five in 2014 and three in 2015.

Abstracts of the 23 documents found on agriculture were then selected for full text review based on a four-scale criterion. The selection criteria were as follows: 1) Relevance: Does the study focus on “transformational change” as a major theme in the title, abstract, or list of keywords? All other synonyms of transformation were excluded, 2) Eligibility: Was the study supported by a theoretical framework or hypothesis on how to achieve transformational change? 3) Study Design: Did the study provide an empirical framework or methodology for achieving transformational change? and 4)

Context: Was the study based on agricultural development or climate change adaptation of farmers? Ten studies that were based on carbon-cycles, description of the sugar industry in India, adaptive management from an engineering perspective, land use and political transformation, dry land pastures, efficiency in orchard systems, transformation of flavylium salts and promotion of ultrasonic treatment were excluded. The remaining 13 studies were then analyzed for insights on how other researchers suggest that transformational change can be achieved.

The findings show that most of the conceptions of transformational change as a term are linked to the IPCC (2012) conceptualization that proposes to achieve transformational change by reducing vulnerability and increasing adaptive capacity through key words like incremental, radical, anticipatory, intentional, deliberate, marginal or non-marginal transformation, adaptation and variants of it (Stanturf ,2015; Pinkard *et al.*, 2015; Marshall *et al.*, 2014; Ash *et al.*, 2012; Kristjanson *et al.*, 2012; Rickards & Howden, 2012; Van Latesteijn & Andeweg, 2011).

While all the selected publications propose a hypothesis about how to achieve transformational change, five of them explicitly identify theories that underpin the change. Sanderson *et al*. (2015) suggest the use of a “Real Options for Adaptive Decisions” (ROADs) framework, which is an extension of a theory from the mathematics of stochastic optimization usually used in agricultural economics to achieve transformational change. Rodriguez *et al*., (2014) propose the use of a “whole farm model” which is a quantitative modeling of a participatory research approach traditionally based on a qualitative or constructivist paradigm. Marshall *et al.* (2014) recommend testing an association between transformational capacity and resource dependence (Pfeffer &Salancik, 1978; Hillman *et al*., 2009) in their attempt to quantify the extent of transformational change among peanut growers in Australia. Allen *et al.*

(2014) recommend the use of a heuristic framework for exploring the aspects of transformational change, based on Social Learning theory called Social Learning for Integrated Management (SLIM). The framework incorporates local or indigenous experiential knowledge into traditional agronomic research practices. Finally, Sumberg and Sabates-Wheeler (2011) propose a theory of change to study the agricultural transformational change process associated with home-grown school feeding (HGSF) programmes.

All the documents that mentioned the term transformational change and agriculture were related to climate change. However, an article by Uphoff *et al.* (2011) is the only article which explicitly outlines how transformational change can directly improve agricultural production involving a crop variety. They suggest the use of a System of Rice Intensification (SRI) practices that farmers can follow to improve productivity in light of the climate change phenomenon. Jiggins *et al.* (2011) and Van Latesteijn, & Andeweg, (2011) propose the need for innovation in fostering transformational change in the agricultural sector to curb the harmful impacts of global environmental change and ensure sustainable development. They argue for social innovation in formal and informal regulations and institutions across all sectors in line with the agricultural innovation systems (AIS) paradigm.

Stanturf (2015) is the only article that explicitly refers to transformational change and also indicates that behavioural, institutional, and/or social barriers could impede adaptation but could be overcome by conducting "risky" research that extend the bounds of knowledge and practice to fit future conditions. None of these articles discuss using theories of transformational change per se.

Based on these findings, this thesis adopts the analytical framework used by Marshall *et al.* (2014) with some slight modification to analyze transformational change. The author is aware that besides these articles that expressly mention transformational change in the abstract, title or list of keywords and categorized as being in the agricultural subject area in the Scopus database, there are a host of other researchers like Adger *et al.* (2004), Moser & Ekstrom (2010), and Jones *et. al.* (2012), who discuss aspects of transformational change and climate change adaptation albeit under different terminology, contexts or disciplines that may be more associated with geography and migration studies, environmental science, climatology, planetary science and other fields. However, these studies are not necessarily focused on agriculture, the focus of this thesis.

2.4 Conceptual Framework

The conceptual framework shown in Figure 3 summarises and outlines the key conceptual, ideological, and theoretical underpinnings of the study to enable the empirical measurement and evaluation of constructs (Kumar, 2011). The thesis is developed around two main concepts: (1) Smallholder perceptions of climate change impacts and (2) the smallholder behavioural change process from a theoretical perspective. The study attempts to disaggregate smallholder perceptions and behavioural change using Prochaska's (1992) transtheoretical stages of behavioural change theory (TTM) which is to an extent inherent in Roger's (2003) Diffusion of Innovation theory. Although the TTM is incorporated into Roger's Diffusion theory because of its ability to explain the different stages of behavioural change from a psychological perspective, it has not been fully developed or explored as part of mainstream theoretical considerations for behavioural change in the agricultural extension literature.

The conceptual framework highlighting key theoretical and conceptual underpinings of the empirical study.

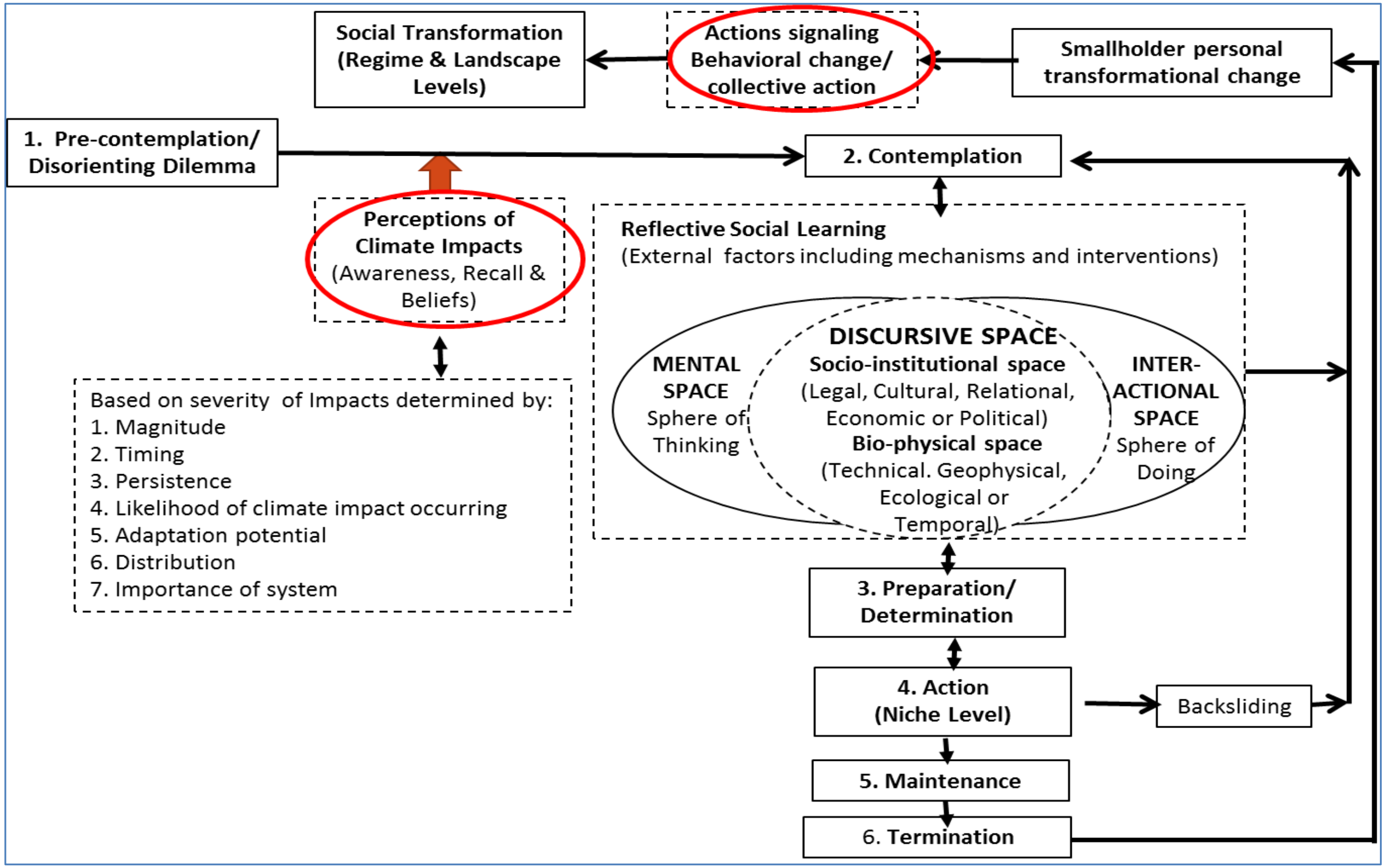


Figure 3: Conceptual framework. Authors own creation inspired by works cited.

The study is premised on the fact that climate change impacts magnify threats to smallholder livelihoods. It is well recognized that smallholder responses to climate change impacts span the gamut in diversity and scope (IPCC, 2007; 2012). However, if policy makers and others in the agricultural development and extension nexus are to address the issue of declining productivity, examining the socially differentiated pathways to the transformation from the use of manual hand dug wells to mechanized tube-well irrigation processes and their relevance to the challenges faced by smallholder farmers is imperative. Part of understanding the social differentiation amongst people is to understand the sources of psychological and cognitive differences at the individual level as a result of their perceptions. The thesis seeks to investigate the relationship between smallholder perceptions and their individual transformation process in response to climate change impacts.

What are the key constructs that will enable the measurement and evaluation of the relationship between smallholder perceptions and the transformation process? According to DuSautoy (1962), "*a crop failure is merely a statistic to the government: to a village it is its livelihood*" p.837). A loss of livelihood does not only represent a loss in the time and efforts spent on cultivation but also a loss of a means of survival: food, income, savings, assets and access to resources (Chambers and Conway, 1991). In the 21st century, loss of livelihoods through climate change impacts such as drought, floods, incidence of pests, crop failure and other climate change impacts still inflict a painful and traumatic experience on those affected (McNamara & Westboy, 2011).

Niles *et al.* (2015) assert that "*farmers perceive and respond to climate change in part due to their personal experiences with climate change and the limiting factors within their system* [including]…*historical climate changes, agro-ecological contexts, infrastructure and adaptation capacity* (p.178). Similarly, Adger *et al*. (2009) posit that "social limits" to smallholders which are "*endogenous to society and hence contingent on ethics, knowledge, attitudes to risk and culture*" (p. 335). This suggests that individual perceptions, consisting of their experiences and recall of historical climate events are important cognitive and psychological factors that influence responses and changes in behaviour along the behavioural change process while knowledge, attitudes and culture are mediums for facilitating change.

Traditionally, Agricultural Extension has been concerned with education comprising of both teaching and learning processes aimed at producing changes in human behaviour in three main areas:*" changes in* ***knowledge*** *or things known, changes in* ***skills*** *or things done* (**practices**), and *changes in* ***attitudes*** *or things felt"* (Dunsberry, 1966, p. 853). These are commonly referred to by the acronym "KAPS" in Extension education and practice. Changes in knowledge can be broad pertaining to different types of knowledge.

Knowledge is also defined as "*the facts or experiences known by a person or group of people; the state of knowing; consciousness or familiarity gained by experience or learning; erudition or informal knowledge; specific information about a subject,"* [while to know is defined as] "*…to understand, be aware of, or perceive; to be sure or aware of; to experience, especially deeply; to be intelligent, informed, or sensible enough, to be able to distinguish or discriminate…*" (Collins Dictionary, 2005, p. 882).

Thus in essence, knowledge has to do with awareness, acquisition of experience, certainty about perceived facts and information that helps in distinguishing, discriminating and making judgments. Similarly, Leeuwis and van den Ban define knowledge as, "*the basic means through which we understand and give meaning to the world around us*". Jones, Datta and Jones (2009), refer to knowledge as a practical, empirical, context-specific or theoretical interpretation or understanding of a subject or issue which may be derived from formal and informal sources of understanding, like experience.

Nyirenda-Jere and Kazembe (2014), report that there are two main types of knowledge: tacit and explicit although there are several others such as formal, informal, indigenous or traditional, participatory or citizen's, project, programme or research knowledge, all of which overlap and fall within these two broader categories of knowledge. Explicit knowledge is defined as *"knowledge that can be consciously understood and articulated"* whereas tacit knowledge is defined as "*knowledge that the knowledge holder is not aware of; expressed through experience"* (Nyirenda-Jere & Kazembe, 2014, p. 10).

For smallholders, explicit knowledge will include learned and codified knowledge that is expressly stated, obtained from agricultural extension agents, input dealers and others educating them about specific techniques. Tacit knowledge would be "*practical know-how that is not easily expressed or stated*" (Wagner, 1991, p. 173). Tacit knowledge would include those pieces of knowledge obtained through their own trial and error experiences or passed down from ancestors through observation, oral tradition, cultural traditions, customs and beliefs which they cannot explain based on underlying principles but are practical unconscious knowledge (Giddens, 1984; Leeuwis & van den Ban, 2004; Jones *et al.*, 2009).

Whether explicit or tacit, knowledge is stored in memory. According to de Jong and Ferguson-Hessler (1996), besides the epistemological and ontological differences in classifying knowledge, memory plays an important part in determining the different dimensions of knowledge. They argue that a key differentiator between an expert and a novice is not that one has a more superior mind but rather differences in the system or method of storage and recall of large amounts of knowledge in memory differs between an expert and a novice. Thus, it is expected that recall can be a key variable in determining social, psychological and cognitive differentiation. They posit further that knowledge can have different dimensions in terms of quality or depth and structure ranging from a surface level to really deep, unstructured to highly-structured knowledge.

De Jong and Ferguson-Hessler (1996) also emphasise the fact that knowledge can be strategic or domain specific. Domain specific knowledge can then be declarative or factual, procedural or conditional. Finally, they elaborate on four distinct types of knowledge that they deem appropriate for problem solving. These are: situational knowledge, procedural knowledge and strategic knowledge. The point of this thesis is not to classify, explain, distinguish or interrogate the differences in knowledge but to acknowledge that there are different types and dimensions of knowledge. What is of relevance in this thesis is that in solving problems, both experienced experts and inexperienced people or novices rely on different types of explicit and tacit knowledge that are stored in memory and are therefore dependent on recall.

Research has shown that observation and recall play a central role in teaching and learning of indigenous knowledge. Mudege (2007) reports that in certain villages in Africa, *"When cattle are being treated or given preventative*

> *chemicals, men and boys in the village congregate at the cattle kraals to observe the whole proceedings. Sometimes even small boys, who are too young to be of help, are invited to observe so that if they ever face that same problem in the future, they will recall the knowledge of their fathers"* (p. 119).

Therefore, in dealing with behavioral change and practices of smallholder farmers in the face of climate change, what they recall cannot be ignored. Some may recall knowledge and responses from the past to inform current decisions, actions and behaviours (Monroe, 2014; Mudege, 2007). This is why recall was included in this study as an important variable in determining the perceptions of smallholders.

Besides recall, smallholder belief systems cannot be ignored and should be understood by experts and other development workers who intend to encourage behavioural change (Leeuwis & van den Ban, 2004; He *et al.*, 2010). In this thesis, the term "belief" is used as a proxy for measuring the underlying belief systems that people may have. The Collins English Dictionary defines belief as "*a principle accepted as true, especially without proof; opinion; conviction; religious faith; trust, confidence*" (Collins Dictionary, 2005). People can indeed accept their own opinions as fact based on experience and circumstances even if they are not theoretically proven or accurate. Leeuwis and van den Ban (2004) present a model that states that "*what farmers and other human beings do or do not do depends on what they: BELIEVE TO BE TRUE about the biophysical and social world (i.e. what they know); ASPIRE to achieve (i.e. what they want); think they are ABLE to do; and what they think they are ALLOWED and/or EXPECTED to do"* (Leeuwis & van den Ban, 2004, p. 65). Thus, beliefs and the recall, cognitive and psychological processes that guide what people think are very pivotal to what behavioural changes they pursue.

According to He *et al. (*2010), beliefs are "*ways in which people structure their understanding of reality [about] what is true and what is false"* (p. 928). They posit that although different people hold different attitudes, beliefs and values, which are learned psychological constructs, the beliefs people hold are primarily founded on previous experience. In contrast, Values are defined as "***behavioral ideals or preferences for experiences*** *[that] function as enduring concepts of good and bad, right and wrong*" (He *et al.*, 2010, p. 928). They posit that values contribute to a person's self-identity or concept of self whereas attitudes are "*learned predispositions to respond to a person, object, or idea in a favorable or unfavourable way*". Therefore, in comparing beliefs, attitudes and values in relation to behavioural change, they conclude that on a continuum of least to most lasting, attitudes are the most fleeting or ephemeral - most likely to change and least enduring whereas values are the most lasting or enduring behavioural traits and least likely to change over time. Values are the cognitive and psychological maps and compass that shape the enduring long-term pathways along the transformational behavioural change process.

Although beliefs may be derived from knowledge and experiences, in this thesis, beliefs are considered to be different from knowledge because beliefs can be derived from a variety of sources including experiences and values and not just knowledge alone. According to Mudege (2007),

> *"Frequently, people's beliefs can prevent people from adopting - or sometimes encourage them to adopt - certain behaviours. It is important then for rural development workers to understand the belief systems of the people they work with, since this will enable them to negotiate the beliefs and changes in behaviour without antagonising people"* (p. 122).

In this research, it is important to understand smallholder belief systems not only to avoid antagonizing them, but also to understand the subtle socio-cultural and socio-psychological, value driven notions that inform their tacit knowledge that contribute to their perceptions of climate change impacts and their stage in the transformational change process. In this research, explicit knowledge is captured or operationalized through a variable called "**awareness**" while values, subtle culture induced dispositions and the tacit knowledge that drive or informs their attitude to do something in a particular way, are captured through a variable called "**beliefs**".

Over the last half century, the agricultural extension research and practice have evolved from change at the individual level to social change. Consequently, agricultural research and practice have been guided by a number of approaches ranging from ‘Instrumental or Persuasive’ to ‘Interactive or Communicative’ approaches to effecting behavioural change. Roger’s Diffusion of Innovation theory (Rogers, 1995; 2003) is a hallmark of the theories that have guided Instrumental or Persuasive approaches while Communication theory, Learning theory, Social learning theory, Cognition dissonance theory, and Negotiation theory are examples of theories that have guided the Interactive or Communicative approaches (Leeuwis & van den Ban, 2004). The concept of ‘Social learning’ which is embedded in most of the Communicative approaches is used to investigate learning processes to solve problems amongst groups of individuals, communities, and members of social systems as a way of facilitating social transformation (Wildemeersch, 2007). These communicative theories were examined and considered but not found to be suitable for achieving the objectives of this research which were aimed at understanding the relationship between perceptions and the individual transformational change process.

He *et al. (*2010) analyzed a number of theoretical models related to attitudes, beliefs and values that motivate individual behavioural change. These theoretical models include: the Attitude Model, Rational-Economic Model (REM), Information Model, Positive reinforcement (PR), Elaboration Likelihood Model (ELM) and the Transtheoretical Model (TTM). They found that most of these models do not give a comprehensive view of the different stages of the individual transformational process and more importantly have a mechanism for distinguishing less durable change from more durable or enduring transformational change. They argue that a theory that seemed to capture the notion of enduring change systematically in its entirety and scope was the transtheoretical model or Stages of Change theory. This research therefore follows the He *et al. (*2010) in selecting the transtheoretical or stages of change theory for this reason.

The conceptual framework attempts to synthesize and operationalize all of these concepts about awareness, recall and beliefs to link smallholder perceptions to the transformational change process. It serves as a heuristic framework that merges the concept of individual cognitive and psychological transformation through perception with climate change adaptation (O'Brien, 2011), and the transtheoretical or stages of individual behaviour change model (Moore, 2005), with the social and socio-technical transformation processes (Geels, 2002; 2007) illustrated in Figure 3.

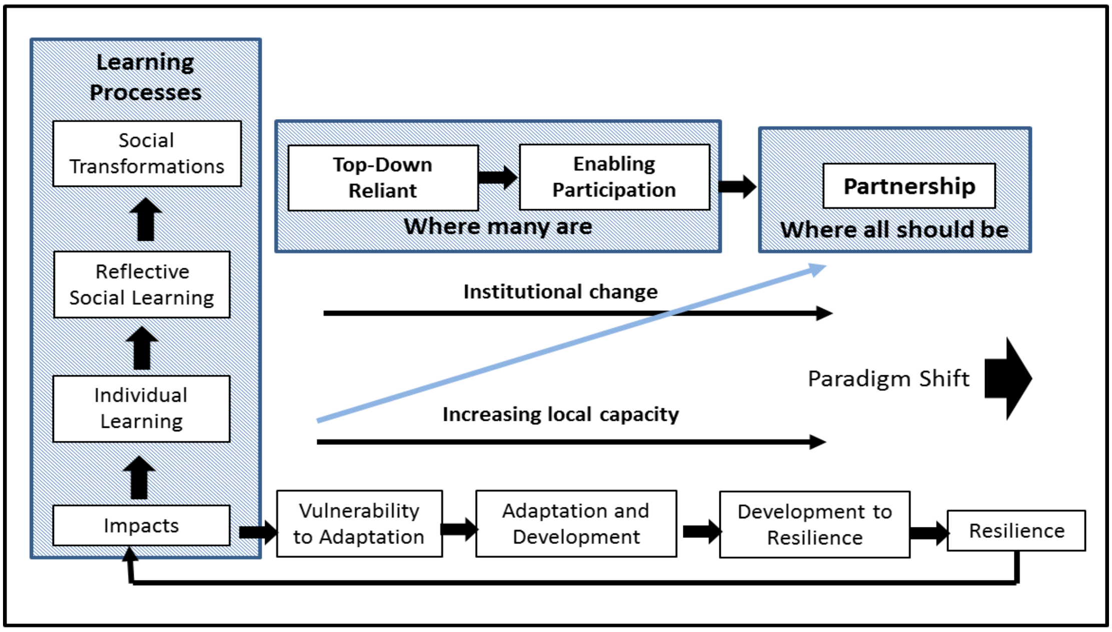
The IPCC's fifth assessment report (SREX) (IPCC, 2012) presents current knowledge on climate change adaptation, and social transformation in a model by O'Brien *et al.* (2011) which merges climate change adaptation and disaster risk management research. (Figure 4). The model proposes that once people become vulnerable, they adapt to climate impacts and once they adapt it leads to resilience. Resilience is said to have a direct influence on climate change impacts. In looking at the model, a number of questions arise. Do all people perceive impacts equally or feel equally vulnerable? Do people necessarily go straight from feeling vulnerable to adapting or are there different stages in between? Do people have different options (mechanisms) and pathways which determine individual responses which culminate into societal and social transformation?

While there has been extensive research on climate change adaptation, there are still many unanswered questions and a lack of consensus about how the transformational process occurs (Ostrom, 2010; O'Brien, 2012). Little evidence exists on how the inconsistencies between theory and practice of transformational change affects stakeholders (Sumberg & Sabates-Wheeler, 2011) especially smallholder adaptation to climate change impacts. O'Brien (2012) calls for "*developing a critical body of research on deliberate transformation as a response to global environmental change*" (p. 667). This body of knowledge can build on existing theories such as Rogers' Diffusion of Innovations theory and the theories of transformational change.

The Diffusion of Innovations theory is perhaps one of the most comprehensive theories on adoption and change, yet it is deficient in explaining how smallholder transformations from a psychological and cognitive perspective. Theories of transformation which underpin innovation suggest that people respond to situations based on their knowledge, perceptions, frames of reference, and habits of mind (Rogers, 2003; Mezirow, 2000), and may in fact retrogress or backslide along the way (Prochaska, 2000; Moore, 2005); however, little research exists about how the process occurs when climate impacts are concerned.

This thesis hopes to illuminate possible linkages between smallholder perceptions of climate change impacts and existing theories of transformational change and also contribute to discussions on extending Rogers' Diffusion of Innovation Theory from socio-psychological and cognitive dimensions to help predict transformational change. It is expected that such perspectives would enhance the development of mechanisms to safeguard farming industries and the livelihoods and food security of smallholder farmers in Africa. The following illustrations highlight the current model of transformational change, which elaborates the views of O'Brien *et al.* (2011) as cited by the IPCC (2012) as well as a series of illustrations which culminate into the proposed conceptual framework for this study in Figure 3.

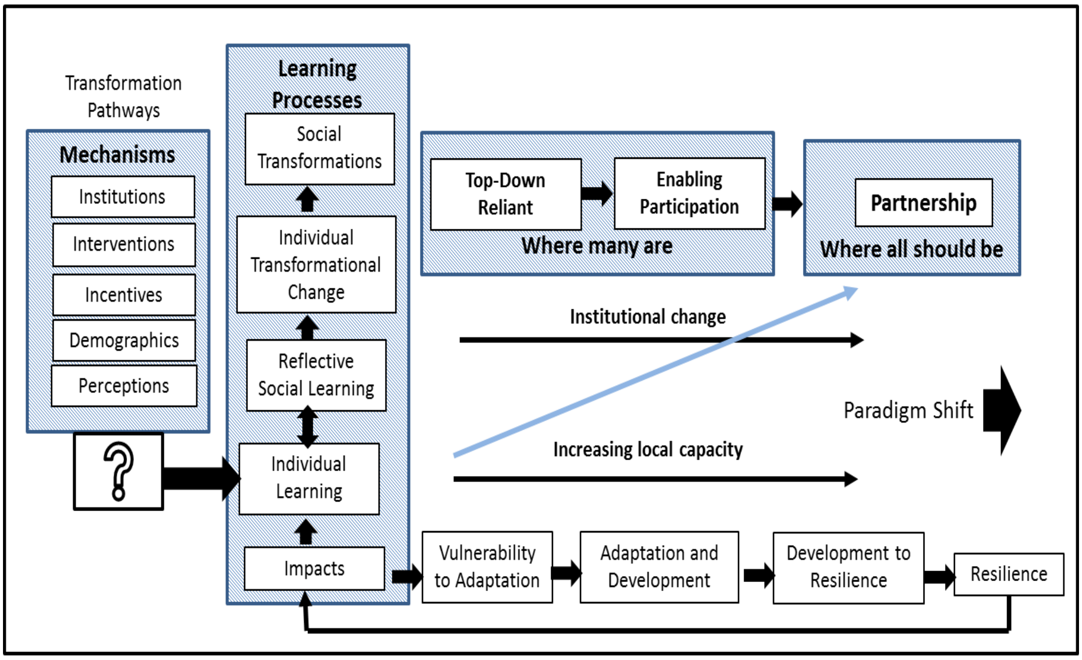
A model of transformational change suggested by O'Brien *et al.* (2011).



Source: O'Brien *et al.*. (2011) as cited in IPCC , 2012, p. 324

Figure 4: Model of learning and transformational change presented in IPCC SREX.

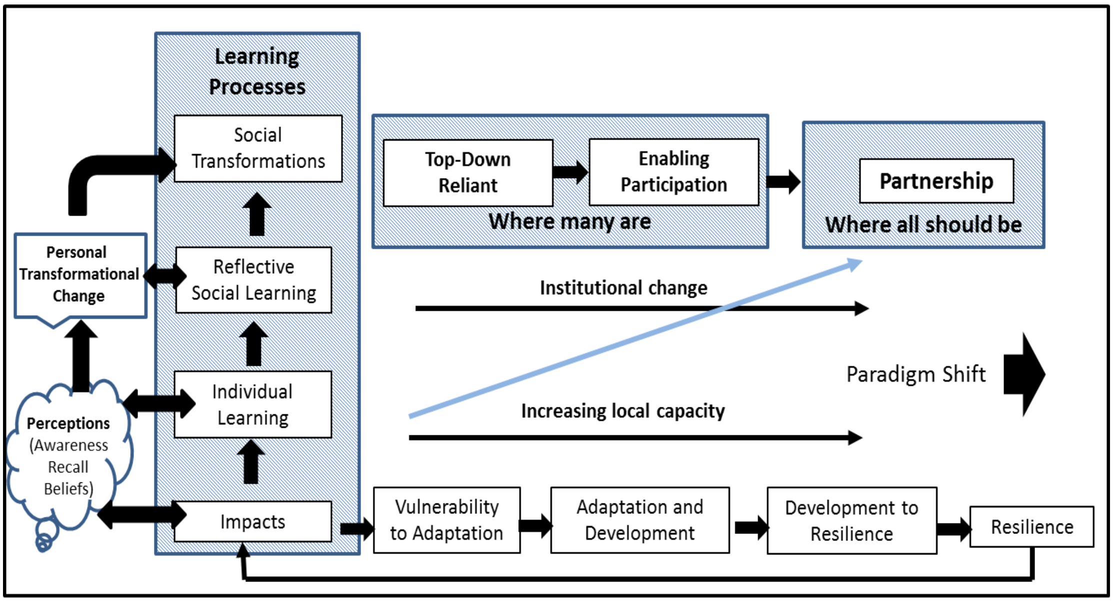
It is well recognised that various mechanisms in the form of agricultural interventions (Djurfeldt *et al.*, 2005; Hall *et al.*, 2006; Scoones *et al.*, 2008), market and social institutions, incentivess (North, 1991; Smelser & Swedberg, 2005; Hounkonnu *et al*, 2012; Nederlof & Pyburn, 2012; Quarmine *et al.*, 2012; Adjei-Nsiah *et al.*, 2013) and perceptions (Mudege, 2007; Adger et al., 2009; Spence *et al.*, 2011; Hansen *et al.*, 2012) affect individual learning and thereby transformation. However, how these mechanisms impact the smallholder transformational process is not yet well understood (Adger et al., 2009; Ostrom,2010; Niles *et al.*, 2015). Therefore, the focus of this research was to find out how available mechanisms impact transformational change processes and pathways of smallholders as shown in Figure 5.



Source: Author's own illustration adapted from O'Brien *et al.*. (2011) as cited in IPCC , 2012, p. 324

Figure 5: Mechanisms on smallholder transformational change processes.

According to Hansen *et al.*, (2012) perceptions are of practical importance because they relate to a person's ability to recognize long-term climate change and appreciate the need to take actions to curb emissions and negative human induced climate change impacts. Thus. factors leading to social, cognitive and psychological barriers are linked to perceptions hinder transformational change at the individual level (Adger et al., 2009; Niles *et al.*, 2015). Thus, from a theoretical and empirical perspective, the study sought to investigate perceptions at the individual or personal level and incorporate it into the existing framework for transformational change as shown in Figure 6.

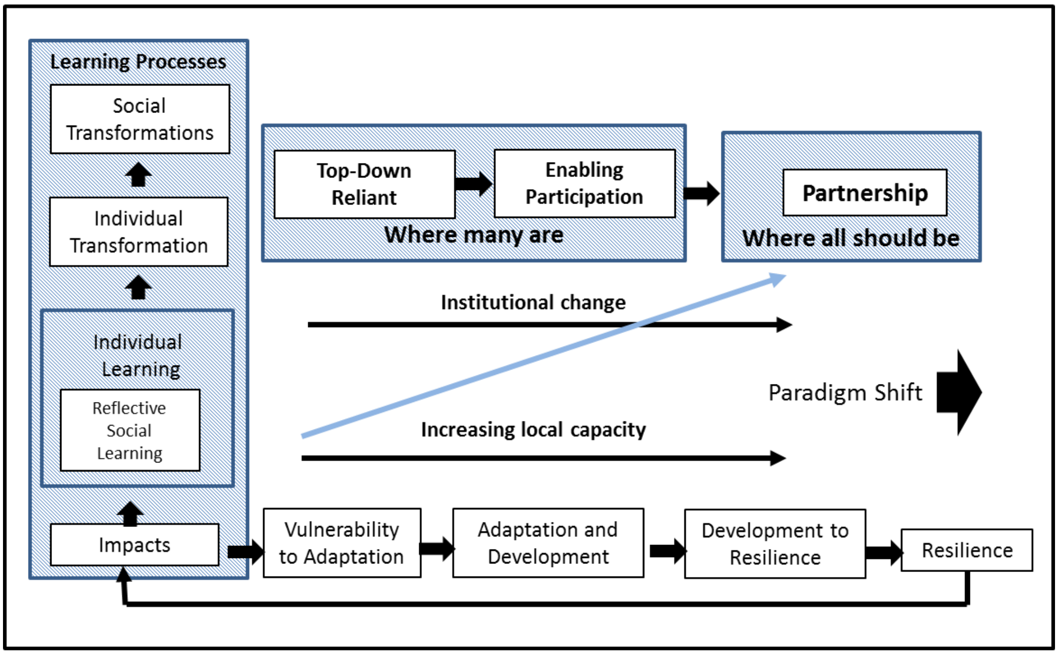


Source: Author's own illustration. Adapted from O'Brien, et. al. (2011). How do individual perceptions contribute to personal transformational change which then shapes social transformation during the climate change adaptation process?

Figure 6: Incorporating perceptions and personal transformational change.

This research thus probed for new insights into the relationship between perceptions such as awareness, recall and beliefs and the stages of smallholder transformational behavioural change process in climate change adapation. This thesis argues that to improve agricultural productivity, there is a need to assess if mechanisms and pathways designed by agricultural research, extension and education involving individual and social reflective learning explicitly lead to individual transformation and are not just assumed to do so. The study therefore sought to unravel how individual perceptions such as awareness, recall and beliefs affect the individual learning process as depicted in Figure 7.

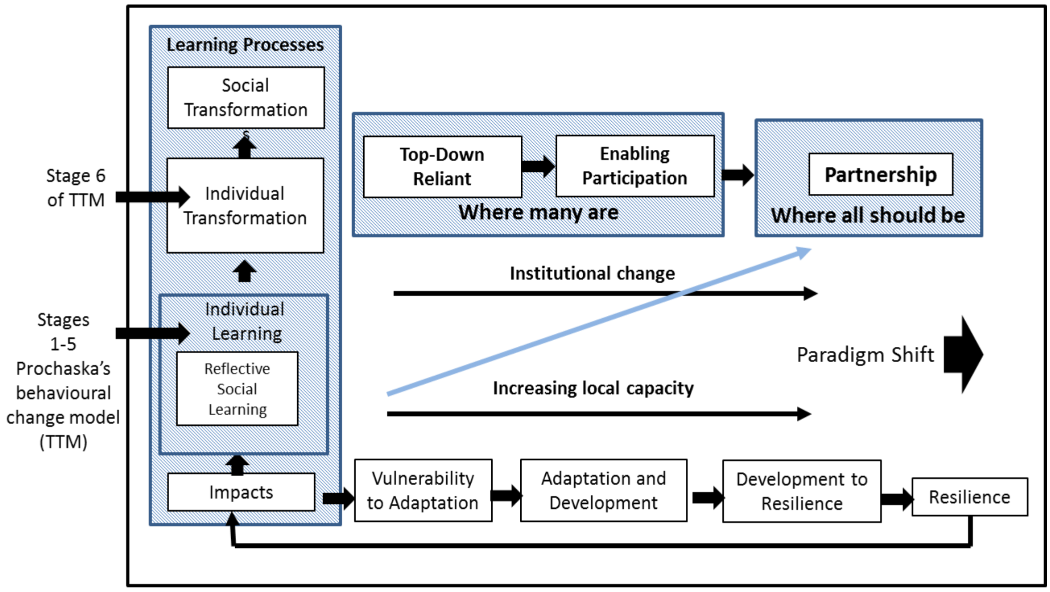
As per the theories of transformational change (Moore, 2005), it also maintains that monitoring and tracking the personal or individual transformation process is a precondition for achieving societal transformation as shown in Figure 7. Another dimension of the argument is that reflective social learning does not occur as a stand-alone exercise after individual learning occurs as proposed by O'Brien *et al.* (2011) but rather occurs through an iterative process within the individual learning process (Moore, 2005) as illustrated in Figure 7.



Source: Author's own illustration adapted from O'Brien *et al.* (2011) as cited in IPCC , 2012, p. 324

Figure 7: Reflective social learning within individual transformation process.

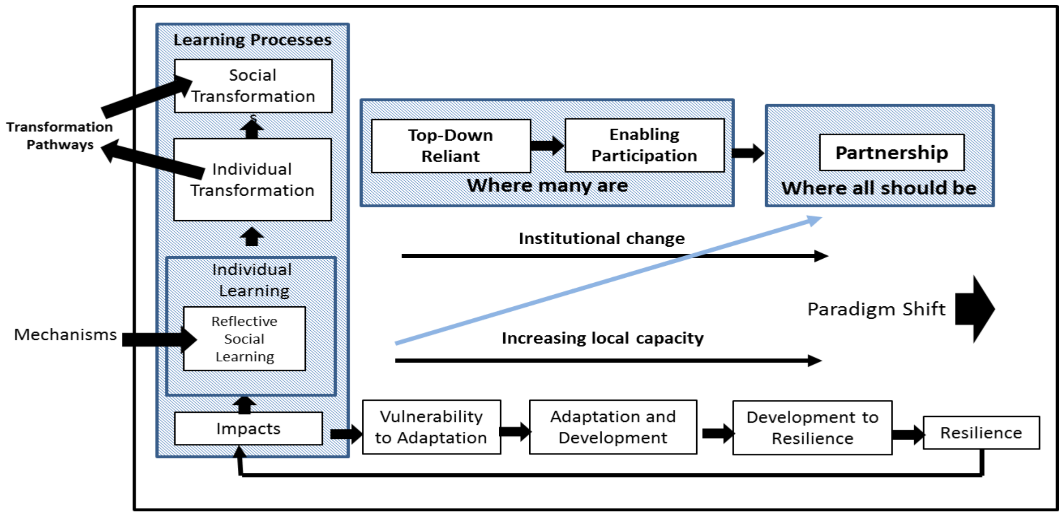
The proposed conceptual model for this study, on which the empirical work is based, incorporates three main concepts into the framework for transformational change proposed by O'Brien *et al.* (2011). The six stages of the transtheoretical or stages of change model form the main theoretical framework that underpins this study as shown in Figure 8.



Source: Author's own illustration adapted from O'Brien *et al.* (2011) as cited in IPCC , 2012, p. 324

Figure 8: Incorporating 6 stages of transtheoretical theory into O'Brien framework.

Ultimately, the stages of change culminate into individual transformation which then influence transformation pathways at the societal level as in Figure 9.



Source: Author's own illustration adapted from O'Brien *et al.* (2011) as cited in IPCC , 2012, p. 324

Figure 9: Individual transformation, a precondition for societal transformation

Figure 10 shows a summary of key dependent and independent variables indicating actions signalling transformational change used to determine the latent variable of transformational change for purposes of this study.

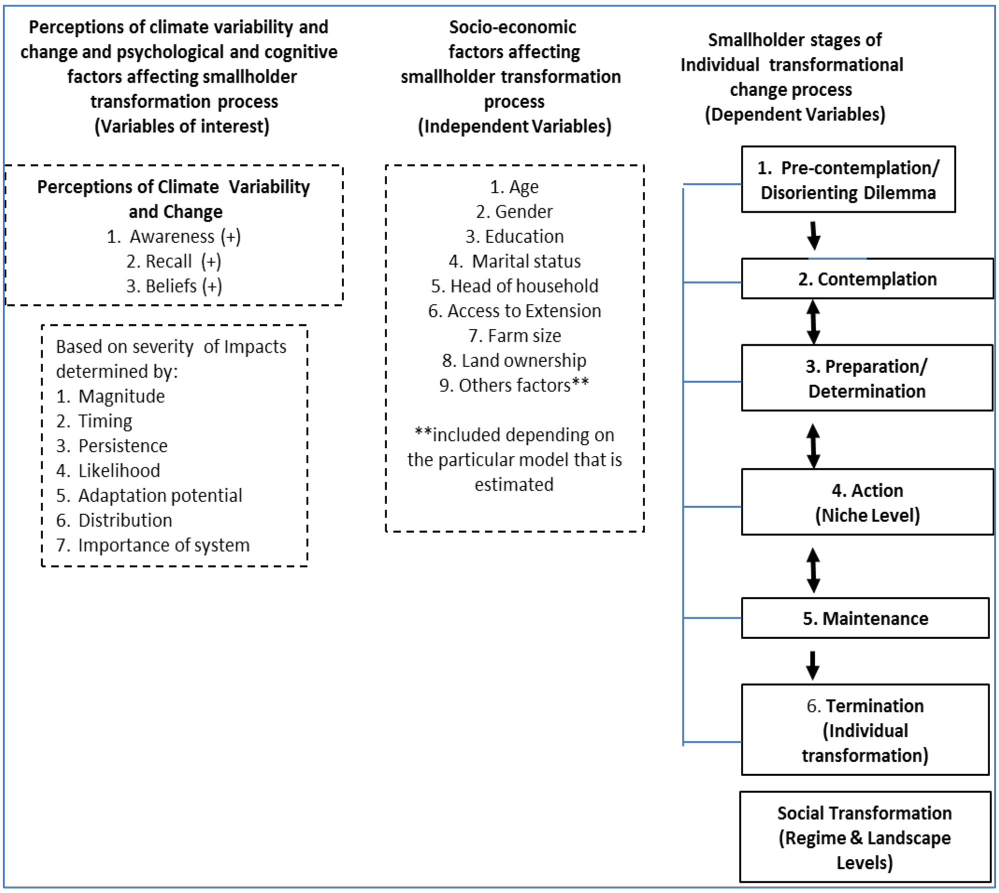


Figure 10: Key dependent and independent variables in conceptual framework.

Finally, all the key concepts and variables are put together in a conceptual framework to show the sequence of the transformational change process as proposed by this thesis. It includes (1) The six stages of the transtheoretical or stages of change model which forms the main theoretical framework that underpins this study (2) Elements of the discursive space by Leeuwis and Aartes (2011) which represent how external factors, intermediation mechanisms, like extension services, interactions with other members or actors in the social system, influence individual learning during the contemplation stage; and (3) Smallholder perceptions of climate change impacts. The arrows indicate explicit and implicit assumptions connecting the variables and concepts under investigation as shown in the conceptual framework.

2.5 Definition of Key Terms

2.5.1 Climate Variability and Change

Climate is typically defined in the Soil Atlas of Africa, as the weather averaged over a period of about thirty years (Jones *et al.*, 2013). By extension, climate change is defined as "any change in climate over time, whether due to natural variability or as a result of human activity" (IPCC, 2007, p.6). Climate change is also defined as: *"A change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcings, or to persistent anthropogenic changes in the composition of the atmosphere or in land use"* (IPCC, 2012, p. 3).

Similarly, the United Nations Framework Convention on Climate Change (UNFCCC) defines climate change as "change in climate that is directly or indirectly attributed to human activity that alters the composition of the global atmosphere and that is in addition to natural climate variability observed over comparable time periods" (IPCC, 2007, p.6). In this thesis, change in climate that is due to naturally or anthropogenic factors occurring over short time periods is referred to as "climate variability" whereas "climate change" refers to change in climate that is caused by both natural and human-induced or anthropogenic factors over long periods of time (IPCC, 2007, p.6). Some of the natural causes of climate variability include the natural weather systems and cycles related to the provision of ecosystem services. Biological systems responsible for plant growth, the formation of soil, marine and fresh water hydrology, forest systems and the provision of other eco-system services all affect micro-climate conditions and thereby climate variability. Anthropogenic drivers of climate change include: demography, land-use change, cultural practices, agricultural production, and technological advancement (IPCC, 2007, p. 115; Rosenzweig *et al*., 2007).

A climate change impact is defined as a "specific change in a system whether harmful or beneficial caused by its exposure to climate change" (IPCC, 2007, p. 781). Climate impacts include changes in rainfall pattern, increasing air and water temperatures, sea level rise and increase in the incidence of droughts, floods and disease outbreaks (IPCC, 2007). According to the IPCC (2007) the degree of climate change impact is determined by magnitude, timing, persistence, likelihood, adaptation potential, distribution of impacts and importance of the system(s) being impacted (Mendelsohn *et al.* 2000a, b; Stige *et al.*, 2006). It is assumed that a person who becomes aware of climate change or has any perception of climate change impacts would have come to this realization because of one of these seven determinants of climate change impacts suggested by the IPCC.

2.5.2 Climate change adaptation

Climate change adaptation or simply adaptation refers to adjustments in natural or human systems in response to actual or expected climate stimuli or effects, which moderates harm or exploit beneficial opportunities (IPCC, 2012). According to the IPCC (2007) various types of adaptation exist including anticipatory, autonomous, and planned adaptation. Anticipatory adaptation is also called proactive adaptation. It occurs when people deliberately make adjustments before impacts of climate change are observed. Autonomous Adaptation is also referred to as spontaneous adaptation. It does not necessarily constitute a conscious response to climatic stimuli but is triggered by ecological changes in natural human systems. It is recognized that anticipatory, autonomous, and planned adaptation can occur under various circumstances; however in this thesis the term adaptation is used to refer to adaptation in general comprising any of these types. This is because whether anticipatory, autonomous, or planned, the thesis seeks to establish the link between perceptions and the adaption process. The study also uses the term adaptation synonymously with transformation but with the understanding that adaptation can occur to various extents but that transformation refers to a more complete or ultimate form of adaptation.

2.5.3 Climate-sensitive agricultural practices

Leeuwis and van den Ban (2004, p. 61) describe "practices" as recurrent patterns of human behaviour or actions over a period of time. The IPCC (2007) defines climate-sensitivity as reacting to elevated temperatures that would arise if CO_2 levels double above pre-industrial levels. By extension, in this thesis, climate-sensitive agricultural practices refer to the recurrent patterns of behaviour that occur in smallholder farmers, whether consciously or sub-consciously, in response to rising temperatures and other conditions that are induced by rising climate change related CO_2 levels in the atmosphere.

The IPCC (2007, 2012) presents a plethora of existing literature on adaptation and mitigation of climate change in the agricultural sector. Rather than a separate set of practices, mitigation is increasingly seen as a necessary component of the adaptation process (Marshall *et al.*, 2014). Therefore, this thesis will not deliberately highlight distinctions between the adaptation or mitigation practices of farmers. Instead, the thesis focuses on how smallholder perceptions contribute to behavioural change in general, be it adaptive or mitigative, and the impact of these practices on agricultural productivity, food security and better livelihoods. Smallholder behavioural change is analysed from three main angles to establish how transformational change occurs at the individual level. The three angles are conceptually, theoretically and statistically.

2.5.4 Transformational change

Although smallholder transformation may be a latent phenomenon, transformation of their old and current practices into new patterns of behaviour and actions are observable and can in principle be measured to track productivity. The special report on managing the risks of extreme events and disasters to advance climate change adaptation (SREX) published by the IPCC in 2012 is one of the most comprehensive reviews of new knowledge to date on climate change based on articles and other materials published up to May, 2011. It shows a shift in current debates from adaptation to achieving "transformation" within the "adaptation process", to protect the earth system from climate change impacts and extreme events.

Although the concept of achieving "transformation", "transformational", or "transformative" change in agriculture is not so new, it has re-emerged as a popular, if not dominant, cross-cutting theoretical and ideological option for agricultural development, particularly in relation to climate related risks and vulnerabilities. Calls for transforming agricultural practices and systems in response to climate change abound. The literature suggests three main categories of changes needed to combat climate change: (1) incremental changes, (2) radical changes and (3) both radical and incremental occurring simultaneously. In this thesis, transformational change is defined as *the process of achieving fundamentally different and irreversible innovation at the individual or system level by harmonising perceptions, experiences and aspirations with available resources at an ecologically sustainable pace* (Author's own definition).

This definition is coined with inspiration from the works of previous researchers: Roling & Jiggins (1997), Leeuwis & van den Ban (2004), Geels & Schot (2007), Andeweg and van Latesteijn (2010), Ostrom (2010), O'Brien (2012), Wollenberg *et al*. (2012), Marshall *et al.* (2014) and the IPCC (2007; 2012) who explicitly or implicitly advocate for a fundamentally new and radical approach to framing, researching and ensuring productivity in the agricultural sector.

This definition is also consistent with the IPCC synthesis of literature which presents evidence that “actions that range from incremental steps to transformational changes are essential for reducing risk from weather and climate extremes” (IPCC, 2012, p. 439).

2.5.5 Mechanisms

It is well recognized that “mechanisms” are needed to engender transformation across all scales and spheres of society including the agricultural sector (Adger et al., 2004; Beddington et al., 2012). However, the term “mechanism” is often used in context and is seldom explicitly defined in literature. For example, according Pike et al. (2010), to change perceptions and behaviours that drive global warming and thereby climate change, leaders and policy makers everywhere must “become aware of and utlize the fundamentals of effective climate communications, outreach and behavioral change mechanisms” (p. 5). Here the term “mechanism” is not explicitly defined but rather defined in the context of “behavioral mechanism” to mean changes in beliefs, assumptions and thoughts about climate change. Similarly, Boyd et al. (2004) who assess the effectiveness of the Clean Development Mechanism (CDM) in achieving sustainable development, describe a mechanism as a cost-effective “market based mechanism” or “instrument” used to reduce or regulate the level of emissions in developing countries. There are also many uses of the term across other academic disciplines in the natural sciences. As a result of the contextual nature of the use of the term, for the purpose of this thesis, a dictionary definition of mechanism is used with the understanding of Boyd et al. (2009) who refer to it as an instrument. Therefore, a mechanism is considered to be “*an assembly of moving parts* [ideas, theories, programmes, interventions, Agricultural Extension approaches] *performing a complete functional motion, often being part of a large machine* [effort, goal, agenda, programme]*; a linkage; the agency or means by which an effect is produced or a purpose is accomplished; the structure or arrangement of parts of a machine or similar device, or of anything analogous; routine methods or procedures; techniques"* (Random House Dictionary, 2016).

2.5.6 Pathways

A pathway is defined as a "*track which a person can walk along; a set of actions that you can take in life*" (McIntosh, 2013, p.1124). The agricultural extension literature identifies several innovation pathways that have been used to solve the issue of low productivity in the agricultural sector. Similarly, a few distinct pathways can be traced through the climate change literature to show the paths taken by various stakeholders as shown in Table 2.1.

2.5.7 Institutions

Conventionally, human nature, the activities of firms, markets and social mechanisms are thought to be at the core of most economies (Coase, 1937) while social structures or institutions such as formal and informal rules and regulations, property rights, laws, constitutions, traditions, customs, taboos, modes of conduct (North, 1990, 1991) and social relations (Granovetter, 1973, 1995; Geels, 2007; Smelser & Swedberg, 2005) shape pathways to socio-economic transformation and wellbeing. Yet in recent decades, the unprecedented rate of climate variability and anthropogenic climate change has emerged as a critical threat to the stability of livelihoods, food security, and general wellbeing of economies (Beddington *et al*., 2012).

2.5.8 Perceptions

Based on behaviourist theories of behavioural change (Bandura, 1977); it is assumed that behavioural actions are triggered by external stimuli such as perceptions. In this research, smallholder farmer perceptions are operationalized by measuring their level of awareness, recall and beliefs about climate change variability and impacts. Awareness is thought to be the knowledge, information, or data that constitute a person's understanding of the world that may be learned from others or developed innately (Bandura, 1977; Blackmore, 2007) which then becomes reflected in adaptive behaviour (Pauw, 2013). Recall is measured as the knowledge, information, or data that indicates the level of understanding or experience of climate change, which may have been acquired at a prior time but kept in memory and recounted from the past. Recall could reveal if problems have been encountered before or if the emerging phenomenon is entirely new, unfamiliar or unprecedented. According to the IPCC (2012), beliefs and prior experiences with disaster influence proactive behaviour in preparedness towards future disasters.

Beliefs are deeply rooted conceptions of social norms or values about what is good or bad. Beliefs are closely linked with local social norms, values, ethnicity, culture and population characteristics (Tanner & Mitchell, 2008). Belief systems may influence how local people respond to situations determine degree of self-efficacy in taking charge of situations, finding solutions, engaging passively, or transitioning/ interacting across different spheres and time horizons (O'Brien & Sygna, 2013). Beliefs may also drive speculation, rational or irrational attitudes, as well as different dispensations towards risk, all of which influence the transformation process (IPCC, 2012).

2.6 Theoretical framework

The entry point of this research is that agricultural Extension and the transformational change process are theory laden praxes. Improving either thus requires investigations into their underlying theories. Traditionally, agricultural extension has been supported by a broad range of theories from psychology, rural sociology, economics and education such as Experiential learning theory (Kolb, 1984), Diffusion of innovations theory (Rogers, 1962, 2003), Social learning theory (Bandura, 1977), Theory of reasoned action (Ajzen & Fishbein, 2000), Participatory theory (Pretty, 1995), Network theory (Granovetter, 1973; 1995), and Negotiation and mediation theory (Pruit & Carneval, 1993), to name a few. Most extension delivery methods have been guided by these theories although Roger's (2003) Diffusion of Innovations theory has been dominant.

Besides the IPCC's fifth assessment report (SREX), suggestions to explore "transformational change" from a theoretical perspective have analysed the concept from a variety of angles including the use of "framing" (Andeweg and van Latesteijn, 2010), land-use management (Roling & Jiggins, 1997), socio-technical innovations (Geels & Schot, 2007), facilitation techniques (Groot, 2002), innovation brokers and other intermediaries (Howells, 2006; Klerkx *et al.*, 2009) and collective action or community engagement techniques to manage common resource dilemmas (Ostrom, 2012; Kumasi & Asenso- Okyere, 2011).

The main theories of transformational change are the Transformational Learning Theory (TLT) by Mezirow and associates, and the Transtheoretical Model (TTM) by Prochaska and colleagues. Mezirow (1996) describes the transformative learning Theory (TLT) as a ten phase process of using a prior interpretation to construe a new or revised interpretation or meaning of one's experience, beliefs, attitudes and entire perspectives, in order to guide future action (Mezirow, 1996, p. 162; Moore, 2005).

The transtheoretical model (TTM) by Prochaska and colleagues is defined as an adult learning theory that explains the deep, structural shift in thoughts, feelings, and actions. It is a shift of consciousness that dramatically and irreversibly alters our self-locations; our relationships of power in interlocking structures of class, race, and gender; our body of awareness, our vision of alternative approaches to living; and our sense of possibilities for social justice, peace and personal joy (Moore, 2005 p.82). Moore (2005) found that instead of being entirely different, the two theories of transformational change TLT and TTM are complementary and could be used together. Therefore, to obtain deep and fundamentally different structural and functional shifts in behaviour change in relation to climate change, the two theories of transformational change could be considered.

Rogers (2003) incorporates Prochaska's transtheoretical or stages of behaviour change theory into his original Diffusion of Innovation theory developed in earlier years (Rogers, 1962; 1995). Incorporating the transtheoretical model helps Rogers to explain the innovation decision process further to demystify the psychological and cognitive underpinnings of behavioural change at various stages or points in time. Rogers is able to theorize that the stages of the innovation-decision process such as the Knowledge, Persuasion, Decision, Implementation and Confirmation stages in his original theory correspond to the stages of behaviour change in Prochaska's transtheoretical model. The six stages of Prochaska's stages of behaviour change model which consist of: Pre-contemplation, Contemplation, Preparation, Action, Maintenance and Termination. Table 2.4 outlines the steps of transformation as per the TLT and TTM side by side in comparison to the steps suggested by Rogers' diffusion of innovation theory.

Most diffusion studies use Rogers' theory starting from "knowledge" as the first step when potential innovators come into contact with an innovation. There is little focus on other aspects of the theories, indicating that stimuli or impetus for change may emerge from an innate psychological desire for self-change, from symptoms of distress or discomfort with their current or previous circumstances, from recall of unpleasant, unusual or disorienting dilemmas perhaps posed by exposure to unprecedented climate impacts such as severe crop failures or loss.

Table 2. 4 Comparison of Rogers Diffusion of Innovation theory and Prochaska's Transtheoretical Stages of behavioural change model

	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Stage 6
Diffusion of Innovation theory (Rogers, 2003)	**Knowledge**	**Persuasion**	**Decision**	**Implementation**	**Confirmation /Adoption**	
Conceptualization of innovation decision process	Become aware of an innovation and has some idea of how it functions	Form a favourable or unfavourable attitude towards the innovation	Engage in activities that lead to a choice to adopt or reject the innovation	Put an innovation into use	Evaluate the results of an innovation-decision already made	
TLT Phases (Mezirow, 1992)	**Disorienting Dilemma**	**Contemplation**	**Preparation/ Determination**	**Action**	**Maintenance**	**Termination**
Conceptualization of phases of transformational change by TLT (Mezirow, 1992; Moore 2005)	Failure of normal problem solving. Disorienting dilemma	Self-examination Critical assessment Recognize discontent	Explore new options (roles, actions, and relationships). Plan a course of action.	Initiate a course of action. Acquire knowledge, skills and competencies. Provisionally try new roles. Build competence and self-confidence.	Continue to build competence and self-confidence. Reintegration of new perspective (assimilation).	Transformed perspective – emancipation.
TTM Processes of change (Prochaska, 1992)	**Pre-contemplation**	**Contemplation**	**Preparation/ Determination**	**Action**	**Maintenance**	**Termination**
Conceptualization of process of transformational change by TTM (Prochaska et al. 1992; Moore 2005)	Unaware of or resistant to recognize or modify a problem. Biopsychosocial lifestyle dysfunction	Consciousness raising. Helping relationships. Social liberation. Emotional arousal (dramatic relief). Environmental reevaluation. Self-reevaluation.	Helping relationships. Self-reevaluation. Social liberation. Emotional arousal Self-liberation. Reinforcement management.	Helping relationships. Self-liberation. Social liberation. Reinforcement management. Counterconditioning (countering) Stimulus control	Helping relationships. Self-liberation. Reinforcement management. Counter-conditioning Stimulus control	Full stabilization and integration have been achieved.
Framework in Context of Thesis	**Pre-contemplation**	**Contemplation**	**Preparation/ Determination**	**Action**	**Maintenance**	**Termination**
Empirical indicators based on TLT & TTM	Individual does not believe there is a problem yet upset, disoriented, troubled due to climate impacts	Aware that a problem exists. Thinking about solution but has not yet taken action.	Focused on actively pursuing a change within 30 days.	Actively pursuing choice of action for about six month.	Consistently using irrigation or hybrids for more than six months. Has some doubt. May revert.	Permanent change. Has no temptation or desire to revert to previous behaviour or situation.

Source: Author's own creation.(Adapted from Rogers, 2003).

Prochaska *et al.* (1992), delineate the transformational change process into a six-stage self-motivational process. The six (6) stage pathway for transformational behavioural change as per the TTM are: (1) Pre-contemplation; (2) Contemplation; (3) Preparation; (4) Action; (5) Maintenance; and (6) Termination (Moore, 2005) as captured in Table 2.4. The processes are described as being both covert and overt activities and sentiments that individuals undergo when they attempt to make a change in behaviour. Effective change is said to depend not only on doing the right things or engaging in the right processes but also engaging in them at the right time (Prochaska *et al.*, 1992; Moore, 2005; Keller & McGowan, 2001). This time element is a critical distinction because it makes the TTM more of a time bound process unlike Rogers Diffusion of Innovations or transfer of technology process that occurs over time but not according to any specific time parameters.

2.6.1 Relationship between perceptions and smallholder behaviour change

The IPCC (2012) argues that for individuals and groups, perceptions of risk based on psychological or cognitive and cultural factors, such as values and beliefs, are the main drivers of adaptive behaviour. Individual characteristics such as gender, age, wealth, ethnicity, livelihoods, entitlements, health, and settlements are most significant although cognitive barriers also affect how individuals receive and interpret climate or advance warning meteorological information (IPCC, 2012, p. 313). Similarly, Adger *et al.* (2009) contend that social and individual factors such as values, ethics, risk, knowledge and culture impose limitations on actions taken within the adaptation process although they need not to and can be overcome through interventions. They base their argument on insights from history, sociology and psychology and other disciplines that delve into human behaviour.

Traditional behaviourist theory by Watson, Skinner, and Pavlov, emphasize the relationship between individual behaviour and environmental stimuli based on a system of rewards and punishments (Keenan, 2000). This represents one stream of thought on why exposure to stimuli influences individual perceptions in a way that prompts individuals to act. In contrast, social learning theory offered an alternative stream of thought that attributes the relationship between perceptions and actions to internal feelings of self-efficacy and cognitive function (Bandura, 1977) based on the ability to look at and learn from others by imitation (Keenan, 2000).

It has been known since the mid-1970s' that smallholder development and successful adoption of technology, improved crop varieties and practices depends not only on their willingness to participate in decision-making, contribute labor and money to complement projects, but also their local actions involving their consciousness, experiences, creativity, and ability to effect permanent changes in perspectives and social processes (Uphoff *et al.*, 1979 as cited in Groot, 2002).

The existing theories of transformational change by Mezirow (1992, 1994), and Prochaska *et al.* (1992) provide conceptual and empirical evidence about the role perceptions, cognition, social support and other factors play in enabling transformational change at the individual level. Research has revealed other empirical data that indicate a link between perceptions about climate change and decisions taken by farmers during the adaptation process (Byrant *et al.*, 2000).

O'Brien *et al.* (2011) analyze transformational change over a continuum from vulnerability to a state of resilience to climate change impacts. In their illustration, individual learning about climate change impacts culminates into social transformation through local capacity building and institutional change. This thesis argues that in order to fully understand the nature and process by which smallholders achieve transformational change in agricultural systems, thorough investigation of their perceptions as well as mechanisms and pathways are needed. Investigating perceptions are necessary to understand how smallholders are stimulated by environmental stimuli such as climate change impacts to become aware of and develop cognitive abilities to deal with key climate impacts.

2.6.2 Measuring transformation in theory and practice

In formal education, measurements are carried out to ascertain the impact of learning activities on the knowledge, attitudes, skills and practices of target audiences through assessments and evaluations. Yet in the practice of Agricultural Extension as an informal educational learning activity, there is a focus on monitoring and evaluation of "projects" instead of ascertaining behaviour change over time, by measuring cognition, social or critical learning processes among smallholders or target audiences using a systematic theory based approach (Groot, 2002).

The dominant top-down transfer of technology paradigm (O'Brien *et al.*, 2011) is undergirded by Rogers' (2003) Diffusion of Innovations theory which recognizes and pre-supposes different adopter categories and their level of innovativeness and readiness to innovate. Therefore, in most agricultural research and development activities, pre-analytical assumptions and choices are made a priori (Groot, 2002; Djurfeldt *et al.*, 2005; Guijt, 2008; Davis, 2008) about the psychological and cognitive levels of participants, their perceptions, beliefs, abilities, capacity, disposition and propensity to innovate or transform. As such, smallholders and other target populations are often treated as a homogenous group of actors with the same propensity to engage in transformational change (He et al, 2010; Uphoff, 1979 as cited in Groot, 2002). Consequently, mechanisms and pathways that enable smallholder transformational change are not well understood or documented from the smallholders' perspective

(IPCC, 2012). This represents an inconsistency in our application of available theories that guide the practice of transformation (Sumberg and Sabates-Wheeler (2011) that is not measured or tracked.

Empirical evidence based research has shown that farmers' capacities to transform are based on individual characteristics (Marshall *et al.*, 2014). Smallholders operate based on their individual experiences, beliefs, perceptions or value systems (He et al., 2010) and often realize the degree of impact or stage of progress in the transformation or innovation process when maladaptation occurs or when adoption, adaptation or innovation stalls (IPCC, 2012; Wollenberg, *et al.*, 2012). Similarly, the tendency to 'backslide' (Mezirow, 2000; Prochaska and Associates, 1992) is also not measured or made explicit during the learning process (Groot, 2002).

Transformational change is a construct found in several learning theories. It is framed as the outcome of a three stage learning process consisting of single, double and triple loop learning that provides a framework for measuring and distinguishing between the different types of behavioural changes that occur during the learning process. In single-loop learning, behavioural changes are made to optimize and implement actions but the underlying mental models or frames of reference used to process or assess expected and observed data are not changed (Pelling *et. al*. 2008). Double-loop learning goes beyond single-loop learning to ensure that corrective actions or the right things are done. This includes critical thinking, challenging underlying mental models, reframing different goals and objectives to identify what works and why (Flood & Romm, 1996). Finally, Triple-loop learning refers to learning that questions deeply held assumptions, social structures, cultural norms, dominant value structures, special interests and power relations and their implications and consequences for actions taken (Pelling, 2008).

Triple loop learning shapes perceptions and actions based on an assessment of alternatives, long and short term objectives and the significance of available resources on potential interventions to be implemented and thus promotes transformation, as shown in Figure 11. Thus, from a theoretical perspective, the different levels of the learning loop can be used to determine the degree of transformation progressively from the single loop to the triple loop learning which is equivalent to a degree of learning that ensures transformation.

From an empirical perspective, it is difficult to measure transformation for a variety of reasons. According to Niles *et al.* (2015), the adaptation process is location specific and occurs differently from location to location or region to region based on agro-ecological, socio-economic and climatic impacts and factors. The degree of transformation that is expected in response to these factors and ecological conditions depends on existing infrastructure and adaptive capacity (IPCC, 2007; 2012). Besides heterogeneity in circumstances, there is also a lack of understanding about how psychological aspects of farmer experiences, perceptions and concerns about climate impacts affect farmer decision-making and ability to transform their practices through learning (Adger *et al.*, 2009; Niles *et al.*, 2015).

Niles *et al.* (2015) attempt to measure the "psychological distance" between farmers within their agro-ecological context of climate change by theoretically linking "Liebig's Law of the Minimum," an established principle in ecology with the Theory of "Psychological Distance" by Liberman and Trope (2008) from psychology.

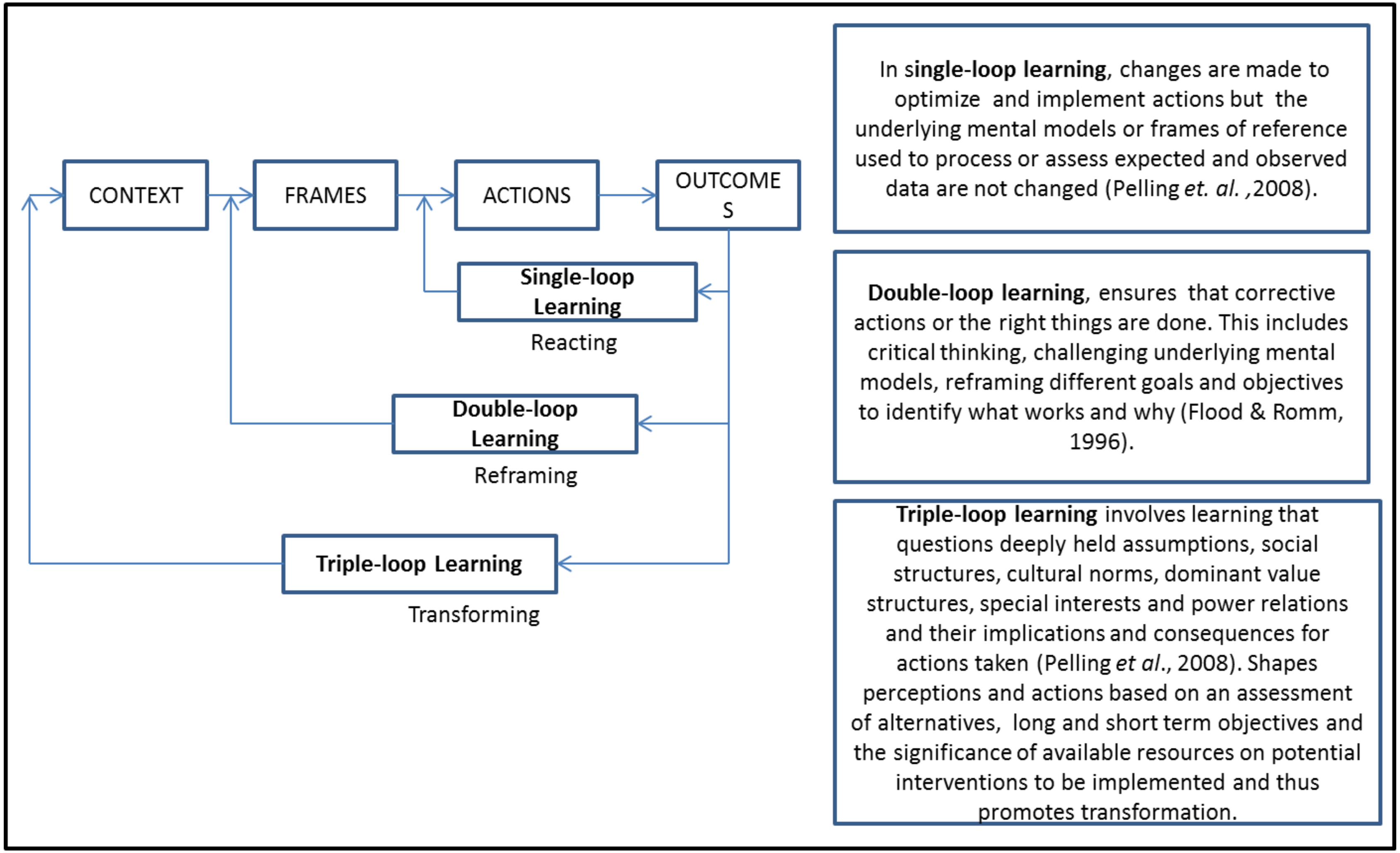


Figure 11: Critical learning theory (Adapted from Pelling *et al.*, 2008)

Based on their analysis of the enablers and constraints of farmer decision making across farming systems and regions, they conclude that farmer decision-making and thereby adaptive behaviours within agricultural systems are influenced by learning which is usually the most limiting factor. This evidence suggests that measuring socially differentiated factors based on cognitive and psychological considerations could provide an indication of farmers' propensity to transform within an agro-ecological farming system in the context of climate change adaptation. Furthermore, Garcıa de Jalon, Silvestri, Granados, and Iglesias (2015) argue that besides economic and biophysical constraints, behavioural barriers should be considered and included as a starting point for quantitative analyses that involve modeling the determinants of behavioural barriers and constraints in the adaptation process. They also highlight the fact that modeling social barriers in farmers' adaptation studies is complicated since the process includes individual level parameters such as interactions between individuals and institutions, individual values and perceptions which are not so easy to identify and measure.

2.6.3 The proposed model for transformation

Available studies on climate change adaptation in the IPCC (2007, 2012) can be categorized into five broad areas: (1) Vulnerability, exposure, resilience to various climate change impacts, extreme events, at the global, national and local levels; (2) Livelihoods, food security and health; (3) Risks and responses, global adaptation and mitigation options, financing, disaster risk management and early warning systems, mainstreaming; (4) Research methods, assessments, modeling, capacity building towards opportunities and challenges in social, managed and natural ecosystems, thresholds, predictions, scenarios; and (5) Developing capacity, barriers, social and other limitations to the adaptation process (IPCC, 2012). This research falls into the last stream of literature that explores theoretical, methodological and psychological perspectives on overcoming social limits to the adaptation process.

The overarching hypothesis is that smallholder farmers may be constrained by their perceptions of climate change along the adaptation process. This thesis proposes a conception of perceptions that combines awareness knowledge, recall and beliefs of smallholder along the transformational change process (Moore, 2005). This conceptualization is based on the fact that there is little research on understanding how the disorienting dilemma, emotional distress and other cognitive, psychological barriers caused by climate change impacts affect farmers' capacity to deal with the climate change phenomenon and how this translates into the behavioural change process. This thesis argues that perceptions serve as the first triggers to smallholder learning and the transformational change process. Further, tracking and assessing individual transformational change from stage to stage and in a time-bound manner as proposed by the Transtheoretical or stages of behavioural change model is a precondition to achieving transformational change.

For simplicity, this thesis uses the six stages of the TLT and TTM together as suggested by Moore (2005) to trace the process of transformational change among smallholders. The idea of a "disorienting dilemma" which is the first step of the TLT is incorporated into the first step of the TTM. This is based on the assumption and premise that climate change impacts such as droughts and floods pose a certain disorienting dilemma to smallholders especially if those occurrences are unprecedented (IPCC, 2007).

Research has shown that smallholders are generally anxious, unhappy, confused or disoriented about the unpredictable and erratic rainfall patterns and other risks posed by the worsening climate conditions. McNamara and Westboy (2011) found that elderly women in Erub Isand on the Torres Strait of Australia showed signs of "sadness, worry, fear and distress, along with a declining sense of self, belonging and familiarity" all of which are associated with a condition called Solastalgia with regards to climate change impacts on their livelihood activities.

Based on critical learning theory (Pelling *et al.* 2008), it is expected that once people experience unexpected climate change impacts such as droughts, and it causes them to become unhappy, uncertain or disorientated, they will commence the learning processes from single learning loop to double to triple learning loop when they become completely transformed in their everyday practices, behaviour and habits (Mezirow, 1994). While Rogers' diffusion of innovations theory also refers to innovators becoming aware of new innovations, it does not specifically mention the trigger that sets off the transformation process as a disorienting, uncertain or unpleasant experience (such as crop losses and failure caused by droughts) as depicted in the theories of transformational change. The aim of this thesis therefore is to investigate the linkage between these perceptions and the transformational change process.

As shown in Figure 12, new dimensions on individual transformational change and perceptions such as awareness, recall and beliefs are inserted into the transformation change framework by O'Brien *et al.* (2011) which represents current thinking about the climate change adaptation process. The study used a framework by Marshall *et al.*, (2014) to measure and operationalize transformational change to fit the context of the study.

This thesis argues that the current thinking on climate change adaptation as depicted by O'Brien *et al.* (2011) does not emphasize individual transformation. However, research has found that individual transformation is a precursor to transformation at other scales including societal transformation (Mezirow, 1996, Marshall *et al.*, 2014). This thesis thus attempts to make a contribution to the transformation literature by inserting individual transformation as a step between individual learning and reflective social learning and uses the stages of behavioural change model to provide empirical evidence. This does not mean that reflective social learning automatically or necessarily occurs during the individual transformation process. It is expected that reflective social learning will enhance the individual transformation within the learning process as depicted in Figure 12.

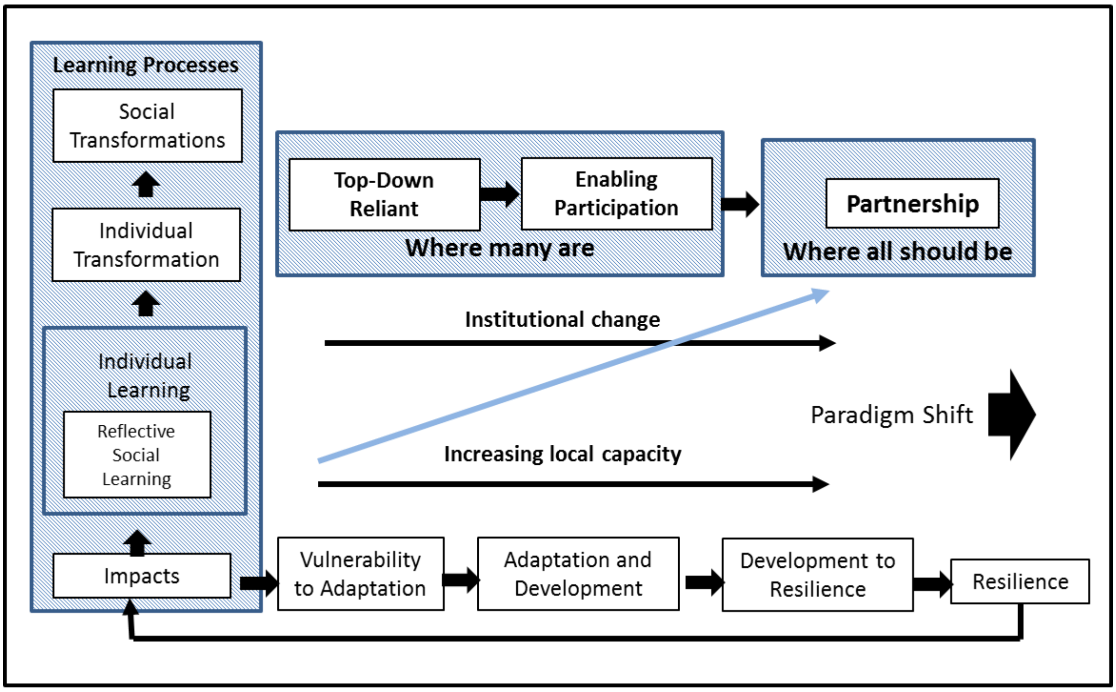


Figure 12: Individual transformation within learning (Adapted from O'Brien, 2011)

2.6.4 Achieving Transformational Change

Traditionally, smallholders have been expected to transform their behaviour along pathways that ensure increased productivity by adopting technical, social and institutional innovations (Rogers, 1995; 2003; Roling, 1989; Uphoff, 1979 cited in Groot, 2002; Leeuwis & Van den Ban, 2004). Since the emergence of the climate change phenomenon, there has been recognition of the importance of altering existing pathways for achieving smallholder productivity with those that can result in climate-sensitive-practices that are transformational in nature (Andeweg & van Latesteijn, 2010; Wollenberg *et al*., 2012).

Despite the numerous urgent calls for transformation as a way of improving agricultural productivity and sustainability (Wals & van der Leij, 2007; Hailu & Campbell, 2014; Smith & Wollenberg, 2012; IPCC, 2012), there is no consensus on the process for achieving transformational change (O‘Brien, 2012) among smallholder farmers in Africa. The process for achieving transformation has been ambiguous, and implicitly rather than explicitly laid out in the agricultural extension literature and in many of the key policy, practitioner and research, guidelines albeit in emerging debates about ‘climate-smart agriculture’ (CSA).

Beddington *et al.* (2012) present an interesting schematic for analyzing the dynamics of food security with respect to climate change and thresholds. He proposes expanding the “safe space” through investments and changes in policy that encourage widespread use of sustainable agricultural practices that reduce GHG emissions and protect farmer incomes. He also offers two pathways for synthesizing evidence into policy actions at the national level:

“*For developed countries, this means transforming incentives and markets to steer public and private investments toward efficient, sustainable agricultural* *practices. For developing countries, this means increasing investment in agricultural development emphasizing "climate-smart" practices and food security* (Beddington *et al.*, 2012, p. 289).

This highlights a dichotomy in institutional mechanisms and pathways for addressing climate change in developed and developing countries: one which fosters robust market based mechanisms and access to incentives versus another based on a linear prescriptive paradigm of knowledge and technology transfer on "climate-smart agriculture".

A report produced by the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS) and the Technical Centre for Agricultural and Rural Cooperation (CTA) suggests that, "*agriculture across Africa must undergo a significant transformation to meet the multiple challenges of climate change, food insecurity, malnutrition, poverty and environmental degradation*" (Hailu & Campbell, 2014, p. 2). The report offers eight key strategies based on a diverse range of climate-smart approaches comprising of farm-level techniques to international policy instruments and finance mechanisms which are intended to serve as models for transforming Africa's agriculture (Hailu & Campbell, 2014).

According to the climate-smart sourcebook (2013), during The Hague Conference on Agriculture, Food Security and Climate Change in 2010, the FAO defined climate-smart agriculture (CSA) as a three part concept for achieving sustainable development through economic, social and environmental policies to address food security and climate challenges. The CSA approach aims at improving the livelihoods and food security of smallholders and others by enhancing "*the management and use of natural resources and adopting appropriate methods and technologies for the production, processing and marketing of agricultural goods*" (CSA

Sourcebook, p. ix). CSA relies on promoting practices, policies and institutions that may not be new but have been used in the context of climatic change, which may be unfamiliar to smallholder farmers, herders and fisher-folk (CSA Sourcebook, p. ix).

Some of the methods used in disseminating the CSA approach as presented in the sourcebook (2013) include Farmer Field Schools (FFS). A variety of FFS have emerged for Integrated Pest Management, Integrated Crop Management; FFS for agricultural landscapes: Sustainable Land Management (SLM) and watershed scale FFS; FFS for pastoralists and climate field schools. Besides FFS, other train-the-trainer approaches, e-learning and other tools have been developed by the FAO targeted at smallholders, scientists, governments, policy makers, civil society activists, rural development workers, agricultural extension agents and other actors in the agricultural sector. From an agricultural extension perspective, it is interesting to note that most of the CSA methods that have been proposed to deal with low agricultural productivity in the 21st century are dominated by the top-down transfer of technology paradigm of the 1950s. This view is consistent with what O'Brien *et al.* (2011) depict in their illustration about where most people are in dealing with climate change impacts in the adaptation process.

While some authors consider the Farmer Field Schools to be a purely top-down approach (Gemo *et al.*, 2005; Axinn, 1998), others (Davis, 2008, Scoones *et al.*, 2008) consider it to be a participatory approach. Nevertheless, although the FFS approach has been successful in Integrated Pest Management programmes in parts of Asia, there is little hard evidence about its effectiveness in other contexts. This is because, like most extension models, FFS programmes often "*rely on ex post evaluations, which are not able to provide rigorous results" on how the program compares to alternative programs or to the counterfactual situation of not having the FFS …future studies* *would be aided by collecting baseline data, obtaining panel data, and using experimental designs*" (Davis, 2008, p. 23). This thesis responds to the call made by Davis (2008) and others who propose that new theoretical and methodological perspectives are needed in ensuring transformational change to alleviate the persistent low productivity problem amongst smallholder farmers and in view of the climate change phenomenon.

While CSA strategies may be helpful and may have project-level Monitoring and Evaluation (M&E) to meet specific project outcomes, there is no mechanism to measure or ensure transformation per se at the individual farmer level that will culminate into aggregate societal transformation. While market-based mechanisms and institutions are self-sustaining, permanent and transformational in nature in terms of their adoption and use, project based interventions may only last until the end of the project. More holistic research is needed to understand the drivers and components of transformational capacity and stage of transformation at the individual level to make project outcomes more sustainable and to avert the harmful climate impacts that pose a threat to livelihoods and food security.

Transformational change would not only help mitigate the disruptive effects of climate change in agricultural systems but also help smallholders harness new opportunities presented in the global agricultural sector. Actors, networks and mechanisms often bring new opportunities, skills, knowledge and other resources to the table. Farmers must recognize and understand the changes around them in order to transform effectively to engage mechanisms or mitigate threats. Yet, the potential for "Transformation", "Transformative" or "Transformational change" as a construct is not well crystallized in agricultural development. As such, despite increasing emphasis on the need for "transformational change" in the agricultural sector, there are few studies that are undergirded by existing theories of "transformational change" although these theories as proposed by Mezirow (1992, 1996, 2000), or Prochaska *et al.* (1992) have been around for decades (Moore, 2005). The main premise of this thesis is to investigate how "transformation" or "transformational change" can serve as a meaningful academic construct for promoting improvements in agricultural productivity praxis in Africa.

2.7 Chapter Summary

This chapter presented historical and current synthesis of literature on impacts of climate change, climate change adaptation and the potential for smallholder transformational change in achieving agricultural productivity. This chapter also presented the evolution and a number of definitions of Agricultrural Extension, conceptual and theoretical frameworks for the study and key definitions that guide the research in filling the knowledge gap about our understanding of smallholder transformation in the field of Agricultural Extension. The next chapter will be on various aspects of the methodology, research design, sampling technique, data collection methods and analytical and empirical models used in the study.

CHAPTER THREE: METHODOLOGY

3.1 Introduction

The basic research conducted seeks to add to existing knowledge by developing an evidenced-based heuristic framework for exploring the stages of smallholder transformational change based on Prochaska's behavioural change model (TTM) for agricultural extension research and practice. Mixed methods (Creswell *et al.,* 2006) research design consisting of both qualitative and quantitative methods of inquiry was used to establish the scientific basis for addressing the research questions and specific objectives. From an ontological perspective, the phenomenon of smallholder behavioural change was viewed from the constructivist viewpoint.

The ontology of a research is important because it helps the researcher identify and define what it is that is being researched. It helps the researcher identify the nature of the study. A study that seeks to understand the nature of a phenomenon is usually descriptive in nature. This is because a description aids in the identification and characterization of the type and scope of the phenomenon. In contrast, a research that is primarily trying to prove that something works or does not, must also clearly define the nature, limits and scope of that which is to be examined and how it exists. Identifying a clear ontological perspective helps the researcher to have clarity about the aim and purpose of the research (Van de Ven, 2007).

Another important aspect of the research process is to identify its epistemological perspective. This establishes how the inquiry ought to be carried out to ascertain that we know or have found out what it is that the researcher set out to find out. For example, if the researcher set out to prove that something works, then it stands to reason that there should be a comparison of sorts to test that which is being examined against a standard or otherwise proven through experimentation or other means that there has been a proof or not. Over time and for engaged scholarship, certain research traditions have been established as logical ways of approaching research given the nature or objectives of the research. These established logical ontological and epistemological perspectives help researchers ensure rigor and general acceptance of research methodology and practices within the scientific community (Kumar, 2011).

Some researchers are strictly inductive or deductive in their logical reasoning and approaches to research whereas others are more relaxed and prefer a blend of the two dominant approaches based on what works in fulfilling the objectives of the study according to a particular regime. The constructivist ontological perspective subscribe to an inductive logical reasoning approach. They generally aim at understanding a phenomenon in totality based on available evidence and then narrow down to decide on what specific conclusions emerge from the research. They use mostly qualitative approaches, descriptions and narratives to provide a rich understanding of both the phenomenon and context. In contrast, positivists look at research problems from a specific perspective and try to deduce a broad generalizable principle from the study for wider replicable application. The positivists generally use quantitative approaches and philosophies such as measurements and hard facts to reach conclusions. The pragmatists usually blend the two and have a practical attitude of thinking about what works to capture the essence of a situation (Van de Ven, 2007).

In this thesis, from an ontological perspective, the phenomenon of smallholder transformational behavioural change was viewed from the constructivist viewpoint yet from an epistemological perspective, pragmatic positivistic ethos were needed to determine, explain and analyze the nature, extent and variations in the phenomenon. From a mode of inquiry perspective, the research is exploratory in nature not because it is a pilot or feasibility study or a prelude to undertaking a major study but intentionally exploratory to offer flexibility in integrating the qualitative descriptive, and quantitative explanatory techniques needed to develop, refine and test the proposed framework (Kumar, 2011, p. 11-14).

3.2 Research Design

The research design is the overall plan and structure conceived by the researcher from stating of the hypotheses to study design, sample selection, data collection and analysis, to analyzing the results to answer the research questions or address the research objectives (Kumar, 2011). A three step sequence of qualitative, quantitative and qualitative retrospective-prospective quasi experimental research design was used to analyze the relationships between smallholder perceptions and location-dependent factors such as socio-economics and how they lead to transformational change.

The first of the three part sequence was a qualitative desk review of available literature particularly assessment reports of the Inter-Governmental Panel on Climate Change (IPCC, 2001, 2007 and 2012), other relevant secondary and grey literature examining the historical context of the research problem, context for the study and definition of key words. In addition, an informal survey of potential respondents using qualitative data collection methods such as open-ended interviews, field visits, observation, and a few focus group discussions were used across all agro-ecological zones of Ghana from September 2012 to May 2014.

The purpose of these field visits was to ascertain physical differences in the agro-ecological conditions and factors driving anthropogenic climate change across the country, and to identify a suitable study area for the quantitative study. Selection criteria were used to purposively determine an appropriate study location. The criteria used were as follows: (1) Vulnerability to climate change impacts, (2) A long history of crop production to trace changes over time (3) Evidence of smallholder use of climate-sensitive mechanisms, (4) Awareness of climate change in the area.

Once a study area was selected, the second phase of the study commenced with designing an interview schedule, determining the study population, sample size, reliability and validity of the survey instrument, pretesting and collecting data using a group of enumerators from the Ministry of Food and Agriculture (MoFA) and the Ghana Education Service (GES). Items and questions included in the interview schedule were obtained from literature and from discussions with a panel of experienced members of the farming community who served as experts in ensuring the face and construct validity of the instrument. A five-point Likert scale was used to measure smallholder perceptions on a scale of Strongly Disagree to Strongly Agree. The instrument also included open-ended and binary “Yes” or “No” type questions.

Key socio-economic data were identified based on previous studies and a set of variables and aspects of an analytical framework endorsed by Garcia de Jalon *et al.* (2015) for the study of social barriers to climate change adaptation among smallholder farmers. The survey data were analyzed using STATA version 13.0 and 14.0. Instead of identifying typologies of farmers as in the Garcia de Jalon *et al*. (2015) framework, an analytical framework inspired by Marshall *et al*. (2014) was used to measure transformational change. Although Marshal *et al.* (2014) used the framework to measure transformational capacity it was found to be suitable after slight modification for analyzing transformational change in the context of this study. The conceptual and theoretical linkage between perceptions, beliefs, cognitive and psychological impacts of climate change on farmer behaviour was established with inspiration from studies by Haden *et al.* (2012) and Niles *et al.* (2015) which analyzed farmers’ perceptions and psychological distance. Finally, a qualitative analysis was conducted to interpret the meaning of the statistical results. A framework by Geels and Schot (2007) guided discussions on how individual transformation conceptually leads to societal transformation. The researcher shared results to seek concordance with respondents.

3.3 Profile of the Study Area

The Keta Anglo area (5 º 47’31”N; 0 º 54’01”E) is a low-lying coastal plain approximately 130km from Accra, in the Keta Municipal Assembly of the Volta Region, in southeast Ghana which lies east of the Volta River and south of the Keta lagoon (Awadzi *et. al*., 2008). According to a profile report, the Keta Municipal Assembly, formerly the Anglo District Assembly (see Appendix V), covers a total surface area of 1,086km^2 of which approximately 362km^2 or 30% is covered by lagoons including the Keta, Angaw Agbatsivi, Logui, Nuyi and Klomi lagoons. The largest of these is the Keta lagoon is about 32km long and 12km wide at its widest segment. The highest point is about 53m above sea level while the lowest point is about 1 to 3.5m below sea level (KMA, 2013). There are three main geographically distinct belts, namely the Narrow Coastal Strip, the Lagoon Basin (which is the middle belt), and the Northern Plains. This study was conducted along the narrow coastal strip that consists of the Keta and Ada soil series (Awadzi *et. al*., 2008) as shown in Figure13.

The general climate in the coastal savannah is characterized by humid tropical weather with 600-1200 mm of annual rainfall favoring two rainy seasons: March to July and September to October. Mean annual rainfall is reported at about 880 mm, with an evapotranspiration rate of 1590 mm and 75% humidity. Average annual temperature ranges from 26^{o}C to 31^{o}C. Despite high temperatures and other challenging conditions, the narrow coastal strip, also called the Keta sand spit area and covering an area of about 300m^2, has a very well established horticultural system that relies on widespread manual hand-dug and pump-operated well-based irrigation (Awadzi *et. al*., 2008).

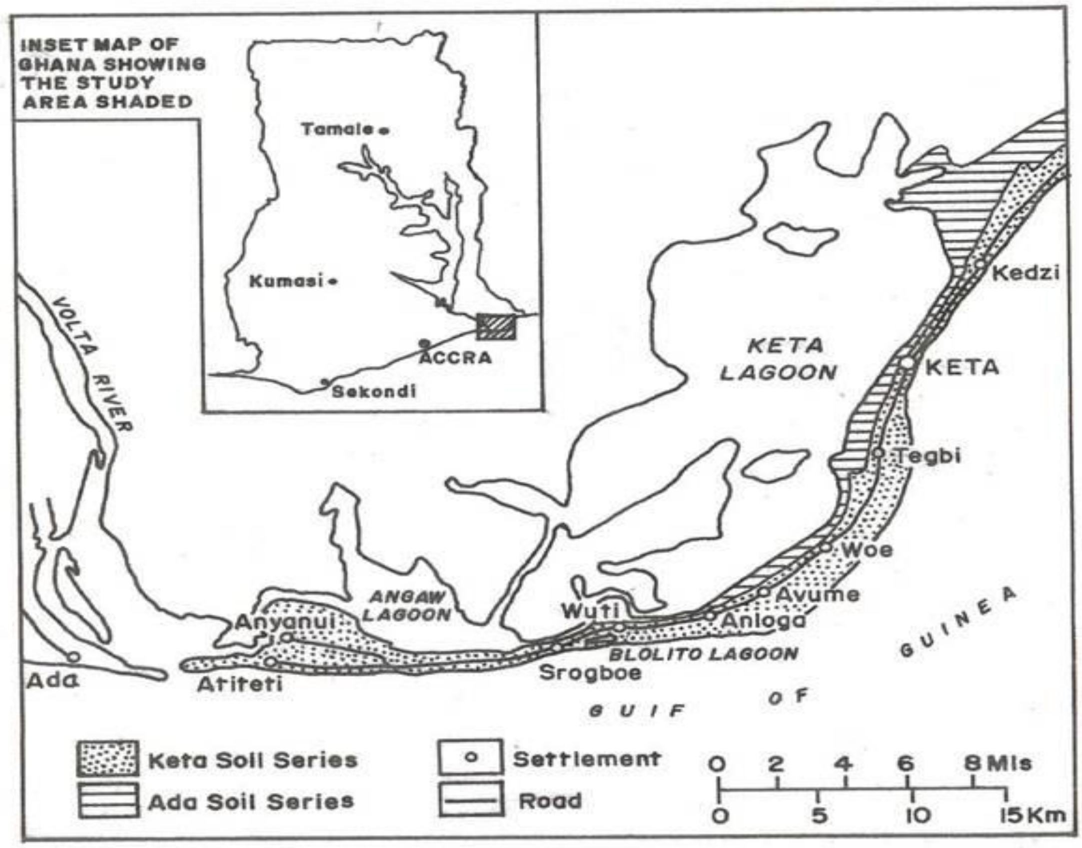


Figure 13: Map of Ghana showing the study area (Source: Awadzi *et. al.*, 2008)

The soil in the Keta area is composed of two main soil types: the Ada series and the Keta series. The Ada series is waterlogged in the wet season and completely dry in the dry season, leaving high levels of salt at the surface. The Keta soil series consists of sandy loams along the flood plains of the Keta lagoon which has been used for intensive shallot production for several centuries (Awadzi *et. al*., 2008).

According to a study by Ocloo (1996), although shallots or *allium aescalonicum* were reported among the list of crops grown along the coastal stretch as early as 1774, the "shallot revolution" which marked the beginning of the shallot industry in the Keta area is reported to have started around 1930 following the demise of the sugarcane, vegetable oil and coconut industries from 1900 to 1930. Accounts by Ocloo (1996) show a stark contrast between the ecological conditions under which shallots were cultivated on the coastal strip from the early 1900s compared to conditions that pertain today, at the dawn of the 21st century. Ocloo (1996) maintained that for centuries vegetable oil was produced from oil palm kernel collected from wild palm trees that were "*dispersed under jungle conditions and in the marshy low islands and depressions*" (p. 64). He reports that the palm trees "*grew crowded among other trees in the jungle*"; however human practices such as urbanization, over-exploitation of the trees to produce ropes, baskets, mats, wine, and other consumables led to the extinction of the palm trees and the forest vegetation cover.

Instead of a forest or jungle, in 2013, the Keta Municipal Assembly reported that the Keta area, which is now part of the Coastal Savannah agro-ecological zone, is delineated into four vegetative zones most of which are characterized by short grasses, with tall grasses in some places used for mat and hat weaving, mangroves used for fuel wood, and interspersed short and medium sized trees such as an occasional "Palmira" palm or baobab tree, with relatively higher density of neem trees in the south-eastern part of the municipality, along the coastal strip near Whuti.

From about 1908, the palm/vegetable oil industry was succeeded by coconut plantations which were well tended and fertilized with cow dung from herds of about five to 50 cattle owned by each plantation. It is reported that by 1933, there were over 3,800 cattle in the Keta area owned by 187 coconut farmers (Ocloo, 1996, p. 66). However, from 1932, the Cape St. Paul Wilt disease destroyed the coconut plantations and affected the ecology of the area (KMA, 2013).

Until the 1960s, farmers in the Keta area used local organic fertilisers such as "small fish or *lavi*, anchovy or *aborbi*, sardines or *deyi*, vomer gibbiceps or *ngogbavie*, tilapia or *togo/hawui*, and shrimps or *aborludzihe"* (Ocloo, 1996, p. 119). Besides these, the farmers also used bat dropping or *drumi*, cow dung or *nyimi*, and poultry dropping or *koklomi* during various stages of the cultivation process during the raining season. However, in contrast the production of shallots now occurs year round on an eight-week cycle for up to four, five or six times per year with no fallow period in between (Awadzi *et al.*, 2008).

In recent decades, high yields of shallots of 2-3 kg per m^2 or 10 to 15 times returns from a cluster of bulbs are only possible because of intensive use of poultry and cow manure, about 1.3 kg of cow dung per m^2 per season in addition to other farm and household residues and compost spread over sand beds of 1 to 2 metres wide by 15 metres long where the shallots are grown at about 10 cm intervals (Awadzi *et. al.*, 2008). The shallots are usually intercropped with pepper, okro, tomatoes, cassava or maize for household food purposes depending on the season.

The Keta Municipality, is now become known not only for its shallots but has also become one of the major vegetable producing areas in the Volta Region of Ghana. Over the years, the area has been affected by severe sea erosion and climate change linked to inappropriate farming practices and other anthropogenic factors, such as deforestation of mangroves and sand winning, which have destroyed many wetlands, biodiversity, public infrastructure and also pose a severe threat to lives and livelihoods especially along the major shallot producing areas located in the flood plains of the Angaw and Keta lagoons (KMA, 2013).

As a result of the rapid rate of coastal erosion the Government of Ghana commissioned of the Keta Sea Defence Project in December 1999 at a cost of over 84 million United States Dollars consisting of a $72 M loan from the EXIM Bank of United States of America and $12 M from the Government of Ghana (Dordor, 2005). Besides erosion the most severe climate change impacts that have been felt include the dwindling in size of the lagoons and creeks due to low rainfall levels, excessive evaporation and siltation which have caused severe droughts and reduced the volume of water in the Keta lagoon (KMA 2013). These factors directly affecting recharge rates and the availability of ground water for the shallot industry. Currently the Srogboe-Dzita stretch is under severe sea erosion which has affected several communities along the coastal strip including the major shallot producing areas of Anloga, Anyanui, Agbledomi, Dzita, Atorkor, Srogboe, Whuti, Woe and Tegbi (KMA 2013).

Naturally, shallots grow best in fertile, well-drained soils during the rainy season (Ocloo, 1996, p. 68) and thus it is not surprising that during the Gold Coast era, they were most commonly cultivated in the forest agro-ecological areas such as the Keta area. Although the terrain has changed from a forest to savannah zone, the Keta sand spit area has a low water table linked to an underlying aquifer which serves as a source of irrigation through a system of wells on most farmlands, some of which date back to over a hundred years (Awadzi *et al.*, 2008).

There are two main types of groundwater based irrigation systems in the Keta area, namely permanent shallow-well systems and the shallow-tube well irrigation systems, both of which are usually lined with cement bricks and mortar. According to Namara *et al*. (2010), there are two categories of irrigation systems in Ghana: the conventional and emerging irrigation systems. The conventional systems are those that are large-scale in nature initiated and developed by the Government of Ghana, nongovernmental organizations (NGOs), communities or individuals for public use. The emerging systems are irrigation systems established and developed by private entrepreneurs, and farmers, either on their own or with very little governmental or external assistance.

According to Namara *et al.* (2010), the types of irrigation systems found in the Keta area are considered to be emerging irrigation systems, which include groundwater irrigation systems connected to a shallow fresh water aquifer with an alluvial depth of less than 20 m. These systems are operated manually, or with mechanical, mobile or small-scale pumping technologies Irrigation is said to have been practiced in the Keta area from as early as 1880. In 2008, it was estimated that there were over 34,000 permanent shallow-wells in the Keta coastal strip covering a total area of about 1,052 ha. as shown in Table 3.1 (Namara *et al.*, 2010).

Table 3. 1 No. of shallow wells and area under irrigation in Keta area

Wells and areas under irrigation along the Keta lagoon

Location	No. of wells	Area under irrigation (ha)
Anloga	12,272	452
Anyanui-Dzita Agbledome	10,864	268
Atorkor Srogbe Whuti	5,187	132
Woe	4,057	111
Tegbi	1,883	89
Total	34,263	1,052

Source: Namara et al., 2010

Each shallow-well is estimated to be about 1-14 m deep and 1 to 2 m in diameter however tube well irrigation systems which are at depths of 6-9 m are believed to have started around 1989. Shallow-wells are usually built close to the farm beds with as many as 100 wells per ha. in the Keta coastal strip. Unlike the shallow-wells that use rope and bucket to draw water manually, tube well irrigation systems consist of the use of poly vinyl carbonate (PVC) pipes, electric pumps, sprinklers, valves and other water distribution systems that cost about US$246.5 to construct in 2007 with a monthly electricity bill of about US$35.2 to operate the pump.

Indeed, climate change impacts like droughts and erratic rainfall which lead to the drying of shallow-wells in the lowland banks of the Keta lagoon are putting pressure on farmers to expand their cultivation to upland areas of the Keta coastal strip near the beach and consequently adopt tube-well irrigation. Despite the cost of the tube-well irrigation system, Namara *et al.* (2010) maintain that these emerging irrigation systems are being developed at a faster rate than conventional systems and therefore cover areas that are many folds larger than the conventional, public or government owned irrigation systems. However, research (Robinson, 1998; Awadzi *et al.*, 2008; Namara *et al.*, 2010) shows that if the exploitation of groundwater by tube-well irrigation systems continues unmonitored, it could damage the fragile freshwater lens resulting in saltwater intrusion from the large body of saline water underneath the aquifer. Farmers need to understand and adopt climate-sensitive practices to safeguard their livelihoods against salt intrusion and other climate induced impacts.

Yet, it is reported that, "*the extension service is inadequate. In the absence of support from public extension systems, farmers are experimenting to find out appropriate agronomic practices, on-farm water management or irrigation techniques, and crop protection practices unaided"* (Namara *et al*., 2010, p. viii).

Figure 14: Shallow-well aged over 100 years, Dornorgbor (Personal collection).

Figure 15: Irrigating from a shallow-well, Dornorgbor (Personal collection).

Figure 16: Shallow-wells along the beds of a farm (Personal collection).

Figure 17: Tube-wells along the beds of a farm, Dornorgbor (Personal collection)

3.4 Study Population

The target population for the study were all smallholder farmers above 18 years of age farming along the Keta Coastal strip. According to the 2010 national Population and Housing Census (PHC), the KMA had a population of about 147,618 inhabitants. The population consisted of 46.4% males and 53.6% females. In 2010, 12.9% of the population declared that they had no religion, 59.9% were Christians, 1.0% Muslims, 25.4% Traditionalists and 0.8% other religions. The PHC defined a household as "*a person or group of persons who lived together in the same house or compound and shared the same housekeeping arrangements. In general, a household consists of a man, wife, children and other relatives or a house help who may be living with them*" (PHC, 2010, p. 41). The KMA had about 37,700 households of which 77.6% had a household size of five or less people and 33.4% had six or more individuals. About 51.3% of the households were headed by males while 48.7% were female headed households. About 30% of the population consisting of 14.8% males and 15.2% females had a mobile phone.

Approximately 65.4% of the population were literate out of which 44% were male and 56% were female. The statistics showed that although KMA had more females than males, the males were more educated than the females. About 19% of the population were uneducated or had never attended any school or received formal education. Among this group the females who had not attended were three times more than the males who had not attended. The majority of the population, 54.8%, had obtained Basic level education, 8.6% Secondary, 1.6% Vocational or Technical and about 3.5% had Tertiary level education. Approximately 25,000 household members or 17% of the population were employed in the agricultural sector across the Keta municipality, of which 49% were males and 51% females.

3.5 Sampling Procedures

To obtain a representative sample, stratified random sampling and snowballing techniques were used in selecting respondents. The communities along the coastal strip including the major shallot producing areas such as Anloga, Anyanui, Agbledomi, Dzita, Atorkor, Srogboe, Whuti, Woe and Tegbi were selected based on their identification in the literature (Ocloo, 1996; KMA, 2013) and divided into different strata. Six major towns: Anloga, Anyanui, Dzita, Whuti-Srogboe, Woe and Tegbi were purposively selected based on the following criteria:

1. Representative sample towns located along the coastal sand strip identified in the literature with active farmers using irrigation (Ocloo, 1996; Awadzi *et al.*, 2008; Namara *et al.*, 2010; KMA, 2012).
2. Towns with famers involved in intensive shallot and vegetable cultivation who have not abandoned their farmlands due to erosion or trading activities at the market. Lashibi and Lagbati, suburbs of Anloga which were initially thought to be representative towns were later dropped as enumerators confirmed that they were mostly market towns with virtually no farms.
3. Towns reported to have experienced climate change impacts such as floods, droughts and coastal erosion over the years and received some climate change awareness training in the past years (KMA, 2012).

3.5.1 Identification of respondents

The national census data provided an estimate of the population in the Keta Municipal Assembly. However, this information was not disaggregated at the community level. To obtain a relative count of residents per community, an official count of registered voters above eighteen years of age by constituency was obtained from the Keta Municipal Electoral Commission for each of the selected communities.

This provided a snapshot of the relative population per community which served as a proxy of the working population above 18 years of age.

Respondents were identified and categorized as smallholder farmers based on discussions with the Ministry of Food and Agriculture (MOFA) as well as with the help of Mr. Edward Ahiabor, a key informant and former District Chief Executive of the Keta Municipal Assembly. Mr. Ahiabor was also a National Best Farmer and an experienced and influential opinion leader on farming matters in the municipality. According to the Ministry of Food and Agriculture at Keta Municipal area, out of the 60,000 inhabitants, only about 3,500 were smallholder farmers, with about 1646 of them registered as members of Farmer Based Organizations (FBOs). Some out of this number may have received prior United Nations Development Programme (UNDP) and the Ghana Environmental Protection Agency (EPA) climate change related awareness training in 2011.

The key informant added that there are about 10,000 farmers in the Keta coastal strip, of which about 25% are large farmers with land holdings greater than 2 acres to about 20 acres, 30% medium sized farmers with land holdings between 1 to 2 acres and the remaining 45% or 4,500 smallholder farmers with land holdings of less than 1 acre. Between the information received from the MOFA office and the key informant, it was determined that there are approximately between 3,500 and 4,500 smallholders with land holdings of less than 1 acre in the Keta coastal strip area.

A sampling frame consisting of a list of farmers in Farmer Based Organizations (FBOs) was obtained from the MOFA Keta office. A list of participants who participated in a United Nations Development Programme (UNDP) Climate Change awareness programme was also obtained from the Keta Municipal Planning Office.

3.5.2 Estimation of sample size

The Keta MOFA estimated that only about 3,500 of the 60,000 inhabitants were farmers, with 1,646 farmers in FBOs as shown in Table 3.2.

Table 3. 2 Summary of estimates made about sample population

Source of data	Total KMA Population	Coastal Strip	Total Farmers	Smallholder Farmers	FBO
National Population and Housing Census 2010	147,618		25,000		
KMA 2010 Profile Report	133,661				
KMA 2013 Projection	154,088				
Electoral Commission	96,559	50,991			
MOFA, Keta		60,000		3,500	1,646
Key Informant			10,000	4,500	2,000

Source: Author's own compilation with data from the various sources listed.

According to the KMA (2013) the major shallot producing areas were Anloga, Anyanui, Agbledomi, Dzita, Atorkor, Srogboe, Whuti, Woe and Tegbi. However, their current population estimates included all inhabitants of these towns. Therefore, for the purpose of this study, the Electoral Commission's estimate of 50,991 adults 18 years of age and above of valid registered voters per constituency for the 2012 national election was used as the sampling frame to determine the relative proportion of active people at the community level.

A formula by Bowerman *et al.* (2001, p. 256-264) was adapted for determining the sample proportions and actual sample size of respondents needed per community as follows:

$$p = \frac{X}{N} \quad and \quad \hat{p} = \frac{x}{N}$$

where:

$p = population \quad proportion$

$\hat{p} = sample\ proportion$

$N =$ total number of elements in the population

$X =$ number of elements in the population that possess a specific characteristic

$x =$ number of elements in the sample that possess a specific characteristic

$n =$ sample size

Based on the above, the total target population size (N) was estimated at 50,991. The MOFA estimate of 3,500 was used to determine the sample size of smallholder farmers along the Keta coastal strip. The number of elements in the sample that possesses a particular characteristic (x) being smallholders is 3,500. Thus the sample proportion

$$\hat{p} = \frac{x}{N}\text{. Therefore } \hat{p} = \frac{3500}{50{,}991} = 0.068639$$

The confidence interval for a population proportion can be calculated by the following formula if the population size n is large.

$$p = \left[\hat{p} \pm z_{0.025} \sqrt{\frac{\hat{p}\left(1 - \hat{p}\right)}{n-1}} \right]$$

The sample size n is said to be large enough if $100(1-\alpha)$ if $n\hat{p}$ and $n\left(1-\hat{p}\right)$ are at least 5. In that case, the theoretically correct interval is

$$\left[\hat{p} \pm z_{\alpha/2}\sqrt{\frac{p\left(1-p\right)}{n}}\right]$$

To obtain the sample size needed to make the error bound in this interval equal to B, the margin of error, was set to

$$= z_{\alpha/2}\sqrt{\frac{p\left(1-p\right)}{n}} = B \textit{ to solve for } n$$

$$n = p(1-p)\left(\frac{z_{\alpha/2}}{B}\right)^2$$ Thus for a 95% confidence level and margin of error, p equals 0.025 rounded to 0.03

$$n = 0.69(1-0.69)\left(\frac{1.96}{0.03}\right)^2$$

Therefore, the ideal sample size for the entire coastal strip was…

$$n = 0.064239\left(\frac{1.96}{0.03}\right)^2 = 272$$

The stratified proportional allocation method was then applied to the sample size to estimate the number of smallholders to be surveyed in each community as follows:

$$\hat{n} = \frac{\hat{p}\left(1-\hat{p}\right)\hat{x}\left(\hat{p}\left(1-\hat{p}\right)\left(\frac{z_{\alpha/2}}{B}\right)^2\right)}{x} = \frac{n\,\hat{p}}{x}(\hat{x})$$

where $\hat{x}$ is the estimated population of the community.

Results are shown in Table 3.3.

Table 3. 3 Estimated sample size per community

Community	Population of the community ($\hat{x}$)	Sample size when B=0.03 (n)	Number of smallholders in the population (x)	Sample proportion ($\hat{p}$)	Sample size per community ($\hat{n}$)
Anloga (Avume)	2,241	272	3,500	0.068639	12
Anloga (Agorve)	2,172	272	3,500	0.068639	12
Anloga (Dornogbor)	1,241	272	3,500	0.068639	7
Anloga (Kportorgbe)	2,188	272	3,500	0.068639	12
Anloga (Lagbati)	1,921	272	3,500	0.068639	10
Anloga (Lashibi)	2,156	272	3,500	0.068639	12
Anloga (Setsinu)	3,103	272	3,500	0.068639	17
Anyanui	1,952	272	3,500	0.068639	10
Whuti-Srogboe	3,811	272	3,500	0.068639	20
Dzita	1,548	272	3,500	0.068639	8
Dzita Agbledomi	2,793	272	3,500	0.068639	15
Woe	6,139	272	3,500	0.068639	33
Tegbi	7,876	272	3,500	0.068639	42
TOTAL	39,141				209

Source: Field data computed from sources listed in Table 3.2

As a result of this estimation, about 200 smallholder farmers were targeted for the quantitative survey along the coastal strip. Based on this same estimation, another sample of 200 farmers who were members of farmer based organizations (FBOs) were selected within the coastal strip. It was assumed that the FBO members would have a more extensive support system, information and opportunities for reflective social learning relative to non-FBO farmers for comparison purposes.

To select the FBO members, a sampling frame of farmer based organizations listing was obtained from the Ministry of Food and Agriculture a copy of which is available in the appendix. The individuals on the list were numbered and the numbers randomized using Microsoft Excel. The respondents belonging to FBOs were then selected from the particular stratum or town to the interviewed. Those who could be located by the enumerators and available were interviewed. However, not many of them were found.

In lieu of those particular individuals on the list, the enumerators randomly identified farmers who were FBO members in the community and interviewed as replacements.

3.5.3 Focus group discussions

Focus group discussions (FGD) were used to solicit qualitative data from individuals sharing a certain characteristic (Silverman, 2011). About ten focus groups of men, women, elderly, and youth were held across all the selected communities to collect qualitative and historical information, as well as to clarify terminologies and assess key issues that were used in the construction of the survey instrument. Some FGD were preceded by town hall meetings to introduce the community to the research and survey process to be carried out by the enumerators. Interview guides and checklist were used to guide the interactions during the FGD. The focus groups were carried out in a longitudinal design when one interview or discussion followed the other in an attempt to corroborate and piece together the evidence from various sources until a saturation point was reach where no significantly new additional insights emerged (Silverman, 2011).

All interviews were recorded in writing literally and analysed in real-time and later using conventional content and thematic analysis (Silverman, 2011). Data from the open-ended interview questions were analysed based on the relevance of sequence to smallholder actions taken in light of climate change impacts. Responses were also analysed for words and phrases that reflected themes studied in this research. Some of the themes included “climate change phenomenon”, the concept of “change or transformation” that has occurred over time, “institutional changes”, “climate change impacts like droughts, floods, biodiversity loss”, and “impacts on livelihoods”. Copies of the interview guides and checklists used for moderating the FGDs can be found in the appendix.

Figure 18: Focus group discussion with men at Avume (Personal collection)

Figure 19: Focus group discussion of women, Dornorgbor (Personal collection)

Figure 20: Focus Group Discussion with men at Setsinu (Personal collection)

Figure 21: Pre-testing of survey instruments, Dornorgbor (Personal collection)

3.5.4 In-depth interviews

A few in-depth interviews were conducted collaboratively with particular members of the community to gather more insights, experiences and historical perspectives of changes that have occurred over the years (Silverman, 2011). The narratives obtained from the in-depth interviews were used as a complement to the survey data to unearth the authentic complexities and nuanced views of smallholder beliefs and how smallholders define, interact with and transform as a result of climate change impacts in the study area. The snowball technique (Kumar, 2011) was used to identify the potential interviewees starting from suggestions from the key informant and interviewees who had participated in the UNDP training or in the study conducted by Ocloo (1996). Interviews typically lasted for about an hour to two hours and were held in English or in the local Ewe language at the residence of the interviewee.

3.5.5 Development of the survey instruments

The survey instruments were developed based on themes identified in the literature and through the focus group discussions. The instrument comprised of six sections labelled A through F with open and closed ended questions. A five-point Likert scale was used to measure the extent of agreement or disagreement and the beliefs and perceptions of farmers. Some questions required only binary ‘yes’ or ‘no’ answers. Some constructs were measured using single items while others used multiple-tem scales (Kloek *et al.*, 2004). A copy of the instrument is available in Appendix II.

3.5.6 Validity, reliability and response rate

A group of experts consisting of the supervisory team and experienced farmers on the field were used to ascertain construct validity and face validity. The questionnaires were pre-tested with the enumerators during three one day training sections where enumerators' understanding of questions and explanations of key terms and concepts in the instrument were calibrated to ensure inter-enumerator reliability. Thereafter, a copy was pretested with the cross-section of the community and finalized before the actual use. In all, about 30 questionnaires were used for these training and pre-testing exercises which were excluded from the survey results. The response rate was above 90%. Most respondents were approached following a group community town hall style meeting or focus group discussion in which the authors informed the community about the nature of the research and allowed community members to ask questions. The author believes that these introductory meetings helped enumerators as they approached members of the community individually to conduct the surveys. Only a few survey instruments were not fully completed due to time constraints or persistent interruptions or other reasons. These were the surveys that were categorized and used in determining the non-response rate.

Factor analysis was conducted during the empirical data analysis to ensure construct validity of items included in measuring the various concepts. The purpose of the factor analysis was to calculate an F score which is a weighted mean of factors that were selected to represent the construct under study. The Cronbach's Alpha was calculated to ensure inter-item reliability and internal consistency. In other words, the Cronbach's Alpha was used to ensure that selected questions used to capture particular themes would be interpreted similarly at all times. A Cronbach's Alpha value of at least 0.60 suggested by Churchill (1979, cited in Gan *et al.*, 2006) as a benchmark of internal consistency and reliability in exploratory studies was used. Validity and reliability of the qualitative data was mainly ensured through triangulation of data among the various FGDs and interviewees.

3.5.7 Data collection

Over 400 structured interviews were conducted using the standardized pre-tested survey instruments to obtain an in-depth understanding of how smallholders perceive the climate change phenomenon and what mechanisms and pathways could lead to transformational change. Data were collected from September 2012 to December 2012 and from April to November 2014. Further qualitative data was collected in January 2016 when results of the study were shared with some members of the community to seek concordance prior to the publication of findings in this thesis document.

3.6 Climate Variability and Change in Ghana

Ghana has a total of about 23.8 million hectares of land, 13.6million hectares or 57.1% is agricultural land area, of which 6.3million hectares or 26.5% was under cultivation in 2005 (FAO, 2005). According to FAOSTAT (2015) 15.5 million hectares or 65% of land in Ghana is currently under cultivation. The country is divided into six agro-ecological zones as shown in Figure 22.

From north to south the agro-ecological zones with mean annual rainfall are: Sudan Savannah Zone, 1000mm per annum; Guinea Savannah Zone, 1000mm; Transition Zone, 1300mm; Semi-deciduous Forest zone, 1500mm; Rain Forest Zone, 2200mm and the Coastal Savannah Zone, 800mm (FAO, 2005).

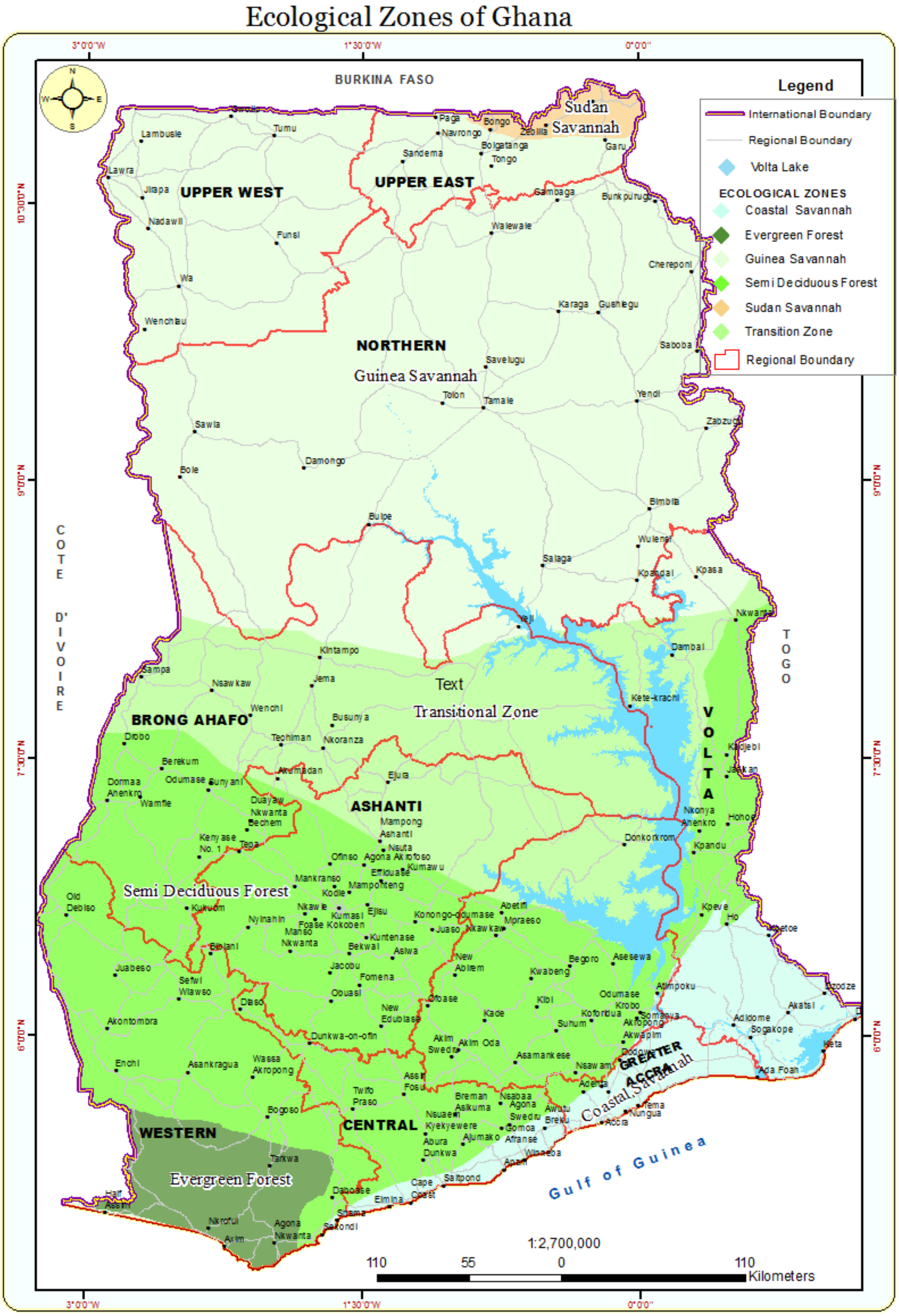


Figure 22: Agro-ecological zones of Ghana (CERGIS, 2012).

Ofori-Sarpong (2001) reported that the Sudan Savanna agro-ecological zone has less trees and less vegetation cover now than in previous decades and has been affected by population growth and human activities such as deforestation, exploitation of vegetation for fuel wood, prolonged bush burning, and clearing of land for intensive cultivation which are the key drivers of climate change in Northern Ghana.

The effects of climate change are seen throughout the country in the intensification of droughts and desertification due to shortage of surface and ground water which affect the hydrological cycles and water availability (Gyampoh *et al.*, 2008). Ofori-Sarpong (2001) confirmed that climate change has occurred in Northern Ghana through the analysis of historical rainfall levels over a sixty-year period from 1931 to 1990. Annual mean rainfall for 1961 to 1990 was 986.1mm, which was 9.3% lower than the annual mean rainfall from 1931 to 1960. Furthermore, 19 or 63.3% of the 30 years between 1961 and 1990 were drought years with annual mean rainfall lower than 1036.9 mm for the sixty-year period from 1931 to 1990.

Similarly, an analysis of rainfall data from 1950 to 2000 by Owusu and Waylan (2013) confirmed a change in climate. They found that climate variability in Ghana occurs more frequently than the El Nino Southern Oscillation (ENSO) induced climate variability that occurs globally. They attributed this to the southward shift of the Inter Tropical Convergence Zone (ITCZ) which has eroded the north-south bi-modal rainfall regime which was characteristic of the West African monsoonal climate system. Their study also revealed that climate variability has a significant effect on poverty levels and the food security of farmers whose households depend on rain-fed agriculture. They proposed the introduction of irrigation and access to credit as possible adaptation strategies to assist farmers. Also in 2013, a study by Tachie-Obeng, Akponikpe and Adiku examined farmer practices and crop models to determine climate change adaptation strategies to improve maize production in Ghana. Their studies were situated in Wa in the Sudan Savannah agro-ecological zone and in Wenchi in the Forest Savannah transition zone of Ghana. Results of the study showed that over a 40 year period from the 1960s to 2000, there was a need to delay sowing days by six weeks in the savannah agro-ecological zone and by four weeks in Wenchi in the Forest Savannah transition zone of Ghana from the historical reference dates of 1st May to 15th May and from 15th March to 15th April respectively in the major rainy season. They noted that delaying the sowing dates increased yields by 8.2% for the cropping season whereas using a heat-tolerant maize variety increased yields by more than 30%.

In terms of food production, maize and cassava are the staples grown across all ecological zones. About 50% of maize is produced in the forest-savannah Transition zone compared to only 5% in the Sudan Savannah Zone, 15% in the Guinea Savannah Zone, 20% from the Semi-deciduous Forest zone, 4% from the Rain Forest Zone, and 6% from the Coastal Savannah Zone. Based on mean annual rainfall levels and potential for crop production, the Coastal Savannah Zone is the most vulnerable ecological zone in Ghana. This is because, unlike most soils in Ghana that are highly weathered, consisting of productive sandy loams, soils in the Coastal Savannah agro-ecological zone of Ghana, especially the Keta sand spit area, comprise of coarse sandy clay loams (FAO, 2005; Owusu-Bennoah *et. al*, 2000) which do not support many of the cash and tree crops that thrive in other ecological zones such as rubber, cocoa, palm or sheanut. Thus farmers in the coastal savannah have limited opportunity to diversity their crop types, rendering their livelihoods vulnerable. According to the Ghana climate change impacts, vulnerability and adaptation assessment conducted by the Environmental Protection Agency (EPA) in 2008, some of the key climate change impacts in Ghana affecting land and, therefore, agriculture are: soil erosion, hardening of soils, drier conditions, loss of biodiversity, increased obnoxious weeds, decreased productivity of the land.

A study on livelihood adaptation measures adopted by farming households in Ghana by Antwi-Agyei, Stringer and Dougill (2014) found that households combine a range of on-farm and off-farm livelihood adaptation strategies to mitigate the negative impacts of climate change such as droughts and crop failure on their livelihoods. On-farm strategies used include varying sowing and planting dates, crop diversification, and using improved and early maturing varieties that mature faster than usual. Households also engage in off-farm strategies to diversity livelihoods. They also depend on the support of relatives and friends, and change types of food consumed and composition of diets. They recommend that policy makers should develop better targeted and socially differentiated climate adaptation policies that empower farmers to diversify their livelihoods and share local adaptation strategies through appropriate communication channels (Antwi-Agyei *et al*., 2014).

3.7 Factors Affecting Smallholder Agriculture in Ghana.

The term “smallholder” is defined differently across countries and agro-ecological zones from landholdings of less than one hectare in some places to less than 10 hectares or10 units of livestock in other places (Dixon *et al.*, 2007). During a household survey in northern Ghana, Fosu-Mensah *et al.* (2010) found that perceptions about new technologies, farm size, education, access to extension services, credit facilities and markets were major factors that influenced farmers’ decisions to adopt new climate-sensitive practices in northern Ghana. Similarly, Yaro (2013) found that socially differentiated characteristics such as educational background, marital status, livelihood activities, gender roles and non-climatic factors impact how smallholders respond to climate change impacts in Ghana. This confirms that besides their perceptions of climate change impacts smallholders are influenced by their other non-climatic socio-economic and psychological factors. However, this thesis argues that it is not enough that research can identify these factors. The impact of these socio-economic factors and perceptions on actions and practices must be well understood, interpreted and tracked at the individual level in order to achieve transformation (He *et al.*, 2010; Prochaska *et al.*, 1992).

Smallholder crop farmers in communities along the Keta sand strip area in the Coastal Savannah agro-ecological zone of Ghana were purposively selected for the study based on the severity of climate change impacts in that region and the degree of vulnerability farmers' face as a result of the naturally harsh conditions in the coastal savannah terrain coupled with the multiple stresses of climate change impacts. The conditions in the coastal savannah, and in the Keta area in particular, have been affected by severe coastal erosion, which has been perceived as a climate change impact resulting from sea level rise. The region has also experienced meteorological and hydrological droughts and a complex tension between the human-environment systems (Metzger *et al.*, 2006) that pertain in that area due to over-exploitation of common natural resources for various livelihood strategies. They have also been selected based on certain innovative practices exhibited such as being the first community to adopt irrigation (Namara *et al.*, 2010) and other climate-sensitive agricultural practices in Ghana (Ocloo, 1996). They serve as a natural experiment for a nested case study that depicts both the phenomenon of behavioural change and the context of climate change adaptation.

The building of the Akosombo dam, which created one of the world's largest man-made lakes in the early 1960s, is estimated to have covered over 95% of the Volta river basin. The ensuring reduction in sediment flow to the coast resulted in an unprecedented rate of erosion and coastal retreat (Ly, 1980). It is reported that since the 1970s, there has been declining rainfall levels in West Africa, and Ghana in particular, leading to meteorological droughts which were most severe in 1983, 1998 and 2007, affecting both rain-fed agriculture and power generation (Owusu *et al.*, 2008). Even so, the effect of climate change and development activities on water supply and demand is expected to worsen in the coming years as shown in Table 3.4. Residents and particularly smallholder farmers across Africa, in Ghana and throughout the study area perceive these environmental changes as related to water availability such as annual, inter-annual, and seasonal variations in precipitation, soil moisture levels, reduction in groundwater and availability of water (Ofori-Sarpong, 2001; Owusu & Waylen, 2013; Tachie-Obeng *et al.*, 2013).

As smallholders and others observe these water-related climate change impacts, it is expected that some may have data, information, knowledge and wisdom that increase their awareness, recall and beliefs about the climate change phenomenon. Nyirenda-Jere and Kazembe (2014) define data as specific facts and observations; information as data points with context or "know what"; knowledge as information with meaning or "know how"; and wisdom as knowledge with insights. They argue that all knowledge can be either tacit or explicit knowledge, formal or informal, indigenous or traditional knowledge, participatory or citizen's knowledge, project or programme knowledge, and research knowledge. In this thesis, it is assumed that any of these types of knowledge influence awareness, recall and beliefs about climate change impacts and can therefore not be ignored in analyzing the link between smallholder perceptions of climate variability and change and the transformational change that occurs within the adaptation process.

Table 3. 4 Effect of climate change and development on water supply and demand (IPCC, 2012)

Elements of the water cycle	Impact from development activities	Impact from Climate change
Annual precipitation	No or minor impact	Expected to increase globally during the 21st Century, with potentially great spatial variations.
Inter-annual variations in precipitations	No impact	Expected to increase everywhere
Seasonal variability of rainfall	No impact	Expected to increase everywhere
Soil moisture stress (droughts)	Limited impact: some agricultural practices can deplete soil moisture faster than natural vegetation	Moisture stress to generally increase as a result of increasing variability of rainfall distribution (longer periods without rain) and increasing temperatures
Floods	Moderate impact: flood intensity and impact can be exacerbated by changes in land use and unplanned development in alluvial plains	Increased as a result of increasing frequency and intensity of extreme rainfall events
River discharge	High impact in water scarce areas, where reservoir construction and water diversion for agriculture and other uses are modifying runoff regimes and reducing annual flow. Large-scale water conservation measures also have an impact on river discharge	Increased variability as a result of changes in rainfall patterns. Changes in snow and glacier melt induce changes in seasonal patterns of runoff. Changes in annual runoff expected to vary from region to region
Groundwater	High impact: large-scale development of groundwater resources in many regions are already threatening the sustainability of aquifers in many dry areas	Varies as a function of changes in rainfall volumes and distribution. Impact is complex, with floods contributing to increasing recharge, and droughts leading to increased pumping
Evapotranspiration	Limited impact in agriculture: some crops have higher evapotranspiration rates than natural systems, other less	Increases as a function of temperature increases
Water quality (in rivers, lakes and aquifers)	High impact from pollution in highly developed areas	Moderate impact through temperature increases
Salinity in rivers and aquifers	High impact from water withdrawal in highly developed areas (mostly in arid regions)	Potentially high impact where sea water level rise combines with reduced runoff and increased withdrawal

Source: Adapted from IPCC (2012)

Based on behaviourist and social learning theories, it is expected that smallholders take actions based on perceptions of these water-related stimuli. In such an environment, more measured policies about individual and collective water use and other common resources are needed (Roling & Jiggins, 1997; Ostrom, 1999; Ostrom, 2010). This thesis underscores the importance of understanding smallholder perceptions of the climate change phenomenon and suitable theories to predict track and interpret smallholder behavioural change in a nuanced and differentiated way as they face climate change impacts such as water stress and shortages that are projected to worsen in the coming decades.

3.8 Data Analysis

Both qualitative and quantitative analyses were utilised in this thesis (Creswell, 2006; Semenza, 2008). The qualitative data analyses were mainly in the form of sequence, content and thematic analyses (Kumar, 2011; Silverman, 2011). The results of the cross-sectional survey (Semenza *et al.* 2008) were analysed using descriptive statistics and cross tabulation - which is a joint frequency distribution of two or more categorical variables to describe the association between the discrete or categorical variables. Pearson's Chi Square analyses were used to test for association between the variables (Marshall *et al.*, 2014). The categorical variables were analyzed mostly descriptively with simple percentages and with Chi-square tests to determine the existence of relationships between the perception and socio-economic variables (Semenza *et al*, 2008), according to the general Chi Square equation:

$$X^2 = \sum_{i=1}^{n} \frac{(O_i - E_i)^2}{E_i}$$

Where

O = observed frequencies

E = expected frequencies

Both binary and ordered logistic regression analyses were conducted to determine the nature of relationships among the dependent and the explanatory variables (Garcia de Jalon *et al.*, 2015). Three empirical logistic regression models were used to test the relationships between the dependent perception and transformational change variables and rest of the independent variables (Xie *et al.*, 2001). Logistic regression also called Logit regression was selected instead of Ordinary Least Squares (OLS) regression as the main statistical model for analyzing these relationships because of the categorical nature of the dependent variables and the fact that the field data available is cross-sectional rather than longitudinal, parametric or time series data. STATA software was used to generate results from the field data for the analyses to determine the probabilities in the form of odds ratio of the independent variables relative to the reference categories of the dependent variables.

3.8.1 *Variables*

Rainfall amount, air and water temperature, sea level rise and increase in the incidence of droughts, floods and disease outbreaks are the most common signs of climate change (IPCC, 2007) and are therefore among the perceptions of key climate change impacts studied in this research. According to the IPCC (2007), the degree of climate change impacts can be measured by magnitude, timing or frequency, persistence of impacts, likelihood, adaptation potential, spatial distribution of impacts and importance of the system (s) being impacted. The thesis examines smallholder perceptions: awareness, recall and beliefs about these impacts and the relationship between these perceptions and the transformational change process. Actual recorded rainfall amount is compared to smallholder perceptions of rainfall to judge the degree of accuracy of perceptions as a proxy for cognitive and psychological barriers.

However, an empirical analysis of rainfall, air and water temperature, sea level rise and increase in the incidence of droughts, floods and disease outbreaks as key objective data is beyond the scope of this research.

Anderson (2010) posits that in thinking about improving productivity, the gap between actual and potential yields that is eroded by climate variability and change can be recovered with about 250 mm of rainfall, and good seasonal, or short-term management and cultural practices such as good crop and cultivar varieties, appropriate fertilizer use, weed, insect and disease control, combined with long-term strategies such as soil water, acidity and fertility management practices. Therefore in terms of climate-sensitive agricultural practices, this study sought to assess if smallholders perceptions of these climate-sensitive farming practices to improve productivity and bring about change in behaviour. Three categorical perception variables of “awareness”, “recall” and “beliefs” are used to measure climate-sensitive practices. Each of these is a binary variable that can take on the value of “0” and “1”. In the case of awareness, the variable “climaware” takes the value of “0” if smallholders are not aware and “1” if they are aware. Similarly, for recall and beliefs the variables “climrecall” and “climbelieve” take on the value of “0” and “1” respectively if smallholders recall, do not recall, believe or do not believe in a the climate change phenomenon or impact.

Adoption and use of tube-well irrigation is considered as a major climate-sensitive practice used to mitigate the effects of droughts due to low rainfall in the study area. Based on the theoretical framework, it is hypothesised that smallholders undergo different stages of change in the adoption of tube-well irrigation. Therefore the main variable used in measuring the transformational change process is “stage”. “Stage” is a categorical variable with six levels representing the six stages of the transformational change process: Pre-contemplation, Contemplation, Preparation, Action, Maintenance and Termination which are coded 0, 1, 2, 3, 4, and 5 respectively. These are ordered in ascending order so that Contemplation which has a value of 1 is greater than the value 0 for pre-contemplation. Literature shows that the distances or intervals between the six levels of an ordinal scale may not be the same or equal. This means that the time or conditions that will be required for a smallholder to move from pre-contemplation to contemplation may be different from the time or conditions required for that same smallholder to move from the stage of contemplation to Preparation or from Maintenance to Termination.

Different socio-economic factors affect climate change adaptation and thereby the transformation process including Age, Education, Gender, Household head status, access to Extension, Farm size and Marital status (IPCC, 2012) were explained. This study attempts to assess the socially differentiated perceptions of climate change impacts based on these socio-economic factors. Key socio-economic variables for this study were identified based on previous studies (IPCC, 2007; 2012; Fosu-Mensah *et al.*, 2010; Yaro, 2013), and from the climate change literature broadly. A set of variables and aspects of an analytical framework endorsed by Garcia de Jalon *et al.* (2015) for the study of social barriers to climate change adaptation among smallholder farmers is used. Theoretical expectation was that variables like gender and age will have a negative association whereas education, farm size, and access to weather information will have a positive relationship with behavioural change as shown in Table 3.5.

Table 3. 5 Summary of socio-economic variables in climate change analyses

Prior hypotheses of socio-economic factors influencing behavioural barriers to adoption of actions against climate change			
Variables	Expected effect on changing behaviour due to climate change	Expected effect on displaying behavioural barriers to adoption	Expected type of farm or farmer more likely to display behavioural barriers to adopt climate change actions behavioural barriers to adoption
Gender (male)	Negative	Positive	Male farmers
Age	Negative	Positive	Older farmers
Education	Positive	Negative	Less educated
Land ownership	Positive	Negative	Tenants farmers
Livestock ownership	Positive	Negative	Farms with small number of livestock
Farm size	Positive	Negative	Small farms
Members on-farm	Positive	Negative	Farms with small number of members
Members off-farm	Positive	Negative	Farms with small number of members working off-farm
Distance to market	Negative	Positive	Farms located far away from markets
Credit access	Positive	Negative	Farmers without access to credit
Food aid	Negative/positive	Negative/positive	Not applicable
Access to weather forecast information	Positive	Negative	Farmers without access to climate information

Source : Adapted from Garcia de Jalon *et al*. (2015).

Besides these socio-economic variables, Garcia de Jalon *et al*. (2015) introduce several new psychological and cognitive variables to determine behavioural barriers including: skepticism, lack of concern, fatalism and helplessness, externalizing responsibility, blaming lack of adequate policy, reluctance to change, and lack of knowledge to change. Kloek et al (2004) also examined psychological factors that determine the stage of behavioural change associated with healthy diet intake. Attitude and Self efficacy were the psychological factors used. This research study draws inspiration from both studies although variables used in the work done by Garcia de Jalon *et al*. (2015) were found to be interesting. Although these psychological variables are not measured directly in this study, they are considered important underlying reasons why a person may not move from the contemplation to action stage of the transformation change process.

From the theoretical framework discussed earlier, the focus of this study is to assess smallholder perceptions as measured by level of awareness, recall and beliefs. These are measured descriptively and statistically where possible on a five-point Likert scale (Kloek *et al.,* 2004). Social differentiation is measured using both the socioeconomic and perception variables. The impact of external factors, mechanisms and interventions are captured through variables such as ‘contact with NGOs’ and ‘access to extension services’. The construct of Extension is operationalized by assessing the number of times that extension agents or personnel visit or interact with farmers. These variables helped in testing the impact of endogenous and exogenous factors on smallholder stage of transformation. Extraneous variables were eliminated by building them into the study where possible.

3.8.2 *Analytical framework*

Garcia de Jalon *et al*. (2015) present a three-step analytical framework as follows:

(1) Exploring barriers to behavioural change by collating views of stakeholders through focus group discussions,

(2) Defining a typology of behavioural barriers by analyzing a spectrum of barriers from skepticism to lack of knowledge using principal component analysis (PCA) of survey data,

(3) Understanding the socio-demographic determinants of barriers by analyzing the marginal effects of the determinants using a binary Logit model as shown in Figure 23.

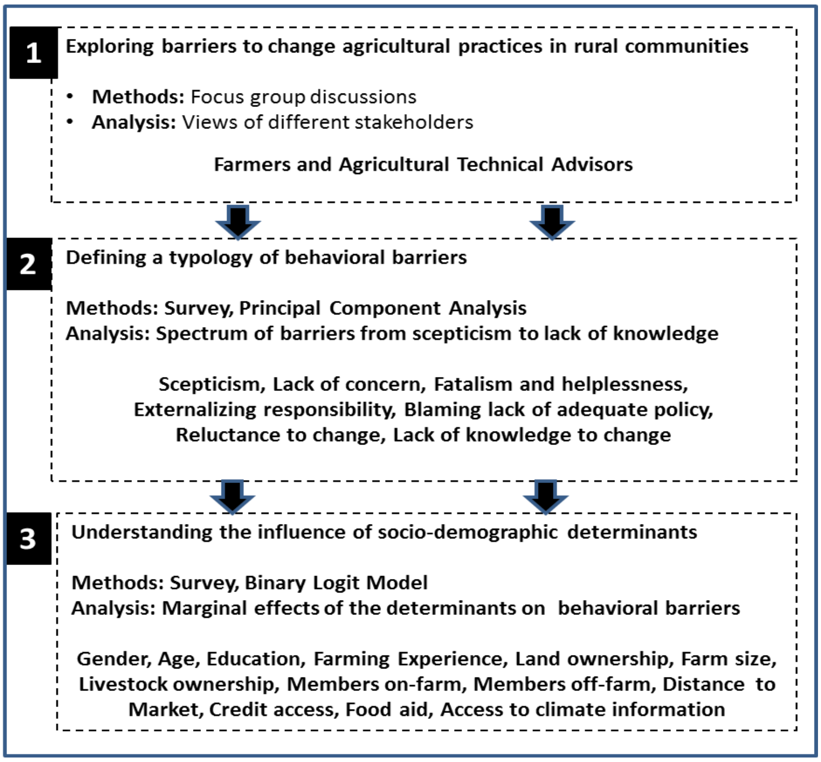


Figure 23: A three-step analytical framework by Garcia de Jalon *et al.* (2015)

From a methodological and analytical perspective, this thesis followed a similar 3-step approach like Garcia de Jalon *et al*. (2015). Focus group discussions, factor analysis (instead of PCA) and logistic regression models based on survey data were used. A key strength of the Garcia de Jalon *et al*. (2015) framework is that it is designed to determine the likelihood of farmers to display certain behaviours using a binary Logit model. Typically, quantitative analytical models mainly focused on using economic and biophysical data due to the unavailability and difficulties of incorporating the concept of social and psychological barriers into mainstream statistical models. However, the Garcia de Jalon *et al*. (2015) framework provides a template for advancing debates about several socio-psychological or cognitive variables some of which are considered in this work (shown in Figure 24).

From a theoretical perspective, while the Garcia de Jalon *et al*. (2015) model was good at identifying typologies of barriers, it was also quite limited in its ability to measure transformational change. Therefore the framework was modified, as illustrated in Figure 24. Even so, it added depth to the scope of social barriers that could be considered for understanding behavioural and institutional constraints that hinder climate change adaptation amongst smallholders. In the third step, two sets of logistic models are compared to see if there is a difference between the restricted or simple model and the preferred model (Tjernstrom & Tietenberg, 2008). A likelihood ratio test was used to compare the fit of the simple or restricted model to the preferred or full model (Yegbemey *et al.*, 2013).

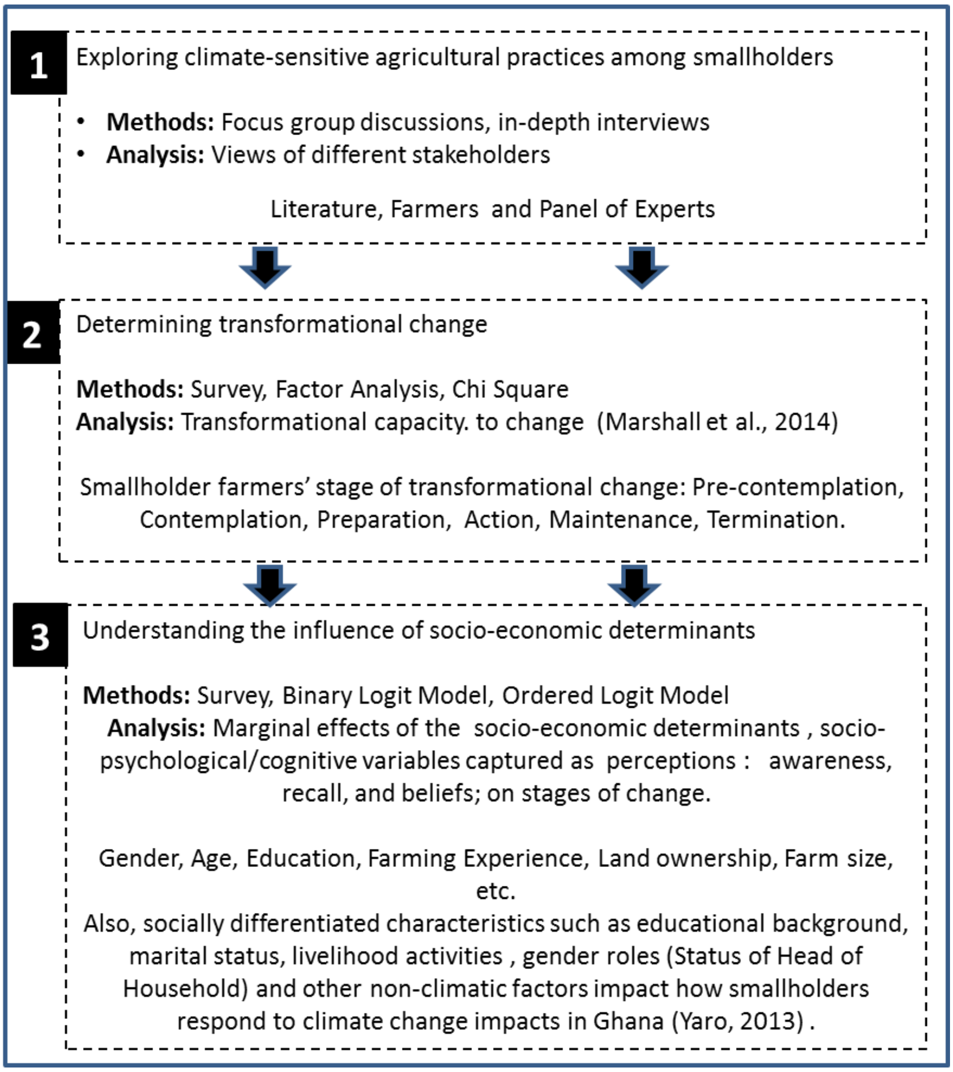


Figure 24: Analytical framework adapted from Garcia de Jalon *et al.* (2015)

A framework inspired by Marshall *et al*. (2014) was used to determine transformational change in lieu of the construct of "typology of social barriers" that was used by Garcia de Jalon *et al*. (2015). Although Marshal *et al.* (2014) used the framework to measure transformational capacity it was found to be suitable after slight modification for analyzing transformational change in the context of this study. For discussion purposes, the conceptual and theoretical linkage between perceptions, beliefs, cognitive and psychological impacts of climate change on farmer behaviour was established with inspiration from studies by Haden *et al.* (2012) and Niles *et al.* (2015) which analyzed farmers' perceptions and psychological distance. Finally, a framework by Geels and Schot (2007) guided discussions on how individual transformation conceptually leads to societal transformation. The researcher shared results to seek concordance with respondents (Silverman, 2011).

The multi-level perspective (MLP) by Geels (2002), and Geels & Schot (2007), which takes its roots from New Institutional Economics, proposes three distinct categorizations for technological and socio-technical change: (i) Reproduction, which refers to incremental changes along existing trajectories, described as taking radical (niche) opportunities from relative obscurity to the fore (Geels & Kemp, 2007, p. 444); (ii) Transformation, which refers to changes in direction along an existing trajectory (ibid); and (iii) Transition, which refers to a discontinuation along the current trajectory to a new trajectory and system (Geels & Kemp, 2007, p. 444).

In this research, smallholder perceptions were analyzed on both a time scale - recall of climate impacts, and context - how this affects their stage of transformation. While the study does not attempt to measure socio-technical change as per the MLP model, the thesis draws on the conceptual and analytical strengths of the MLP to support discussions about the processes (mechanisms and pathways) by which smallholders and other actors interact amongst themselves beyond the individual level to achieve societal transformation as depicted in Figure 25.

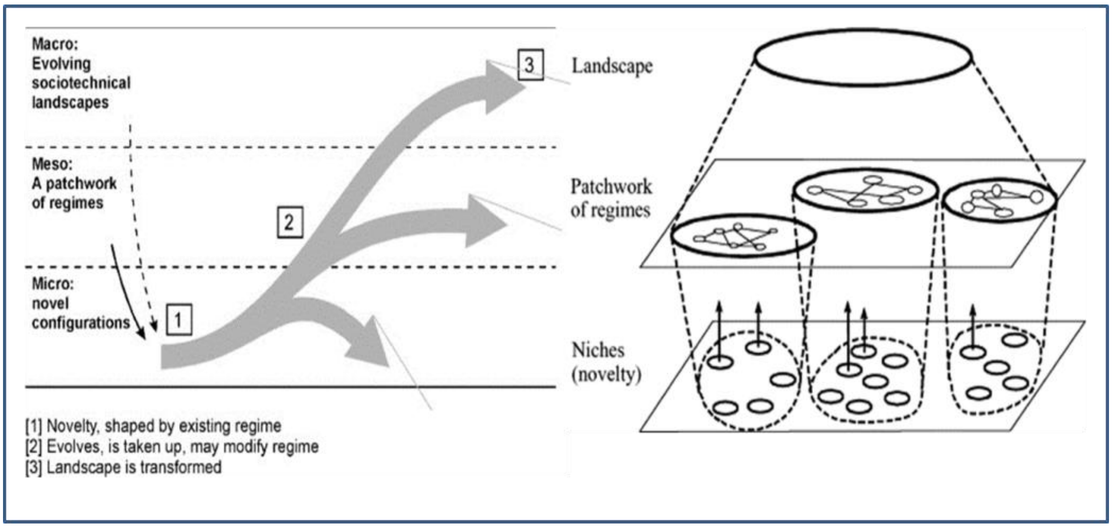


Figure 25: Geels' (2002) multi-level perspective.

3.8.3 *Empirical Models*

Although it has been noted that it is very difficult to measure agricultural Extension impacts using quantitative cause and effect statistical relationships (Purcell & Anderson, 1997; Davis, 2008, Garcia de Jalon *et al.*, 2015) logistic and probit regression models help to determine the likelihoods or probabilities of predictor or independent variables on outcomes. In this thesis, both binary and ordered logistic models are used to determine the likelihood or probability of whether a farmer has perceived climate change impacts or not based on the effects of the independent variables and to determine the probability of a farmer being in a particular stage in the transformational change process or not.

The independent variables used are based on the climate change adaptation (Fosu-Mensah *et al.*, 2010; Yaro, 2013). Data on smallholder perceptions about climate change impacts and stages of adopting climate-sensitive practices along the transformational change process were collected during the field study. The climate-sensitive practice of adopting tube-well irrigation is one of the observable practices used as a proxy for the latent variable of transformational behaviour change. This is because the impact of the explanatory variables on the outcome variable of transformational change and perceptions cannot be measured directly except as latent phenomena. The logistic regression model assumes that there is an underlying non-linear relationship between the dependent and independent, explanatory or predictor variables as shown in the following equations. In all the logistic empirical models, the dependent variable measuring some aspect of the climate change or behavioural change phenomenon is assumed to be predicted by a latent equation:

$$\text{Pr}ob(y_i = 1) = \frac{1}{1 + \exp^{-x_i\beta}}$$

Where Y is the dependent variable and x_i is a matrix of independent variables where $i = 1...,n$ number of variables.

The proposed empirical model can be written under the general form:

$$C\lim atePercetionVariable = f\left(Age, Edu, Gen, Hoh, Ext, Farm, Mstat + Land + \varepsilon\right)$$

The dependent variables for estimating perception: “awareness”, “recall” and “beliefs” are “Climaware”, “Climrecall”, and “Climbelieve” respectively.

$$C\lim aware = f\left(Age, Edu, Gen, Hoh, Ext, Farm, land, Mstat + \varepsilon\right)$$

Where

Climaware =1 if the respondent is aware of climate change or otherwise 0.

$$C\lim recall = f\left(Age, Edu, Gen, Hoh, Ext, Farm, land, Mstat + \varepsilon\right)$$

Where

Climrecall =1 if the respondent recalls a climate change event or otherwise 0.

$$C\lim believe = f\left(Age, Edu, Gen, Hoh, Ext, Farm, land, Mstat + \varepsilon\right)$$

Where

Climbelieve =1 if the respondent believes climate is changing or otherwise 0.

The discrete or categorical dichotomous dependent variable, “climaware”, measures whether an individual is aware of climate change or not. The dependent variable is based on the question asked in the questionnaire found in the appendix: “Have you heard about climate change?” Respondents answered by indicating “Yes” or “No” coded as “1” and “0” respectively. “Climaware” as a variable measures the propensity to adapt to climate change based on ones level of awareness. Similarly, Climrecall is a discrete or categorical dichotomous dependent variable which measures whether an individual recalls a climate change event that happened in the past or not. The empirical model measures the relationship between recall and socio-economic variables. The dependent variable “Climrecall” measures the propensity to adapt to climate change based on ones level of recall. The dependent variable is based on the question asked in the questionnaire (found in the appendix): “Can you remember a year in the past twenty years in which extreme weather/crop loss was particularly severe?” Respondents answered by indicating “Yes” or “No” coded as “1” and “0” respectively. Similarly, Climbelieve is a discrete or categorical dichotomous dependent variable which measures whether an individual believes that the climate is changing or not. The dependent variable, “climbelieve”, measures whether an individual believes the climate is changing or not. The variable is based on the question asked in the questionnaire found in the appendix: “Do you believe the climate is changing?” Respondents answered by indicating “Yes” or “No” coded as “1” and “0” respectively.

Gliem and Gliem (2003) found that single items are inadequate for measuring certain constructs such as attitudes and psychological attributes. They suggest *a summated, multi-item scale versus a single item question* (Gliem & Gliem, 2003, p.82). Therefore, besides the single questions indicated above, there are several other questions based on a five-point Likert scale that were designed to measure smallholder beliefs about climate change impacts to ensure construct reliability and internal consistency. "Climbelieve_index" is a composite variable which measures the propensity to adapt to climate change impacts based on smallholder beliefs. Smallholder beliefs towards climate change impacts based on the magnitude, timing, persistence, likelihood, distribution, importance of the system and adaptation potential (IPCC, 2012) are captured in questions as follows (see questionnaire in Appendix II):

"Do you believe that there is a change in air and water temperature?"

"Do you believe there us a change in duration of droughts?"

"Do you believe there is a change in frequency of flooding?"

"Do you believe there is a change in crop damage and failure?

"Do you believe there is a change in the size and intensity of tidal waves?

Participants responded on a five-point Likert scale with 1 indicating "Strongly reduced", 2 for "reduced", 3 for neutral", 4 for "increased", and 5 for " seriously increased. Factor analysis was used to identify how various items contribute to the construct of smallholder beliefs about climate change impacts. The cronbach's alpha was used to determine inter-item reliability for the set of items that constitute the composite variable used in the estimation as shown in the results section. Thus, beliefs were measured using two variables: "Climbelieve" and "Climbelieve_Index".

"Climbelieve_Index" as a composite variable was calculated using the mean score of items representing the construct of climate belief (Gan *et al.*, 2006). The "Climbelieve" variable was regressed on the socio-economic variables in a binary logit model while the mean scores representing the composite climate belief variable "Climbelieve_Index" was regressed on the socio-economic factors in a multiple regression model. The socio-economic factors were represented by Betas (β) 1 to 10 are coefficients of explanatory or predictor variables.

$Age(-) =$ Age of respondent measured in years

$Edu(-) =$ Educational level of respondent

$Gen(+,-) =$ The Gender of the respondent, that is male or female

$Hoh(+) =$ Head of Household

$Ext(+) =$ Access to Extension Services

$Fbo(+) =$ Member of a Farmer Based Organisation

$Farm(+) =$ Farm size measured in acres (Log of farm size is used in the estimations)

$Mstat(+) =$ Marital Status

$Land(+) =$ Land Ownership

$\varepsilon =$ Error term

The climate change adaptation literature reports a broad range of hypotheses about the expected influence of various explanatory variables on adaptation related dependent variables. Wood *et al*. (2014) hypothesise that farmers with greater access to meteorological information, wealth or assets such as land, greater social interaction such FBO participation adapt better. It is expected that Extension, Land ownership, Farm size and FBO participation will all have positive impacts on the likelihood of farmers' awareness, recall and beliefs about climate change impacts.

The Logit condition which requires that dichotomous dependent variables must have sufficient numbers of 0s and 1s was met. The logit models limit the possible outcomes of the dependent variable to an infinite set of values between 0 and 1 only. These are the odds ratios. The odds ratio can be interpreted as the chance or probability of something happening which is 1 versus the chance or probability that it will not happen, 0. Thus the slope coefficient in a logit regression model measures the change in the log-odds ratio for a unit change in the dependent variable with a unit change in the independent variable. Hence, if the coefficient is positive, then it means that as the value of the independent variable increases the odds that the dependent variable will be equal to 1 also increases. For example, if the coefficient of the independent variable is 0.4%, it suggests that a unit increase, that is 1% increase in the independent variable will result in a 0.4% increase in the log of the odds of the dependent variable. Usually, the actual coefficient is ignored and only the sign of the coefficient is maintained to give a general indication of the direction of the probability. In this thesis either the sign or interpretation of the coefficient are used.

Finally, an ordered logistic model was used to assess the relationship between the dependent variable "stage" and the socio-economic and perception variables. The six level categorical variables "Stage" measures the likelihood of transformational change being determined by the socio-economic and perception variables. The restricted empirical model follows the general form:

$$Stage = f\left(Age, Edu, Gen, Hoh, Ext, Farm, Mstat + \varepsilon\right).$$

3.8.4 *Limitations of the study*

One of the main limitations and challenges faced was a lack of standardization in terminology pertaining to smallholder farmers. Going by the FAO (2014) definition, a smallholder farmer is defined as a farmer with less than 1 hectare or 2.5 acres of land. However, during the pre-testing of the questionnaire in the study area, a key informant indicated that farmers with land holdings greater than 2 acres are considered to be large farmers, those with land holdings between 1 to 2 acres are considered to be medium sized farmers while and the remaining farmers with land holdings less than 1 acre were considered to be smallholder farmers. Therefore, these terms familiar to the communities were maintained for consistency, although by FAO standards, almost all farmers who were surveyed would have been considered smallholders except for a very few outliers who had significantly large landholdings greater than 1 hectare or 2.5 acres.

Another limitation pertaining to lack of standardization was with regards to the determination of farm-sizes. In most cases farmers did not know their farm sizes exactly and there was no standard bed-size or plot-size. The locals referred to old plot sizes of 100m by 100m while others referred to plot sizes of 100m by 70m and 70 by 70m which we termed “new plot sizes”. Thus, during data collection, the enumerators had to be sure to clarify what type of plot size was being reported for the calculation of farm size. Therefore, farm-sizes were calculated based on estimated dimensions of farm beds and number of farms owned or cultivated.

Finally, the lack of standardization of key concepts like “climate change” and “climate change impacts” in the local language “Ewe” meant that additional days were spent in training enumerators to ensure consistent interpretation and administration of the survey instruments.

3.9 Chapter Summary

Chapter three was on methodology and therefore explored various aspects of the reesach design, sampling and data collection techniques used, the analytical framework, description of the variables and empirical models for exploring the stages of smallholder transformational change based on Prochaska’s behavioural change model (TTM). The next chapter will present toe results of the research per the research objectives. Each of the four research objectives will be explored as a sub-section and its own discussion, summary, conclusions and recommendations.

CHAPTER FOUR: RESULTS AND DISCUSSION

4.1 Introduction

This thesis seeks to advance existing knowledge in agricultural Extension to help farmers, researchers, practitioners and others in the agricultural development nexus to understand factors relating to the smallholder transformational change process and its effectiveness. The research took its point of entry from the fact that there is an inconsistency between the theory and practice of Extension which may hinder efforts to transformation agriculture by improving agricultural productivity in the face of climate change. Based on literature, three possible explanations for the inconsistency identified were (1) A deficiency in the theoretical or ideological framework used to guide the transformation process in Extension, (2) The perceptions of smallholders themselves due to their socio-economic characteristics and cognitive barriers such as level of awareness, recall and beliefs that hinder their ability to transform, and (3) The limited availability of mechanisms and pathways for achieving transformation.

Three research questions were formulated to guide the inquiry based on these inconsistencies with the main objective of establishing a link between smallholder perceptions of climate change impacts / psychological or cognitive factors, socio-economic factors and the transformational change process as a way of improving agricultural productivity in light of climate variability and change. To accomplish this objective, six specific sub-objectives were established. These objectives were achieved using both qualitative and quantitative analyses. Data were collected using a semi-structured survey instrument and qualitative tools such as focus group discussions (FGDs), in-depth interviews and observation. Results from the study based on the six specific research objectives follow.

4.2 The relationship between smallholder farmer perceptions and transformational change.

The purpose of specific objective 1 was to determine the relationship between smallholder farmer perceptions such as their level of awareness, beliefs and recall of climate change and their transformational change process. The six stages of the transformational change process which are a continuum range from “PC” = Pre-contemplation; “C” = Contemplation; “P” = Preparation; “A” = Action; “M” = Maintenance; “T” = Termination.

A smallholder in the Pre-contemplation (PC) stage means that the individual does not believe there is a problem although that smallholder may be upset, disoriented, or troubled by climate impacts. A smallholder in the Contemplation (C) stage means that the smallholder is aware that a problem exists and is thinking about a solution but has not yet taken action. A smallholder in the Preparation (P) stage means the smallholder has gone beyond the awareness stage, has decided to take an action and is focused on actively pursuing a change within 30 days. The Action stage (A) indicates that a smallholder has been actively pursuing a choice of action for about six months. The Maintenance (M) stage indicates that the smallholder has been consistently using irrigation or hybrid seeds for more than six months. The smallholder is not entirely transformed but has some doubts and may revert back to previous practices during this period or overcome these doubts and proceed to full transformation. The Transformation (T) stage is the final stage of the transformational change process indicates permanent change. In this stage, the smallholder has no temptation or desire to revert to previous behaviour or practices but has fully and irreversibly adopted and adapted to the change in practice. A smallholder can only be in one of these six stages at a time.

4.2.1 The relationship between smallholder awareness and transformational change

Table 4.1 shows the distribution of smallholder farmers along the different stages of the transformational change process based on their awareness of the climate change phenomenon. The scores are a crosstabulation of responses from two questions. The first question was: “What stage are you in dealing with changes in the weather with regards to rainfall pattern, droughts, etc. by adopting the use of tubewell irrigation system? (Select only one, which best describes the individual’s stage)”. From left to right the results show that about 6.59% or 28 respondents were in the Pre-contemplation (PC) stage. About 34.35% or 146 smallholders were in the Contemplation (C) stage and finally 18.59% or 79 respondents were in the Termination (T) stage. For each of these stages some participants were either aware of climate change impacst or not aware. Less than 1.88% were “Not aware” and also in the “Pre-contemplation stage”. This means that these respondents were both unaware of climate change concept or phenomenon and had also not thought about changes in weather as a problem to their farming activities. In contrast, about 4.71% or 20 of the smallholders were “Aware” of the climate change phenomenon but still at the “Pre-contemplation” stage. This interpretation is consistent for all scores in the table.

Table 4. 1 Awareness of climate change along the stages of transformation

		Stages						
Awareness		PC	C	P	A	M	T	Total
Not aware		8	16	2	6	0	8	40
	(%)	1.88	3.76	0.47	1.41	0	1.88	9.41
Aware		20	130	42	114	8	71	385
	(%)	4.71	30.59	9.88	26.82	1.88	16.71	90.59
Total		28	146	44	120	8	79	425
	(%)	6.59	34.35	10.35	28.24	1.88	18.59	100

Source: Field data

The results show that an overwhelming majority of smallholder farmers are aware of the climate change phenomenon in the study area. Out of over four hundred farmers who were surveyed, about 91% were aware of the climate change concept or phenomenon as shown in Table 4.1. This is consistent with literature (Semenza *et al.*, 2008). Over 50% of farmers reported that they heard of the climate change phenomenon through radio stations and also on television in 2013 and 2014. About 11% received information through the Ministry of Food and Agriculture (MOFA) agents and none or zero percent through local newspapers as show in Table 4.2.

Table 4. 2 Smallholder sources of weather related information about climate change

	Source	Freq.	Percent
1	Radio	131	50.58
2	TV	64	24.71
4	Radio & TV	51	19.69
5	Radio, TV, & MoFA	11	4.25
3	MoFA	1	0.39
7	Radio, TV, MoFA, & Newspaper	1	0.39
6	Newspaper	0	0
	Total	259	100.00

Source: Field data

Nyirenda-Jere & Kazembe (2014) report that smallholder farmers usually obtain knowledge and information through peer-exchanges, formal and informal extension advisory services and through mass media channels such as radio and television. This finding is important because, it reveals smallholders' reliance on extension delivery services and mass media channels for climate related information.

Often, it is assumed that smallholders are not explicitly aware of the climate change phenomenon but rather intuitively or through experience and tacit knowledge. However, results in Table 4.3 support the view that besides experience or tacit knowledge, a majority are also influenced by deliberate educational programmes delivered via mass media channels such as radio and television but not newspapers. The results show that over 17% of those who receive their information through radio are at the contemplation stage while only about 4% are in the termination stage.

This result is consistent with Hyland *et al.* (2015) who report that”*while awareness of climate change is a powerful predictor of behavioural intentions, it is independent from the belief that climate change will have negative impacts”* (p.3) This implies that awareness of climate change does not necessarily mean that people have similar beliefs about the phenomenon and its potentially harmful impacts. It also means that awareness of climate change does not necessarily lead to a call to action or behavioural change. Klerkx and Jansen (2010) confirm this in findings of a study on nutrient management. They report that although farmers had a lack of awareness about nutrient seepage in environmental management, the awareness of the knowledge did not also lead the farmers to a proactive attitude to take remedial action.

Table 4. 3 Sources of climate and weather related information and stage of transformation

			Stages				
Source	PC	C	P	A	M	T	Total
Radio	4	45	21	46	4	11	131
(%)	1.54	17.37	8.11	17.76	1.54	4.25	50.58
TV	4	20	5	20	3	12	64
(%)	1.54	7.72	1.93	7.72	1.16	4.63	24.71
Radio & TV	2	19	4	21	0	5	51
(%)	0.77	7.34	1.54	8.11	0	1.93	19.69
Radio, TV & MoFA	0	3	1	7	0	0	11
(%)	0	1.16	0.39	2.7	0	0	4.25
MoFA	0	0	0	0	0	1	1
(%)	0	0	0	0	0	0.39	0.39
Radio, TV, MoFA, Newspaper	0	1	0	0	0	0	1
(%)	0	0.39	0	0	0	0	0.39
Newspaper	0	0	0	0	0	0	0
(%)	0	0	0	0	0	0	0
Total	10	88	31	94	7	29	259
(%)	3.86	33.98	11.97	36.29	2.7	11.2	100

Source: Field data

It is therefore recommended that awareness about climate change and climate change impacts be done through educational programmes (Hailu & Campbell, 2014) via mass media channels like the radio, television and through extension agents to help them take an action.

4.2.2 The relationship between smallholder beliefs and transformational change

Research has shown that perceptions of risk correspond to beliefs about adverse consequences or negative concerns about things that people hold dear and value (Leiserowitz 2006; Dietz *et al.* 2007; Brody *et al.* 2012; Arbuckle *et al.* 2015). In other words, although awareness is good, beliefs and values are the key drivers of action.

Beliefs about climate change with regards to temperature and stage of transformation

When asked if smallholders believed that the climate was changing or not, over 97% of respondents reported that they believed the climate is changing as shown in Table 4.4.

Table 4. 4 Beliefs about climate change with regards to temperature and stage of transformation

			Stages				
Belief	PC	C	P	A	M	T	Total
No	1	6	1	4	0	0	12
(%)	0.24	1.41	0.24	0.94	0	0	2.82
Yes	27	140	43	116	8	79	413
(%)	6.35	32.94	10.12	27.29	1.88	18.59	97.18
Total	28	146	44	120	8	79	425
(%)	6.59	34.35	10.35	28.24	1.88	18.59	100

Source: Field data

It was interesting to note that the majority of smallholders who believed that the climate is changing with regards to temperature were in the contemplation stage. About a third had taken an action and none of the smallholders who did not believe that the climate was changing was in the termination stage.

When asked about their beliefs on how the climate was changing with regards to climate change impacts like temperature and rainfall, about 78% of smallholders believed that the climate was worsening while only 4% believed that it was improving. About 18% were not sure if the climate was improving or worsening or believed that there was no change in climate as shown in Table 4.5. These results show that about one in four people in the study area may be unsure about the changes in climate. It also shows that almost 70% of the smallholders are between the contemplation and action stage. This is important because it gives an insight into the diversity of smallholder views about changes in climate where concerted action and resources could be targeted.

Table 4. 5 Beliefs about how climate is changing with regards to temperature and stage of transformational change.

			Stages				
Beliefs	PC	C	P	A	M	T	Total
Improving	3	4	1	7	1	1	17
(%)	0.71	0.94	0.24	1.65	0.24	0.24	4
Not sure/ No change	3	31	4	36	0	3	77
(%)	0.71	7.29	0.94	8.47	0	0.71	18.12
Worsening	22	111	39	77	7	75	331
(%)	5.18	26.12	9.18	18.12	1.65	17.65	77.88
Total	28	146	44	120	8	79	425
	6.59	34.35	10.35	28.24	1.88	18.59	100

Source: Field data

Beliefs about changing climate with regards to negative climate impacts

Respondents were then asked if they believed that there are changes in specific climate change impacts. Responses were measured on a five-point Likert scale where one (1) represents strongly disagree to five (5), strongly agree, as shown in Table 4.6. The results show that on average, most respondents agreed that there was a change in air and water temperature with a mean score of 3.94, this was followed by changes in the size and intensity of waves at 3.17, then by crop damage and failure, incidence of pests, and duration of droughts, with mean score of 2.67, 2.59 and 2.53 respectively. The highest was agreement about change in air and water temperature, perhaps because this was what is most perceptible to smallholders. The cronbach's alpha which is a measure of inter-item reliability was 0.726. The highest variability in responses was crop damage and failure with a standard deviation of 1.62.

Table 4. 6 Beliefs about changing climate with regards to negative climate impacts

Negative Climate Change Impacts	Obs	Min	Max	Std. Dev	Mean	Scale **
Change in air and water temperature	427	1	5	1.43	3.94	High
Duration of drought	429	1	5	1.62	2.53	High
Incidence of pests	427	1	5	1.61	2.59	High
Crop damage and failure	428	1	5	1.62	2.67	High
Size and intensity of waves	427	1	5	1.48	3.17	High

Source: Field data. **Scale of agreement: Low = Mean =<2.50, High = Mean >2.50

A close look at smallholder beliefs about negative climate change impacts relative to their stage in the transformational change process revealed that the smallholders in the Preparation and Action stages of the transformational change process had the highest level of agreement with regards to all the climate change impacts. With regards to perceptions about air and water temperature, the mean score for those in the Action stage was highest at 4.67 on a five-point Likert scale followed by Preparation stage at 3.98, Contemplation at 3.87, Maintenance at 3.32 and Termination at 3.32. Those at the Pre-contemplation stage had the lowest level of agreement with a mean score of 2.85 on a five-point Likert scale. Also across all the indicators of negative climate change impacts, those at the Preparation and Action stages are most similar in the views about climate change impacts as reflected in the average scores of 3.19 and 3.17 respectively as in Table 4.7.

Table 4. 7 Beliefs about negative climate impacts by stage of transformational change

Stage of Transformation	Air & Water Temperature	Duration of Drought	Incidence of Pests	Crop Damage & Failure	Size and intensity of Waves	Average
Pre-Contemplation	2.85	2.00	2.19	2.23	3.16	2.49
Contemplation	3.87	2.60	2.66	2.73	3.17	3.01
Preparation	3.98	2.77	2.88	2.68	3.55	3.17
Action	4.67	2.75	2.62	2.77	3.16	3.19
Maintenance	3.50	2.50	2.13	2.38	2.88	2.68
Termination	3.32	2.09	2.42	2.57	2.99	2.68
Total	3.94	2.53	2.59	2.67	3.17	2.98

Source: Field data. **Scale of agreement: Low = Mean =<2.50, High = Mean >2.50, N=425

Hyland *et al.* (2015) report that individuals become increasingly likely to take actions or adopt practices to protect and sustain the environment as their awareness of and personal responsibility for an environmental issue increases and their appraisal of its risk become more acute. Smallholders are generally more concerned about their production activities, yields and livelihoods, therefore their perception of negative climate change impacts associated with crop damage and failure could give an indication of their appraisal of the risk and thereby their propensity to take personal responsibility to take action or transform their practices. A look at the distribution of responses for crop damage and failure (Table 4.8) shows that the majority 39.14% and 14.56% believed that the magnitude, likelihood and frequency of crop damage and failure had strongly increased or increased respectively. Yet, surprisingly, a total of about 40% of the smallholders who had such beliefs were in the pre-contemplation and contemplation stage and had not yet taken an action although they acknowledged that negative climate change impacts has strongly increased or increased over time.

Table 4. 8 Nature of climate change impacts and stage of transformational change

	Stages						
Nature of change	PC	C	P	A	M	T	Total
Seriously increased	13	56	16	51	2	26	164
(%)	3.1	13.37	3.82	12.17	0.48	6.21	39.14
Increased	5	17	6	9	4	20	61
(%)	1.19	4.06	1.43	2.15	0.95	4.77	14.56
Neutral	0	12	5	9	0	9	35
(%)	0	2.86	1.19	2.15	0	2.15	8.35
Reduced	5	24	10	19	1	10	69
(%)	1.19	5.73	2.39	4.53	0.24	2.39	16.47
Seriously reduced	3	33	7	32	1	14	90
(%)	0.72	7.88	1.67	7.64	0.24	3.34	21.48
Total	26	142	44	120	8	79	419
(%)	6.21	33.89	10.5	28.64	1.91	18.85	100

Source: Field data

Based on literature about the intense erosion and rapid rate of sea level rise on the West African coastline and especially in Keta, it was expected that an overwhelming majority would report that the size and intensity of tidal waves has strongly increased. Instead, there seems to be almost an even split between the majority of about 25% of the respondents who believe that the tidal waves have strongly reduced and about 21.53% who believe that it has strongly increased, as shown in Table 4.9. This dichotomy can be explained by the fact that those who believe that it has reduced may be reporting the mitigating effects of the sea defense wall, which was a hard-structural long-term engineering response by the government of Ghana against the climate change impact of sea level rise and coastal erosion.

Table 4. 9 Beliefs about change in the size and intensity of tidal waves and stage of transformation

			Stages				
Nature of belief	PC	C	P	A	M	T	Total
Seriously increased	5	34	7	29	1	14	90
(%)	1.2	8.13	1.67	6.94	0.24	3.35	21.53
Increased	0	15	5	22	3	8	53
(%)	0	3.59	1.2	5.26	0.72	1.91	12.68
Neutral	9	20	7	12	1	30	79
(%)	2.15	4.78	1.67	2.87	0.24	7.18	18.9
Reduced	8	39	7	15	2	19	90
(%)	1.91	9.33	1.67	3.59	0.48	4.55	21.53
Seriously reduced	3	34	18	42	1	8	106
(%)	0.72	8.13	4.31	10.05	0.24	1.91	25.36
Total	25	142	44	120	8	79	418
(%)	5.98	33.97	10.53	28.71	1.91	18.9	100

Source: Field data

Beliefs about awareness and concern about climate change and propensity to take action.

According to Hyland *et al.*, (2015), the more concerned people are about climate change impacts the more likely they are to take remedial action. Therefore, based on the results obtained it was expected that a majority of smallholders in the Keta, Anglo area would be increasingly likely to take action based on their level of awareness and concern. When asked specifically if they were concerned, a majority of the respondents (72%) strongly agreed and an additional 25% agreed that people were becoming more aware and concerned about climate change in the Keta area or in Ghana in general as shown in Table 4.10. With regards to their level of concern and stage in the transformational change process, the results revealed a majority of about 34.99% of the smallholders were in the Contemplation stage where they had become aware and admitted that there is a problem and concern but had not yet decided to take any action about it.

Table 4. 10 Beliefs about awareness and concern about climate change in Keta and Ghana

			Stages				
Level of belief	PC	C	P	A	M	T	Total
Strongly Disagree	0	3	0	1	0	0	4
(%)	0	0.74	0	0.25	0	0	0.99
Disagree	0	0	0	2	0	0	2
(%)	0	0	0	0.5	0	0	0.5
Neutral	0	2	0	2	0	0	4
(%)	0	0.5	0	0.5	0	0	0.99
Agree	4	33	10	19	3	33	102
(%)	0.99	8.19	2.48	4.71	0.74	8.19	25.31
Strongly Agree	22	103	33	87	4	42	291
(%)	5.46	25.56	8.19	21.59	0.99	10.42	72.21
Total	26	141	43	111	7	75	403
(%)	6.45	34.99	10.67	27.54	1.74	18.61	100

Source: Field data

Changing practices reference level of awareness

The study probed how smallholders were changing their practices as a result of their level of awareness and concern about climate change and its impacts. There were 152 responses which revealed that farmers are engaged in a wide range of changes in practices. A majority referred to changes in agronomic practices such as shifting cultivation, intercropping, changes in planting, weeding and fertilizer application methods as well as change in methods generally.

Some farmers mentioned that they had changed farming systems to monocropping, organic farming and also altered cropping patterns. Some mentioned that they were using more chemicals in farming. They described these inputs as “toxic” chemicals needed to improve yields and prepare the land instead of burning. Others mentioned changes in watering or irrigation practices and the adoption of tube well irrigation associated with farming in the uplands. A good number responded that they had changed their bush burning practices. During land preparation, instead of burning residue across the whole farm, most farmers now practice zero-tillage and gather residue at particular spots on the farm and burn those specifically, as shown in Figure 26 and 27. Nevertheless, there is still burning of farm residue in the study area which releases GHG emissions into the atmosphere.

Figure 26. Zero tillage and spot burning in study area (Personal collection)

Figure 27. Spot burning during land preparation (Personal collection)

Some of the practices also revealed a number of beliefs held by the farmers. A number of farmers reported that they believed that the use of tube-well irrigation has caused their wells to dry-up and are now looking into "*unirrigated farming*". A 48-year-old farmer from Dornorgbor, Egbenya Dornor reported that he believed "*tube-well irrigation is making the land dry*". Another a farmer, 62-year-old Kodzu Thomas Amegago reported that he believes that the climate change is as a result the fact that the *"gods are left hungry. People of today are not obeying rules and regulations of the gods".* Some farmers believed that there should be no changes in practices because "*the weather changes by itself for its own purpose".* Finally, a 60-year-old farmer from Agorve, Joseph Yao Dedzo reported that as a result of the change in climate, many farmers are now "*calling on powers to cause rain*".

Use of superstition to cope with climate change impacts

A question posed in the questionnaire to measure the extent to which changes in practices are driven by superstitious beliefs shows that while a majority of about 67% of respondents disagreed, about 19% or approximately one out of every five farmers either agree or strongly agree that farmers hold superstitious beliefs and are using "juju" or black magic and superstition in farming as a remedy to negative climate change impacts as shown in Table 4.11. The results also show that about 33.83% of smallholders constituting the majority were in the contemplation stage. This indicates that although they had acknowledged and recognized that climate change is a problem and that others are using superstition in farming, they had not yet taken any action to change their farming practices. The results also show that about 19% or 77 of the smallholders were in termination stage meaning that they had adopted the use of tube-well irrigation as a solution to climate change impacts. Out of this group, 13 agreed and 2 strongly agreed to the use of superstition in farming.

Table 4. 11 Beliefs about use of juju and superstition in farming due to climate change impacts

			Stages				
Level of belief	PC	C	P	A	M	T	Total
Strongly Disagree	12	64	18	68	5	27	194
%	2.96	15.8	4.44	16.79	1.23	6.67	47.9
Disagree	6	22	9	14	0	27	78
%	1.48	5.43	2.22	3.46	0	6.67	19.26
Neutral	1	19	11	17	0	8	56
%	0.25	4.69	2.72	4.2	0	1.98	13.83
Agree	7	11	2	7	2	13	42
%	1.73	2.72	0.49	1.73	0.49	3.21	10.37
Strongly Agree	0	21	4	8	0	2	35
%	0	5.19	0.99	1.98	0	0.49	8.64
Total	26	137	44	114	7	77	405
	6.42	33.83	10.86	28.15	1.73	19.01	100

Source: Field data

With regards to beliefs leading to transformation of practices, smallholders were asked if they believed that certain practices that are known to cause climate change are being curbed as a result of awareness and concern about climate change impacts. About 45.8% disagree or strongly disagreed that climate change causing practices were being curbed as shown in Table 4.12.

Table 4. 12 Belief about changes in practices that cause climate change and transformation process

			Stages				
Level of belief	PC	C	P	A	M	T	Total
Strongly Disagree	8	34	15	32	1	21	111
	2.08	8.85	3.91	8.33	0.26	5.47	28.91
Disagree	3	25	10	19	0	8	65
	0.78	6.51	2.6	4.95	0	2.08	16.93
Neutral	0	14	3	10	0	3	30
	0	3.65	0.78	2.6	0	0.78	7.81
Agree	4	23	7	15	5	31	85
	1.04	5.99	1.82	3.91	1.3	8.07	22.14
Strongly Agree	9	36	6	30	2	10	93
	2.34	9.38	1.56	7.81	0.52	2.6	24.22
Total	24	132	41	106	8	73	384
	6.25	34.38	10.68	27.6	2.08	19.01	100

Source: Field data

When polled about specific practices that cause climate change, the results show that overall, there is a belief that human practices such as deforestation of forests and mangroves, bush burning, grazing of livestock, salt mining and agricultural land use and practices with mean scores of 4.54, 3.96, 3.62 and 3.47 respectively, lead to climate change rather than natural or supernatural forces which has a relatively low mean score of 2.89. Culture and natural or supernatural forces have the highest dispersion of views and low scores signaling that there is a higher level of disagreement about the belief that they are strong causes of climate change as shown in Table 4.13. A scale developed by Marshall *et al*., 2014 where a mean score greater than 2.5 was rated as High and equal or below 2.5 was rated as Low was used to interpret the responses.

It is surprising that despite the high level of awareness and concern about the climate change phenomenon and its causes, when it comes to behavioural change, smallholders report that they do not see any changes in practices to reverse or remedy the causes of climate change they have identified. About 19% or almost one out of five believed that people were using supernatural forces climate change to provide remedies for the climate change impacts affects farming activities. In an interview conducted with some elders of the community to clarify the beliefs and practices being adopted to remedy the climate change impacts, it was found that smallholders are desperately looking for solutions from all avenues to address the worsening climate change impacts. The following except provides some insights:

> *"It hasn't rained since last July. All the wells are dry. We have decided to suspend planting this season. In fact, it is has been a terrible year. We are not sure what to do. We just had a meeting yesterday to discuss what to do. Some say we should just go ahead and make some sacrifices to the gods. I do not mind as long as it does not involve any human blood. After all if it works it is good for us all. It has worked in the past. We are seriously thinking about it..."* Mr. Roland Tudzi, Keta, January 2016.

Beretti *et al.* (2013) attribute this to awareness and risk perception which affect the behavioural capacity to implement adaptation and mitigation measures. Behavioural capacity can be defined as the latent potential of behavioural change to affect improvement in the environment. This means that psychologically as people perceive risk they are more inclined to take action to protect their interests. A look at smallholder believes about the causes of climate change relative to their stage in the transformation change process reveals that those at the Maintenance stage of the transformational stage process have the highest agreement about practices that cause or contribute to climate change in the study area. They have a mean score of 3.81 on a five-point Likert scale of strongly disagree being 1 to strongly agree being 5. This is followed by people in the Action stage with a mean score of 3.52 as in Table 4.13.

Table 4. 13 Beliefs about causes of climate change

Causes of Climate change	PC	C	P	A	M	T	Total	Scale High>2.5 Low=<2.5
Deforestation of forests & mangroves	4.43	4.58	4.36	4.54	4.50	4.63	4.54	High
Bush burning/ grazing of livestock	3.46	4.11	3.84	3.95	4.25	3.94	3.96	High
Salt mining	4.07	3.69	3.59	3.43	4.00	3.59	3.62	High
Agricultural land use & practices	2.82	3.49	3.02	3.63	4.13	3.59	3.47	High
Dams	3.68	3.41	2.74	3.23	4.25	3.71	3.38	High
Building of settlements & infrastructure	2.52	3.20	3.47	3.64	3.75	3.11	3.30	High
Culture	3.14	3.23	3.61	3.22	3.63	2.63	3.16	High
Natural/Supernatural Forces	2.79	2.93	3.32	3.33	2.75	1.96	2.89	High
Sand winning	2.46	2.65	2.11	2.70	3.00	2.74	2.62	High

Source: Field data

4.2.3 The relationship between smallholder recall and transformational change

The transtheoretical stages of change model hypothesises that once people become aware, they go through the Contemplation stage after which they may decide to take an Action (Moore, 2005). However, according to Spence, Poortinga, Butler, and Pidgeon (2011), one of the reasons why people may not take action to curb climate change impacts is that they lack first-hand experience of its harmful effects. It is hypothesised that individuals who have direct experience of the climate change impacts and recall these experiences would be more likely to be concerned and thus more inclined to undertake sustainable or transformative behavioural changes. In contrast those who have not experienced it may be less likely to take action or purse change. Smallholders also depend on explicit and tacit knowledge from recall which they complement with indigenous knowledge passed down through oral tradition which relies heavily on recall (Agrawal, 1995; Mudege, 2007). Therefore, in investigating the link between smallholder perceptions and the transformational change process, this thesis attempts to examine how smallholder recall of climate change impacts they may have experienced relates to their transformational change process.

Recall of severe climate event and stage of transformational process

As a first step in exploring the relationship between smallholder recall and the stages of the transformational stage process, smallholders were asked if they could recall any severe climate change events in the past twenty years. Results shown in Table 4.14 reveal that about 83% of smallholders reported that they could recall a severe climate change event that impacted them in the past twenty years. This means that about four out of five smallholders could recall a first-hand experience with severe climate change impacts that affected them. The results show that for those who could recall, a majority were in the earlier stages of Pre-contemplation (5.77%), Contemplation (27.03%, and Preparation (8.92%) amounting to over 41% of smallholders. Only about 4.7% of smallholders in the Termination stage of the transformational change process had no recall of a severe climate event in the past twenty years, while about three times this number or 13.9% could recall a severe climate change event in the last twenty years. This suggests that recall does not automatically lead to adoption or full transformation or Termination stage. Perhaps other socio-economic characteristics may also be important as found by other researchers (Yaro, 2013; Garcia de Jalon *et al.*, 2015).

Table 4. 14 Recall of severe climate event in the last twenty years and stage of transformational process

	PC	C	P	A	M	T	Total
Do not recall	5	21	7	12	1	18	64
(%)	1.31	5.51	1.84	3.15	0.26	4.72	16.8
Recall	22	103	34	100	5	53	317
(%)	5.77	27.03	8.92	26.25	1.31	13.91	83.2
Total	27	124	41	112	6	71	381
(%)	7.09	32.55	10.76	29.4	1.57	18.64	100

Source: Field Data

Smallholders were also asked if they could recall when they first started experiencing climate change impacts. The results also show that a majority of about 37% of the smallholders recall that they started experiencing climate change impacts less than five years ago. This is followed by about 31% who recall that they started experiencing it about 10 years ago. Altogether, over 70% believe that they started experiencing the phenomenon about 20 years ago. In focus group discussion held at Agorve in April 2014 where farmers were asked about when they first noted changes in climate, some farmers reported:

> *"The change started 20 years, I have been farming for 60 years, I have seen many weather events but because I'm not educated, I did not note that well. Mostly, the crops now burn out and that is serious and a worry to us so we need help. From 1986/ 87 there was a hig flood but after that we did not witness floods of that nature. Our shallots flooded in the lowland".*

> *"Also in 2008, we had to collect the tomatoes and take them to the upland. It was June 4th the depression flooded. We also have new "Ntazi" diseases. It affects the bulb and roots then transmit it to the leaves. I believe it starts with the soil/fungal diseases as a result of changes in the soil".*

With regards to stage in the transformational change process it was surprising that the majority of smallholders were in the Contemplation stage as shown in Table 4.15.

Table 4. 15 Recall of when climate change impacts were first experienced and stage of transformation

	PC	C	P	A	M	T	Total
Less than 5 years	5	44	18	61	3	27	158
(%)	1.18	10.35	4.24	14.35	0.71	6.35	37.18
About 10 years	11	44	15	30	2	33	135
(%)	2.59	10.35	3.53	7.06	0.47	7.76	31.76
About 15 years	6	33	6	18	1	17	81
(%)	1.41	7.76	1.41	4.24	0.24	4	19.06
About 20 years	4	10	4	7	0	2	27
(%)	0.94	2.35	0.94	1.65	0	0.47	6.35
More than 20 years	2	8	0	1	0	0	11
(%)	0.47	1.88	0	0.24	0	0	2.59
More than 30 years	0	5	1	3	1	0	10
(%)	0	1.18	0.24	0.71	0.24	0	2.35
Not sure how long	0	2	0	0	1	0	3
(%)	0	0.47	0	0	0.24	0	0.71
Total	28	146	44	120	8	79	425
(%)	6.59	34.35	10.35	28.24	1.88	18.59	100

Source: Field data

Recall of severe climate events and their impacts on smallholder livelihoods

Besides the link between smallholder Recall of when climate change impacts were first experienced and their stage of transformation, Smallholder views from a focus group discussion held at Avume on 23rd April 2014 were obtained. Focus group discussion provides additional insights about how smallholders perceive climate change and their recall of climate impacts on their livelihoods.

> *"The hot weather has affected our crops. It depends on the crops grown but in some years the crops have been burnt by the hot weather. In 2013 the rainfall pattern was not encouraging. No rain at all in the latter part of the year. Some crops do not survive the drought so applying manure was a waste of time".*

> *"Last year [2013], the water table decreased and that affected the growth of the plants especially tomatoes. We planted*

tomatoes in the first season from June, July to August. In the second season we planted onion and in the third season from January to March we planted okro and maize. We experienced only a few showers therefore the water table was very low. All our tomatoes got burnt by the heat and did not make it to the flowering stage".

"Yes, besides last year [2013] another year in which we suffered severe drought compared to last year was in the 1986/1987 season. The lagoon dried completely to the point that no fish was found in it".

"Since that time, some fish and animals that could be found in those days can no longer be found. "Gbolonu", "Kporlor", "Getsu", "Dado", "Adehe" are gone and do not exhist nowadays".

"Others like "Akpa", "Borlu", "Eflo", "Gala", "Edzi" and "Gborvilolo" which were plentiful in those days have now declined considerably. They somehow exhist but are not as common as they were before that time".

Recall has a powerful impact on perceptions because it helps smallholders put emerging conditions in perspective. It helps them assess how conditions vary from their previous knowledge and expectations which have been developed over time. They recall occurrences, explanations and beliefs about occurrences according to their societal norms. They are able to form certain perceptions based on the new stimuli and past memories, knowledge, beliefs or perceptions. A study by Steyaart and Jiggins (2007, p. 578) found that, there was "*a general lack of understanding of the context and history of the problematic situations addressed by policy, although such an appreciation is needed to identify the constraints and the opportunities for new actions to succeed".* If the importance of recall is formally incorporated into interventions, farmers, researchers and other development workers would gain a better understanding of the context and nature of problems and opportunities to improve productivity.

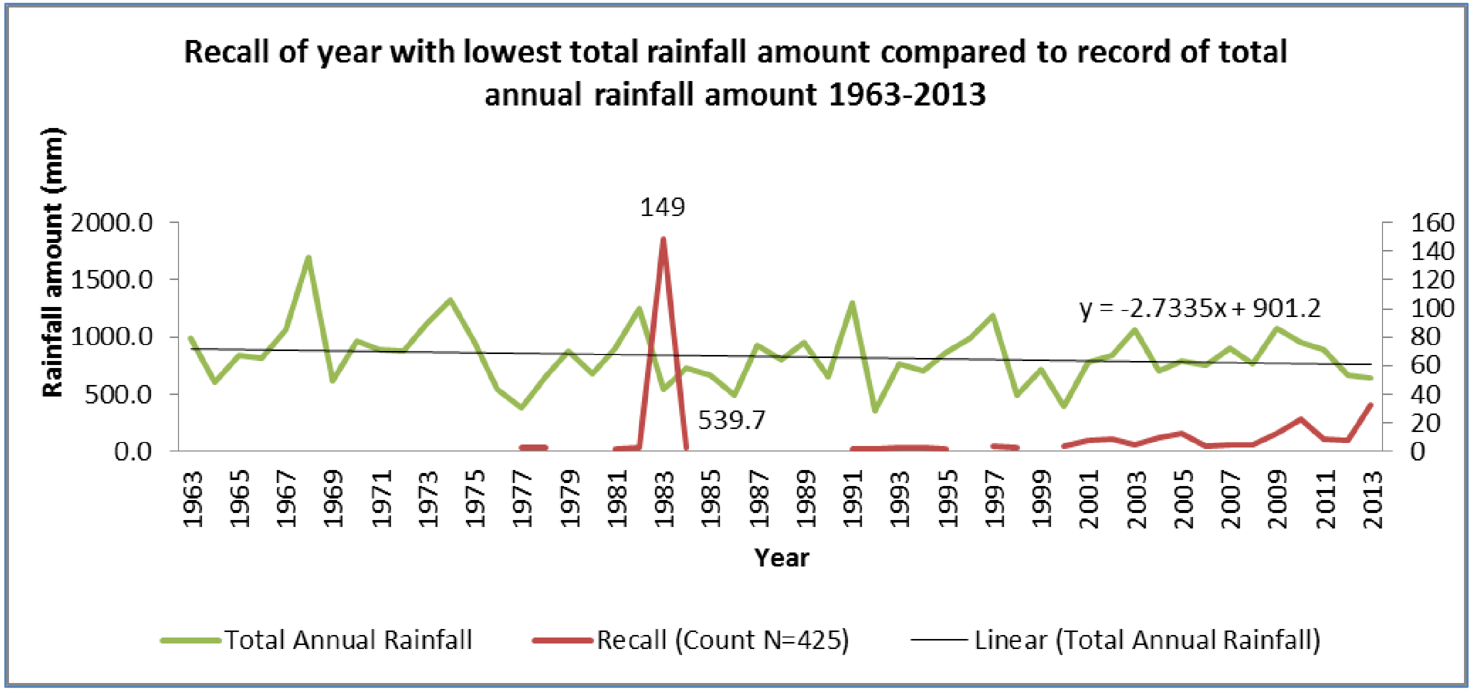
Bloom's taxonomy (Anderson *et al.*, 2001) identifies the ability to recognize and recall facts as the most fundamental component of knowledge. In this study smallholders have experienced at first-hand some personal climate change impacts such as crop failure and losses and feel discouraged by the unpredictable rainfall pattern. The findings reveal that recall about past environmental conditions and biodiversity are all important facts that smallholders can easily relate to. Therefore, if agricultural Extension is to help farmers appreciate knowledge about the effects of climate change impacts on natural resources and institutions governing resources, then recall should be incorporated as a first step.

Recall of climate change impacts compared to recorded rainfall levels

A comparison of smallholder recall of climate change impacts with recorded rainfall levels was done. Recall was compared with recorded rainfall data to establish the degree of accuracy of their recall. In assessing perceptions of climate variability and change, Hansen *et al.* (2012) compared the distribution of mean surface air temperature in units of standard deviation from the normal distribution "bell curve" as the point of reference. They believed that this was a method of comparison that the lay public would appreciate. This thesis compares smallholder recall with recorded total annual rainfall data from 1963 to 2013. It is true that farmers are not usually concerned about total annual rainfall but about the distribution, timing, reliability and pattern of rain during a season. However, the comparison focused on identifying convergence or divergence along specific points in time that are identified in the literature where significant climate events are said to have occurred. If there were a high number of people who recalled a certain year and at the same time there was a very high or low rainfall amount, then this was interpreted as a convergence between smallholder recall and the recorded data.

Owusu *et al.*, (2008) reported that low rainfall amounts led to severe meteorological droughts across most of Ghana in 1983, 1998 and 2007. They further reported that this had a devastating effect on rain-fed agriculture. There is a high level of convergence regarding 1983 as a year of severe climate event recalled by smallholders which is also consistent with recorded data and the literature. As shown in the results in Figure 28, about 149 or 35.06% of smallholders recalled 1983 as a year when they experienced severe climate change impacts such as drought, crop failure and losses, hunger, and famine. In 1983, a low rainfall amount of about 537.9mm was recorded. Although not the lowest level of rainfall on record, it is interesting that 1983 was the year most farmers recalled.

An explanation could be because the duration and magnitude of climate impacts that occurred simultaneously compounded the effect on the total system, well-being and livelihoods of the farmers. The drought affected the lagoon and availability of fish so smallholders could not rely on their fishing as a source of supplementary food thus affecting food security. During the interviews and discussions, smallholders reported that they recalled this because of the impact it had on them and their families personally. A farmer recalled that in those days, the lagoon had dried up so people would walk across from Anloga to the Anyako end to harvest tiger nuts called "Anyakofie" to sustain themselves on the juice. He recalls that many people died or abandoned their farms and livelihoods and migrated to Nigeria to seek greener pastures.



Total Annual Rainfall in Ada from 1963 to 2013

N	Mean	Median	Std. Dev.	Skewness	Min	Max
51	830.13	819.00	256.69	0.72	359.20	1696.4

Figure 28: Comparison of recall of climate impacts with recorded rainfall data

Source: Rainfaill data from Ghana Meteorological Agency, Accra. Other from Field data.

An additional level of analysis was done to investigate those who recalled a climate change impacts in 1983 in comparison to those who did not. The analysis also examined the stage of those who recalled these events in 1983 relative to those who did not mention 1983. A comparison between those who recalled 1983 specifically compared to the rest of the smallholders showed that, a greater number who recalled (18.59%) were in Termination stage than those who did not recall (13.67%) as shown in Table 4.16.

Table 4. 16 Stage of transformational change for those who recalled 1983 versus those who did not

	PC	C	P	A	M	T	Total
Do not recall 1983	20	96	32	65	5	58	276
(%)	4.71	22.59	7.53	15.29	1.18	13.65	64.94
Recall 1983	8	50	12	55	3	21	149
(%)	1.88	11.76	2.82	12.94	0.71	4.94	35.06
Total	28	146	44	120	8	79	425
(%)	6.59	34.35	10.35	28.24	1.88	18.59	100

Source: Field data

According to recorded data, the worst year in terms of drought, with the lowest level of rain was actually 1992 with a total rainfall amount of 359.20 mm. Similarly, the two other worst years between 1963 and 2013 were 1977 with 373 mm and the year 2000 with 394 mm as shown in Figure 29. The year 1983 was actually only the 8th worst year in terms of total rainfall amount. Thus, at first glance it may appear that the farmers were mistaken in their recall. However, a nuanced view taking into account the start of the rainy season shows that 1983 was the only year where there was no rain until April with the worse total rainfall recorded from January to April. For smallholders, this is significant because it disrupted the planting season and caused crops planted earlier in anticipation of the start of the rainy season in March to wither. It is therefore not surprising that despite the fact that the total rainfall amount was not the lowest, the majority of farmers recalled 1983 as a year in which they experienced a devastating climate change impact.

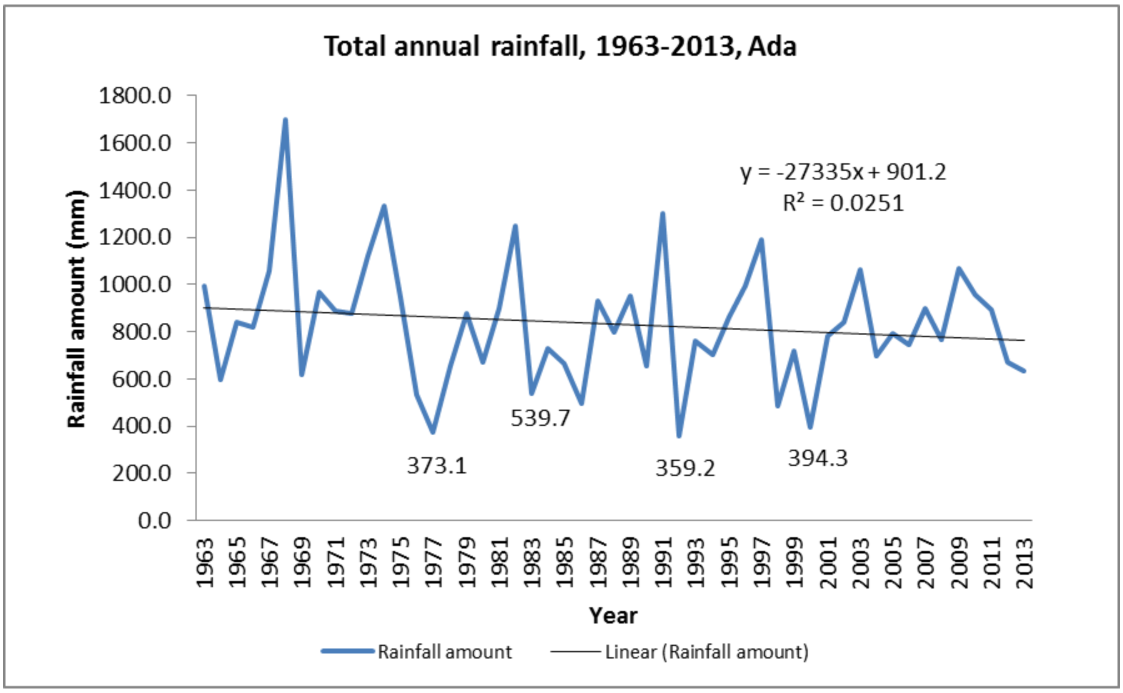


Figure 29. Trend of annual rainfall amount 1963-2013, Ada

Source: Rainfall data from Ghana Meteorological Agency, Accra.

4.2.4 Conclusions: Smallholder perceptions and transformational change

Smallholder perceptions were measured using three dimensions: awareness, recall and beliefs about climate change. In conclusion, the results show that there is widespread awareness of the climate change phenomenon in the study area which is consistent with literature (Fosu-Mensah et al., 2010). However, awareness did not automatically translate into a high level of climate-sensitive practices (Kloek et al., 2004). This is again consistent with literature. Hyland et al. (2015) argue that" while awareness of climate change is a powerful predictor of behavioural intentions, it is independent from the belief that climate change will have negative impacts" (p.3). One of the negative beliefs that was quite prevalent was their perceptions about the use of superstitious beliefs as a remedy againgt climate change impacts. Rogers (2003) posits that individuals are not easily convinced by innovation messages unless the innovations are perceived to be relevant and fit with their needs, attitudes and beliefs. When it comes to beliefs and climate change, about 20% of respondents in the survey agree that smallholder farmers use "juju" referring to spiritual sacrifices and rituals as a remedy against climate change. In contrast, recall of a severe climate event was not a good predictor of a smallholder's likelihood to be at the termination stage of the transformation process although recall of the timeframes or duration of change was a significant predictor. This could be interpreted to mean that as people may have more lasting or meaningful perceptions about a range of events occurring over a period of time than attributing change to a single event. Indeed, the climate change phenomenon occurs over a period of time.

4.3 The relationship between smallholder socio-economic characteristics and perceptions about climate change.

This section addresses specific objective two by analyzing the effects of socio-economic factors on smallholder perceptions of climate change. Smallholder perceptions of climate variability were captured in the three perception variables: climaware, climbelief, and climrecall. Socio-economic characteristics used were age, gender, education (Edu), marital status (Mstat), landownership (Land), access to extension delivery (Extension), status as Head of household (Hoh) and farm size (logFarmsize).

4.3.1 Tests of association between socio-economic variables and perceptions

Chi-square (X^2) analyses were used to test for association and independence between the perception and socio-economic variables. The results shown in Table 4.17 reveal that the relationship between climate change awareness (ClimAware) and Head of Household (Hoh), as well as ClimAware and access to Extension services (Extension) were significant at the 5% level. ClimAware also had a significant relationship with membership in a Farmer Based Organization (FBOmember) at the

10% significance level. The X^2 tests also show a significant relationship between smallholder beliefs (ClimBelief) about climate change with regards to temperature and access to Extension delivery services (Extension). The relationship was significant at the 5% significance level. Finally, the tests of association showed a significant relationship between smallholder recall (ClimRecall) and access to Extension services at the 5% significance level as shown in Table 4.17.

It was surprising that the relationship between climate change awareness (ClimAware) and Gender, Age, and Education were not significant. Based on the literature (Garcia de Jalon *et al.*, 2015), it was expected that Gender and Age would have a negative association with perceptions of climate change impacts. However, Education was expected to be positive. Similarly, the relationships between climate change awareness and land ownership, as well as marital status were not significant.

Findings about the importance of Extension are consistent with the literature. Below *et al*. (2011) found that access to agricultural Extension is vital to increased agricultural productivity and adaptation to climate change impacts.

Table 4. 17 Chi-square results between socio-economic characteristics and awareness

Relationship	DF	Pearson's Chi-square	Probability Value	Conclusion
ClimAware and Gender	1	0.4225	0.516	Not significant
ClimAware and Age	56	40.411	0.942	Not significant
ClimAware and LowEdu	1	0.5564	0.456	Not significant
ClimAware and MidEdu	1	0.0091	0.924	Not significant
ClimAware and HiEdu	1	1.1819	0.277	Not significant
ClimAware and Edu	7	5.6162	0.585	Not significant
ClimAware and HH	1	6.6327	0.010**	Significant at 5%
ClimAware and Extension	1	6.4342	0.011**	Significant at 5%
ClimAware and Ownership	1	0.6936	0.405	Not significant
ClimAware and MaritalStatus	1	0.5965	0.440	Not significant
ClimAware and FBOmember	1	2.7621	0.097*	Significant at 10%

Source: Field data

Besides this they also emphasize that public investment in rural infrastructure, access to inputs and the technically efficient use of inputs, as well as a sound system of education that provides equal access to both men and women are essential for productivity. They further argue that in addition to these, strengthening social capital, and providing access to microcredit services were the best means of improving climate change adaptation of farmers in villages across Tanzania.

With regards to the relationship between smallholder beliefs and socio-economic factors, only access to Extension services was significant at the 5% significance level as shown in Table 4.18.

Table 4. 18 Chi-square results between socio-economic characteristics and beliefs

Relationship	DF	Pearson's Chi-square	Probability Value	Conclusion
ClimBelief and Gender	1	0.0376	0.846	Not significant
ClimBelief and Age	56	34.004	0.991	Not significant
ClimBelief and LowEdu	1	0.1098	0.740	Not significant
ClimBelief and MidEdu	1	1.5183	0.218	Not significant
ClimBelief and HiEdu	1	1.3542	0.245	Not significant
ClimBelief and Edu	7	7.4809	0.381	Not significant
ClimBelief and HH	1	0.9052	0.341	Not significant
ClimBelief and Extension	1	6.0660	0.014**	Significant at 5%
ClimBelief and Ownership	1	0.3927	0.531	Not significant
ClimBelief and MaritalStatus	1	0.0076	0.931	Not significant
ClimBelief and FBOmember	1	0.0535	0.817	Not significant

Source: Field data

The relationship between smallholder recall and status as head of household (HH) was significant at the 1% significance level. Similarly access to Extension service also had a significant association at the 5% significance level as shown in Table 4.19. These findings are consistent with the results obtained by Urgessa and Amsalu (2014) who reported that access to Extension was significant and had a positive relationship with smallholder perceptions and adaptation to climate change impacts in the Ethiopia.

They argue that smallholders cannot adapt to climate change impacts unless they first perceive the changes. Access to Extension services broadens smallholder's perceptions. Culturally, it is the head of household who attends meetings and receive information on behalf of the household. It is therefore not surprising that access to Extension had a significant relationship with perceptions and thereby recall as expected.

Table 4. 19 Chi-square results between socio-economic characteristics and recall

Relationship	DF	Pearson's Chi-square	Probability Value	Conclusion
ClimRecall and Gender	1	0.1005	0.751	Not significant
ClimRecall and Age	56	39.245	0.946	Not significant
ClimRecall and LowEdu	1	0.3418	0.559	Not significant
ClimRecall and MidEdu	1	0.1891	0.664	Not significant
ClimRecall and HiEdu	1	0.0796	0.778	Not significant
ClimRecall and Edu	1	8.0712	0.326	Not significant
ClimRecall and HH	1	14.8451	0.00***	Significant at 1%
ClimRecall and Extension	1	6.9044	0.009**	Significant at 5%
ClimRecall and Ownership	1	0.0376	0.846	Not significant
ClimRecall and Maritalstatus	1	0.2300	0.632	Not significant
ClimRecall and FBOmember	1	0.0002	0.988	Not significant

Source: Field data

There are a multitude of factors that could affect smallholder behavioral change. Based on the study by Below *et al.* (2011), it can be said that besides Extension, the other variables they found could have served as control or exogenous factors in explaining the effects of socio-economic variables on smallholder perceptions of climate change impacts. However in this thesis, some of the exogenous factors relevant to the study area could have been increased fragmentation of farmlands, rapid coastal erosion, expansion into uncultivated lands and over-exploitation of land and other natural resources due to formal and informal practices, customs, and the traditional land tenure system in the Keta Anglo area. Over exploitation of natural resources such as mangroves and wetlands destroys habitats thereby reducing bio-diversity, leaving coastal eco-systems vulnerable to climate impacts and shocks (IPCC, 2012). Not all variables can be measured directly in a study. Ownership of land was included as an endogenous variable because land is a scare commodity in the study commodity and therefore its ownership and farm size, serve as symbols of wealth and a proxy for wealth or economic wherewithal (Awadzi *et al.*, 2008, Ocloo, 1996).

4.3.2 Gender and smallholder perceptions of climate change impacts

Gender often stands out among the socio-economic variables because women typically play different roles including the preparation of food involving extraction and use of natural resources such as fuel wood from deforestation of trees, shrubs and mangroves, as well as the use of water for household chores. Men are typically the heads of households and have access to family resources such as land passed down through inheritance and are therefore responsible for the use of land. The Keta area has a unique land tenure system that until recently privileged male children in the inheritance and ownership of land (Ocloo, 1996). Traditionally, after a father dies his land is distributed among all the male children. As a result, land in the Keta area has become fragmented. Nevertheless, as land owners, males have access to the proceeds of farming activities and control farm and household activities. Males therefore have different experiences and pathways in the transformation process than females. It was therefore expected that there would be a relationship between Gender and perceptions of climate change impacts. However, it was surprising that the Chi-square test of association found none of the relationships between gender and the perception variables significant. The results are confirmed by Garcia de Jalon *et al*. (2015) who also obtained negative results in their studies. There were 345 (81.2%) males and 80 (18.8%) females in the study as shown in Table 4.20.

Table 4. 20 Distribution of smallholders by gender (sex) and perceptions of climate change impacts

	Improving	Not sure/No change	Worsening	Total
Female	6	15	59	80
(%)	1.41	3.53	13.88	18.82
Male	11	62	272	345
(%)	2.59	14.59	64	81.18
Total	17	77	331	425
(%)	4	18.12	77.88	100

Source: Field data

4.3.3 Education and smallholder perceptions of climate change impacts

Education is another variable that stands out among the socio-economic variables that has been found to affect attitudes towards climate change impacts (Tjernstrom & Tietenberg, 2008). While it is often assumed that farming is the preserve of illiterates, over 56.8% of stallholders have received up to junior high school level education. The results show that only about 7% of respondents were iliterate with no formal education. About 13.9% had Primary level education, 42.9% who were the majority had Junior High School (JHS) level education, 20.75% had Senior High School (SHS) level education while the remaining with a combined total of about 10% had above SHS level education in vocational, training colleges, polytechnic, university or other tertiary institution as shown in Appendix VI. The ratio of females to males and differences in their educational levels are not surprising because women typically engage in child rearing and other household responsibilities that limit their involvement in formal education.

Three main categories of education were created: “LowEdu” referring to people with no or primary level education; “MidEdu” referring to people with JHS, SHS or vocational level education and “HiEdu” referring to people with polytechnic, graduate or post graduate level education. It was expected that the more educated a smallholder, the more likely the farmer would be aware of, recall past climate impacts or hold specific beliefs about climate change impacts (Spence *et al.*, 2011; Garcia de Jalon *et al.*, 2015). Each category was set as the reference group relative to the other levels. It was surprising that although over 90% of smallholders in the study had SHS level education or below, only 14.88% of then were unsure about their awareness of climate change. Rather, over 73.8% of those with above SHS education were either unsure of the climate change impacts or did not perceive any changes in climate. Similarly, while over 62.9% of those with SHS level education or below thought the climate was worsening, while none or 0% of those with above SHS education thought the climate was worsening asshown in Table 4.21. These findings indicate that the more educated smallholders in the study area with above SHS education may be skeptical, ambivalent, cynical or about their perceptions of climate change impacts.

Table 4. 21 Perceptions of climate change impacts and educational level

	Improving	Not sure/No change	Worsening	Total
Female				
SHS and below	5	13	56	74
(%)	1.31	3.39	14.62	19.32
Above SHS	1	2	3	6
(%)	2.38	4.76	7.14	14.29
Male				
SHS and below	11	57	241	309
(%)	2.87	14.88	62.92	80.68
Above SHS	5	31	0	36
(%)	11.90	73.81	0.00	85.71
Total				
SHS and below	16	70	297	383
(%)	4.18	18.28	77.55	90.12
Above SHS	6	33	3	42
(%)	14.29	78.57	7.14	9.88

Source: Field data

4.3.4 Extent to which socio-economic variables affect perceptions

Despite on-going efforts in research into the factors that affect agricultural productivity and the transformation of smallholder agriculture, there are an infinite list of socio-economic variables, socio-technical and institutional constraints and factors that undermine productivity and pose a danger to food security and livelihoods. Most of these variables could all be investigated in unraveling possible mechanisms and pathways for solving the problem of lack of smallholder productivity. However, not all the variables or relationships can be investigated.

In the following analyses only those socio-economic variables that were found to be significant in the Chi-square tests of association were included in a regression model to determine the extent to which socio-economic factors explain smallholder perceptions: awareness, recall and beliefs about climate change impacts. The dependent variables for estimating perception: "awareness", "recall" and "beliefs" are "Climaware", "Climrecall", "Climbelieve" and "Climbelieve_index" respectively. The significant socio-economic variables used were: Head of household (Hoh), access to agricultural Extension service (Extension), and membership in farmer based organization (FBO). These regression models with only the significant variables can be seen as a restricted. The proposed empirical model with only the endogenous variables used in analyzing the relationships can be written under the general form:

$$C\lim atePercetionVariable = f\left(Hh, Ext, Fbo + \varepsilon\right)$$

However, the rest of the analyses include both the endogenous and exogenous variables.

The proposed empirical model can be written in the general

$$C\lim atePercetionVariable = f\left(Age, Edu, Gen, Hh, Ext, Farm, Land, Fbo + Mstat + \varepsilon\right)$$

Awareness

The results of the logistic regression of awareness on endogenous variables shows that Head of Household (Hoh) and access to Extension services (Extension) were significant at the 1% and 5% significance level respectively. However FBO membership which was significant at the 10% significance level in the Chi-square test was not found to be significant in the logistic regression model. The empirical results show that the explanatory power of the model as indicated by the Chi-square probability value of 0.0017 as shown in Table 4.22 is high. It can therefore be inferred that mechanisms and pathways for effectively addressing smallholder productivity could emphasize the status of heads of households and access to Extension services.

Table 4. 22 Logistic regression of endogenous variables

Logistic Regression				Number of obs	=	425
				LR chi2(3)	=	15.15
				Prob > chi2	=	0.0017***
				Pseudo R2	=	0.0571
				Log likelihood	=	-125.01
ClimAware	Coef.	Std. Err.	z	P>z	[95% Conf.	Interval]
Hoh	1.199876	0.456229	2.63	0.009***	0.305683	2.094068
Extension	1.158228	0.466493	2.48	0.013**	0.24392	2.072537
Fbo	0.404266	0.360954	1.12	0.263	-0.30319	1.111723
_cons	0.785773	0.436034	1.8	0.072	-0.06884	1.640384

Source: Field data

According to Niles *et al.* (2015), "*a major challenge is that climate change adaptation is not a one-size fits all phenomenon; adaptation strategies and farmer responses will vary across regions (Berry et al., 2006) based on agro-ecological contexts, socio-economic factors (Adger et al., 2009), climatic impacts, and existing infrastructure and capacity. Despite this heterogeneity, there remain gaps in our psychological understanding about how farmer experiences and concerns for varying ecological impacts differentially influences farmer decision-making on adaptation strategies across different farm systems and regions"* (p. 178). Although certain variables that affect farmer experiences and concerns linked to productivity can be identified and measured quantitatively as has been done in other research, it is not always easy to isolate them in agricultural Extension and development (Purcell & Anderson, 1997; Davis, 2008; Garcia de Jalon *et al*., 2015). Thus, both variables of interest (endogenous) and exogenous variables are often included in analyses.

Tjernstrom and Tietenberg (2008) argue that individuals are very vital in influencing climate change policy. Therefore, factors that drive or contribute to decision making at the individual level especially the availability of information are highly relevant (Semenza *et al.*, 2008; Marshall *et al.*, 2014). The results of the binary logistic regression model estimating the relationship between awareness and socio-economic factors are shown in Table 4.23.

Table 4. 23 Logistic regression model with endogenous and exogenous socio-economic variables and climate awareness

Logistic regression					No. of obs =	425
					LR chi2(8) =	21.83
					Prob > chi2 =	0.0052***
Log likelihood =	-121.67				Pseudo R2 =	0.0823
Climaware	Coef.	Std. Err.	z	P>z	[95% Conf.	Interval]
gender	-0.7125	0.5158	-1.38	0.167	-1.72340	0.29838
age	-0.0084	0.0146	-0.57	0.566	-0.03707	0.02029
fbo	0.3428	0.3797	0.9	0.366	-0.40126	1.08695
Logfarmsize	1.0720	0.5562	1.93	0.054*	-0.01812	2.16212
hh	1.2395	0.5306	2.34	0.019**	0.19954	2.27942
Extension	1.1145	0.4751	2.35	0.019**	0.18328	2.04573
land	-0.1506	0.3837	-0.39	0.695	-0.90259	0.60135
mstat	-0.1008	0.4948	-0.2	0.839	-1.07066	0.86904
_cons	1.4063	0.8989	1.56	0.118	-0.35541	3.16807

Source: Field data. *** p<0.01, ** p<0.05, * p<0.1

The results show that the status of respondents as head of household, and access to extension delivery services are significant at the 5% significance level, while farm size was significant at the 10% significance level. Based on these results, it can be concluded that the larger the farm size and access to Extension delivery services, the higher the likelihood of respondents being more aware of climate change impacts. This is in line with expectations because with larger farm sizes, farmers stand to lose more and may be relatively more sensitive to climate impacts than farmers with smaller farm sizes. Also, as shown, heads of households (Hoh) are also more likely to be aware of climate change impacts perhaps because they have control over the use of household resources and thus take investment decisions on behalf of the household. Likewise, they may be more aware because they also take the blame for any adverse effects of their decisions about crop types, planting times and so forth. Marital status was not found to be significant in this estimation although Mandleni and Anim (2011) found it to be a predictor of climate change awareness in their study.

Recall

The recall variable, a categorical variable with seven levels was used in an ordered logit regression model to determine the likelihood of a smallholder perceiving climate change based on socio-economic characteristics. Recall of data, information, explicit and tacit knowledge and from memory plays a role in determining the different types and speed of responses (de Jong and Ferguson-Hessler, 1996). With regards to recall, respondents were more likely to recall climate change impacts in this study area if they were head of household or have access to extension. This was similar to their level of awareness. However, unlike awareness, respondents' recall was not socially differentiated by farm size. The IPCC (2012) identified age as one of the socio-economic factors that affect recall of climate change impacts. Similarly, Garcia de Jalon *et al.* (2015) found that age would have a negative effect on changing behavior due to climate change impacts. However, in this binary logit estimation, using a single item dummy variable to measure the construct of recall, age did not show a significant relationship with recall of climate impacts as follows in Table 4.24.

Table 4. 24 Logistic regression with endogenous and exogenous socio-economic variables and recall of climate change impacts

Logistic regression					No. of obs =	381
					LR chi2(8) =	18.31
					Prob > chi2 =	0.0190
Log likelihood =	-163.31				Pseudo R2 =	0.0531
Climrecall	Coef.	SE.	z	P>z	[95% Conf.	Interval]
gender	-0.2456	0.3865	-0.64	0.525	-1.0030	0.5119
age	-0.0003	0.0123	-0.03	0.979	-0.0245	0.0238
fbo	0.0546	0.3092	0.18	0.860	-0.5515	0.6607
logfarmsize	-0.2385	0.3493	-0.68	0.495	-0.9232	0.4462
Hh	1.4831	0.4337	3.42	0.001***	0.6332	2.3331
Extension	-0.6425	0.2916	-2.2	0.028**	-1.2140	-0.0710
land	-0.0653	0.3084	-0.21	0.832	-0.6698	0.5391
mstat	-0.1233	0.4156	-0.3	0.767	-0.9377	0.6912
_cons	1.0392	0.7523	1.38	0.167	-0.4353	2.5136

Source: Field data. *** p<0.01, ** p<0.05, * p<0.1

However, using an ordered logistic model in which recall was a multiple level variable yielded results in which gender and age were significant at the 1% level, FBO membership and land ownership were significant at the 5% level and Extension at the 10% significance level. These findings are consistent with the literature that socio-economic factors such as age, gender, land ownership, access to Extension services and membership in FBOs explain the likelihood of a smallholder's perception of climate change impacts (IPCC, 2012; Garcia de Jalon *et al.*, 2015, Yegbemey *et al.*, 2013, Yaro, 2013). The positive sign of the age coefficient shows that the older the farmer the more likely the recall, while that of gender means that men, the reference group, are more likely to recall than women. While Urgessa and Amsalu (2014) did not find gender to be significant in their logistic model, they also found access to Extension to be significant although their Extension was specific to farmer-to-farmer Extension. Based on the coefficient, it can be concluded that the log odds for recall would change by. 0.030168 for every directional change when the education variables in the model are held constant as in Table 4.25.

Table 4. 25 Ordered logit regression of socio-economic factors and smallholder recall

Ordered logistic regression				Number of obs	=	425
				LR chi2(8)	=	41.36
				Prob > chi2	=	0.0000***
Log likelihood =	-591.71956			Pseudo R2	=	0.0338
recall	Coef.	Std. Err.	z	P>z	[95% Conf.	Interval]
gender	0.7637723	0.2475332	3.09	0.002***	.2786162	1.248928
age	0.0317947	0.0078339	4.06	0.000***	.0164404	0.0471489
fbo	0.4267591	0.1881053	2.27	0.023**	.0580796	0.7954387
logfarmsize	-0.0968372	0.2240751	-0.43	0.666	-.5360164	0.342342
hh	0.0528947	0.3505404	0.15	0.880	-.6341518	0.7399412
extension	-0.3803018	0.196922	-1.93	0.053*	-.7662618	0.0056582
land	0.3934279	0.1926807	2.04	0.041**	.0157807	0.7710752
mstat	-0.1824631	0.257188	-0.71	0.478	-.6865422	0.3216161

Source: Field data. *** p<0.01, ** p<0.05, * p<0.1

The levels of the ordinal recall variable were: Less than 5 years, about 10 years, about 15 years, about 20 years, more than 20 years, more than 30 years. The marginal effects were calculated to determine the probability in percent that smallholders could recall versus if the smallholder could not recall a severe climate change impact within the last twenty years all things being equal. Based on the results, it can be concluded that the probability that a respondent can recall is approximately 16.67% lower for a male than for a female respondent. Similarly, the probability of a respondent recalling a severe climate change impact will decrease by 9.2% if the respondent belonged to an FBO versus a non FBO member as shown in Table 4.26. The social interpretation given to these results are that perhaps farmers who are privileged in the society as males or who belong to FBOs have more social capital and support and perhaps weather the storms or negative impacts of severe climate impacts better than those without this support or access to resources. A person who lost everything due to a severe climate impact and who did not have the means to recover quickly is more likely to recall the event for longer and more vividly than one who did not overcome it easily.

Table 4. 26 Marginal effects of the relationship between socio-economic factors and recall

Margins,	dydx(*)					
Average marginal effects Model				No. of obs =		425
VCE:	OIM Pr(recall==1),					
Expression:	predict ()		predict()			
w.r.t.:	gender, age, fbo, logfarmsize, hh, extension, land, marriedstat					
	dy/dx	Std. Err.	z	P>z	[95% Conf. Interval]	
gender	-0.1657	0.05222	-3.17	0.002***	-0.268	-0.063
age	-0.0069	0.00164	-4.21	0.000***	-0.010	-0.004
fbo	-0.0926	0.04012	-2.31	0.021**	-0.171	-0.014
logfarmsize	0.0210	0.04857	0.43	0.665	-0.074	0.1164
hh	-0.0115	0.07605	-0.15	0.880	-0.161	0.138
extension	0.0825	0.04226	1.95	0.051*	-0.000	0.165
land	-0.0854	0.04129	-2.07	0.039**	-0.1630	-0.004
mstat	0.0396	0.05572	0.71	0.477	-0.070	0.149

Source: Field data. *** p<0.01, ** p<0.05, * p<0.1

Beliefs

Beliefs were also measured in two main ways. First as a single-item dummy variable where respondents answered ‘yes’ if they had certain beliefs or ‘no’ if they did not. Also a composite variable called “Climbelieve_Index” which constituted a number of items or questions measured on a five-point Likert scale. The items were selected from a group of questions using factor analysis. The factor loadings were used to select the strongest factors to include in the index while the weak ones were eliminated. The factors that were selected based on the factor analysis were “Change in air and water temperature”, “Duration of drought”, “Incidence of pests”, “Frequency and magnitude of crop damage and failure”, and “Size and intensity of waves”. The results are presented in Appendix VII.

The scores of the selected items were summed and an average was calculated. This average representing the mean score was used as the dependent variable in the model to estimate the relationship between socio-economic variables and smallholder beliefs. The results of the estimation reveal that farmer access to Extension delivery had a very significant relationship on smallholder beliefs at the 1% significance level as shown in Table 4.27.

Similarly, the variable FBO had a significant relationship at the 5% level with smallholder beliefs about climate change impacts. FBO was a dummy variable where “1” represented farmers in an FBO and “0”, those not belonging to an FBO. Since the composite variable was numeric, multiple linear regression was used to determine the impact of the socio-economic factors. The results in Table 4.27 show that the model itself was highly significant at the 1% level as indicated by the probability Chi-square.

Table 4. 27 Relationship between socio-economic factors and beliefs about climate change impacts

Logistic regression					No. of obs	= 425
					LR chi2(8)	= 21.83
					Prob > chi2	= 0.0052***
Log likelihood =	-121.67				Pseudo R2	= 0.0823
Climbelief_Index	Coef.	Std. Err.	t	P>[t]	[95% Conf.	Interval]
gender	-0.1592	0.1386	-1.15	0.251	-0.43176	0.11331
age	-0.0062	0.0046	-1.36	0.174	-0.01517	0.00275
fbo	-0.2283	0.1079	-2.12	0.035**	-0.44044	-0.01619
logfarmsize	-0.0357	0.1283	-0.28	0.781	-0.28783	0.21652
hh	0.2630	0.1914	1.37	0.170	-0.11325	0.63931
extension	0.3078	0.1110	2.77	0.006***	0.08964	0.52587
land	0.1544	0.1097	1.41	0.160	-0.06118	0.37007
mstat	0.1880	0.1478	1.27	0.204	-0.10247	0.47852
_cons	2.9657	0.2934	10.11	0.000	2.38884	3.54248

Source: Field data. *** p<0.01, ** p<0.05, * p<0.1

Similarly, FBO membership and access to Extension were significant at the 5% and 1% levels respectively. In the model, Gender, Age, logFarmsize, Head of household, marital status and land ownership were not significant as follows in Table 4.28.

Table 4. 28 Relationship between smallholder beliefs and socio-economic factors

Multiple Regression					No. of obs =	425
					F (8, 416) =	2.38
Source	SS	df	MS		Prob > F =	0.0616*
Model	21.00247	8	2.625309		R-squared =	0.0438
Residual	458.194	416	1.101428		Adj R-squared =	0.0254
Total	479.1965	424	1.13018		Root MSE =	1.0495
Climbelief_Index	Coef.	SE.	t	P>[t]	[95% Conf.	Interval]
gender	-0.1592	0.1386	-1.15	0.251	-0.43176	0.11331
age	-0.0062	0.0046	-1.36	0.174	-0.01517	0.00275
Fbo	-0.2283	0.1079	-2.12	0.035**	-0.44044	-0.01619
logfarmsize	-0.0357	0.1283	-0.28	0.781	-0.28783	0.21652
hh	0.2630	0.1914	1.37	0.170	-0.11325	0.63931
Extension	0.3078	0.1110	2.77	0.006***	0.08964	0.52587
land	0.1544	0.1097	1.41	0.160	-0.06118	0.37007
mstat	0.1880	0.1478	1.27	0.204	-0.10247	0.47852
_cons	2.9657	0.2934	10.11	0.000	2.38884	3.54248

Source: Field data. *** p<0.01, ** p<0.05, * p<0.1

The analysis shows that each of the perception variable (ClimAware, Climbelief and Climrecall) when regressed individually on the socio-economic factors showed a relationship between some of the socio-economic variables and the perception variables. However, it was remarkable that access to Extension was found to be a significant socio-economic predictor variable across all the models whereas marital status, measured with a dummy variable, was not found to be significant in any of the perception models. An explanation could be because of the importance of access to information presented to farmers by Extension staff and organizations which directly influences their awareness, beliefs and recall. Urgessa and Amsalu (2014) found that the provision of weather information with regards to temperature and rainfall significantly and positively impacted the likelihood of perceiving climate change by smallholders in Ethiopia by about 18%. The importance of reforming access to Extension to deliver more relevant and timely information to farmers has been emphasized by various scholars (Christoplos, 2010; Scoones *et al.*, 2008).

4.3.5 Conclusions: Socio-economic variables and their affect on perceptions.

In terms of socio-economic variables and perceptions, only the relationship between Climate change awareness (ClimAware) and Head of Household (HH), and ClimAware and access to Extension services (Extension) were significant. Findings about the importance of Extension are consistent with the literature. Berry et al. (2006) and Niles et al. (2015) assert that climate change adaptation is “not a one-size fits all” phenomenon. As such, it is expected that farmer responses will vary across regions based on certain factors and parameters. In this research, variables ranging from smallholder perceptions of agro-ecological factors, socio-economic factors, existing infrastructure and capacity were all examined. The results highlight that access to agricultural Extension is vital factor to increased agricultural productivity and adaptation to climate change impacts. The role as head of household may be significant because in many patrilinear societies such as the Keta Municipal area, were males are historically privileged in land and other inheritance structures, male headed household also dominate decision making, access to and control of household resources. It is therefore not surprising that Head of Household (HH) was significant.

4.4 Contribution of smallholder socio-economic characteristics to stage of transformational change.

The aim of specific objective three was to evaluate the effects of smallholder socio-economic characteristics on their stage in the transformational change process. Despite efforts made to improve smallholder productivity over the years, smallholder productivity remains low in Africa (Lobell *et al.*, 2009; FAO, 2014). Although transformation has been identified as an important theoretical and conceptual tool for improving agricultural productivity among smallholders, especially in the face of climate variability and change, how to achieve transformation remains uncertain (Adger et al., 2009; Ostrom,2010; Niles *et al.*, 2015). Available research shows that farmer decisions about climate change impacts are affected by socio-economic factors such as age, gender, education, farm size, marital status and access to external mechanisms including Extension services through the government, researchers and NGOs (IPCC,2012; Yaro, 2011; Yegbemey *et al.*, 2013).

The Transtheoretical (Stages of Behaviour Change) Model (TTM) by Prochaska and Associates (1992) has been used widely to explain and investigate individual transformational change (He *et al.*, 2010; Hedeker *et al.*, 1999; Kloek *et al.*, 2004; Semenza *et al.*, 2008). The TTM was incorporated into Roger's Diffusion of Innovations theory (Rogers, 2003) to explain aspects of the individual innovation process. However, Rogers (2003) did not have a specific focus on the effects of climate change impacts and associated interrelations between cognitive and psychological impacts it has on smallholder transformation per se. Therefore, the aim of this objective was to determine the effects of smallholder perceptions of climate change impacts on their stage of transformational change in the context of the negative climate change impacts they are faced with.

The stages of the transformational change process were measured by a multi-level ordinal variable with six stages as follows: Pre-contemplation, Contemplation, Preparation, Action, Maintenance, and Termination. The results of a Pearson's Chi-square test of association between smallholder transformational change process and socio-economic characteristics follows in Table 4.29. The findings reveal that there is a relationship between the transformational change process and Education. The education variable was a categorical variable with eight levels namely: no education, primary, JHS, SHS, Vocational training, Polytechnic, University and post graduate level. Specifically, the transformational change process has a significant relationship with smallholders with a low level of education. Low level education (LowEdu or low_edu) refers to those with no or primary level education only. There is also a statistically significant relationship between smallholder transformational change process and access to agricultural Extension and land Ownership. The relationship between transformational change and gender, age, head of household, marital status and FBO were not significant.

Table 4. 29 Pearson's Chi-square test between socio-economic characteristics and transformational change

Relationship	DF	Chi-square (X^2)	Probability Value	Conclusion
Gender and Transformational change	5	2.8894	0.717	Not significant
Age and Transformational change	280	295.2089	0.255	Not significant
LowEdu and Transformational change	5	16.0355	0.007***	Significant at 1%
MidEdu and Transformational change	5	5.9285	0.313	Not significant
HiEdu and Transformational change	5	4.4799	0.483	Not significant
Edu and Transformational change	35	60.1113	0.005***	Significant at 1%
Hoh and Transformational change	5	0.9678	0.965	Not significant
Extension and Transformational change	5	20.944	0.001***	Not significant
Ownership and Transformational change	5	15.401	0.009***	Significant at 1%
MaritalStatus and Transformational change	5	8.8954	0.113	Not significant
FBOmember and Transformational change	5	8.5866	0.127	Not significant

Source: Field data.

The variables in the significant relationship were used to estimate the extent to which they predict transformational change in a logistic regression model. Two of the formats in which the results of logistic regression are reported are 1) the coefficients of the predictor variables and 2) the odds ratio of the predictors. Although the two report almost the same results they appear to be different. The results which follow in Tables 4.30 and 4.31 were used to highlight the differences in models, the importance of combinations of variables and methodology. In Table 4.30, none of the predictors were significant although the Chi-square probability value of 0.0712 which is greater than 0.05 shows that the model as a whole is not significance at the 5% significance level but at the 10% significance level.

Table 4. 30 Logistic regression of significant relationships between socio-economic factors and transformational change

Logistic regression (Logit)				Number of obs	=	413
				LR chi2(4)	=	8.63
				Prob > chi2	=	0.0712*
				Pseudo R2	=	0.0421
				Log likelihood	=	-98.0705

tube_stage	Coef.	Std. Err.	z	P>z	[95% Conf.	Interval]
low_edu	-0.65812	0.595474	-1.11	0.269	-1.82523	0.508987
a9_educ	0.222285	0.221236	1	0.315	-0.21133	0.6559
extension	-0.10699	0.414772	-0.26	0.796	-0.91992	0.705953
ownership	0.117116	0.414289	0.28	0.777	-0.69488	0.929108
_cons	2.087666	0.882294	2.37	0.018	0.358401	3.816931

Source: Field data

As a result of this, an ordered logistic estimation was done to take into account the six different levels of the transformational change variable. The results which follow show that the model is highly significant at the 1% significance level when the various levels or stages of transformational change are considered relative to the reference stage. Based on the probability value (P-value), only Extension was significant while Education (a9_edu), Low level of Education (LowEdu or low_edu) and land ownership (Ownership) were not significant.

This finding is interesting for two reasons. First, it emphasizes the importance of looking at transformational change across various stages or levels instead of as a single unit process, thus using the ordered logit estimation instead of normal logit estimation. Second, it also shows that there could be differences between the socio-economic factors that could become important whether considering transformational change as a unit or as a series of stages or levels.

According to Kloek *et al.* (2004), the stages of change can be analysed on an ordinal scale using ordinal regression to determine the socially differentiated factors that independently relate to the stages of change as in Table 4.31.

Table 4. 31 Ordered logistic regression of significant relationships between socio-economic factors and transformational change

Ordered logistic regression (ologit)			
	Number of obs	=	413
	LR chi2(4)	=	23.03
	Prob > chi2	=	0.0001***
	Pseudo R2	=	0.0184
	Log likelihood	=	-614.927

tube_stage	Coef.	Std. Err.	z	P>z	[95% Conf.	Interval]
low_edu	-0.27105	0.275696	-0.98	0.326	-0.8114	0.269302
a9_educ	0.131941	0.068666	1.92	0.055*	-0.00264	0.266524
extension	0.675176	0.191936	3.52	0***	0.298988	1.051363
ownership	-0.16787	0.18742	-0.9	0.37	-0.53521	0.199467
/cut1	-2.19204	0.35455			-2.88695	-1.49714
/cut2	0.186177	0.314991			-0.43119	0.803547
/cut3	0.601461	0.316335			-0.01854	1.221465
/cut4	1.997021	0.332298			1.345729	2.648313
/cut5	2.126611	0.33461			1.470787	2.782434

Source: Field data

In the ordered logit estimation, only Extension was significant whereas earlier education and land ownership were found to be significant. The model was therefore run with the some of the socio-economic variables including LowEdu and Education as control or exogenous variables to determine if any other variables would have a different significance level. The results show that the overall model was still significant at the 1% significance level with a Chi-square probability value of 0.0008. However, only Extension was significant with a P-value of 0.001. The rest of the socio-economic variables were not significant as shown in Table 4.32. The Likelihood Ratio (LR) Chi-square is the difference between the log likelihood for the "constant-only" model and the log likelihood for the “full” model consisting of constant and predictors. The number 9 indicates the degrees of freedom or number of predictor or explanatory variables in the estimation.

Table 4. 32 Ordered logistic regression between socio-economic factors and transformation

Ordered logistic regression (ologit)				Number of obs	=	413
				LR chi2(9)	=	28.45
				Prob > chi2	=	0.0008***
				Pseudo R2	=	0.0227
				Log likelihood	=	-612.218
tube_stage	Coef.	Std. Err.	z	P>z	[95% Conf.	Interval]
low_edu	-0.17678	0.285341	-0.62	0.536	-0.73603	0.382483
a9_educ	0.131014	0.068917	1.9	0.057*	-0.00406	0.266087
extension	0.663634	0.194638	3.41	0.001***	0.282151	1.045118
ownership	-0.13295	0.189602	-0.7	0.483	-0.50456	0.238666
gender	0.16758	0.253616	0.66	0.509	-0.3295	0.664659
hh	-0.24437	0.348233	-0.7	0.483	-0.9269	0.438154
marriedstat	0.153839	0.268849	0.57	0.567	-0.3731	0.680773
Fbo	-0.11402	0.185495	-0.61	0.539	-0.47759	0.249539
age	-0.01335	0.008271	-1.61	0.107	-0.02956	0.002863
/cut1	-2.80467	0.616178			-4.01236	-1.59698
/cut2	-0.41266	0.591418			-1.57182	0.746496
/cut3	0.004475	0.591649			-1.15514	1.164086
/cut4	1.411367	0.596414			0.242417	2.580318
/cut5	1.541774	0.597512			0.370671	2.712876

Source: Field data

In contrast, a full model testing the relationship between the stages of transformational change with all the eleven socio-economic variables shows that in addition to Extension, Education and mid-level education specifically were significant. The rest of the variables were not significant. An explanation for this could be because of interaction effects between the variables that may affect the overall effect on the transformational change process. Socially the results can be interpreted to mean that access to Extension could always have a significant impact on transformational change whether isolated as an activity on its own or together with other educational activities. However, the effect of education would be significant relative to the level of education of the smallholders. The results suggest that smallholders with low and mid-level education would benefit more from education than highly educated smallholders. Hence high level education was automatically omitted from the model as the reference or base variable. The model was highly significant with a Chi-square probability value of 0.0002 as in Table 4.33.

Table 4. 33 Ordered logistic regression between all socio-economic factors and transformation

Ordered logistic regression (ologit)				Number of obs	=	413
				LR chi2(10)	=	33.33
				Prob > chi2	=	0.0002***
				Pseudo R2	=	0.0266
				Log likelihood	=	-609.777
tube_stage	Coef.	Std. Err.	z	P>z	[95% Conf.	Interval]
gender	0.115485	0.254109	0.45	0.649	-0.38256	0.613529
age	-0.01379	0.008275	-1.67	0.096	-0.03001	0.002429
low_edu	1.743731	0.920722	1.89	0.058*	-0.06085	3.548312
mid_edu	1.440273	0.657122	2.19	0.028**	0.152338	2.728207
hi_edu	0	(omitted)				
a9_educ	0.434143	0.154397	2.81	0.005***	0.131531	0.736755
hh	-0.30013	0.348992	-0.86	0.390	-0.98414	0.383881
extension	0.663426	0.19499	3.4	0.001***	0.281254	1.045599
ownership	-0.14623	0.190201	-0.77	0.442	-0.51902	0.226556
Fbo	-0.12839	0.186054	-0.69	0.490	-0.49305	0.236272
marriedstat	0.164171	0.269827	0.61	0.543	-0.36468	0.693022
/cut1	-0.50465	1.213261			-2.8826	1.873293
/cut2	1.900837	1.208255			-0.4673	4.268974
/cut3	2.32054	1.209794			-0.05061	4.691693
/cut4	3.738817	1.218776			1.35006	6.127575
/cut5	3.870361	1.219904			1.479394	6.261329

Source: Field data

4.4.1 Relationship between socio-economic characteristics and different stages

The study revealed that overall 28 or 6.6% of the smallholders who participated in the study were in the Pre-contemplation stage. This means that they were not aware of or did not believe there was a problem with climate change impacts and thereby had no intentions of changing their current practices to using the tube well irrigation in the foreseeable future. The majority of them 146 or 34.4% was at the Contemplation stage where they had recognized that climate change impacts were posing a problem.

Smallholders in the Contemplation stage were seriously thinking about finding a solution to their climate related problems but had not yet decided to take action. Forty four participants or 10.4% of the smallholders were at the Preparation stage. This means that that they were actively preparing to make a change within the next 30 days. About 120 or 28.2% were at the Action stage, meaning that they had been actively using the tube well irrigation system for about 6 months. Only eight participants or 1.9% of participants were at the Maintenance stage, meaning that they had been consistently using tube well irrigation as a response to climate change impacts of drought for more than six months. By being at the maintenance stage, the respondents agreed that they were not fully convinced about their choice of action but had some doubts, although they were working to prevent reverting back to old ways of using shallow wells or to pre-existing conditions.

Finally, 79 or 18.9% of the participants were at the Termination stage, meaning that they had fully adopted the use of tube well irrigation as a response to climate change impacts permanently. Smallholders at the Termination stage self-reported that they had totally accepted the use of tube well irrigation with no temptation of reverting back to previous situations. This represents a transformation of not only their farming activities, but also their social, cognitive and psychological pattern of behavior in the use of tube well irrigation. Besides the 6.6% who were still in the Pre-contemplation stage, over 90% of the smallholders were in various stages adopting tube well irrigation systems and consequently transforming their behaviours in response to the persistence droughts. A Chi-square test of association was conducted between the socio-economic variables and the different stages of the transformational change process as shown in Table 4.34 to 4.39. The results show that significant relationships exist between smallholders in the Pre-contemplation stage and their Age, LowEdu, MidEdu and Edu in general (Table 4.34).

Table 4. 34 Pearson's Chi-square test results between socio-economic characteristics and Pre-contemplation stage of transformational change process

Relationship	DF	Chi-square (X^2)	Probability Value	Conclusion
Pre-Contemplation and Gender	1	1.864	0.172	Not significant
Pre-Contemplation and Age	56	74.7954	0.047**	Significant at 5%
Pre-Contemplation and LowEdu	1	9.2273	0.002***	Significant at 1%
Pre-Contemplation and MidEdu	1	3.8268	0.05**	Significant at 5%
Pre-Contemplation and HiEdu	1	0.2526	0.615	Not significant
Pre-Contemplation and Edu	7	14.6352	0.041**	Significant at 5%
Pre-Contemplation and HH	1	0.1191	0.73	Not significant
Pre-Contemplation and Extension	1	0.1044	0.747	Not significant
Pre-Contemplation and Ownership	1	0.0714	0.789	Not significant
Pre-Contemplation and MaritalStatus	1	0.7241	0.395	Not significant
Pre-Contemplation and FBOmember	1	1.8035	0.179	Not significant

Source: Field data

A look at the relationship between smallholders at the Contemplation stage and their socio-economic characteristics reveals that there are significant relationships between the Contemplation stage and Extension and land Ownership as shown in Table 4.35.

Table 4. 35 Pearson's Chi-square between socio-economic characteristics and Contemplation stage of transformational change process

Relationship	DF	Chi-square (X^2)	Probability Value	Conclusion
Contemplation and Gender	1	0.0183	0.892	Not significant
Contemplation and Age	56	60.9936	0.301	Not significant
Contemplation and LowEdu	1	1.6754	0.196	Not significant
Contemplation and MidEdu	1	0.5562	0.456	Not significant
Contemplation and HiEdu	1	2.2973	0.13	Not significant
Contemplation and Edu	7	11.9839	0.101	Not significant
Contemplation and HH	1	0.1424	0.706	Not significant
Contemplation and Extension	1	12.2341	0***	Significant at 1%
Contemplation and Ownership	1	5.4509	0***	Significant at 1%
Contemplation and MaritalStatus	1	1.2468	0.264	Not significant
Contemplation and FBOmember	1	1.329	0.249	Not significant

Source: Field data

The relationship between smallholders at the Preparation stage and their socio-economic characteristics reveals that there are significant relationships between the Contemplation stage and Extension and land Ownership as shown in Table 4.36. The relationship between marital status and the Preparation stage was significant at the 5% level while the relationship with Extension and membership in a farmer based organization (FBOmember) was significant at the 10% level. Granted that in Chi-square tests the 5% significance level is what is typically used to determine association, the significance at the 10% is noted in this study as a slight level of association while the 1% significance level is noted as highly significant. The rest of the variables: gender, age, education, head of household, and land ownership did not show significant relationships with the Preparation stage. This finding was surprising because it was the first time that marital status has showed a significant relationship with any of the stages of transformational change perhaps indicating the significant level of external or social support needed at the Preparation stage.

Table 4. 36 Pearson's Chi-square between socio-economic characteristics and Preparation stage of the transformational change process

Relationship	DF	Chi-square (X^2)	Probability Value	Conclusion
Preparation and Gender	1	0.2728	0.601	Not significant
Preparation and Age	56	65.0202	0.191	Not significant
Preparation and LowEdu	1	3.9041	0.048**	Significant at 5%
Preparation and MidEdu	1	0.2919	0.589	Not significant
Preparation and HiEdu	1	0.1209	0.728	Not significant
Preparation and Edu	7	6.8709	0.442	Not significant
Preparation and HH	1	0.0014	0.971	Not significant
Preparation and Extension	1	3.4643	0.063*	Significant at 10%
Preparation and Ownership	1	0.1922	0.661	Not significant
Preparation and Maritalstatus	1	4.6523	0.031**	Significant at 5%
Preparation and FBOmember	1	2.7981	0.094*	Significant at 10%

Source: Field data

The test of association between smallholders at the Action stage and their socio-economic characteristics reveals that there are significant relationships between the Action stage and Education, with some relationship with a high level of education (HiEdu) specifically. There was also a highly significant relationship with Extension land ownership as shown in Table 4.37. The rest of the socio-economic variables did not show a significant relationship with the Action stage.

Table 4. 37 Pearson's Chi-square between socio-economic characteristics and Action stage of the transformational change process

Relationship	DF	Chi-square (X^2)	Probability Value	Conclusion
Action and Gender	1	0.0129	0.91	Not significant
Action and Age	56	60.6477	0.312	Not significant
Action and LowEdu	1	0.9064	0.341	Not significant
Action and MidEdu	1	0.0019	0.966	Not significant
Action and HiEdu	1	3.4464	0.063*	Significant at 10%
Action and Edu	7	19.3335	0.007***	Significant at 1%
Action and HH	1	0.0759	0.783	Not significant
Action and Extension	1	8.175	0.004***	Significant at 1%
Action and Ownership	1	10.0927	0.001***	Significant at 1%
Action and MaritalStatus	1	2.1147	0.146	Not significant
Action and FBOmember	1	0.7776	0.378	Not significant

Source: Field data

A look at the relationship between smallholders at the Maintenance stage and their socio-economic characteristics reveals that the only significant relationship between the Maintenance stage and socio-economic variables is with land Ownership which was significant at the 5% significance level as shown in Table 4.38.

Table 4. 38 Pearson's Chi-square between socio-economic characteristics and Maintenance stage of the transformational change process

Relationship	DF	Chi-square (X^2)	Probability Value	Conclusion
Maintenance and Gender	1	0.2036	0.652	Not significant
Maintenance and Age	56	39.4414	0.954	Not significant
Maintenance and LowEdu	1	2.0987	0.147	Not significant
Maintenance and MidEdu	1	1.5723	0.210	Not significant
Maintenance and HiEdu	1	0.0627	0.802	Not significant
Maintenance and Edu	7	10.8639	0.145	Not significant
Maintenance and HH	1	0.1268	0.722	Not significant
Maintenance and Extension	1	1.0741	0.300	Not significant
Maintenance and Ownership	1	4.0911	0.043**	Significant at 5%
Maintenance and MaritalStatus	1	0.5237	0.469	Not significant
Maintenance and FBOmember	1	0.0843	0.772	Not significant

Source: Field data

The relationship between smallholders at the final stage of the transformational change process called the Termination stage and their socio-economic characteristics reveals that there are significant relationships between the Termination stage and Extension and membership in an FBO as shown in Table 4.39.

Table 4. 39 Pearson's Chi-square between socio-economic characteristics and Termination stage process

Relationship	DF	Chi-square (X^2)	Probability Value	Conclusion
Termination and Gender	1	0.8385	0.360	Not significant
Termination and Age	56	55.0157	0.512	Not significant
Termination and LowEdu	1	0.1311	0.717	Not significant
Termination and MidEdu	1	0.2249	0.635	Not significant
Termination and HiEdu	1	0.1137	0.736	Not significant
Termination and Edu	7	9.7811	0.201	Not significant
Termination and HH	1	0.7161	0.397	Not significant
Termination and Extension	1	3.4258	0.064*	Significant at 10%
Termination and Ownership	1	0.401	0.527	Not significant
Termination and MaritalStatus	1	1.4722	0.225	Not significant
Termination and FBOmember	1	3.5379	0.060*	Significant at 10%

Source: Field data

4.4.2 Effects of socio-economic characteristics on the stages of transformation.

A summary of relationships between smallholder socio-economic characteristics and their stages of transformational change reveals that there are distinct differences between the factors that affect smallholders at the different stages of the transformational change process. There is a highly significant relationship between low education and the Pre-contemplation stage. There is also a strong relationship between the Pre-contemplation stage and age, and between Pre-contemplation and level of education especially low and mid-level education. While smallholders are highly affected by Extension and land ownership, those in the Preparation stage are strongly affected by marital status, Extension, land ownership, and education. The results show that unlike the Pre-contemplation, Contemplation and Preparation stages that were associated with a low or mid-level education, those who had actually taken action and therefore at the Action stage and were using the tube-well irrigation system were associated with a higher level of education. Unlike smallholders in other stages of the transformational change process, those in the Maintenance stage had a significant relationship with land ownership. This can be interpreted to mean that of all the socio-economic factors considered in this study, land ownership is the most critical factor in determining is a person would progress to become fully transformed or is they would "backslide" or revert back to their earlier practices. This is a very significant and finding which is consistent with the findings of other researchers (Adjei-Nsiah *et al.*, 2013, Djurfeldt *et al.*, 2005; Hounkonnu *et al*, 2012; Nederlof & Pyburn, 2012) who have advocated for alleviating institutional constraints that serve as barriers to smallholder productivity especially in the area of land tenure arrangements. Finally, smallholders in the Termination stage of the transformational only had significant relationships with access to Extension and membership in a farmer based organization at the 10% significance level as shown in Table 4.40.

Table 4. 40 Summary of relationships between socio-economic factors and stages of transformation

Stage of Transformation	Description of smallholder farmer beliefs and actions	Significant Socio-economic variables and significance levels
Pre-Contemplation	Individual does not believe there is a problem. Has no intention of changing in the foreseeable future.	• Low Education (1%) • Age (5%) • Education (5%) • Mid Education (5%)
Contemplation	Aware that a problem exists and is thinking about solutions but has not yet decided to take action.	• Extension (1%) • Land Ownership (1%)
Preparation	Focused and actively preparing for change within 30 days.	• Marital status (5%) • Extension (10%) • FBOmember (10%)
Action	Actively using the innovation (tube well irrigation system) for about 6 months.	• Education (1%) • Land Ownership (1%) • Extension (1%) • High Education (10%)
Maintenance	Consistently using irrigation for more than six months. Has some doubts but works to prevent reverting back to old ways or pre-existing conditions.	• Land Ownership (5%)
Termination	Individual has permanently changed. Has no temptation to revert back to previous situation.	• Extension (10%) • FBOmember (10%)

Source: Field data

This finding was surprising because based on Rogers' diffusion of innovations theory (2003), it was expected that those in the Termination stage which is the final stage of the transformational stage process would be the most innovative with higher levels of education and wealth as measured by land ownership. Instead no significant relationship was found between education or landownership and smallholders at the Termination stage. However, a key assumption and postulation of this thesis that smallholders who have themselves been transformed at the individual level would have a greater affinity to socialize and go beyond the individual transformation stage to achieve societal transformation was realized. The key socio-economic variable used as an indicator of this transformative action was membership in a farmer based organisation (FBO). This it was good that membership in an FBO was confirmed to have a significant relationship even if the significance level was only at 10% interpreted as a slight relationship in this study.

4.4.3 Extent to which socio-economic characteristics affect the stages of change.

After the Chi-square test of association, logistic regression models were run in an attempt to unravel the link between socio-economic factors and the mechanisms and pathways for enhancing the smallholder transformational change process in order to solve the problem of lack of smallholder productivity while promoting climate sensitive practices. In the following analyses two sets of models were estimated. One with only those socio-economic variables that were found to be significant in the Chi-square tests of association to determine the extent to which the socio-economic factors explain smallholder transformational change at the various stages of change. The dependent variables for the estimation were the various stages of change: Pre-contemplation, Contemplation, Preparation, Action, Maintenance and Termination while the predictor or explanatory variables were the socio-economic variables associated with each of the stages. The regression models with only the significant variables can be considered as restricted models with only endogenous variables written under the general form:

$$StageofTransformation = f\left(Socio - economic\text{var}iables\_such\_as\_Ext, Fbo + \varepsilon\right)$$

However, the rest of the analyses include both the endogenous and exogenous variables written in the general:

$$StageofTransformation = f\left(Age, Edu, Gen, Hh, Ext, Farm, Land, Fbo + Mstat + \varepsilon\right)$$

The results of the logistic regression analysis of smallholders in the Pre-contemplation stage regressed over the endogenous variables shows that the overall model was highly significant at the 1% significance level with a Chi-square probability vale of 0.0054. Age and education were the significant predictor variables at the 10% significance level with P-values of 0.064 and 0.086 respectively as shown in Table 4.41.

By definition, a "logit" is the log base e (log) of the odds or chances of success of an outcome relative to failure. The odds ratio can be found by raising e to the power of the logistic coefficient. The log odds of a variable show the number of times the odds of success is larger than the odds for failure. In other words, the number of times of success for the reference category of a variable is larger than the other category. Therefore, the coefficient indicates that the amount of change expected in the log odds when there is a change in the predictor variable when all of the other variables are held constant. Thus, the coefficient for age indicates that the log odds for Pre-contemplation would change by. 0.030168 for every directional change when the education variables in the model are held constant.

Table 4. 41 Logistic regression between endogenous variables and Pre-contemplation stage of the transformational change process

Logistic regression (Logit)				Number of obs	=	413
				LR chi2(4)	=	14.68
				Prob > chi2	=	0.0054***
				Pseudo R2	=	0.0717
				Log likelihood	=	-95.0444
Pre_Contemplation	Coef.	Std. Err.	z	P>z	[95% Conf.	Interval]
age	0.030168	0.016309	1.85	0.064*	-0.0018	0.062134
low_edu	-2.63362	2.211795	-1.19	0.234	-6.96865	1.701423
mid_edu	-2.41701	1.600705	-1.51	0.131	-5.55434	0.720312
a9_educ	-0.6586	0.383195	-1.72	0.086*	-1.40965	0.092451
_cons	0.237833	2.94112	0.08	0.936	-5.52666	6.002322

Source: Field data. *** p<0.01, ** p<0.05, * p<0.1

Conversely, the results of the logistic regression model of smallholders in the Pre-contemplation stage regressed over both the endogenous and exogenous variables shows that the overall model was not significant at the 5% significance level but at 10%. The Chi-square probability value was 0.0758 compared to 0.0054 in the endogenous Pre-contemplation model. Education was the only significant socio-economic variable with a P-value of 0.088 as shown in Table 4.42. The coefficient for Education (a9_edu) indicates that the log odds for Pre-contemplation would decline by -0.6705 for every directional change in educational level when all the socio-economic variables are held constant. This result means that age and education are important factors to consider when engaging smallholders in the Pre-contemplation stage however when other socio-economic factors are present then age is no longer significant but rather the educational level of the farmer.

Table 4. 42 Logistic regression between all socio-economic variables and Pre-contemplation stage of the transformational change process

Logistic regression (Logit)				Number of obs	=	413
				LR chi2(4)	=	16.94
				Prob > chi2	=	0.0758*
				Pseudo R2	=	0.0827
				Log likelihood	=	-93.9146
Pre_Contemplation	Coef.	Std. Err.	z	P>z	[95% Conf.	Interval]
gender	-0.1141	0.507	-0.22	0.822	-1.1082	0.8800
age	0.0266	0.017	1.55	0.122	-0.0071	0.0603
low_edu	-2.6732	2.217	-1.21	0.228	-7.0185	1.6721
mid_edu	-2.5040	1.618	-1.55	0.122	-5.6761	0.6681
hi_edu	0.0000	(omitted)				
a9_educ	-0.6705	0.393	-1.71	0.088*	-1.4411	0.1002
hh	0.7020	0.818	0.86	0.391	-0.9020	2.3060
extension	0.0324	0.429	0.08	0.94	-0.8076	0.8725
ownership	-0.2145	0.426	-0.5	0.615	-1.0503	0.6213
Fbo	0.4421	0.431	1.03	0.305	-0.4022	1.2864
marriedstat	-0.2344	0.560	-0.42	0.675	-1.3314	0.8626
_cons	0.0496	3.017	0.02	0.987	-5.8639	5.9631

Source: Field data. *** p<0.01, ** p<0.05, * p<0.1

The results of the logistic regression analysis of smallholders in the Contemplation stage regressed over the endogenous variables shows that the overall model was highly significant at the 1% significance level with a Chi-square probability value of 0.0001. Age and Extension land ownership were the significant socio-economic variables with P-values of 0.000 and 0.017 respectively as shown in Table 4.43. The coefficient indicates that the amount of change expected in the log odds when there is a change in the predictor variable when all of the other variables in the model are held constant. Thus in this model the logistic coefficient for age is 0.030168 which indicates that the log odds for Pre-contemplation would change by. 0.030168 for every one unit change in age when the education variables in the model are held constant.

Table 4. 43 Logistic regression between endogenous variables and Contemplation stage of the transformational change process

Logistic regression (Logit)				Number of obs	=		425
				LR chi2(4)	=		18.59
				Prob > chi2	=		0.0001***
				Pseudo R2	=		0.034
				Log likelihood	=		-264.126
Contemplation	Coef.	Std. Err.	z	P>z		[95% Conf.	Interval]
extension	-0.8258	0.2364	-3.49	0.000***		-1.2891	-0.3625
ownership	0.5459	0.2289	2.38	0.017**		0.0973	0.9945
_cons	-0.7750	0.1999	-3.88	0.000		-1.1668	-0.3832

Source: Field data. *** p<0.01, ** p<0.05, * p<0.1

Conversely, the results of the logistic regression model of smallholders in the Contemplation stage regressed over both the endogenous and exogenous variables shows that the overall model was highly significant at the 1% significance level with a Chi-square probability value of 0.0059. Access to Extension services and land ownership were the only significant socio-economic variables with P-values of 0.001 and 0.034 respectively as shown in Table 4.44. The coefficient for Extension indicates that the log odds for Contemplation would decline by -0.81579 and that for land ownership would increase by 0.49900 for every directional change each of the variables when all the socio-economic variables are held constant.

Table 4. 44 Logistic regression between all socio-economic variables and Contemplation stage of the transformational change process

Logistic regression (Logit)							
				Number of obs	=		413
				LR chi2(4)	=		24.71
				Prob > chi2	=		0.0059***
				Pseudo R2	=		0.0461
				Log likelihood	=		-255.927
Contemplation	Coef.	Std. Err.	z	P>z		[95% Conf.	Interval]
gender	0.04023	0.29909	0.13	0.893		-0.54598	0.62644
age	0.00401	0.00968	0.41	0.679		-0.01496	0.02297
low_edu	-0.40363	1.09038	-0.37	0.711		-2.54073	1.73346
mid_edu	-0.23754	0.79040	-0.3	0.764		-1.78669	1.31161
hi_edu	0.00000	(omitted)					
a9_educ	-0.20214	0.18097	-1.12	0.264		-0.55683	0.15256
hh	0.15246	0.41242	0.37	0.712		-0.65587	0.96079
extension	-0.81579	0.24261	-3.36	0.001		-1.29129	-0.34029
ownership	0.49900	0.23568	2.12	0.034		0.03709	0.96092
Fbo	-0.18987	0.22538	-0.84	0.4		-0.63161	0.25187
marriedstat	-0.25258	0.30926	-0.82	0.414		-0.85871	0.35355
_cons	0.17366	1.42273	0.12	0.903		-2.61485	2.96217

Source: Field data. *** p<0.01, ** p<0.05, * p<0.1

The results of the logistic regression of smallholders in the Preparation stage regressed over the independent variables of interest shows that the overall model was highly significant at the 1% significance level with a Chi-square probability value of 0.0048. Access to Extension services, FBO membership, and Marital status were the significant socio-economic variables with P-values of 0.037 (5%), 0.096 and (10%) 0.056 (10%) respectively as shown in Table 4.45. The coefficient indicates that the log odds for Maintenance would decrease by 0.8218 for every directional change in access to Extension and the log odds for FBO membership and marital status would increase by 0.5451 and 1.4174 respectively. The log odds are an indication of the probability or chances that a farmer who has access to Extension services, belongs to an FBO and is married will be more likely to be in Preparation stage of the transformational change process. It also indicates that they are the important characteristics for identifying and engaging such a smallholder.

Table 4. 45 Logistic regression between endogenous variables and Preparation stage of the transformational change process

Logistic regression (Logit)				Number of obs	=	425
				LR chi2(4)	=	12.92
				Prob > chi2	=	0.0048***
				Pseudo R2	=	0.0457
				Log likelihood	=	-134.969
Preparation	Coef.	Std. Err.	z	P>z	[95% Conf.	Interval]
extension	-0.8218	0.3943	-2.08	0.037**	-1.5945	-0.0490
Fbo	0.5451	0.3279	1.66	0.096*	-0.0976	1.1877
marriedstat	1.4174	0.7403	1.91	0.056*	-0.0335	2.8683
_cons	-3.4905	0.7328	-4.76	0	-4.9268	-2.0542

Source: Field data. *** p<0.01, ** p<0.05, * p<0.1

Conversely, the results of the logistic regression model of smallholders in the Preparation stage regressed over both the endogenous and exogenous variables shows that the overall model was not significant. The Chi-square probability value was 0.1124 compared to 0.0048 in the endogenous model. Access to Extension services was the only significant socio-economic variable with a P-value of 0.074 (10%) as shown in Table 4.46. The coefficient for Extension indicates that the log odds for Preparation would decline by -0.72245 for every directional change in access to Extension when all the socio-economic variables are held constant. This means that for smallholders in the Preparation stage an intervention that focuses on access to Extension, FBO membership and also considers the marital status would be more effective at predicting change than one which focuses on too many variables. The results show that the inclusion or focus on other variables such as age, education and gender which were of importance to a person at the Pre-contemplation stage actually worsened the log odds or changes of someone to be at the Preparation stage.

Table 4. 46 Logistic regression between all socio-economic variables and Preparation stage of the transformational change process

Logistic regression (Logit)				Number of obs	=	413
				LR chi2(4)	=	15.58
				Prob > chi2	=	0.1124
				Pseudo R2	=	0.0593
				Log likelihood	=	-123.591
Preparation	Coef.	Std. Err.	z	P>z	[95% Conf.	Interval]
gender	-0.16698	0.48239	-0.35	0.729	-1.1124	0.7785
age	0.00694	0.01571	0.44	0.659	-0.0239	0.0377
low_edu	-2.76190	1.74347	-1.58	0.113	-6.1790	0.6552
mid_edu	-1.41021	1.21086	-1.16	0.244	-3.7835	0.9630
hi_edu	0.00000	(omitted)				
a9_educ	-0.31187	0.29059	-1.07	0.283	-0.8814	0.2577
hh	-0.29475	0.69384	-0.42	0.671	-1.6547	1.0652
extension	-0.72245	0.40497	-1.78	0.074*	-1.5162	0.0713
ownership	-0.06423	0.35959	-0.18	0.858	-0.7690	0.6406
Fbo	0.59428	0.35987	1.65	0.099*	-0.1111	1.2996
marriedstat	1.19917	0.76586	1.57	0.117	-0.3019	2.7002
_cons	-0.72977	2.28702	-0.32	0.75	-5.2122	3.7527

Source: Field data. *** p<0.01, ** p<0.05, * p<0.1

The results of the logistic regression analysis of smallholders in the Action stage regressed over the predictor Chi-square probability value variables of interest shows that the overall model was highly significant with a Chi-square probability value of 0.0001. Extension and land ownership were the significant socio-economic variables with P-values of 0.005 and 0.001 respectively as shown in Table 4.47. The coefficient indicates that the log odds for smallholders in the Action stage would increase by. 0.6542 for every directional change in access to Extension services when the other variables in the model are held constant. Similarly, the log odds for smallholders in the Action stage would decrease by 0.7420 for every directional change in land ownership when the other variables in the model are held constant. The socio-economic variables associated with education and especially a high level of education which was found to be significant in the Pearson's Chi-square tests did not turn out to be significant predictors of smallholders in the Action stage in the logistic regression model.

Table 4. 47 Logistic regression between endogenous variables and Action stage of transformation

Logistic regression (Logit)				Number of obs	=	413
				LR chi2(4)	=	22.74
				Prob > chi2	=	0.0001***
				Pseudo R2	=	0.046
				Log likelihood	=	-235.715
Action	Coef.	Std. Err.	z	P>z	[95% Conf.	Interval]
hi_edu	-0.1766	0.6161	-0.29	0.774	-1.3842	1.0310
a9_educ	0.1782	0.1222	1.46	0.145	-0.0614	0.4177
extension	0.6542	0.2306	2.84	0.005***	0.2022	1.1062
ownership	-0.7420	0.2312	-3.21	0.001***	-1.1950	-0.2889
_cons	-1.2857	0.4219	-3.05	0.002	-2.1127	-0.4588

Source: Field data. *** p<0.01, ** p<0.05, * p<0.1

Conversely, the results of the logistic regression model of smallholders in the Action stage regressed over both the endogenous and exogenous variables shows that the overall model was significant at the 5% significance level with a probability Chi-square of 0.0066. Thus, in this case both the restricted and full models were significant. Access to Extension services and land ownership were the same two significant socio-economic variables with P-values of 0.006 and 0.003 as shown in Table 4.48. The coefficient for Extension indicates that the log odds for smallholders in the Action stage would increase by. 0.64574 for every directional change in access to Extension services when the other variables in the model are held constant. Similarly, the log odds for smallholders in the Action stage would decrease by 0.70487 for every directional change in land ownership when the other variables in the model are held constant. It was surprising that Gender, education and status as head of household were not found to be good predictors of the Action stage as found by other researchers (Glanz *et al.*, 1994; Semenza *et al.*, 2008).

Table 4. 48 Logistic regression between all socio-economic variables and Action stage of the transformational change process

Logistic regression (Logit)							
				Number of obs	=		413
				LR chi2(4)	=		24.42
				Prob > chi2	=		0.0066***
				Pseudo R2	=		0.0494
				Log likelihood	=		-234.874
Action	Coef.	Std. Err.	z	P>z		[95% Conf.	Interval]
gender	-0.14978	0.31949	-0.47	0.639		-0.7760	0.4764
age	-0.00761	0.01062	-0.72	0.474		-0.0284	0.0132
low_edu	0.50635	1.10480	0.46	0.647		-1.6590	2.6717
mid_edu	0.30209	0.78654	0.38	0.701		-1.2395	1.8437
hi_edu	0.00000	(omitted)					
a9_educ	0.22420	0.18508	1.21	0.226		-0.1385	0.5869
hh	0.19106	0.44042	0.43	0.664		-0.6722	1.0543
extension	0.64574	0.23473	2.75	0.006***		0.1857	1.1058
ownership	-0.70487	0.23424	-3.01	0.003***		-1.1640	-0.2458
Fbo	0.08992	0.23836	0.38	0.706		-0.3773	0.5571
marriedstat	0.30741	0.35271	0.87	0.383		-0.3839	0.9987
_cons	-1.80177	1.46156	-1.23	0.218		-4.6664	1.0628

Source: Field data. *** p<0.01, ** p<0.05, * p<0.1

The results of the logistic regression analysis of smallholders in the Maintenance stage regressed over the endogenous variables did not yield any appreciable results as shown in Table 4.49.

Table 4. 49 Logistic regression between endogenous variables and Maintenance stage of the transformational change process

Logistic regression (Logit)							
				Number of obs	=		283
				LR chi2(4)	=		-0.00
				Prob > chi2	=		
				Pseudo R2	=		-0.00
				Log likelihood	=		-36.4139
Maintenance	Coef.	Std. Err.	z	P>z		[95% Conf.	Interval]
ownership	0	(omitted)					
_cons	-3.5373	0.3587	-9.86	0		-4.2403	-2.8344

Source: Field data. *** p<0.01, ** p<0.05, * p<0.1

Conversely, the results of the logistic regression model of smallholders in the Maintenance stage regressed over both the endogenous and exogenous variables shows that the overall model was not significant at the 5% or 10% significance levels. The probability Chi-square was 0.5125. Since the Pearson's Chi-square tests of association revealed that there was a significant relationship between land ownership and smallholders at the Maintenance stage it was assumed that land ownership would be significant predictor of the maintenance stage. Surprisingly, age was the only significant socio-economic variable at the 10% significance level with a P-value of 0.067 as shown in Table 4.50. The coefficient for age indicates that the log odds for Pre-contemplation would decline by -0.08119 for every directional change when all the socio-economic variables are held constant.

Table 4. 50 Logistic regression between all socio-economic variables and Maintenance stage of the transformational change process

Logistic regression (Logit)				Number of obs	=	221
				LR chi2(4)	=	7.23
				Prob > chi2	=	0.5125
				Pseudo R2	=	0.105
				Log likelihood	=	-30.7904
Maintenance	Coef.	Std. Err.	z	P>z	[95% Conf.	Interval]
gender	-1.56341	0.97949	-1.6	0.11	-3.4832	0.3564
age	-0.08119	0.04437	-1.83	0.067*	-0.1682	0.0058
low_edu	0.00000	(omitted)				
mid_edu	0.64157	2.77746	0.23	0.817	-4.8022	6.0853
hi_edu	0.00000	(omitted)				
a9_educ	0.08499	0.65191	0.13	0.896	-1.1927	1.3627
hh	0.48919	1.17706	0.42	0.678	-1.8178	2.7962
extension	1.07062	0.77453	1.38	0.167	-0.4474	2.5887
ownership	0.00000	(omitted)				
Fbo	0.56921	0.78124	0.73	0.466	-0.9620	2.1004
marriedstat	-0.52538	0.93869	-0.56	0.576	-2.3652	1.3144
_cons	-0.10972	5.02049	-0.02	0.983	-9.9497	9.7303

Source: Field data. *** p<0.01, ** p<0.05, * p<0.1

The results of the logistic regression model estimating the probability of smallholders being in the Termination stage regressed over the endogenous variables shows that the overall model was significant at the 5% significance level with a probability Chi-square of 0.018. Age and Extension and land ownership were the two significant socio-economic variables with P-values of 0.034 and 0.033 respectively as shown in Table 4.51. The coefficient for the Extension variable indicates that the log odds for the Termination stage would increase by 0.55454 for every directional change in access to Extension when the FBO membership variable in the model is held constant. Similarly, coefficient for the FBO variable indicates that the log odds for the Termination stage would decrease by 0.56207 for every directional change in FBO membership when the Extension variable in the model is held constant. Socially the directional change in the FBO membership refers to a change from being a member to a non-member. According to the results, both access to Extension and FBO membership are significant predictors of the Termination stage of the transformational change process.

Table 4. 51 Logistic regression between endogenous variables and Termination stage of the transformational change process

Logistic regression (Logit)				Number of obs	=	425
				LR chi2(4)	=	8.03
				Prob > chi2	=	0.018**
				Pseudo R2	=	0.0197
				Log likelihood	=	-200.067
Termination	Coef.	Std. Err.	z	P>z	[95% Conf.	Interval]
extension	0.55454	0.26088	2.13	0.034**	0.0432	1.0658
Fbo	-0.56207	0.26331	-2.13	0.033**	-1.0781	-0.0460
_cons	-1.44643	0.18165	-7.96	0	-1.8025	-1.0904

Source: Field data. *** p<0.01, ** p<0.05, * p<0.1

Finally, the results of the logistic regression model of smallholders in the Termination stage regressed over both the endogenous and exogenous variables shows that the overall model was not significant with a probability Chi-square of 0.1252 compared to 0.018 in the endogenous model. Surprising, although the overall model was not significant, four of the socio-economic variables LowEdu, MidEdu Education in general and access to agricultural Extension services were significant with P-values of 0.035, 0.037, 0.035 and 0.048 respectively as shown in Table 4.52. The coefficients for indicate the log odds for the change in the probability of being in the Termination stage for every directional change in each of the significant socio-economic variables when all the other variables are held constant.

Table 4. 52 Logistic regression between all socio-economic variables and Termination stage of the transformational change process

Logistic regression (Logit)				Number of obs =		413
				LR chi2(4) =		15.19
				Prob > chi2 =		0.1252
				Pseudo R2 =		0.0394
				Log likelihood =		-185.043
Termination	Coef.	Std. Err.	z	P>z	[95% Conf.	Interval]
gender	0.447923	0.407066	1.1	0.271	-0.3499	1.2458
age	-0.007106	0.012347	-0.58	0.565	-0.0313	0.0171
low_edu	2.785055	1.323311	2.1	0.035**	0.1914	5.3787
mid_edu	1.985710	0.950187	2.09	0.037**	0.1234	3.8480
hi_edu	0.000000	(omitted)				
a9_educ	0.452414	0.214495	2.11	0.035**	0.0320	0.8728
hh	-0.518277	0.460502	-1.13	0.26	-1.4208	0.3843
extension	0.545935	0.276115	1.98	0.048**	0.0048	1.0871
ownership	0.198900	0.292884	0.68	0.497	-0.3751	0.7729
Fbo	-0.431672	0.287701	-1.5	0.134	-0.9956	0.1322
marriedstat	-0.122015	0.383367	-0.32	0.75	-0.8734	0.6294
_cons	-4.710248	1.704415	-2.76	0.006	-8.0508	-1.3697

Source: Field data. *** p<0.01, ** p<0.05, * p<0.1

A summary of the key findings from all the logistic regression analyses between the socio-economic variables and the different stages of the transformational change process follows. It highlights differences between the P-values for the overall restricted endogenous models relative to the full models which included exogenous variables. The P-values of the restricted models are on top as shown in Appendix VIII.

A comparison of the overall probability Chi-squares of the two models are significant because it represents or illustrates the empirical results of what happens when different mechanisms and pathways are designed and implemented. Except for the smallholders in the Pre-contemplation and Maintenance stages, access to Extension delivery services was a significant predictor of all the other stages. Education only made a significant difference to those in either the Pre-contemplation or Termination stages. Land ownership was a crucial predictor for smallholders in the Contemplation and Action stages while FBO membership and marital status were important predictors for those in the Preparation stage. In terms of agricultural extension theory and practice the different between the two models are important to note because it means that an extension programme which is targeted at people in the Pre-contemplation stage would be more successful if it took age into account whereas age would not be as significant or important for those in the other stages of the transformational change process. The results are consistent with the findings and recommendations of Semenza *et al.* (2008) who advocate for in-depth analyses of the relationship between socio-economic or demographic factors and transformational change at the various stages of change.

4.4.4 Conclusions: Effect of socio-economic characteristics on stages of change.

The results indicate that socio-economic characteristics such as: Education, Extension and Land ownership are significant indicators of smallholder stage of transformational change.

- Access to extension and education are significant indicators of smallholder stage of behavior change. This is consistent with literature (Below et al, 2015). Recall is a significant predictor of the probability of a smallholder being in the termination stage of transformational change specifically. Between the three socio-economic characteristics: Education, access to Extension services and Land ownership, access to Extension was the best predictor of the probability of being in a particular stage of transformational change. Although the literature also highlights that educational programmes to create awareness do not automatically translate into a high level of climate-sensitive practices (Kloek et al., 2004).

4.5 The extent to which smallholder perceptions explain their stage of transformational change and actions.

The aim of specific objective four was to determine the extent to which smallholder perceptions explain their stages of transformational change and actions. As human beings, it is virtually impossible to look at circumstances around us "*with an empty mind*" completely devoid of our own sentiments, knowledge and experiences (Leeuwis & van den Ban, 2004, p. 367). Behaviourist theorists argue that exposure to stimuli or occurrences around us influence perceptions and drive individuals to act (Kenaan, 2000). Therefore, perceptions are fundamental to human existence, actions and transformation.

Transformation from peasant to industrial agriculture has propelled many countries to become economically prosperous (Djurfeldt *et al.*, 2005, Yumkella *et. al.*, 2011). Yet, the slow pace of transformation in smallholder agriculture in Africa endangers food security and livelihoods in the coming decades due to the unprecedented rate of climate variability and change which is affecting agricultural productivity (Djurfeldt *et al.*, 2005; Wollenberg *et al.*, 2012; IPCC, 2012). Transformation research has evolved from focus on the individual (Mezirow, 2000;

Prochaska, 2000) to the societal or systems perspective (Hall *et al.*, 2006; Scoones *et al.*, 2008; Hounkonnu *et al,* 2012). However, there is an emerging strand of literature that is revisiting the importance of individual learning and transformation (Adger *et al.*, 2009; Ostrom, 2010; Moser & Ekstrom, 2010; Marshall *et al.*, 2014, Niles *et al.*, 2015). While this thesis leans towards the emerging strand, the novelty of this empirical research is that, it compares two conceptual pathways for achieving transformational change, which also represent two methodological and theoretical approaches to improving smallholder productivity. The two pathways are: (1) investigating the socio-economic variables and factors external to the smallholder which justify the use of various mechanisms and methods to achieve improved agricultural productivity and livelihood outcomes; and (2) using an alternative pathway which builds on the existing pathway by incorporating concepts and variables internal to the smallholder while engaging with the larger socio-environmental context. This, in essence, constitutes a new perspective on understanding the individual transformational change process and its interrelation with theory and practice. These socio-psychological and cognitive perception variables are smallholder awareness, recall and beliefs.

To assess the direct and contextual effects of the socio-economic and perception variables on the transformational change process, two models were estimated and the results compared using a likelihood ratio test to statistically determine which model explains the phenomenon of transformational change better (Tjernstrom & Tietenberg, 2008; Yegbemey *et al.*, 2013).

4.5.1 Results of the existing model

The existing model which is also the simple or restricted model comprises of the "stage" variable as the dependent variable regressed on the socio-economic variables while the model for the alternative pathway added the perception variables to the existing model. The dependent variable "stage" was a six level ordinal variable depicting the self-reported (Semenza *et al.*, 2008) stage of transformational change which the smallholder identified with according to the transtheoretical stages of change model. Respondents could only select one of the six stages of the categorical variable "stage" representing the stages of the transformational change process: Pre-contemplation, Contemplation, Preparation, Action, Maintenance and Termination which were coded 0, 1, 2, 3, 4, and 5 respectively.

Smallholder stage was regressed on socio-economic variables - gender, age, participation in farmer based organization, farm size, status as head of household, access to agricultural Extension services, land ownership and marital status. This was considered to be the existing model, reflecting the variables identified in the literature (Fosu-Mensah *et al.*, 2010; Yaro, 2013; Garcia de Jalon *et al.*, 2015). Results of the ordered logit model reveal that age, farm size and access to Extension delivery services were statistically significant as expected (Table 4.53). Age and farm size were significant at the 5% level and access to Extension services at 1% as. This means age, farm size and access to Extension services are good predictors of the odds of ratio of a smallholder farmer being in the Pre-contemplation stage of the transformational stage process relative to an advanced stage. This is as much as this model can tell us. It gives an overview relative to the reference category and without their perceptions about climate change impacts.

Table 4. 53 Smallholder stage of transformation regressed on socio-economic variables

VARIABLES	(Existing Model) stage
gender	0.144
	(0.243)
age	-0.0168**
	(0.00801)
fbo	-0.231
	(0.183)
logfarmsize	1.192***
	(0.231)
hh	-0.423
	(0.335)
extension	0.522***
	(0.193)
land	-0.0451
	(0.187)
mstat	0.0687
	(0.263)
Observations	425

Standard errors in parentheses

Source: Field data. *** p<0.01, ** p<0.05, * p<0.1

4.5.2 Comparison between the existing and proposed models

The perception variables were then added to the existing model in a step-wise manner. All the perception variables: Climaware, Climrecall and Climbelieve were statistically significant when added to the estimated model. A comparison of the existing and proposed models (Table 4.54) reveals that farm size and access to Extension were significant at either 1% or 5% across all models. This gives a very strong indication that the perception variables are good predictors of the likelihood of smallholder stage in the transformational change process relative to odds of being at the Pre-contemplation stage. Age was a significant factor at the 5% level across all the models except for the model which included recall. This was surprising because recall was statistically significant at the 1% level. This suggests that there could have been some interaction between age and recall as indicated in the literature.

Proposed model 1, which added only Climaware, showed that Climaware was significant at the 10% significance level. Proposed model 2 showed that Climrecall was significant at the 1% significance level. Proposed model 3, which included Climbelieve_Index, a composite of beliefs showed that Climbelief_Index was not significant. Proposed model 4, which was analysed by adding Climbelief measured as a single item and therefore binary showed that Climbelief was significant at the 5% significance level.

When all the ordered logistic regression models were run to describe the odds of the perception variables explaining smallholder stage, it results revealed that recall was the most significant socio-psychological factor while age, farm size and Extension, the most significant socio-economic factors. It was surprising that FBO membership was not significant in either the existing model or the proposed models. Gender, status as head of household, land ownership and marital status were also not significant in these models as shown in Table 4.54.

To determine the net effect of all these variables together on the stage of transformational change, they were put together in the same model. The results are shown in Table 4.55. Again, it was surprising that Age and status as Head of Household which were hitherto not significant in the individual models turned out to be statistically significant at the 10% level when all the perception variables were included in the same model. Climrecall and Climbelieve were significant at the 5% significant level whereas Climaware was significant at the 10% level.

Table 4. 54 Comparison of the existing and proposed individual perception variable models

VARIABLES	(Existing Model) stage	(Proposed Model 1) stage	(Proposed Model 2) stage	(Proposed Model 3) stage	(Proposed Model 4) stage
gender	0.144	0.168	0.243	0.142	0.103
	(0.243)	(0.243)	(0.246)	(0.243)	(0.243)
age	-0.0168**	-0.0167**	-0.0129	-0.0169**	-0.0187**
	(0.00801)	(0.00802)	(0.00814)	(0.00805)	(0.00805)
fbo	-0.231	-0.246	-0.190	-0.233	-0.243
	(0.183)	(0.183)	(0.184)	(0.184)	(0.183)
logfarmsize	1.192***	1.155***	1.171***	1.191***	1.213***
	(0.231)	(0.233)	(0.232)	(0.231)	(0.232)
hh	-0.423	-0.515	-0.458	-0.420	-0.434
	(0.335)	(0.339)	(0.336)	(0.336)	(0.339)
extension	0.522***	0.478**	0.473**	0.525***	0.619***
	(0.193)	(0.195)	(0.194)	(0.194)	(0.198)
land	-0.0451	-0.0349	0.0222	-0.0433	-0.0329
	(0.187)	(0.187)	(0.190)	(0.188)	(0.188)
mstat	0.0687	0.0717	0.0589	0.0703	0.0828
	(0.263)	(0.264)	(0.263)	(0.264)	(0.264)
Climaware		0.614*			
		(0.353)			
Climrecall			-0.197***		
			(0.0738)		
Climbelief_index				-0.00859	
				(0.0830)	
Climbelieve					0.426**
					(0.172)
Constant cut1		-2.595***	-3.251***	-3.081***	-2.414***
		(0.606)	(0.558)	(0.607)	(0.612)
Constant cut2		-0.168	-0.808	-0.670	0.0122
		(0.588)	(0.527)	(0.579)	(0.591)
Constant cut3		0.308	-0.326	-0.196	0.486
		(0.589)	(0.527)	(0.579)	(0.591)
Constant cut4		1.737***	1.110**	1.231**	1.925***
		(0.593)	(0.531)	(0.584)	(0.598)
Constant cut5		1.860***	1.234**	1.354**	2.051***
		(0.594)	(0.532)	(0.585)	(0.599)
Observations	425	425	425	425	425

Standard errors in parentheses

Source: Field data. *** p<0.01, ** p<0.05, * p<0.1

In this proposed model, which was the full model, gender, belonging to an FBO, land ownership and marital status were the only variables that were not statistically significant. A comparison of the existing model to the full proposed model in a likelihood ratio test resulted in a Chi-square probability value of 0.001 in which is highly significant at the 1% significance level (Table 4.55). It can therefore be concluded that the socio-psychological perception variables proposed in this thesis are good predictors of the stage of transformational change.

Table 4. 55 Proposed model with all socio-psychological variables

Ordered logistic regression

				No. of obs =		425
				LR chi2(12) =		64.63
				Prob > chi2 =		0.000***
Log likelihood =	-616.092			Pseudo R2 =		0.0498
stage	Coef.	Std. Err.	z	P>z	[95% Conf.	Interval]
gender	0.2486	0.2471	1.01	0.314	-0.236	0.733
age	-0.0135	0.0082	-1.64	0.100*	-0.030	0.003
fbo	-0.2031	0.1853	-1.1	0.273	-0.567	0.160
logfarmsize	1.1524	0.2347	4.91	0.000***	0.692	1.612
hh	-0.5802	0.3451	-1.68	0.093*	-1.256	0.096
extension	0.4969	0.2026	2.45	0.014**	0.100	0.894
land	0.0358	0.1907	0.19	0.851	-0.338	0.410
mstat	0.0658	0.2640	0.25	0.803	-0.452	0.583
Climaware	0.6685	0.3610	1.85	0.064*	-0.039	1.376
Climrecall	-0.2182	0.0750	-2.91	0.004**	-0.365	-0.071
ClimBelief_index	0.0588	0.0864	0.68	0.496	-0.111	0.228
Climbelieve	0.4177	0.1780	2.35	0.019**	0.069	0.767

Source: Field data. *** p<0.01, ** p<0.05, * p<0.1

The likelihood ratio test which is a measure of the overall explanatory power of the full model relative to the restricted model resulted in a Likelihood ratio Chi-square probability value of 0.0017 which is statistically significant at the 1% significance level as shown in Table 4.56.

Table 4. 56 Likelihood ratio test of the existing model with the proposed full model

Likelihood-ratio test	LR chi2(4)	=	17.34
(Assumption: m1 nested in m2)	Prob > chi2	=	0.0017***
. test Climaware Climrecall Climbelieve_index Climbelieve			

(1) [tube_stage]Climaware = 0
(2) [tube_stage]Climrecall = 0
(3) [tube_stage]Climbelieve_index = 0
(4) [tube_stage]Climbelieve = 0
chi2(4) =   16.91
Prob > chi2 =   0.0020

Source: Field data. *** p<0.01, ** p<0.05, * p<0.1

The marginal effects of the full model indicates that with a one acre increase in farmsize the probability of perceiving climate change impacts and its effects on smallholder stage of transformational change decreases by 6.8%. Similarly, a directional change in access to Extension services, meaning the difference between if a smallholder has access to Extension services or not decreases the probability of smallholder farmers perceiving climate change impacts and its effects on smallholder stage of transformational change by 2.93%.

As expected, different smallholder farmers are in different stages of the transformational change process based on their perceptions. The marginal effects of the perception variables indicate that with every directional change in awareness, the probability of perceiving climate change impacts and its effects on determining smallholder stage of transformational change decreases by 3.95%. Similarly, with every directional change in recall, the probability of perceiving climate change impacts and its effects on determining smallholder stage of transformational change increase by 1.29%. Finally with every directional change in belief, the probability of perceiving climate change impacts and its effects on determining smallholder stage of transformational change decreases by 2.47% as shown in Table 4.57.

Table 4. 57 Marginal effects of socio-economic and socio-psychological/ perception variables

Margins,	dydx(*)					
Average marginal effects				Number of obs =		425
Model VCE:	OIM					
Expression:	Pr(recall==1),		predict()			
dy/dx w.r.t.:	gender, age, fbo, logfarmsize, hh, extension, land, mstat					
		Delta Method				
	dy/dx	Std. Err.	z	P>z	[95% Conf. Interval]	
gender	-0.0147	0.0148	-0.99	0.32	-0.0436	0.0142
age	0.0008	0.0005	1.58	0.113	-0.0002	0.0018
fbo	0.0120	0.0111	1.08	0.281	-0.0098	0.0338
logfarmsize	-0.0680	0.0177	-3.84	0.000***	-0.1027	-0.0333
hh	0.0342	0.0211	1.62	0.104	-0.0071	0.0755
extension	-0.0293	0.0129	-2.28	0.023**	-0.0545	-0.0041
ownership	-0.0021	0.0113	-0.19	0.851	-0.0242	0.0200
marriedstat	-0.0039	0.0156	-0.25	0.803	-0.0344	0.0267
Climaware	-0.0395	0.0223	-1.77	0.077*	-0.0832	0.0043
Climrecall	0.0129	0.0049	2.65	0.008***	0.0033	0.0224
Climbelieve_index	-0.0035	0.0051	-0.68	0.498	-0.0135	0.0066
Climbelieve	-0.0247	0.0112	-2.2	0.028**	-0.0466	-0.0027

Source: Field data. *** p<0.01, ** p<0.05, * p<0.1

The results show that smallholders are indeed at different levels or stages of readiness, willingness, and ability to engage in transformational change due to a combination of cognitive, psychological and socio-economic factors that shape their stages in the transformational change process as found by other researchers (Glanz *et al.*, 1994; He *et al.* 2010; Niles *et al.*, 2015; Semenza *et al.*, 2008).

4.5.3 Conclusions: Comparison between the existing and proposed models

The result of the likelihood ratio test confirms that including the perception variables are highly significant at the 1% significance level. Perceptions of climate change impacts measured through “awareness”, “recall” and “beliefs” are highly significant predictors of a smallholder’s likeholoo. Not all smallholders have the same level of readiness, willingness, capacity and ability to change due to both socio-economic characteristics and perceptions (He, et al. 2010). Based on this finding, the study therefore concludes that, use of the Transtheoretical Model to disaggregate smallholder perceptions about climate change is effective for the measurement, monitoring and documentation of changes. The results show clearly that models that incorporate the perception variables were better predictors of the likelihood of a smallholder stage in the transformation process.

4.6 Smallholder stage of change and societal transformation.

Analysis of the relationship between smallholder stages of transformational change and actions signaling societal transformation. A study by Tjernstrom and Tietenberg (2008), investigated how factors that influence individuals' attitudes about climate change ultimately impact national climate change policies. The study revealed that individual attitude and perceptions about information availability, openness of society and trustworthiness of government also influence attitudes which in turn shape macro-level policies about climate change. This transition from the individual niche level through institutional changes to the regime level and ultimately to the national or landscape level can be traced along a transformational change pathway suggested in the Multi-Level Perspective (MLP) framework by Geels (2002).

Geels (2002), Geels & Schot (2007) propose that transformations occur within social systems over relatively short periods of time while transitions occur over long periods of time including centuries. In the agricultural sector, one example of a transformational change is what occurred in the Indian agricultural system during their era of the Green Revolution from 1952 to 1975 (Parayil, 1992). It is reported that the Indian agricultural system went through a lasting and irreversible transformation from using pre-industrial human and animal powered implements to using a package of HYVs, plows and other mechanized tools that made India self-sufficient in grain production and thereby food secure (Parayil, 1992). The transformational change in the Indian Agricultural System is said to have occurred within a rapidly short period of two decades (Parayil, 1992).

It can be said that on the whole, society is moving along an existing trajectory towards sustainable development (Scoones, 2009; Beddington *et al.*, 2012). What this thesis calls for is not business as usual or a complete discontinuation of old approaches, but rather for a change in direction along the existing trajectory to achieve higher productivity, food security and better livelihoods at a faster, socio-ecologically and economically sustainable rate by incorporating two new elements into the Diffusion of Innovation theory and AIS concept as shown in Figure 30. These two elements are (1) linking smallholder psychological or cognitive perceptions by way of awareness, recall and beliefs, into the transformation process; (2) disaggregating and categorizing individual perceptions and socially differentiated socio-economic characteristics based on their stage of transformation as they move along the transformation process.

Proposed Extension of Rogers' (2003) Diffusion of Innovation Theory

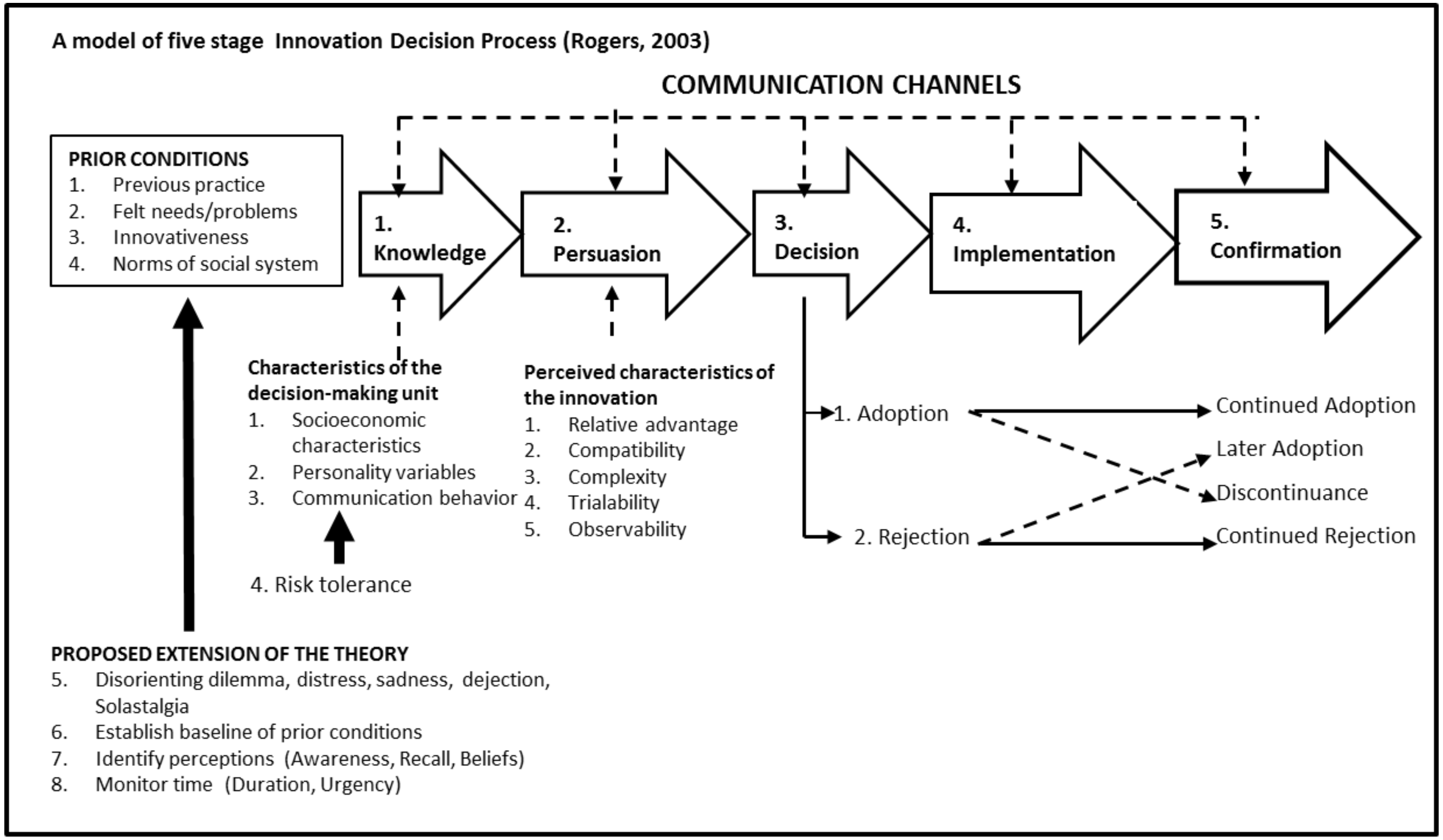


Figure 30: Proposed extension of Rogers' five stage innovation-decision process (Adapated from Rogers, 2003, p. 170)

4.6.1 Change in climate-sensitive practices at the niche level

What agronomic and other practices have they adopted or changed as a result of climate change impacts? The research reveals a range of the climate-sensitive agronomic practices smallholders are using to overcome the climate change impacts they face. The results show that there is highest level of agreement about the use of hybrid seeds in response to the negative climate change impacts. This has a mean score of 4.47 on a five-point Likert scale. This is followed by changes in planting dates (4.27), intercropping (4.12) and the use of mulch or mulching (4.10). Other climate-sensitive practices include changes in land preparation practices involving slash and burn (3.94), using more chemicals on the same piece of land to increase productivity (3.8), transporting soil from one area to another (3.71), and expansion of cultivation to new farmlands (3.67). The use of more chemicals is usually considered to be intensification whereas expansion to other farm lands is known to be an expansion strategy. The use of the tube-well irrigation system is a major climate sensitive practice studied in this research. The level of agreement about its use was 3.50, followed by weather forecasting 3.48, integrated mixed livestock and crop farming 2.78, crop insurance 2.66, and agroforestry 2.49 as in Appendix IX.

Although deforestation of forests and mangroves was identified by a majority of smallholders as the primary cause of climate change, agro-forestry was the least of practices used to remedy climate impacts in the study area. This may be because the Keta area has such a small land mass between the sea and the Keta lagoon, as shown in Figure 13 by Awadzi *et al.* (2008). A land that was previously used to grow coconut plantations on a commercial scale (Ocloo, 1996) has now been ravaged by coastal erosion and the negative effects of climate change and reduced to growing vegetables. The unprecedented increases in temperature and erratic weather patterns mean that farmers are unable to rely on their previous experience and knowledge completely in interpreting the impact of the meteorological changes and how to effectively address the issue of low productivity. Increased temperatures and humidity exacerbate fungal and bacterial growth thus increasing the disease burden on crops and lowering productivity. Smallholders who can afford it, transform their farming techniques by adopting climate-sensitive technical innovations like HYVs, change planting dates, use intercropping, mulching, intensification, tube-well irrigation and other practices to mitigate the harmful effects of climate change on their farming activities (Table 4.58).

Farmers are faced with new diseases that are often a mix of fungal and bacterial growth with which they are unfamiliar with and cannot easily diagnose or remedy. Lack of technical expertise, advisory services, links to research and other institutions or well-resourced laboratories leave smallholders vulnerable to excessive chemical use, crop and livelihood losses. High mean night-time temperatures affect flowering, reduce yields, and thus demand higher doses of inorganic fertilizer and other chemicals. High doses of inorganic fertilizer increase production costs and pose the risk of leaching through the porous sand into groundwater.

4.6.2 Change in climate-sensitive practices at the regime level

Due to poverty, most farmers are unable to obtain sufficient or appropriate inputs, farm labor, or mechanized implements. As a result, farming is tedious and expensive. Where mechanized equipment such as water pumps for irrigation or power tillers exist, farmers struggle with limited energy sources and have to purchase electricity or gasoline to power them at an exorbitant cost. Consequently, some smallholders try to cut costs by using excessive chemicals in activities like weeding where weedicides are used in lieu of hiring additional farm hands. Unfortunately, low educational levels and inadequate literacy skills hinder the ability to properly apply fertilizers, weedicides and other chemicals. This poses a threat to smallholder productivity, their health, and that of other farmers and consumers.

Table 4. 58 Climate-sensitive practices adopted and stage of transformational change

Climate-sensitive practices	PC	C	PC	A	M	T	Scale High>2.5 Low=<2.5
Change in planting dates	3.86	4.23	4.59	4.63	4.00	3.81	High
Intercropping	3.68	4.33	4.09	4.13	4.50	3.86	High
Mulching	4.14	4.06	4.25	4.12	4.00	4.06	High
Stopped slash& burn	3.04	3.87	4.07	4.50	4.13	3.44	High
Use of agro-chemicals	4.11	3.94	3.43	3.63	4.00	3.90	High
Use of high yielding varieties	3.36	4.00	3.59	3.73	3.63	3.35	High
Carting of soil	3.36	4.00	3.59	3.73	3.63	3.35	High
Expansion into new lands	3.75	3.59	3.48	3.95	3.75	3.47	High
Total	3.66	4.00	3.89	4.05	3.95	3.66	High
Use of tube well irrigation	2.33	2.69	3.37	4.30	3.13	4.29	High
Weather forecast	2.86	3.44	3.70	3.58	4.13	3.42	High
Integrated farming	2.32	2.64	2.80	3.03	3.38	2.48	High
Crop insurance	2.36	2.56	2.79	2.76	2.88	2.71	High
Agro forestry	1.86	2.47	2.64	2.71	3.38	2.27	Low
Average	3.19	3.56	3.59	3.77	3.75	3.43	High

Source: Field data

In this study, belonging to a farmer based organization (FBO) was chosen as a proxy to represent the transition in smallholder attitudes beyond the individual transformation to socialize with others to attain a common national goal such as bringing about societal transformation (Table 4.59). Social transformation is measured by their desire and choice of belonging to a farmer based organization (FBO) to take collective action to improve agricultural productivity or to address weather and resource related problems. One explanation is that their desires are motivated by their perceptions about information availability, openness of other members of society to work and share in problem solving and trustworthiness of government programmes to support FBOs (Tjernstrom & Tietenberg, 2008).

Table 4. 59 FBO membership and smallholder stages of transformational change

Stage of transformation	Not member	Member	Total
Pre-contemplation	12	16	28
	42.86	57.14	100
	5.13	8.38	6.59
Contemplation	86	60	146
	58.9	41.1	100
	36.75	31.41	34.35
Preparation/Determination	19	25	44
	43.18	56.82	100
	8.12	13.09	10.35
Action	62	58	120
	51.67	48.33	100
	26.5	30.37	28.24
Maintenance	4	4	8
	50	50	100
	1.71	2.09	1.88
Termination	51	28	79
	64.56	35.44	100
	21.79	14.66	18.59
Total	234	191	425
	55.06	44.94	100
	100	100	100
Pearson chi2 (5)	=8.5866	Pr =	0.127
Likelihood-ratio chi2 (5)	=8.6185	Pr =	0.125
Kendall's tau-b	=-0.0406	ASE=	0.044
Gamma	=-0.0661	ASE=	0.071
Fisher's exact			0.122

Source: Field data

4.6.3 Change in climate-sensitive practices at the landscape level

According to Hansen, Sato and Ruedy (2012) globally sea level has been rising at a rate over 3 mm per year or 3 m per millennium, a rate that is much higher than any recorded rate of sea level during the past several thousands of years which has led to coastal erosion in many parts of the world. Appeaning Addo, Walkden and Mills (2008) report a mean rate of erosion in the Accra region to be 1.13 m/yr (±0.17 m/yr). While coastal erosion is caused by a multiplicity of factors such as coastal sediment geology, strength of tidal waves, wave activity, sea level rise, stormy weather and human activities, one of its biggest and most perceptible impacts that cause people to notice climate changes are the effects of coastal erosion on washing away land for economic activities and settlements, as high as 70% of buildings in the Keta area (Boateng, 2012).

It is believed that including these two elements would shed more light on the linkage between smallholder ability to improve productivity by harnessing emerging mechanisms along their transformation pathways. Geels' (2002, 2007) multi-level perspective (MLP) provides a useful analytical schema for looking at change across various levels of an innovation system. It is an ideal framework for analyzing change beyond the individual level. This is because it distinguishes between opportunities at the niche (individual experimental level), regime (institutional) and landscape (macro-level with various institutions that become norms) was shown in Figure 25.

At the societal level, ttransformation occurs when individuals and groups struggle on multiple dimensions to search, learn, and negotiate entrenched practices in markets, regulations, and cultural settings at the niche or individual experimental level, to bring about fundamental, irreversible broad-based changes in the landscape as depicted in Figure 25 (Leeuwis & Van den Ban, 2004; Geels, 2002). The pathways analysed in this study included one investigating socio-economic variables representing transformation as usual (O'Brien, 2011), and another with the proposed psychological or cognitive perception variables: awareness, recall and beliefs.

4.6.4 Conclusions: Change in climate-sensitive practices at the societal level

This section reveled that smallholders respond to opportunities at the niche (individual experimental level), regime (institutional) and landscape (macro-level differently and therefore need more nuanced interventions targeting various institutions to facilitate their transformational change process.

4.7 Chapter Summary

This chapter presented results of the empirical data that was analysed using various methods according to the four research objectives of the study. The qualitative approaches provided descriptions, discreptive statistics and quotations from respondents in the study. The statistical results were also presented per research objective. A short conclusion and recommendation was provided per research objective to help bridge the existing knowledge gap and provide recommendations to help farmers, researchers, practitioners and others in the agricultural development nexus to understand factors relating to the smallholder transformational change process in relation to their perceptions of the impacts of climate change. The next chapter will present conclusions of the research as a whole. The chapter comments on the entire research from the conceptual framework to the methodoly to the results obtained.

CHAPTER FIVE: CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

Climate change impacts have emerged as a critical threat to food security, smallholder livelihoods and the wellbeing of the earth system. Low and erratic precipitation and high mean temperature levels which directly affect agricultural productivity influence activities of smallholders in taking actions to counter their negative impacts such as droughts and floods. In Africa, persistent low agricultural productivity and rising population have perpetuated issues of food insecurity, malnutrition and loss of livelihoods (FAO, 2013). According to the European Union, a 2^{o}C increase in global mean temperature above pre-industrial levels (Adger *et al.*, 2009) may result in water-related problems, starvation, malnutrition and loss of livelihoods (World Bank, 2012). About 250 million Africans especially smallholder farmers, women, children and coastal dwellers at the bottom of the economic pyramid in developing regions and Africa are most vulnerable to climate change due to poverty and low adaptive capacity (IPCC, 2007). New evidence on extreme events and disaster risk (IPCC, 2012) suggest that in the future, climate impacts and extreme events will occur in unprecedented and erratic ways. This place a burden on the individual's ability to perceive and assess an impact accurately and recognize when to act. In other words, individuals need both adaptive and mitigative capacities adequately perceive and to respond to the extent of vulnerability they are faced with or when and how to act in response to the impending impact or event. It is assumed that individuals can rely on early warning systems but once the early warning signals are identified and issued, then what next? How do they adapt? And how do they transform? The concert of activities, resources and abilities needed to assist themselves in times of impacts or extreme events is what is termed the so-called transformational capacity (IPCC, 2012).

The aim of this research was to analyze the link between smallholder perceptions and theor transformational change process. The literature review unearths inconsistencies and weaknesses that may arise in pursuing the dual goals of achieving transformational change and agricultural productivity 1) using an old paradigm and theoretical framework which depends on the top-down transfer of technology model at the core to promote transformational change or 2) using a qualitative action research approach that does not explicitly track changes at each stage of individual transformation; or 3) not basing approaches on proven theories of transformational change at the individual level. The study therefore examined mechanisms and pathways for achieving transformational change of smallholder agriculture. Gaps identified in previous research smallholder perceptions and socio-economic factors as posing barriers to the transformation process. The thesis therefore examined the impacts of perceptions and socio-economic factors on smallholder transformational change. The analysis was based on the transformational change process suggested by the Transtheoretical Stages of change theory which posits that individuals go through six main stages of change namely: Pre-contemplation, Contemplation, Preparation, Action, Maintenance, and Termination.

The thesis used both quantitative and qualitative analyses. The quantitative analyses consisted of using descriptive statistics, Chi-square and logistic regression analyses of field data collected through a questionnaire. Participants responded to both open ended and closed ended questions most of which were on a five-point Likert scale. The responses to the open-ended questions as well as data from focus group discussions (FGD) and in-depth interviews were analysed using content and thematic analyses as per Silverman (2011).

5.2 Smallholder perceptions of climate change

One of the main findings of the thesis is that the "one-size-fits-all" approach a phrase that has been used by other scholars, that is characteristic of most Extension delivery methods undermines efforts to transform smallholders to increase productivity. This is because individuals are indeed at different levels or stages of readiness, willingness, and ability to engage in transformational change due to a combination of cognitive, psychological and socio-economic factors that shape their attitudes, beliefs and values. With regards to perceptions, it was found that smallholders experienced climate change impacts through a variety of ways.

The results of the analyses revealed that over 91% of smallholders were aware of the climate change phenomenon in the study area. Over 78% of smallholders believed that the climate was worsening while only 4% believed that it was improving. About 18% were not sure if the climate was improving or worsening or believed that there was no change in climate. However, the high level of awareness did not automatically translate into a high level of action. This is because although over 91% of smallholders were aware of the climate change phenomenon, only 79 or 18.59% were in the termination stage where they had irreversibly adopted tube-well irrigation as a solution to the persist increases in temperature, longer duration of meteorological droughts. A majority of 146 oe 34.35% of the respondents were in the contemplation stage meaning that they had realized that there was a problem with climate change impacts but were yet to take an action.

Smallholders reported that they perceived the most changes in climate impacts through changes in air and water temperature with a mean score of 3.94 on a five-point Likert scale. This was followed by size and intensity of waves, frequency and extent of crop damage and failure, incidence of pests, and changes in the duration of drought with mean scores of 3.17, 2.67, 2.59 and 2.53 respectively. A scale developed by Marshall *et al.* (2014), was used to interpret the scores where mean scores greater than 2.5 were considered to be high while those equal to or less than 2.5 were considered to be low. It was interesting to note that the majority of 39.14% of smallholders believed that the magnitude, likelihood and frequency of crop damage and failure had strongly increased about 40% of these smallholders with such beliefs were in the pre-contemplation and contemplation stages of the transformational change process and had not yet taken an action.

Another interesting finding was that although over 67% of smallholders disagreed to this, about 19% or approximately one out of every five farmers either agreed or strongly agreed that farmers hold superstitious beliefs and are using “juju” or black magic and superstition in farming as a remedy to negative climate change impacts. Data obtained from the focus group discussions confirmed that some farmers rely on indigenous and tacit knowledge rather than scientific knowledge, have a firm belief in tradition and are willing to offer libation and perform other rituals if needed as a solution to the negative climate change impacts they face. This is an indication that there may be some confusion about the scientific, tacit and indigenous knowledge available on climate change impacts and possible solutions or remedies available to smallholders.

5.3 Smallholder socio-economic factors and perceptions

The analysis sought to understand the effects of smallholder perceptions and socio-economic factors on their transformational change process. The results of the Chi-square (X^2) analyses used to test for association and independence between the perception and socio-economic variables revealed that the relationship between climate change awareness (ClimAware) and Head of Household (Hoh), as well as ClimAware and access to Extension services (Extension) were significant at the 5% level. ClimAware also had a significant relationship with membership in a Farmer Based Organization (FBOmember) at the 10% significance level. The X^2 tests also show a significant relationship between smallholder beliefs (ClimBelief) about climate change with regards to temperature and access to Extension delivery services (Extension). The relationship between smallholder recall (ClimRecall) and access to Extension services was significant at the 5% significance level. It was surprising that the relationship between climate change awareness (ClimAware) and Gender, Age, and Education were not significant. Climate change awareness, beliefs and recall were the perception variables used to measure and explain the socio-psychological factors that affect the smallholder transformational change process.

The perception variables served as intervening variables in the model. First they were dependent variables but were later added to the socio-economic variables in the existing model as independent or predictor variables. The logistic regression models were used to assess the extent to which the socio-economic variables could predict smallholder perceptions and transformational change. The socio-economic variables that were found to have a significant relationship with the perception or stage of transformational change variables were used in a regression model. This was called the endogenous or restricted model with only the variables of interest. They represent one pathway to the transformation change process. These endogenous or restricted models were then compared with the full models that had the full complement of endogenous and exogenous variables. The results clearly show that there are remarkable differences between the restricted and full models. The current paradigm in the evolution of agricultural Extension research and development represents a pathway to achieving smallholder transformation in the face of climate variability and change. These findings seek to contribute to the existing knowledge in agricultural Extension about the effects of socio-economic variables on smallholder perceptions.

5.4 Smallholder perceptions and transformational change

The current climate change adaptation literature also presents several perspectives on ways of achieving transformation. One of the contributions this thesis sought to make was in provide evidence for the conceptual, theoretical and methodological refinement in mechanisms and pathways for transforming of smallholder agriculture. The results clearly show that the smallholder transformational change process cannot be taken for granted. Smallholders at various stages of the transformational change process are affected by very different socio-economic and perception variables. Finally, incorporating the perception of ClimAware, ClimBelief and ClimRecall increases the explanatory power of the restricted model as shown in the LR Chi-square of 0.017 which is significant at the 5% significance level. This symbolizes that the current system or paradigm of agricultural extension theory and practice with regards to smallholder transformation could benefit from the proposed theoretical and methodological refinement which focuses on the individual transformational change as a necessary precursor to societal transformation.

According to the UNEP there is an urgent need to monitor adaptation actions in formats that are can be factually represented using quantitative or numeric data in the form or graphs, charts, etc. which progressively document change. Prior to the establishment of the Millennium Development Goals (MDGs) attempts to ensure sustainable and equitable growth among the poor did not result in sustainable outcomes. Establishing the MDGs helped to measure, track and recognize factors impacting sustainable development in a more tangible and socially differentiated manner. How do we know to what extent climate-smart practices have transformed smallholder behaviour over time or what stage of the transformational process they are in? This research posits that not every socio-economic variable affects smallholders in the same way. However, if smallholders are lumped together in current agricultural Extension methods under emerging methods that are essentially the Transfer of Technology or Diffusion of innovations paradigm, not much will be achieved. The results of the analysis using Prochaska's stages of change model reveal that not all the stages of transformation are the same. New theories, mechanisms and pathways that focus on individual socially differentiated are needed to apply resources effectively in order to ensure climate-sensitive transformational change of smallholder agriculture in Ghana and along coastal zones with similar agro-ecological conditions as the study area.

The results also show that smallholder perceptions do in fact impact smallholder farmers along transformational change process. The findings of this research show rely on knowledge, beliefs and values developed over time whether explicit or tacit to resolve the ever-changing dynamics of climate change impacts on their livelihoods. The fact farm size and access to Extension were significant at either 1% or 5% across all models gives a very strong indication that the perception variables are good predictors of the likelihood of smallholder stage in the transformational change process relative to odds of being at the Pre-contemplation stage. Also, access to Extension and land ownership were statisticaly significant predictors of smallholder perceptions. What this means is that good, reliable information and land tenure issues play a significant role in determining the pace at which smallholders respond to climate change impacts. This is not surprising in the context of the Keta area, and the degree of fragmentation of land over the years due to their peculiar inheritance system where land holdings are divided among male children. Also, smallholders find themselves in an agro-ecologically disadvantaged area in the coastal Savannah where the soils are sandy and marginal at best requiring the intensive incorporation of manure and other organic matter to improve fertility and water holding capacity for improved productivity. This means that farmers are constantly under stress from high production costs.

5.5 Recommendations

Summary of recommendations

It is recommended that the Ministry of Food and Agriculture, researchers and development partners could:

- Engage smallholders in ways that can unravel their thoughts, beliefs, and memories about climate change impacts.
- Design Extension approaches that target underlying perceptions and beliefs and appeal to what people recall over a period of time. This could help smallholders adapt in holistic transformative ways that conform with their values at the individual level.
- Focus on interventions that do more than create awareness.
- Promote theory based Extension approaches to guide practice.
- Differentiate training of smallholders according to socio-economic characteristics and stage of transformational change.
- Target achieving transformational change through land ownership/ land tenure issues that affect smallholder perceptions.
- Consider gender roles of partcipants, particularly the importance of addressing Heads of Households, understanding their perspectives, motivations, aspirations and other factors

that affect their decision making at the individual level that contribute to their transformational change process.

- Improve smallholder productivity in relation to climate change by addressing gender issues through education and use appropriate educational methods that disaggregate the educational and other socio-economic characteristics of various smallholders instead of assuming that most smallholders have a low level of education.
- Pay closer attension to the effectiveness of Extension programmes by incorporationing issues about Land ownership and other socio-economic characteristics that are of importance to smallholder farmers.
- Access to agricultural Extension and approaches that incorporate recall are vital to increased agricultural productivity and adaptation to climate change impacts.

Further research

With this backdrop, it is imperative that agricultural researchers, practitioners and the global community join forces in offering new ideas, knowledge and practical solutions by harnessing smallholder perspectives in addressing climate impacts to overcome the low productivity problem from the roots. Both basic and applied research is needed in investigating these problems of land tenure and improved access to Extension services to help smallholders craft desired responses. Future research on transformational change and its relationship with smallholder livelihoods and the Sustainable Development Goals (SDGs).

This thesis recommends that future or follow-on research could be done by collecting and using panel data to assess multi-level thresholds of change model. Also more targeted educational programmes that incorporate the wonder of human ingenuity to create new institutions from the smallholder farmers' perspective to mitigate problems, through the creation of a ”discursive space” for transformational change based on theories of transformational change and also incorporating awareness knowledge, recall and beliefs is a key mechanism for facilitating behavioural change. From a methodological perspective, it is recommended that future researches investigate possible interactions between the socio-economic and perception variables. For instance, there could have been some interaction between age and recall as indicated in the literature.

Various researchers have provided models and frameworks on achieving social transformation. However, this thesis argues that there is a missing link in the transformation process which hinders smallholders’ ability to take advantage of available mechanisms to fully transform or effectively engage in the social transformation process. The missing link investigated in this thesis was the effect of smallholder perceptions and social differentiation on their stage of transformation. Two main strands of research that may emerge could be:

1. Exploring smallholder decision making based on recall of previous experiences. This can be done for instance by using suitable Extension methods that engage farmers’ recall of traditional land tenure practices.
2. Incorporating the stages of behavioural change model within the current socio-economic framework unravels how smallholder perceptions lead to climate-sensitive agricultural practices. The linkages between the various stages could help to explain how smallholder perceptions contribute to their pathways for transformational change.
3. Further research into methods that work in concert, their success rate, enablers and constraints in moving smallholders from one stage to the other and the nuances of how transformational, irreversible change is

achieved could help us to better understand how to design specific mechanisms along specific pathways to enhance smallholder transformation. Looking at perceptions and mechansims instead of methods could help establish smallholder propensity to become fully transformed in taking advantage of mechanisms and other external factors that could help them overcome low productivity in the face of climate variability and change.

5.6 Chapter Summary

The chapter presents a summary of conclusions and recommendations. In brief, thesis advocates for Extension to facilitate and incorporate socio-psychological cognitive perception variables such as awareness, recall and beliefs in their development programmes and interventions in addition to traditional socio-economic variables. Relevant socio-economic factors like land ownership, and access to extension, can be considered first as a way of understanding the extent of changes, and climate related problems that have occurred over time and to build on what smallholders already know. Building on smallholders' indigenous knowledge helps facilitators and other intermediaries to better understand underlining belief systems while they interact with smallholders in their contexts and using concepts that are familiar to them. It also facilitates co-learning that helps smallholders to appreciate and become engaged with innovation and changes to their way of life that is transformational in nature.

The thesis joins other researchers who propose that individual transformation can spur larger, societal movements and transformations. Yet, a large scale social movement of hype and rhetoric cannot ensure individual transformation. At best, it may create awareness but may not necessarily lead to "transformational change". It is recommended that among other things, the concept of smallholder stage in the transformation process should be disaggregated to gain better insights into the factors that affect their productivity. It is also recommended that future research should examine the various thresholds at which smallholders move from one stage to another to better plan agricultural Extension interventions that meet smallholders at their point of need.

REFERENCES

Adebayo, S. A., & Oladele, O. I. (2012). A review of selected theories and their applications to information seeking behavior and adoption of organic agricultural practices by farmers. *Life Science Journal, 9*(3), 63-66.

Adger, W. N., Arnell, N. W., & Tompkins, E. L. (2005). Successful adaptation to climate change across scales. *Global Environmental Change, 15*(2), 77-86.

Adger, W. N., Dessai, S., Goulden, M., Hulme, M., Lorenzoni, I., Nelson, D. R., ... & Wreford, A. (2009). Are there social limits to adaptation to climate change? *Climatic Change, 93*(3-4), 335-354.

Adjei-Nsiah, S. & Kermah, M. (2012). Climate change and shift in cropping system: from cocoa to maize bazed cropping system in Wenchi area of Ghana. *British Journal of Environment and Climate Change, 2*(2), 137-152.

Adjei-Nsiah, S., Adu-Acheampong, R., Debrah, K., Dembele, F., Lassine, S., Ouologuem, B., & Zannou, E. (2013). Defying "the pervasive bias" against African smallholders: identifying entry points for institutional change. *Development in Practice, 23*(7), 857-871.

Agoumi, A. (2003) Vulnerability of North African countries to climatic changes: adaptation and implementation strategies for climatic change. Developing Perspectives on Climate Change: Issues and Analysis from Developing Countries and Countries with Economies in Transition. IISD/Climate Change Knowledge Network, 14 pp. http://www.cckn.net//pdf/north_africa.pdf

Agrawal, A. (1995). Dismantling the divide between indigenous and scientific knowledge. *Development and Change, 26,* 413-439.

Ajzen, I., & Fishbein, M. (2000). Attitudes and the attitude-behaviour relation: Reasoned and automatic processes. *European Review of Social Psychology, 11*(1), 1-33.

Allan, C., Nguyen, T. P. L., Seddaiu, G., Wilson, B., & Roggero, P. P. (2013). Integrating local knowledge with experimental research: case studies on managing cropping systems in Italy and Australia. *Italian Journal of Agronomy, 8*(2), 15.

Anderson, L. W., Krathwohl, D. R., & Bloom, B. S. (2001). A taxonomy for learning, teaching, and assessing: A revision of Bloom's taxonomy of educational objectives. Allyn & Bacon.

Andeweg, K., & van Latesteijn, H. C. (Eds.). (2010). The Transforum model: Transforming agro innovation toward sustainable development. Springer Science & Business Media.

Appeaning Addo, K., Walkden, M., & Mills, P. (2008). Detection, measurement and prediction of shoreline recession in Accra, Ghana. ISPRS *Journal of Photogrammetry and Remote Sensing*, *63* (5), 543–558.

Asenso-okyere, K., Davis, K. & Aredo, D.C. (2008). Advancing Agriculture in Developing Countries through Knowledge and Innovation. IFPRI. Synopsis of an Internation Conference, IFPRI, Washington DC, November 2008.

Ash, A., Thornton, P., Stokes, C., & Togtohyn, C. (2012). Is proactive adaptation to climate change necessary in grazed rangelands? *Rangeland Ecology & Management, 65* (6), 563-568.

Argyris, C., & Schön, D. (1995). Organizational learning: A theory of action perspective, 1978. Massachusetts: Addison-Wesley Publishing Company.

Awadzi, T. W., Ahiabor, E., & Breuning-Madsen, H. (2008). The Soil-Land use System in a Sand Spit Area in the Semi-Arid Coastal Savanna Region of Ghana–Development, Sustainability and Threats. *West African Journal of Applied Ecology*, *13*(1), 132-143.

Axinn, G. H. (1998). Guide on alternative extension approaches. Agricultural Education and Extension Service, Human Resources, Institutions and Agrarian Reform Division. Food and Agriculture Organization of the United Nations, Rome.

Balarane, A., & Oladele, O. I. (2012). Awareness and use of agricultural market information among small scale farmers in Ngaka Modiri Molema District of North West Province. *Life Science Journal*, *9*(3), 57-62.

Bandura, A. (1977). Social learning theory. General Learning Press, New York.

Bandura, A., Adams, N. E., & Beyer, J. (1977). Cognitive processes mediating behavioural change. Journal of personality and social psychology, 35(3), 125.

Barrett, C. B. (2010). Measuring Food Insecurity. *Science*, *327*(850). DOI: 10.1126/science.1182768.

Beddington, J. R., Asaduzzaman, M., Clark, M. E., Bremauntz, A. F., Guillou, M. D., Howlett, D. J. B., & Nobre, C. A. (2012a). What next for agriculture after Durban. *Science*, *335*(6066), 289-290.

Beddington, J., Asaduzzaman, M., Fernandez, A., Clark, M., Guillou, M., Jahn, M., ... & Scholes, R. (2012b). Achieving food security in the face of climate change: Final report from the Commission on Sustainable Agriculture and Climate Change.

Beddington, J. R., Asaduzzaman, M., Clark, M. E., Bremauntz, A., Guillou, M. D., Jahn, M. M., & Scholes, R. J. (2012c). The role for scientists in tackling food insecurity and climate change. *Agric. Food Secur, 1*(10).

Blackmore, C. (2007). What kinds of knowledge, knowing and learning are required for addressing resource dilemmas?: a theoretical overview. Environmental Science & Policy, 10 (2007), 512-525.

Boateng, I. (2012). An application of GIS and coastal geomorphology for large scale assessment of coastal erosion erosion and management: a case study of Ghana. *Journal of Coastal Conservation*. DOI 10.1007/s11852-012-0209-0.

Boyd, E., Hultman, N., Roberts, J. T., Corbera, E., Cole, J., Bozmoski, A., ... & Liverman, D. M. (2009). Reforming the CDM for sustainable development: lessons learned and policy futures. environmental science & policy, 12(7), 820-831.

Brady, N., & Weil, R. (2008). The nature and properties of soils. 14th ed. Pearson Education, Inc. Upper Saddle River, New Jersey, USA.

Chambers, R., & Conway, G. (1991). Sustainable rural livelihoods: practical concepts for the 21st century. *IDS Discussion Paper 296*. Institute of Development Studies (UK).

Chambers, R., & Conway, G. (1992). Sustainable rural livelihoods: practical concepts for the 21st century. Institute of Development Studies (UK).

Checkland, P. B. (1981). Systems Thinking, Systems Practice . J. Wiley and Sons Chichister.

Christopolos, I. (2010). Mobilizing the potential of rural and agricultural extension. Danish Institute for International Studies. Food and Agriculture Organization of the United Nations. Office of Knowledge Exchange, Research and Extension. *The Global Forum for Rural Advisory*. Rome, 2010.

Coase, R. H. (1937). The nature of the firm. *Economica, 4*(16), 386-405.

Collins English Dictionary (2005). *Collins English Dictionary*. Harper Collins Publishers. Market House Books Ltd. Aylesbury, England. pp. 95.

Collinson, M. (2001). Institutional and professional obstacles to a more effective research process for smallholder agriculture. *Agricultural Systems, 69*(1), 27-36.

Creswell, J. W., Shope, R., Plano Clark, V. L., & Green, D. O. (2006). How interpretive qualitative research extends mixed methods research. *Research in the Schools,* 13(1), 1-11.

Davis, K. E. (2008). Extension in Sub-Saharan Africa: Overview and assessment of past and current models, and future prospects. *Journal of International Agricultural and Extension Education*, 15(3), 15-18.

De Jong, T. & Ferguson-Hessler, M. G.M. (1996). Types and qualities of knowledge. *Educational Psychologist*, *31*(2), 105-113.

Derissen, S. & Latacz-Lohmann, U. (2013). What are PES? A review of definitions and an extension. *Ecosystem Services*, 6, 12-15.

Dethier, J. & Effenberger, A. (2012). Agriculture and development: A brief literature. *Economic Systems, 36*, 175–205.

Dewey, J. (1938). An as experience. *Education.*

DFID (2012). Systematic Reviews in International Development: An Initiative to Strengthen Evidence-Informed Policy Making. London, UK.

Dixon, J., Tanyeri-Abur, A., & Wattenbach, H. (2007). Smallholders, globalization, and policy analysis: Framework for analyzing impact of globalization on smallholders. FAO Corporate Document repository. Retrieved on March 2, 2016 from http://www.fao.org/docrep/007/y5784e/y5784e02.htm#fn1

Djurfeldt, G., Holmes, H., Jirström, M., & Larsson, R. (2005*)*. The African Food Crisis: Lessons from the Asian Green Revolution. Wallingford, UK, CABI.

Dobbin, F. (2005). *Comparative and historical approaches to economic sociology*. In The Handbook of Economic Sociology. Smelser, N. J. & Swedberg, R. (Eds.) 2nd Ed. New York: Princeton University Press. pp. 26-48.

Dordor, M. S. K. (2005) The genesis of the Keta Sea Defence Project. *The Volta Monitor: An investment, tourism and cultural magazine*, *1*, 38-54.

Dormon, E. N. A., Van Huis, A., Leeuwis, C., Obeng-Ofori, D., & Sakyi-Dawson, O. (2004). Causes of low productivity of cocoa in Ghana: farmers' perspectives and insights from research and the socio-political establishment. *NJAS-Wageningen journal of life sciences*, *52*(3), 237-259.

Dormon, E.N.A., Leeuwis, C., Fiadjoe, F.Y., Sakyi-Dawson, O. & van Huis, A. (2007) Creating space for innovation: the case of cocoa production in the Suhum-Kraboa-Coalter District of Ghana. IJAS, Special Issue *Convergence of Sciences Research West Africa 5* (2&3), 232–246.

Dusenberry, H. (1966). An Extension reference manual. In R. E. Burton (Ed.), Volume II, Selected readings to accompany Getting Agriculture Moving.(1st Ed. , pp. 850-881).

DuSautoy, P. (1962). The organization of a community development and Extension education. In R. E. Burton (Ed.), Volume II, Selected readings to accompany Getting Agriculture Moving.(1st Ed. , pp. 837-849)

Ellis (1992). In Oladele, I. O. (2013). Linkage between Gown and Town: My experience in Sub-Saharan Africa and South East Asia. Inaugural lecture. North West University (Mafikeng Campus), Mmabatho, South Africa.

FAO (2005), Fertilizer use by crop in Ghana. Food and Agriculture Organization of the United Nations, Rome.

FAO (2009). High Level Expert Forum - How to Feed the World in 2050. Office of the Director, Agricultural Development Economics Division Economic and Social Development Department. Viale delle Terme di Caracalla, 00153, Rome, Italy.

FAO (2013). The state of food and agriculture: Food systems for better nutrition. Food and agriculture organization of the United Nations, Rome, Italy. ISSN 0081-4539.

FAO (2014). The state of food and agriculture: Innovation in family farming. Food and agriculture organization of the United Nations. Rome, Italy. ISSN 0081-4539.

Feldman, A. (2007). Validity and quality in action research. *Educational Action Research, 15*(1), p. 21–32.

Flood & Romm, (1996) Double and trible loop learning. In Groot (2002) Demystifying facilitation of multi-actor learning processes. Published doctoral thesis. Wageningen University. The Netherlands.

Fosu-Mensah, B. Y., Vlek, P. L. G., & Manschadi, A. M., (2010). Farmers' perception and adaptation to climate change: A case study of Sekyedumase District in Ghana. World Food System, a contribution from Europe. Centre for Development Research (ZEF), University of Bonn, Germany.

Gan, C., Clemes, M., Limsombunchai, V. & Weng, A. (2006) A logit analysis of electronic banking in New Zealand. *International Journal of Bank Marketing, 24*(6), p. 360-383.

Garcı´a de Jalo´n, S., Silvestri, S., Granados, A. & Iglesias, A. (2015). Behavioural barriers in response to climate change in agricultural communities: an example from Kenya. Reg Environ Change (2015) 15:851–865 DOI 10.1007/s10113-014-0676-y.

Gebrehiwot, T., & van der Veen, A. (2015). Farmers prone to drought risk: why some farmers undertake farm-level risk-reduction measures while others not?. Environmental management, 55(3), 588-602.

Ghana Environment and Climate Change Policy Action Node (GECCPAN) (2015). Agricultural Extension Guideline for Service Providers in Ghana. Council for Scientific and Industrial Research - Science and Technology Policy Research Institute (CSIR-STEPRI). Accra, Ghana.

Geels, F. W. (2002). Technological transitions as evolutionary reconfiguration processes: a multi-level perspective and a case-study. Research policy, 31(8), 1257-1274.

Geels, F. W., & Kemp, R. (2007). Dynamics in socio-technical systems: Typology of change processes and contrasting case studies. Technology in society, 29(4), 441-455.

Geels, F. W., & Schot, J. (2007). Typology of sociotechnical transition pathways. Research policy, 36(3), 399-417.

Gemo, H., Eicher, C. K., & Teclemariam, S. (2005). Mozambique's experience in building a national extension system. Michigan: Michigan State University Press.

Giddens, A. (1984). The constitution of society: Outline of the theory of structuration. University of California Press.

Glanz, K., Patterson, R. E., Kristal, A. R., DiClemente, C. C., Heimendinger, J., Linnan, L., & McLerran, D. F. (1994). Stages of change in adopting healthy diets: fat, fiber, and correlates of nutrient intake. Health Education & Behaviour, 21(4), 499-519.

Glover, D., Sumberg, J., Andersson, J. A. (2016). The adoption problem; or why we still understand so little about technological change in African agriculture. Outlook on Agriculture, 45(1), pp 3-6. Retrieved online on 15th April, 2016 from: http://www.ingentaconnect.com/contentone/ip/ooa/2016/00000045/00000001/art00001

Granovetter, M. S. (1973). The strength of weak ties. The American Journal of Sociology, 78, p. 1360-80.

Granovetter, M. (1995). Getting a job: A study of contacts and careers. University of Chicago Press.

Greenwood, D. J., & Levin, M. (2007). Introduction to Action Research: Social Research for Social Change: Social Research for Social Change. SAGE publications.

Groot, A. E. (2002). Demystifying facilitation of multi-actor learning processes. Published doctoral thesis. Wageningen University. The Netherlands.

Guijt, I. (2008). Rethinking Monitoring for Collective Learning in Rural Resource Management (Doctoral dissertation, Wageningen University, Wageningen, The Netherlands).

Gyampoh, B. A., Indinoba, M., & Amisah, S. (2008). Water Scarcity Under a Changing Climate in Ghana: Options for livelihoods adaptation. Development (51), p. 415–417. doi:10.1057/dev.2008.46Hall, A., Janseen, W., Pehu, E., & Rajalahti, R. (2006). Enhancing agricultural innovation: How to go beyond the strengthening of research systems. World Bank, Washington, DC.

Haden, V. R., Niles, M. T., Lubell, M., Perlman, J., Jackson, L. E., (2012). Global and Local Concerns: What Attitudes and Beliefs Motivate Farmers to Mitigate and Adapt to Climate Change? PLoS ONE 7(12): e52882. doi:10.1371/journal.pone.0052882

Hall, A., Janseen, W., Pehu, E., & Rajalahti, R. (2006). Enhancing agricultural innovation: How to go beyond the strengthening of research systems. Washington, DC: World Bank.

Hailu, M. & Campbell, B. (2014). Evidence of impact: Climate-smart agriculture in Africa'. CCAFS Working Paper no. 86. Copenhagen, Denmark: CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). Available at: http://ccafs.cgiar.org/publications/evidence-impact-climate-smart-agriculture-africa

Hansen, J., Sato, M. & Ruedy, R. (2012). Perception of climate change. PNAS. 109 (37). p. 14726–14727.

Hedeker, D., Mermelstein, R. J., Weeks, K. A. (1999). The threshholds of change model: An approach to analysing stages of change data. *Annals of behavioural medicine, 21*(1), p. 61-70.

Hekkert, M. P., Suurs, R., Negro, S. O., Smits, R. E. H. M., & Kuhlmann, S. (2007). Functions of innovation systems: A new approach for analyzing technological change. Technological Forecasting and Social Change. 74(4), 413-32.

He, H. A., Greenberg, S., & Huang, E. M. (2010, April). One size does not fit all: applying the transtheoretical model to energy feedback technology design. In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, p. 927-936). ACM.

Hillman, A. J.; Withers, M. C. & Collins, B. J. (2009). Resource dependence theory: A review. *Journal of Management, 39*(6) 1401-1427.

Howard, J., Crawford, E., Kelly, V., Demeke, M., & Jeje, J. J. (2003). Promoting high-input maize technologies in Africa: the Sasakawa-Global 2000 experience in Ethiopia and Mozambique. *Food Policy. (28),* p. 335-348.

Howells, J. (2006). International and the role of intermediaries in innovation. Research Policy, 35, 715-728

Hounkonnou, D., Kossou, D., Kuyper, T. W., Leeuwis, C., Nederlof, N., Roling, N., Sakyi-Dawson, O., Traore. M., & van Huis, A. (2012). An innovation systems approach to institutional change: Smallholder development in West Africa. Agricultural Systems.

IFPRI, (2010). Policy Benchmarking and Tracking the Agricultural Policy Environment in Nigeria. Nigeria Strategy Support Programme. Report No. NSSP 005.

IPCC (2007). Climate change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M. L. Parry, O.F. Canziani, J. P. Palutikof, P. J. van der Linden and C. E. Hanson, Eds., Cambridge University Press: Cambridge, UK.

IPCC (2012). Managing the risks of extreme events and disasters to advance climate change adaptation. A special Report of Working Group I and II of the Intergovernmental Panel on Climate Change [Field, C. B, V. Barros, T. F., Stocker, D. Quin, D. J. Dokken, K. L. Ebi, M. D. Mastrandrea, K. J. Mach, G. K. Plattner, S. K. Allen, M. Tignor, and P. M. Midgley (Eds.)]. Cambridge University Press, Cambridge UK, and New York, NY, USA, 582pp.

Jiggins, J., & Röling, N. (1997). Action research in natural resource management. *Etudes et Recherches sur les Systemes Agraires et le Developpement*, 151-167.

Jiggins, J., Ison, R., Collins, K., Colvin, J., Jiggins, J., Roggero, P. P., Seddaiu, G., ... & Zanolla, C. (2011). Sustainable catchment managing in a climate changing world: new integrative modalities for connecting policy makers, scientists and other stakeholders. *Water resources management, 25*(15), 3977-3992.

Jiggins, J. (2012). Diagnostic research in support of innovation. NJAS-Wageningen Journal of Life Sciences, 60, 115-121.

Jones, G.E., & Garforth, C. (1998). The history, development and future of agricultural extension. In B. E. Swanson, R. P. Bentz & A. J. Sofranko (Eds.), Improving Agricultural Extension. A reference manual (p. 1-16). Rome: FAO

Jones, N., Datta, A. & Jones, H. (2009) Knowledge, policy and power: Six dimensions of the knowledge–development policy interface. ODI, London.

Jones, A., Breuning-Madsen, H., Brossard, M., Dampha, A., Deckers, J., Dewitte, O., & Le Roux, P. (2013). Soil atlas of Africa.

Kates, R. W., Travis, W. R., & Wilbanks, T. J. (2012). Transformational adaptation when incremental adaptations to climate change are insufficient. *Proceedings of the National Academy of Sciences*, 109(19), 7156-7161.

Keenan, T. (2000). *Theories of Development: An introduction to child development*.

Kellogg, C. (1957). *We seek; We learn*. In R. E. Burton (Ed.), Volume II, Selected readings to accompany Getting Agriculture Moving.(1st Ed). , pp. 549-564.

Keta Municipal Assembly (KMA) (2013). *Profile of Keta municipal*. Office of the Chief Economic Planning Officer of the Keta Municipal Assembly. Keta Municipal Assembly. Keta.

Klerkx, L. W. A., Hall, A., Leeuwis, C. (2009). Strengthening agricultural innovation capacity: Are innovation brokers the answer? International Journal of Agricultural Resources, Governance and Ecology, 8(5/6), 409-38.

Klerkx, L., Aarts, N., & Leeuwis, C. (2010): Adaptive management in agricultural innovation systems: The interactions between innovation networks and their environment. Agricultural Systems, 103 (2010) 390-400.

Kloek, G. C., van Lenthe, F. J., van Nierop, P. W. M., Mackenbach, J. P. (2004). Stages of Change for Fruit and Vegetable Consumption in Deprived Neighborhoods. *Health Education & Behavior, 31* (2), p. 223-241.

Kolb, D. (1984). Experiential learning: Experience as the source of learning and development.

Koutsouris, A. (2015). 'Critical'Extension: Against the Treadmill (?) "They are not going to be able to copy this", Fighting the cooperative corner and creating third spaces of cooperation in food and farming, 81.

Koutsouris, A. (2012). Facilitating Agricultural Innovation Systems: a critical realist Approach. Studies in Agricultural Economics. 114 (2012), 64-70.

Kristjanson, P., Neufeldt, H., Gassner, A., Mango, J., Kyazze, F. B., Desta, S., ... & Coe, R. (2012). Are food insecure smallholder households making changes in their farming practices? Evidence from East Africa. Food Security, 4(3), 381-397.

Kumar, R. (2011). Research methodology: A step-by-step guide for beginners. Sage publications.

Kumasi, T. C., & Asenso-Okyere, K. (2011). Responding to land degradation in the highlands of Tigray, Northern Ethiopia. International Food Policy Research Institute (IFPRI), 1142, 44.

Leeuwis, C., & Aarts, N. (2011). Rethinking communication in innovation processes: creating space for change in complex systems. Journal of Agricultural Education and Extension, 17(1), 21-36.

Leeuwis, C., & Van Den Ban (2004). Communication for rural innovation: Rethinking agricultural extension; 3rd ed., Oxford: Blackwell Science.

Lewin, K. (1946). Action research and minority problems. *Journal of Social Issues,* 2(4), 34-46.

Lincoln, Y.S. & Guba, E. G. (1985). Naturalistic inquiry. Newbury Park: Sage Publications.

Lincoln, Y.S. & Guba, E. G. (2000). Paradigmatic Controversies, Contractions and Emerging Confluences. In Norman K. Denzin an Yvonna S. Lincoln (eds). The handbook of qualitative research (second edition). p. 163-188, London: Sage.

Lobell, D. B., Cassman, K. G., & Field, C. B. (2009). Crop Yield Gaps: Their Importance, Magnitudes, and Causes. Annual Review of Environment and Resources; 34

Lu, Y., Nakicenovic, N., Visbeck, M., & Stevance, A. S. (2015). Policy: five priorities for the UN sustainable development goals-comment. Nature, 520(7548), 432-433.

Ly, C. K. (1980). The role of the Akosombo Dam on the Volta River in causing coastal erosion in central and eastern Ghana (West Africa). Marine Geology, 37(3-4) p. 323-332.

Mahanty, S., Suich, H., Tacconi, L. (2013). Access and benefits in payments for environmental services and implications for REDD+: Lessons from seven PES schemes. Land Use Policy, 31, 38-47.

Mandleni, B. & Anim, F. D. K. (2011). Climate change awareness and decision on adaptation measures by livestock farmers in South Africa. Journal of Agricultural science, 3(3), p. 258-268.

Marquardt, M., & Waddill, D. (2004). The power of learning in action learning: a conceptual analysis of how the five schools of adult learning theories are incorporated within the practice of action learning. Action Learning: Research and Practice, 1(2), 185-202.

Marshall, N. A., Dowd, A. M., Fleming, A., Gambley, C., Howden, M., Jakku, E., .. & Thorburn, P. J. (2014). Transformational capacity in Australian peanut farmers for better climate adaptation. Agronomy for sustainable development, 34(3), 583-591.

McIntosh, C. (Ed.). (2013). Cambridge advanced learner's dictionary. Cambridge University Press.

McNamara, K. E. & Westboy, R. (2011). Solastalgia and the gendered nature of climate change: An example from Erub Isa lnd, Torees Strait. EcoHealth, 8 (2), 233-236.

Mendelsohn, R.; Morrison, W.; Schlesinger, M. E. & Andronova, N. G. (2000a). Country-specific market impacts from climate change. Climate Change, 45, 553-569

Mendelsohn, R.; Dinar, A. & Dalfelt, A. (2000b) Climate change impacts on African agriculture. Preliminary analysis prepared for the World Bank, Washington, DC, 25 p. as cited in IPCC 2007.

Metzger, M. J., Rounsevell, M. D. A., Acosta-Michlik, L., Leemans, R., & Schröter, D. (2006). The vulnerability of ecosystem services to land use change. Agriculture, Ecosystems & Environment, 114(1), 69-85.

Mezirow, J. (1992). Transformation theory: Critique and confusion. Adult Education Quarterly, 42(4), 250-252.

Mezirow, J. (1994). Understanding transformation theory. Adult Education Quarterly, 44(4), 222-232.

Ministry of Agriculture (2012). A framework for development of smallholder farmers through cooperative development. Ministry of Agriculture, Forestry and Fisheries Republic of South Africa. Pretoria. Retrieved on March 3, 2016 from http://www.nda.agric.za/doaDev/sideMenu/cooperativeandenterprisedevelopment/docs/FRAMEWORK-%20OF%20SMALL%20FARMERS%20(2).pdf.

Monroe, J. T., Lofgren, I. E., Sartini, B. L., & Greene, G. W. (2014). The Green Eating Project: web-based intervention to promote environmentally conscious eating behaviours in US university students. Public Health Nutrition, 18(13), 2368-2378.

Moore, M. J. (2005). The transtheoretical model of the stages of change and the phases of transformative learning comparing two theories of transformational change. Journal of Transformative Education, 3(4), 394-415.

Moser, S. C. & Ekstrom, J. A. (2010). A framework to diagnose barriers to climate change adaptation. PNAS, 107(51), 22026–22031.

Mudege, N. (2007). An ethnography of knowledge: the production of knowledge in Mupfurudzi resettlement scheme, Zimbabwe. Brill.

Mytelka, L., & Farinelli, F. (2000). Local clusters, innovation systems and sustained competitiveness. UNU/INTECH Discussion Paper, (2005).

Nagel, U.J. (1998). “Alternative Approaches to Organizing Extension”. In Swanson, B.E., Bentz, R.P., & Sofranko, A.J., (1998). Improving Agricultural Extension: A Reference Manual. Rome: FAO.

Namara, R. E., Horowitz, L., Kolavalli, S., Kranjac-Berisavljevic, G., Dawuni, B. N., Barry, B., & Giordano, M. (2011). Typology of irrigation systems in Ghana. International Water Management Institute (IWMI) Working Paper, 142.

Nederlof, E. S., & Pyburn, R. (2012). One finger cannot lift a rock: Facilitating innovation platforms to trigger institutional change in West Africa. , Amsterdam: Royal Tropical Institute.

Niles, M. T., Lubell, M. & Brown, M. (2015). How limiting factors drive agricultural adaptation to climate change. Agriculture, Ecosystems and Environment, (200), p.178-185.

North, D. C. (1990). Institutions, institutional change and economic performance. Cambridge University Press. New York: Cambridge.

Nyirenda-Jere, T. P. R. & Kazembe, J. A. (2014). Improving Policymaking for Agricultural and Rural Developmentin Africa: The role of ICTs and Knowledge Management. IIED Working Paper. IIED, London. ISBN 978-1-78431-087-5. Retrieved 21st January 2016 from http://pubs.iied.org/14636IIED

. O´Brien, K. & Sygna, L. (2013) Responding to climate change: The three spheres of transformation. Proceedings of Transformation in a Changing Climate, 19-21 June 2013, Oslo, Norway. University of Oslo (p.16-23).

O’Brien, K. (2012). Global environmental change II From adaptation to deliberate transformation. Progress in Human Geography, 36(5), 667-676.

O’Brien, G.; Devisscher, T.; & O’Keefe, P. (2011). The adaptation continuum: Groundwork for the future. Lambert Academic Publishing, Germany. Cited in IPCC, 2012.

Ocloo C. F. (1996). *The Anlo Shallot Revolution 1930s–1992*. Norwegian University of Science and Technology, Department of History, Trondheim.

OECD Global Forum on Agriculture (2010). The economic importance of agriculture for sustainable development and poverty reduction: findings from a case study of Ghana.

Oladele, I. O. (2011) 'Knowledge Levels and Perceived Effect of Climate Change on Extension Delivery in North West Province, South Africa'. *Journal of Agricultural & Food Information, 12*(1), p. 91 -101.

Oladele, I. O. (2013). Linkage between Gown and Town: My experience in Sub-Saharan Africa and South East Asia. Inaugural lecture. North West University (Mafikeng Campus), Mmabatho, South Africa.

Osikabor, B., Oladele, I. O., & Ogunlade, I. (2011). Worth assessment of information and their access points by small scale cassava farmers in Nigeria. *South African Journal of Agricultural Extension, 39*(2), 69-78.

Ostrom, E. (1999). Coping with tragedies of the commons. Annual review of political science, 2, p.493-535.

Ostrom, E. (2010). Nested externalities and polycentric institutions: must we wait for global solutions to climate change before taking actions at other scales? Econ Theory. DOI 10.1007/s00199-010-0558-6

Owusu, K., Waylen, P., & Qiu, Y. (2008). Changing rainfall inputs in the Volta basin: Implications for water sharing in Ghana. Geojournal, 71 (2008), p. 201-210. DOI 10.1007/s10708-008-9156-6.

Owusu, K., & Waylen, P. (2013). Identification of historic shifts in daily rainfall regime, Wenchi, Ghana. Climate Change, 117 (1-2), 133-147.

Owusu-Bennoah, E., Awadzi, T. W.; Boateng, E.; Krogh, L.; Breuning-Madsen, H.; & Broggaard, O. K. (2000). Soil properties of toposequence in the moist semideciduos forest zone of Ghana. West African Journal of Applied Ecology, 1 (2000), 1-10.

Parayil, G. (1992). The green revolution in India: A case study of technological change. Technology and Culture, 33(4), 737-756.

Parris, K. (2003). Some concepts and future developments: developing agri-biodiversity indicators as a tool for policy makers. *Trace Metals and other Contaminants in the Environment*, *6*, 797-829.

Pelling M, High C, Dearing J, Smith D, 2008, "Shadow spaces for social learning: a relational

understanding of adaptive capacity to climate change within organisations" Environment and

Planning A 40 867–884

Pinkard, E., Battaglia, M., Bruce, J., Matthews, S., Callister, A. N., Hetherington, S., … & Musk, R. (2014). A history of forestry management responses to climatic variability and their current relevance for developing climate change adaptation strategies. Forestry ,88 (2), p. 155-171

Pfeffer, J., & Salancik, G. R. (1978). The external control of organizations: A resource dependence perspective. New York: Harper & Row.

Pretty, J., Gugit, I, Thompson, J. & Scoones, I. (1995). Participaratory Learning and Action: A Trailer's Guide, London: IIED.

Pretty, J. N. (1995). Participatory learning for sustainable agriculture. World Development, 23(8), p. 1247-1263.

Prochaska, J. O., DiClemente, C. C., and Norcross, J. C. (1992). In search of how people change: Applications to addictive behaviours. American Psychologist, 47(9), 1102-1113.

PROVIA (2013). PROVIA Guidance on Assessing Vulnerability, Impacts and Adaptation to Climate Change. Consultation document., United Nations Environment Programme, Nairobi, Kenya, 198 pp. Available at http://www.unep.org/provia

Pruitt, D. G., & Carnevale, P. J. (1993). Negotiation in social conflict. Thomson Brooks/Cole Publishing Co. In Leeuwis, C., & Van Den Ban (2004). Communication for rural innovation: Rethinking agricultural extension; 3rd ed., Oxford: Blackwell Science.

Purcell, D. L. & Anderson, J. R. (1997). Agricultural Extension and Research: Achievements and Problems in National Systems. Washington, D.C.: The World Bank Operations Evaluation Department.

Urgessa, T. & Amslau, B. (2014). Farmer perceptions and adaptation to climate change: Heckman's two stage sample slection model. *Ethiopian Journal of Environmental Studies & Management, 7*, 832-839.

Quarmine W., Haagsmaa, R., Sakyi-Dawson, O., Asante, F., van Huis, A., Obeng-Ofori, D. (2012). Incentives for cocoa bean production in Ghana: Does quality matter? *NJAS - Wageningen Journal of Life Sciences*. (60-63), p. 7-14.

Random House Dictionary. (2016) mechanism. (n.d.). Dictionary.com Unabridged. Retrieved February 15, 2016 from Dictionary.com website http://dictionary.reference.com/browse/mechanism

Rapoport, R. N. (1970). Three dilemmas in action research with special reference to the Tavistock experience. *Human relations,* 23(6), 499-513.

Rickards, L., & Howden, S. M. (2012). Transformational adaptation: agriculture and climate change. Crop and Pasture Science, 63(3), 240-250.

Rivera, W. & Alex, G. (eds) (2004): Decentralised systems: Case studies of international initiatives. (Paper 8) Washington DC: The World Bank

Rivera, W. M., Qamar K.M. & Crowder L.V. (2001). Agricultural and rural extension worldwide: Options for institutional reforms in developing countries. Rome: FAO of the UN.

Rodriguez, D., Cox, H., & Power, B. (2014). A participatory whole farm modelling approach to understand impacts and increase preparedness to climate change in Australia. *Agricultural Systems*, 126, 50-61.

Rogers, E. (1995). Diffusion of Innovations. 4th edition. New York: Free Press.

Rogers, E. (2003). Diffusion of Innovations. 5th edition. New York: Free Press.

Röling, N. G. (1997). The soft side of land: Socio-economic sustainability of land use systems. ITC Journal, 3(4), p. 248-262.

Röling, N. G. (1992): The emergence of knowledge systems thinking: A changing configuration. *Knowledge and Policy: The International Journal of Knowledge Transfer and Utilisation, 5*, 42-64.

Rosenbloom, D. (2017). Pathways: An emerging concept for the theory and governance of low-carbon transitions. *Global Environmental Change*, 43, 37–50.

Rosenzweig et al. (2007). Rosenzweig, C., Casassa, G., Karoly, D. J., Imeson, A., Liu, C., Menzel, A., & Hanson, C. E. (2007). Assessment of observed changes and responses in natural and managed systems. *Climate change*, 79-131.

Ruttan, V. W. (2002). Productivity growth in world agriculture: sources and constraints. The Journal of Economic Perspectives, 16(4), 161-184.

Sanderson, T., Hertzler, G., Capon, T., & Hayman, P. (2015). A real options analysis of Australian wheat production under climate change. *Australian Journal of Agricultural and Resource Economics*.(Article in press).

Sanderson, T., Hertzler, G., Capon, T., & Hayman, P. (2015). A real options analysis of Australian wheat production under climate change. Australian Journal of Agricultural and Resource Economics. (Article in press)

Schein, E. H. (1983). The Role of the Founder in the Creation of Organizational Culture (no. Tr-12-onr). Alfred P. Sloan School of Management. Cambridge, MA.

Schein, E. H. (1987). Process Consultation. Vol. 2. Reading, MA.: Addison.

Semenza, J. C., Hall, D. E., Wilson, D. J., Bontempo, B. D., Sailor, D. J. & George, L. A. (2008). Public Perception of Climate Change: Voluntary Mitigation and Barriers to Behavior Change. *American Journal of Preventive Medicine, 35*(5), p. 479-489.

Scoones, I. & Thompson, J. (1994). Knowledge, Power and Agriculture- Towards a Theoretical Understanding. In Scoones, I and Thompson, J. (Eds). Beyond Farmer First: Rural People's Knowledge, Agricultural Research and Extension Practice. London: International Public Actions.

Scoones, I. (1998). Sustainable rural livelihoods: a framework for analysis.

Scoones, I., Thompson, J., & Chambers, R. (2008). Farmer First Revisited: Innovation for Agricultural Research and Development, Workshop summary report. April, 2008.

Seini, W., Musah, A. B., & Bonsu, O. A. Y. (2014). Market participation of smallholder maize farmers in the upper west region of Ghana. *African Journal of Agricultural Research*, *9*(31), 2427-2435.

Silverman, D. (2011) Interpreting qualitative data. (4th ed.). SAGE Publications Ltd. London, U. K.

Smelser, N. J., & Swedberg, R. (2005). 1 Introducing Economic Sociology. The handbook of economic sociology, 1.

Smith & Wollenberg, (2012). In Wollenberg, E.; Nihart, A.; Tapio-Bistrom, M.; & Grieg-Gran, M. (Eds). *Climate Change mitigation and agriculture.* Earthscan. London.

Spence, A., Poortinga, W., Butler, C. & Pidgeon, N. F. (2011). Perceptions of climate change and willingness to save energy related to flood experience. *Nature Climate Change, 1*(April), 46-49.

Stafford-Smith, M., Gaffney, O., Brito, L., Ostrom, E., & Seitzinger, S. (2012). Interconnected risks and solutions for a planet under pressure—overview and introduction. *Current Opinion in Environmental Sustainability, 4*(1), 3-6.

Stanturf, J. A. (2015). Future landscapes: opportunities and challenges. *New Forests*, 46(5-6), 615-644.

Stern, N. (2006). What is the economics of climate change? *World Economics. 7*(2).

Stige, L. C., Stave, J., Chan, K. S., Ciannelli, L., Pettorelli, N., Glantz, M., ... & Stenseth, N. C. (2006). The effect of climate variation on agro-pastoral production in Africa. *Proceedings of the National Academy of Sciences of the United States of America*, *103(*9), 3049-3053. (cited in 1PCC 2007 page 439).

Sumberg, J., & Sabates-Wheeler, R. (2011). Linking agricultural development to school feeding in sub-Saharan Africa: Theoretical perspectives. *Food Policy, 36*(3), 341-349.

Swanson, B. E., (1998). Improving agricultural extension: A reference manual. FAO. Rome.

Tachie-Obeng, E., Akponikpe, P. B. I., & Adiku, S. (2013). Considering effective adaptation options to impacts of climate change for maize production in Ghana. *Environmental Development*, 5(1), p. 131-145.

Swanson, M. D., Kobayashi, M., & Tewfik, A. H. (1998). Multimedia data-embedding and watermarking technologies. *Proceedings of the IEEE, 86*(6), 1064-1087.

Tanner, T., & Mitchell, T. (2008) Entrenchment or enhancement: could climate change adaptation help to reduce chronic poverty*? IDS Bulletin 39*(4), 6-15.

Tjernstrom, E. & Tietenberg, T. (2008). Do differences in attitudes explain differences in national climate change policies? *Ecological Economics, 65*(2), p. 315–324.

Tschakert, P., & Dietrich, K. A. (2010). Anticipatory learning for climate change adaptation and resilience. *Ecology and society, 15*(2), 11.

United Nations Environment Programme (UNEP), (2014). Keeping Track of Adaptation Actions in Africa. Targeted Fiscal Stimulus Actions Making a Difference. Nairobi: UNEP. ISBN: 978-92-807-3377-8

Uphoff, N. T., Cohen, J. M., & Goldsmith, A. A. (1979). Feasibility and application of rural development participation: a state-of-the-art paper.

Uphoff, N., Kassam, A., & Harwood, R. (2011). SRI as a methodology for raising crop and water productivity: Productive adaptations in rice agronomy and irrigation water management. *Paddy and Water Environment*, *9*(1), 3-11.

Van de Ven, A. H. (2007). Engaged scholarship: a guide for organizational and social research: a guide for organizational and social research. OUP Oxford.

van Latesteijn, H. C., & Andeweg, K. (2011). The need for a new agro innovation system. In The TransForum Model: Transforming agro innovation toward sustainable development (p. 1-19). Springer, Netherlands.

Vellema, S. (2012). Action research and institutional change. In Nederlof, E. S., & Pyburn, R. (Eds). One finger cannot lift a rock: Facilitating innovation platforms to trigger institutional change in West Africa. (p. 121-123). Royal Tropical Institute, Amsterdam.

Wals, A. E., J. & van der Leij, T. (2007). In Social learning towards a sustainable world : principles, perspectives, and praxis. Ed.Wals, A. E. J. , Wageningen Academic Publishers.

Ward, A., Minja, E., Blackie, M., Edwards-Jones, G. (2007). Beyond participation – building farmer confidence: Experience from Sub-Saharan Africa. *Outlook on Agriculture*, *36*(4), p. 259–266.

Wise, R.M., Fazey, I., Stafford Smith, M., Park, S.E. & Eakin, H.C. (2014). Reconceptualising adaptation to climate change as part of pathways of change and response. *Global Environmental Change*, *28*, 325–336.

Wollenberg, E.; Nihart, A.; Tapio-Bistrom, M.; & Grieg-Gran, M. (2012). Climate Change mitigation and agriculture. Earthscan. London.

Wood, S. A., Jins, A. S.., Jain, M., Kristjanson, P., & DeFries, R. S. (2014). Smallholder farmer cropping decisions related to climate variability across multiple regions. *Global Environmental Change* (25), p. 163-172.

Woodhill, J. (2002). Sustainability, social learning and the democratic imperative. Lessons from Australian Landcare movement. In Leeuwis, C., Pyburn, R. (Eds.), Wheelbarrows full of frogs: Social learning in rural resource management. Koninklijke Va Gorcum, The Netherlands, pp. 317-331.

World Bank (2005): Successes in Africa’s Horticulture: Opportunities and Challenges. Agricultural Trade Facilitation Study. ESSD Africa, ESW Report

World Bank Group (Ed.). (2012). World Development Indicators 2012. World Bank Publications.

Xie, H., McHugo, G., Sengupta, A., Hedeker, D. & Drak, R. (2001). An Application of the Thresholds of Change Model to the Analysis of Mental Health Data. *Mental Health Services Research, 3(*2), p. 107-114.

Yaro, J. A. (2013). The perception of and adaptation to climate variability/ change in Ghana by smallscale and commercial farmers. *Regional Environmental Change. 6*, 1258-1272.

Yegbemey, R. N., Yabi, J. A., Tovignan, S. D., Gantoli, G., Haroll Kokoye, S. E. (2013). Farmers' decisions to adapt to climate change under various property rights: A case study of maize farming in northern Benin (West Africa). *Land Use Policy*, *34*, 168-175.

Yin, R. K. (2003): *Case study research: design and methods* (3rd ed) Thousand Oaks, CA: Sage.

Yumkella, K. K., Kormawa, P. M., Roepstorff, T. M., Hawkins, A. M. (2011). *Agribusiness for Africa's prosperity.* United Nations Development Organization (UNIDO). Austria.

APPENDIX

APPENDIX I - LIST OF DEFINITIONS

Actor: A person or organization involved in a value chain or sector, with influence or interest in that chain or sector.

Adaptation: Adjustment in natural or human systems in response to actual or expected climate stimuli or effects, which moderates harm or exploits beneficial opportunities. Various types of adaptation exist including: anticipatory, autonomous, and planned adaptation.

Anticipatory adaptation: Adaptation that takes place before impacts of climate change are observed also referred to as proactive adaptation.

Autonomous Adaptation: Adaptation that does not constitute a conscious response to climatic stimuli but is triggered by ecological changes in natural human systems, also referred to as spontaneous adaptation.

Aggregate Impacts: Total impacts integrated across sectors and/ or regions. The aggregation of impacts requires knowledge of (or assumptions about) the relative importance of impacts in different sectors and regions. Measures of aggregate impacts, for example the total number of people affected, or the total economic costs.

Anthropogenic: Resulting from or produced by human beings.

Aquifer: A stratum of permeable rock that bears water. An unconfined acquifer is recharged directly by local rainfall, rivers and lakes, and the rate of recharge will be influenced by the permeability of the overlying rocks and soils.

Arid region: Aland region of low rainfall, where ‘low’ is widely accepted to be <250mm precipitation per year.

Climate: the average weather condition reflecting mean variability of surface weather parameters such as temperature, precipitation, and wind ranging from a period of months to thousands or millions of years. However, it is typically averaged over 30 years.

Facilitator: The person who manages the process of bringing people together as a group and communicating within the group.

Innovation: The use of a new idea or method (Cambridge Dictionary, 2013).

Innovation: Change within a sector, value chain or other domain. It includes a mix of technical, institutional and organizational elements.

Innovation platform: A group of stakeholders that comes together from different levels of society for the purpose of bringing about innovation towards a common concern.

Institution: Rules and regulations, behaviour, formal and informal.

Institutional constraints: The formal and informal rules and regulations and other important cultural, behavioural, and habitual factors that hamper the functioning of a sector or value chain.

Livelihood: The means by which people earn a living.

Stakeholders: People who have a vested interest or stake in the outcome or wellbeing of a particular subject or activity.

Value chain: involves the sequence of production, processing, marketing and distribution of a product, from the producer to the consumer.

APPENDIX II - QUESTIONNAIRE

UNIVERSITY OF GHANA

COLLEGE OF AGRICULTURE AND CONSUMER SCIENCES
DEPARTMENT OF AGRICULTURAL EXTENSION

Questionnaire # _______ Enumerator's name ____

EXPLORATORY STUDY - FARMER PERCEPTIONS OF CLIMATE CHANGE ADAPTATION IN GHANA

According to the intergovernmental panel on climate change (IPCC), by 2020, agricultural production, access to food, size of cropping areas, and yields could decline by as much as 50% in many countries across Africa due to climate variability and change. Millions of African smallholder farmers remain vulnerable to climate induced stresses due to low adaptive capacity. The purpose of this study is to explore opportunities and constraints for enabling innovation among smallholder farmers against the impacts of climate change such as changing rainfall patterns, increasing mean temperature and increase in the incidence of droughts and floods which directly affect agricultural production.

GENERAL AND GEOGRAPHIC INFORMATION

Date of survey (DD/MM/YY)		Location (Town, District)	
Start time: AM/ PM		End time: AM/PM	

SECTION A: FARMER PERSONAL DETAILS

A. Name of respondent (OPTIONAL): ____

A.1. Sex: Male _____ Female _________
A.2. Age: ________
A.3. Current town of residence_________ Native hometown (town, district)________
A.4. Primary occupation (Please tick all that apply):
A.4.1. Farmer ____ Lagoon Fisherman ___ Marine Fisherman___ Other ___

A.5. What other income generating activities do you engage in? (Please tick all that apply)
A.5.1. Trading __ Input dealer _ Irrigation parts__ Electrical parts ___
A.5.2. Food processor__ Restaurant owner__ Buyer/Middleman____

A.5.3. Porter___ Transport ____ Shipping ___ Export ___
A.5.4. Government /worker___ Construction____ Carpenter____
A.5.5. Micro-finance _______________
A.5.6. Salt mining ___ Sand winning_____ Other __________________

A.6. Marital status:
A.6.1. Single, never married _____
A.6.2. Married _____ No. of wives______
A.6.3. Not married, separated, divorced_____ widowed _____ other____

A.7. No. of people in household _____. No. Adults____ No. Children ____

A.8. Are you any of the following? Please answer Y/N___.
A.8.1. Head of household _____
A.8.2. Youth _____
A.8.3. Farmer group "Agblede Habobor" member____ Name of group_______ ___
A.8.4. Farmer group leader __ Religious leader__ Assembly member____
A.8.5. Chief ___
A.8.6. Elder/ traditional council___ Opinion leader__
A.8.7. Other role/responsibility_______________________

A.9. Highest level of education completed: (Please select only one)
A.9.1. None, no formal education _____
A.9.2. Primary level _____ Junior secondary level ___ Senior secondary____
A.9.3. Vocational___ Training college ___Poly___ Graduate/post-graduate____

SECTION B: DETAILS OF FARMING ACTIVITIES

B. How many years have you been farming including your days as a youngster? ____

B.1. When did you start farming as a business? _____

B.2. How many farms do you have? ___

B.3. Where are your farms located? Uplands __ Lagoon__ Depressions __ Outside Keta___?

B.4. How do you measure the size of your farm? No. beds___ Plot(Old 100x100)___ Plot (New 75x75)___ Acres___

B.5. What is the average size of a bed on your farm? ____________x_____________ feet

B.6. What size is each farm (**No. beds/plots**) Please indicate if in Uplands (U) Lagoon-side (L), Depressions (D) or Other location outside Keta municipality (O)?

Farm 1_________Farm 2_________ Farm 3 ________ Farm 4 _________ Farm 5________

What year did you acquire each farm?

Farm 1_________Farm 2_________ Farm 3 ________ Farm 4 _________ Farm 5_________

B.7. How did you get the land or farm plots? (Y/N) Please tick all that apply.

B.7.1. Inherited/ family owned____

B.7.2. Marriage ____

B.7.3. Purchased ____

B.7.4. Permission from Clan ____ Chiefs ___ Assembly____ Pledge/"Worba"_____

B.7.5. Leased/rented ___ If rented how much do you pay **per bed/plot a year** GHC___

B.7.6. Share-cropping /"Dame"___ "Fiabui"____

B.7.7. Farming without permission/squatting _____Other ____

B.8. What was the nature of your contract for the land? Verbal ____ Written ___ Other ___

B.9. Have you ever had land litigation? Y/N____

B.9.1. If yes, is it solved? Y/N____

B.9.2. How was it solved? Family___ Clan elders___ Chiefs____ Court____

B.9.3. How many times have you had land litigation as a farmer? ____

B.10. In case of litigation what is the procedure and who is in charge to get it resolved?

B.11. What is your source of labour? Wife/Husband_ Children_ Hired__ Migrant_

B.12. At what time do you go to the farm in the morning?______ AM, and leave____

B.13. At what time do you go to the farm in the afternoon?_____ PM, and leave____

B.14. **No. of** shallow-lined wells ____ **and No. of** tube wells____ are on your farms?

B.15. Which type of well do you use currently? Shallow-lined __ tube wells__ both__

B.16. **Which year** did you **first** construct a: shallow-lined well ____ Tube well _____?

B.17. **Which year** did you **last** construct a: shallow-lined well ____ Tube well _____?

B.18. **How many deep** is your well? Shallow well _____Ft. Tube-well___ pipes.

B.19. **How long** is one well expected to last? Shallow-lined____ tube well ____ years?

B.20. Please list all the years and no. of shallow wells constructed:
Year_____No.___; Year_____ No.____; Year ____ No._____; Year____, No._____

B.21. Please list all the years and no. of tubewells constructed: Year_____No.___; Year_____ No.____; Year ____ No._____; Year____, No._____

B.22. **How much** will it cost to construct a Shallow well now____ a tube well____GHC

B.23. Parts for constructing tube well are bought? Locally__ Accra___ Aflao__ Other__

B.24. **How many times** do you replace parts of the tube well system **per year? ___**

B.24.1. Sprinkler____ Cost___ each; Valve socket___ Cost____ each; Other_________

B.25. **How many times in a day** do you turn on the sprinkler ___ for how long? ___hrs

B.26. Who operates the pump or valves on a routine/daily basis? Self__ Workers____

B.27. **How** did you learn about or acquire skills to operate the pump?

B.27.1. A friend/Relative___ Extension agent __ Farmer group __ Irrigation specialist__ Plumber___ Experimentation/trial___ Observation ___ Other ____

B.28. **How long** is wait for well to recharge **after use?** Shallow well___ Tube well___

Shallot Production:

B.29. Are you a shallot farmer? (Y/N)_____ (If Yes continue if No move to Vegetable)

B.30. For shallot production, do you purchase seeds?_____ or save seeds______?

B.31. If purchased, how much did you pay for the seeds last season GHC_____

B.32. Are labour costs for shallot production higher than for other vegetables? Y/N___

B.33. Farm labour is increasing difficult to find. Please indicate how difficult:

1= Very easy to find; **2**=Easy; **3**=Neutral; **4**= Difficult **5**=Very Difficult to find. Cost of.

B.33.1. Cutting shallot seeds for planting is increasing(Y/N)__(1),(2),(3),(4),(5) GHC__
B.33.2. Planting is increasing? (Y/N)____ (1), (2), (3), (4), (5) GHC____
B.33.3. Watering? (Y/N)____ (1), (2), (3), (4), (5) GHC____
B.33.4. Weeding? (Y/N)____ (1), (2), (3), (4), (5) GHC____
B.33.5. Hoeing? (Y/N)____ (1), (2), (3), (4), (5) GHC____
B.33.6. Spraying? (Y/N)____ (1), (2), (3), (4), (5) GHC____
B.33.7. Harvesting? (Y/N)____ (1), (2), (3), (4), (5) GHC____

B.33.8. Carting home? (Y/N)____ (1), (2), (3), (4), (5) GHC____
B.33.9. Carting to market? (Y/N)___ (1), (2), (3), (4), (5) GHC____
B.33.10. Storage? (Y/N)____ (1), (2), (3), (4), (5) GHC____
B.33.11. Other activities?____

B.34. What was your best year for shallot production based on highest yield? ____
B.35. How many rafters in a room did you use as storage for shallots that year?_____
B.36. How many rafters in a room did you use as storage for shallots last season?____
B.37. Are you using other forms of storage? Y/N___
List:______________________
B.38. Which is your best location for shallot production? U, L, D, O_________
B.39. How long does shallot last after harvesting before rotting? White__ Red__months
B.40. Are you thinking about stopping shallot production? Y/N____ Why? _________

Vegetable production:

B.41. How many rafters in a room are you using as storage space for vegetables? _____
B.42. Are you using other forms of storage? Y/N___
List:_______________________
B.43. Which is your best location for vegetable production? U, L, D, O__________
B.44. How long do tomatoes last after harvesting before rotting? Local__ Hybrid__days
B.45. Are you thinking about stopping vegetable production? Y/N____ Why? _________

All crops:

B.46. **How many beds/plots** does a bag of cow manure cover per season? ___Cost?___
B.47. How many beds/plots does a bag of **poultry** manure cover per season? ___Cost?_
B.48. When was the last year you used **bat** droppings? _____ Anchovies Borbi"?_____
B.49. How many beds/plots does a bag of bat droppings cover? ____Cost? ___

B.50. What is the **yield/ No. of bags per bed/plot** of crops per season?

Crop	Seed cost per pack	Yield per...	Season1 Major Rainy	Season2 Minor Rainy	Season 3 Dry	No. of beds/ plots	Rank by importance to farmer income
Tomatoes		Crate					
Pepper		Bucket					
Shallots		Bundle					
Onions		Sack					
Spring Onions		Sack					
Okro		Basket					
Butternut		Weight					
Watermelon		Sack					
Carrot		Sack					
Okra		Basket					
Lettuce		Sack					
Maize		Sack					
Cassava		Sack					
Other							

1= Every year; **2**=often; **3**=Neutral/sometimes; **4**= Rarely/occasionally **5**=Not at all

B.51. Are farm residues/compost used to enrich the soil? (1), (2), (3), (4), (5)

B.52. Are you incorporating legumes to enrich the soil? (1), (2), (3), (4), (5)

B.53. What **type** of fertilizer do you use in your farming?

B.53.1. NPK ___ Cost per bag _____Ammonia ___Cost ____Urea _________Cost ____

B.53.2. Cost per bag: Evergreen ______ Green Ok ______ Other____________

B.54. **How many beds/plots** will one bag fertilizer **(50Kg)** cover **per season**?

B.54.1. Tomatoes ___ chilli pepper ___ shallots ___ onions ___ spring onions___ okro __

B.54.2. Butternut squash ___Water/Melon ___ Carrots_____Okra _____ Lettuce _____

B.54.3. Maize _____ Cassava _______ Other crops___

B.55. **How many beds/plots** will a large bottle (1 Litre) weedicide/pesticide cover? __

B.56. What is the **total quantity** (No. 1 L bottles or 1 Kg Bags) of inputs you use on all your farms **per season**?

B.56.1. Total weedkiller _________bottles. GHC _______each. Total GHC_______
B.56.2. Pre emergence weedicides ________bottles. GHC _______each. Total GHC___
B.56.3. Post emergence weedicides _______bottles. GHC _______each. Total GHC___
B.56.4. Pesticides (No. 1 L bottles)______ GHC _______each. Total GHC___
B.56.5. Fungicides (No. 1 Kg bags)______ GHC _______each. Total GHC___
B.56.6. Folia fertilizer (No. 1 L bottles)______ GHC _______each. Total GHC___
B.56.7. Nim extract (No. 1 L bottles)______ GHC _______each. Total GHC___
B.56.8. Other _____(No. 1 L bottles)______ GHC _______each. Total GHC___

B.57. Where do you get information about chemicals to use for your farming?
B.57.1. A friend ____ Relative ______ Extension agent ____ Farmer group ______
B.57.2. Radio ___ TV____ Input dealer _____ Newspaper____ Pamphlets ______
B.57.3. Own experience ____ Experimentation/trial___ Observation ___ Other ____
B.58. How many times do you receive advice from the MoFA office in a year? ___
B.59. How many times in a year do you have discussions with researchers from universities and technical institutions? _____
B.60. How many times in a year do you have discussions with NGOs? _____
B.61. How satisfied are you with public authorities such as the government, municipal assembly, community level authorities with their influence over farming matters?

1= Very satisfied; **2**=Satisfied; **3**=Neutral; **4**= Not satisfied **5**=Very dissatisfied with them:

B.61.1. Collection and use of taxes? (1), (2), (3), (4), (5)
B.61.2. How they ensure fairness among community members (1), (2), (3), (4), (5)
B.61.3. Actions taken about complaints, tariffs, utility charges, etc. (1), (2), (3), (4), (5)
B.61.4. Establishing appropriate laws and guidelines (1), (2), (3), (4), (5)
B.61.5. Creation of awareness and provision of information (1), (2), (3), (4), (5)
B.61.6. Other?___________________________________

B.62. State how satisfied you are with the following:

1= Very satisfied; **2**=Satisfied; **3**=Neutral; **4**= Not satisfied **5**=Very dissatisfied with that:

B.62.1. Use of chemicals really increases yield per bed/plot (1), (2), (3), (4), (5)
B.62.2. Agro-chemicals are harmful to human health (1), (2), (3), (4), (5)
B.62.3. Benefits of using chemicals out-weigh the risks (1), (2), (3), (4), (5)
B.62.4. Chemicals make crops attractive to buyers (1), (2), (3), (4), (5)
B.62.5. Reduce loses in farming (1), (2), (3), (4), (5)
B.62.6. Increase rate of spoilage after harvesting (1), (2), (3), (4), (5)
B.62.7. Reduce soil fertility and number of organisms in soil(1), (2), (3), (4), (5)
B.62.8. Will you stop using chemicals in the near future? Y/N__(1), (2), (3), (4), (5)
B.62.9. Do you plan to use chemicals for a long time? Y/N___(1), (2), (3), (4), (5)
B.62.10. Do you follow instructions strictly per chemical? Y/N_(1), (2), (3), (4), (5)
B.62.11. Does chemical use affect rainfall pattern? Y/N___(1), (2), (3), (4), (5)
B.62.12. Your own ability to manage the changes? (1), (2), (3), (4), (5)

B.63. What is your source of funding for investing into your farm per season?

B.63.1. Personal savings? (Y/N)___ Loan from relatives? (Y/N) _____
B.63.2. Bank loan? (Y/N)____ Microfinance? (Y/N)____ Susu? (Y/N)_____
B.63.3. Government? (Y/N)____ NGO? (Y/N)_____
B.63.4. Fishing? (Y/N)____ Other source_________________________________

C. PERCEPTIONS OF CLIMATE VARIABILITY AND CHANGE

C.1. Have you heard about climate change? (Y/N) ____

C.2. Do you believe that the climate is changing? (Y/N) ___ Improving?___ Worsening?___

1= seriously reduced; **2**=reduced; **3**=neutral; **4**=increased **5**= seriously increased

C.2.1. There is a change in rainfall pattern and amount? (1), (2), (3), (4) (5)
C.2.2. Change in air and water temperature (1), (2), (3), (4) (5)
C.2.3. Duration of drought (1), (2), (3), (4) (5)
C.2.4. Frequency of flooding (1), (2), (3), (4) (5)
C.2.5. Scale/intensity of flooding (1), (2), (3), (4) (5)
C.2.6. Incidence of pests (1), (2), (3), (4) (5)
C.2.7. Crop damage/failure (1), (2), (3), (4) (5)
C.2.8. Size or intensity of tidal waves? (1), (2), (3), (4) (5)
C.2.9. Total catch and ‘catchability’ of marine fish (1), (2), (3), (4) (5)
C.2.10. Total catch and ‘catchability’ of lagoon fish (1), (2), (3), (4) (5)
C.2.11. Variety of catch or composition? (1), (2), (3), (4) (5)
C.2.12. Fish aggregation, spawning and breeding pattern? (1), (2), (3), (4) (5)

C.2.13. Other _______ (1), (2), (3), (4) (5)

C.3. Have you been experiencing these impacts for a long time? (Select only one)
- C.3.1. Recently, Less than 5 years ____
- C.3.2. For about 10 years ____ 15 years ______20 years _____More than 20 years_____
- C.3.3. More than 30 years _____ Not sure how long _____

C.4. Can you remember a year in the past twenty years in which extreme weather/crop loss was particularly severe? (Y/N) ___Which Year ____

C.5. How do you remember this so distinctly? ______________ What happened? ____________________

C.6. Please indicate severity of impact of weather on the following? Scale of 1 to 5. **1**=Severely affected by weather; **2**=Somehow affected by weather; **3**=Equally affected by weather and other factors; **4**=Not affected by weather **5**= Affected by other factors.
- C.6.1. Food prices (1), (2), (3), (4) (5)
- C.6.2. Employment (1), (2), (3), (4) (5)
- C.6.3. Access and availability of food (1), (2), (3), (4) (5)
- C.6.4. Access to fresh water (1), (2), (3), (4) (5)
- C.6.5. Migration (1), (2), (3), (4) (5)
- C.6.6. Health (1), (2), (3), (4) (5)
- C.6.7. Litigation over land (1), (2), (3), (4) (5)
- C.6.8. Change in forests, grasses/ medicinal plants (1), (2), (3), (4) (5)
- C.6.9. Increase in pests, mosquitoes (1), (2), (3), (4) (5)
- C.6.10. Decrease in number of sea turtles fish stock (1), (2), (3), (4) (5)
- C.6.11. Decrease in frogs/alligators/snakes/reptiles (1), (2), (3), (4) (5)
- C.6.12. Change in crabs/ oysters/ shrimps (1), (2), (3), (4) (5)
- C.6.13. Change in birds/ sea gulls (1), (2), (3), (4) (5)
- C.6.14. Other? ___________________

C.7. What do you think is the cause of the change in weather?
1=Strongly Agree; **2**=Agree; **3**=Neutral; **4**=Disagree **5**= Strongly Disagree
- C.7.1. Changes in culture (1), (2), (3), (4) (5)
- C.7.2. Natural/ supernatural forces (1), (2), (3), (4) (5)
- C.7.3. Bush burning/grazing of livestock (1), (2), (3), (4) (5)
- C.7.4. Agricultural land use and practices (1), (2), (3), (4) (5)
- C.7.5. Deforestation of forests and mangroves (1), (2), (3), (4) (5)
- C.7.6. Salt mining (1), (2), (3), (4) (5)

C.7.7. Sand winning (1), (2), (3), (4) (5)
C.7.8. Dams (1), (2), (3), (4) (5)
C.7.9. Building of settlements and infrastructure (1), (2), (3), (4) (5)
C.7.10. Other______________

C.8. Have you **changed farming practices** due to the change in weather?
1=Strongly Agree; **2**=Agree; **3**=Neutral; **4**=Disagree **5**= Strongly Disagree
C.8.1. Have you changed slash and burn due to the weather? (1), (2), (3), (4) (5)
C.8.2. Are you mulching due to the weather (1), (2), (3), (4) (5)
C.8.3. Are you intercropping (1), (2), (3), (4) (5)
C.8.4. Using tube well irrigation (1), (2), (3), (4) (5)
C.8.5. Integrated or mixed livestock and crop farming (1), (2), (3), (4) (5)
C.8.6. Agro-forestry or mixed tree crops with food crops (1), (2), (3), (4) (5)
C.8.7. Crop insurance (1), (2), (3), (4) (5)
C.8.8. Using hybrid varieties (1), (2), (3), (4) (5)
C.8.9. Carting of soil from one area to another (1), (2), (3), (4) (5)
C.8.10. Expansion of farms to new lands (1), (2), (3), (4) (5)
C.8.11. Using same land, more chemical inputs (1), (2), (3), (4) (5)
C.8.12. Weather forecasting (1), (2), (3), (4) (5)
C.8.13. Change in planting dates (1), (2), (3), (4) (5)
C.8.14. No change in practice (Y/N) _____ Other (Y/N) _____(1), (2), (3), (4) (5)

C.9. List the crops you grow in the past 5 years to withstand droughts?

Crop 1 ____________ Crop 2 ______________
Other___________________________________

C.10. List the crops you grow in the past 5 years to withstand floods?

Crop 1 _______________ Crop 2 _____________ Other ______________________________

C.11. **Has agricultural production** changed in the **past twenty years?**
1=Severely changed; **2**=Somehow changed; **3**=Same; **4**=Not changed **5**= Not at all changed. __**Due to?**
C.11.1. Drought/Floods? (Y/N) ______ (1), (2), (3), (4) (5)
C.11.2. Access to extension services? (Y/N) ______ (1), (2), (3), (4) (5)
C.11.3. Machinery and equipment? (Y/N) ______ (1), (2), (3), (4) (5)
C.11.4. Access to markets? (Y/N) ______ (1), (2), (3), (4) (5)
C.11.5. Access to infrastructure, roads? (Y/N) ______ (1), (2), (3), (4) (5)

C.11.6. Income from agriculture? (Y/N) ______ (1), (2), (3), (4) (5)
C.11.7. Access to fertile land? (Y/N) ______ (1), (2), (3), (4) (5)
C.11.8. Labour shortage? (Y/N) ______ (1), (2), (3), (4) (5)
C.11.9. Global economy, oil prices etc? (Y/N) ______ (1), (2), (3), (4) (5)
C.11.10. National economic policies? (Y/N) ______ (1), (2), (3), (4) (5)
C.11.11. Access to credit? (Y/N) ______ (1), (2), (3), (4) (5)
C.11.12. Access to inputs? (Y/N) ______ (1), (2), (3), (4) (5)
C.11.13. Farmer knowledge and technical skills? (Y/N) ______ (1), (2), (3), (4) (5)
C.11.14. More job opportunities? (Y/N) ______ (1), (2), (3), (4) (5)
C.11.15. Modernization and lifestyle changes? (Y/N) ______ (1), (2), (3), (4) (5)
C.11.16. Other ______________________

C.12. What helps you predict the start of rains in a planting season?

D. **1**=Strongly Agree; **2**=Agree; **3**=Neutral; **4**=Disagree **5**= Strongly Disagree

D.1.1. Past experience (Y/N) _____(1), (2), (3), (4) (5)
D.1.2. Fellow farmer (Y/N) _____(1), (2), (3), (4) (5)
D.1.3. MoFA office/ Extension agent (Y/N) ______(1), (2), (3), (4) (5)
D.1.4. Radio/TV/Newspaper weather forecast (Y/N) _____(1), (2), (3), (4) (5)
D.1.5. Personal records showing start of the raining season (Y/N) ___(1), (2), (3), (4) (5)
D.1.6. Count of number of dry days (Y/N) _____(1), (2), (3), (4) (5)
D.1.7. White-faced whistling duck – Mavividetsi (Y/N) ___(1), (2), (3), (4) (5)
D.1.8. Flowering grass along the beaches (Y/N) ___(1), (2), (3), (4) (5)
D.1.9. Flowering of trees (Y/N) ___(1), (2), (3), (4) (5)
D.1.10.SMS message on my mobile phone (Y/N) _____(1), (2), (3), (4) (5)
D.1.11.Input dealer (Y/N) ____(1), (2), (3), (4) (5)
D.1.12.Other means of predicting ________________________

D.2. Which of the sources above is most reliable in helping you predict the start of rains in the planting season?_______

D.3. Do you use weather forecast information from the meteorological department in your planning for the season? (Y/N) _____ Source/Station__________
Why?

D.3.1. Availability / Access/ Medium of dissemination (Y/N) _____ (1), (2), (3), (4) (5)
D.3.2. Reliability (Y/N) ______ (1), (2), (3), (4) (5)
D.3.3. Frequency/ Timing of message (Y/N) ______ (1), (2), (3), (4) (5)
D.3.4. Clarity of forecast (Y/N) __ (1), (2), (3), (4) (5)
D.3.5. Other ____________

D.4. Do you think prediction of changes in weather can be improved? (Y/N) __

D.4.1. More education (Y/N) _______ (1), (2), (3), (4) (5)

D.4.2. Better indicators, technology & measurement (Y/N) _ (1), (2), (3), (4) (5)

D.4.3. Not sure (Y/N)_____Can not be improved (Y/N)___

D.5. Do you think people are becoming aware or concerned about climate change in:

D.5.1. Internationally? (Y/N) _______ (1), (2), (3), (4) (5)

D.5.2. The Keta municipal area or Ghana? (Y/N) _______ (1), (2), (3), (4) (5)

D.5.3. The Anloga area specifically? (Y/N) _______ (1), (2), (3), (4) (5)

D.6. How do you determine that people are becoming more aware or concerned?

D.6.1. TV/Radio public education on climate change? (Y/N)__ (1), (2), (3), (4) (5)

D.6.2. Interventions/policies by government/NGOs? (Y/N) _______ (1), (2), (3), (4) (5)

D.6.3. Use of juju and superstition in farming? (Y/N) _______ (1), (2), (3), (4) (5)

D.6.4. Changes in certain practices that cause change? (Y/N) ___ (1), (2), (3), (4) (5)

D.6.5. List examples of practices that are changing__________________________

***********PLEASE PAUSE FOR A SHORT BREAK BEFORE YOU CONTINUE********

SECTION D: CLIMATE VULNERABILITY AND FOOD SECURITY

E. What percentage of food comes from your own farms versus those purchased? _______

E.1. Does your household have enough food items from your farms to last throughout the year? (1), (2), (3), (4) (5)

E.2. Does your household grow certain crops just for food? (1), (2), (3), (4) (5)

E.3. Who is responsible for growing household food? All __ ; Men__; Women__; Youth___

E.4. Please indicate crops grown for food and no. of beds devoted to household per season:

E.4.1. Tomatoes ___ chilli pepper ___ shallots ___ onions ___ spring onions___ okro __

E.4.2. Maize _____ Cassava _______ Beans/Cowpea _____
Bokobokor_____ Gboma _____ Ademe _____ Alefu______Moringa _____ Other crops _____

E.5. Does your household run out of food before the next season? (1), (2), (3), (4) (5)

E.6. Which month or months of the year does is usually happen? _______

E.7. Has this always been the case? (1), (2), (3), (4) (5)

E.8. Is this shortage a problem for your household? (1), (2), (3), (4) (5)

E.9. Is this common in the community? (1), (2), (3), (4) (5)

E.10. How long have you been experiencing this shortage? (Select only one)

E.10.1. Recently, Less than 5 years ____

E.10.2. For about 5__ 10 ____ 15____ 20 years _____

E.10.3. More than 20 years _____More than 30 years _____Not sure how long _____

E.11. The community has a system for coping with food shortages (Y/N) ____

E.11.1. Acquiring better storage facilities like freezers (Y/N) ___(1), (2), (3), (4) (5)

E.11.2. Processing food into other forms (Y/N) ___(1), (2), (3), (4) (5)

E.11.3. Sharing with relatives and neighbours (Y/N) ___(1), (2), (3), (4) (5)

E.11.4. Trading/exchanging with relatives and neighbours (Y/N) ___(1), (2), (3), (4) (5)

E.11.5. Changing diet (Y/N) ___(1), (2), (3), (4) (5)

E.11.6. Selling crops for cash to buy food from market later (Y/N) __(1), (2), (3), (4) (5)

E.11.7. Other_____________

E.12. Has your household changed food storage methods? (Y/N) __ (1), (2), (3), (4) (5)

E.13. Is there enough power for food processing?(Y/N) __ (1), (2), (3), (4) (5)

E.13.1. Firewood/Charcoal (Y/N) ____ (1), (2), (3), (4) (5)

E.13.2. Kerosene / Gasoline/ Premix (Y/N) ____ (1), (2), (3), (4) (5)

E.13.3. Liquid Petroleum Gas (LPG) (Y/N) ____ (1), (2), (3), (4) (5)

E.13.4. Electricity from national grid (Y/N) ____ (1), (2), (3), (4) (5)

E.13.5. Solar energy (Y/N) ____ (1), (2), (3), (4) (5)

E.13.6. Other _________________________

E.14. Is there enough power for farming/ irrigation?(Y/N) _ (1), (2), (3), (4) (5)

E.14.1. Kerosene / Gasoline/ Premix (Y/N) ____ (1), (2), (3), (4) (5))

E.14.2. Liquid Petroleum Gas (LPG) (Y/N) ____ (1), (2), (3), (4) (5)

E.14.3. Electricity from national grid (Y/N) ____ (1), (2), (3), (4) (5)

E.14.4. Solar energy (Y/N) ____ (1), (2), (3), (4) (5)
E.14.5. Other __________________________

E.15. Cost of power for farming/ irrigation is high? (Y/N) _ (1), (2), (3), (4) (5)
E.15.1. Kerosene / Gasoline/ Premix (Y/N) ____ (1), (2), (3), (4) (5))
E.15.2. Liquid Petroleum Gas (LPG) (Y/N) ____ (1), (2), (3), (4) (5)
E.15.3. Electricity from national grid (Y/N) ____ (1), (2), (3), (4) (5)
E.15.4. Solar energy (Y/N) ____ (1), (2), (3), (4) (5)
E.15.5. Other __________________________

E.16. Will you be using a different source of power for cooking/ food processing soon?(Y/N) __(1), (2), (3), (4) (5)
E.16.1. Kerosene / Gasoline/ Premix (Y/N) ____ (1), (2), (3), (4) (5)
E.16.2. Liquid Petroleum Gas (LPG) (Y/N) ____ (1), (2), (3), (4) (5)
E.16.3. Electricity from national grid (Y/N) ____ (1), (2), (3), (4) (5)
E.16.4. Solar energy (Y/N) ____ (1), (2), (3), (4) (5)
E.16.5. Other __________________________

E.17. What are the sources of drinking water? Well___ Pipeborne ___ Other_________
E.18. Has your household well dried up? (Y/N) __ Which year_________
E.19. How many buckets of water do you use in a week?___ Bags of Sachets water____
E.20. Are women responsible for fetching water for the home? Y/N_(1), (2), (3), (4) (5)
E.21. Has this responsibility shifted over the years? (Y/N) __(1), (2), (3), (4) (5)
E.22. Is climate change the cause of water shortage? (Y/N) __(1), (2), (3), (4) (5)
E.23. Have you re-located your home due to: Flood? (Y/N) __(1), (2), (3), (4) (5)
E.23.1. Wind or rain storm damage? (Y/N) __(1), (2), (3), (4) (5)
E.24. Have any of your family members moved to the city due to weather? (Y/N) __(1), (2), (3), (4) (5)
E.25. Have you reinforced your home or roof due to the weather? (Y/N) __(1), (2), (3), (4) (5)

F. SECTION E: CLIMATE RISK MANAGEMENT AND INSTITUTIONAL SUPPORT

F.1. How much do you spend on farm tools and equipment per year? GHC _____

F.1.1. Does your household use hand tools and equipment? (Y/N) __(1), (2), (3), (4) (5)

F.1.2. Hoe ___ Cutlass ___ Spade/shovel___ pick axe___ other____________________

F.1.3. Does your household use power tillers and tools? (Y/N) __(1), (2), (3), (4) (5)

F.1.4. Will your household start using power tools soon due to changes in climate (Y/N) __(1), (2), (3), (4) (5)

F.2. Have you been receiving advice on what to do in case of the following events?

Event	**(Y/N)**	**Source and year information was received**
Drought		
Floods		
Pests and diseases outbreaks		
Food shortages		

F.3. Does the community need education on climate change? (Y/N) _ (1), (2), (3), (4) (5)

F.4. Do you know of any institution (s) in the area educating the community about climate change? (Y/N) __(1), (2), (3), (4) (5)

F.5. How long have these institutions been active in the area? ____ years

F.6. What issues have these organizations been educating the community about? Mention 3.

F.7. In learning about climate change and related technologies which of these are considered most important? (Select all that apply)

F.7.1. Trust in the person introducing the technology (Y/N) ____ (1), (2), (3), (4) (5)

F.7.2. Face-to-facilitation/ step-by-step guidance (Y/N) ____ (1), (2), (3), (4) (5)

F.7.3. Documentation of processes used? (Y/N) ____ (1), (2), (3), (4) (5)

F.7.4. Relevance to my situation (Y/N) ____ (1), (2), (3), (4) (5)

F.7.5. Available funding (Y/N) ____ (1), (2), (3), (4) (5)

F.7.6. Teaching materials, methods (Y/N) __ (1), (2), (3), (4) (5)

F.7.7. Group discussions (Y/N) ____ (1), (2), (3), (4) (5)

F.7.8. Role playing/Drama/ Participatory methods (Y/N) ____ (1), (2), (3), (4) (5)

F.7.9. Field visits/ tours (Y/N) ____ (1), (2), (3), (4) (5)

F.7.10. Posters/handouts (Y/N) ____ (1), (2), (3), (4) (5)
F.7.11. Online interactions (Y/N) ____ (1), (2), (3), (4) (5)
F.7.12. Aerial photos/GIS/ Satellite images? (Y/N) ____ (1), (2), (3), (4) (5)
F.7.13. Other ______

F.8. What incentives are of interest to farmers to encourage climate sensitive agriculture?

F.8.1. Improved farm production (Y/N) ____ (1), (2), (3), (4) (5)
F.8.2. Better food, clean water, healthy lifestyle (Y/N) ____ (1), (2), (3), (4) (5)
F.8.3. Knowledge, skills on climate change management (Y/N) ____ (1), (2), (3), (4) (5)
F.8.4. More trees, beautiful landscape? (Y/N) ____ (1), (2), (3), (4) (5)
F.8.5. Benefits for future generations(Y/N) ____ (1), (2), (3), (4) (5)
F.8.6. Government or district level payments to farmers? (Y/N) ____ (1), (2), (3), (4) (5)
F.8.7. Certification programmes or schemes (Y/N) ____ (1), (2), (3), (4) (5)
F.8.8. Links to markets (export, regional, international) (Y/N) ____ (1), (2), (3), (4) (5)
F.8.9. Higher prices for farm produce and commodities? (Y/N) ____ (1), (2), (3), (4) (5)
F.8.10. Financing or access to credit? (Y/N) ____ (1), (2), (3), (4) (5)
F.8.11. Crop insurance schemes? (Y/N) ____ (1), (2), (3), (4) (5)
F.8.12. Formation of Farmer Based Organizations(FBO)s?(Y/N) ____ (1), (2), (3), (4) (5)
F.8.13. Supporting farmer learning? (Y/N) ____ (1), (2), (3), (4) (5)
F.8.14. Contract farming? (Y/N) ____ (1), (2), (3), (4) (5)
F.8.15. Solving land tenure issues? (Y/N) ____ (1), (2), (3), (4) (5)
F.8.16. Other ____

F.9. What stage are you in dealing with changes in the weather with regards to rainfall pattern, droughts, etc. by adoption use of **tubewell irrigation system**? (Select only one, which best describes the individual's stage)

#	Stage	Description	Y	N
1	Pre-contemplation	Stage when the individual does not believe there is a problem. Has no intention of changing to tube well use in the foreseeable future.		
2	Contemplation	Person is aware that a problem exists and is seriously thinking about solutions but has not yet decided to take action.		
3	Preparation/ determination	Individual is focused on pursing a change in the immediate future, within the next 30 days. Actively preparing for change.		

4	Action	The stage in which the individual is actively using the tube well irrigation system. Has used for about 6 months.		
5	Maintenance	Consistently using irrigation for more than six months. The individual has some doubts but works to prevent reverting back to old ways of using shallow well and pre-existing conditions.		
6	Termination	Individual has permanently changed. Has no temptations to revert back to previous situation.		
7	None above			

If at **Maintenance Stage,** please answer the following:

F.10. Reverting back to shallow-well use from tube well irrigation due to:

F.10.1. Drying up of wells (Y/N) __(1), (2), (3), (4) (5)

F.10.2. Salt intrusion /Saline water (Y/N) __(1), (2), (3), (4) (5)

F.10.3. High electricity or fuel costs to operate pumps (Y/N) __(1), (2), (3), (4) (5)

F.10.4. Other_______________

F.11. What stage are you in dealing with changes in the weather with regards to rainfall pattern, droughts, etc. by **using hybrid seeds** (Select only one)

#	Stage	Description	Y	N
1	Pre-contemplation	Stage when the individual does not believe there is a problem. Has no intention of changing to hybrids seeds in the foreseeable future.		
2	Contemplation	Person is aware that a problem exists and is seriously thinking about solutions but has not yet decided to take action.		
3	Preparation/ determination	Individual is focused on pursing a change in the immediate future, within the next 30 days. Actively preparing for change.		
4	Action	The stage in which the individual is actively using hybrid seeds. Has used for about 6 months.		
5	Maintenance	Consistently using irrigation for more than six months. The individual has some doubts but works to prevent reverting back to old ways of using local seeds and pre-existing conditions.		
6	Termination	Individual has permanently changed. Has no temptations to revert back to previous situation.		
7	None above			

F.12. Based on lessons learned from the use of as tube well irrigation or hybrid seeds and achieving desired results, which of the following would you agree to?

F.12.1. Working within groups for collective action at the community level is more effective than individually (Y/N) ____ (1), (2), (3), (4) (5) F.12.2. Working with individuals leads to more collective action than with groups. (Y/N) ____ (1), (2), (3), (4) (5)

F.12.3. In the future, it would be better for individuals to think about how climate change is affecting them (Y/N) ____ (1), (2), (3), (4) (5)

F.12.4. In the future, it would be better for the community to take communal action against climate change (Y/N) ____ (1), (2), (3), (4) (5)

F.13. Is there anything you would like to say about the weather or climate change?

F.14. Has any of your tube well irrigation plots been taken up for other uses? (Y/N)___

F.15. State the use:______________________

F.16. Number of plots taken up ____? State the year____

F.17. If all the tube well plots are taken over from you what will you do to earn a living? _____________________

Thank You!

APPENDIX III - LIST OF FUNCTIONAL FBO'S

SLIST OF FUNCTIONAL FBO'S WITHIN THE KETA MUNICIPALITY.

Name of FBO	Location	Number Of Members		
		M	F	Total
Azorko Multipurpose Co-operative Society	Woe	14	9	23
Agbenyega Vegetable Farmers/Marketers Association	Agorve	19	15	24
Alornesor Co-operative Farmers/Marketers Society	Tsiame	18	7	25
Anyanui Dzolali Vegetable .Farm Association	Anyanui	16	17	33
Apeanyo Vegetable Farm & Market Association	Anyanui	10	10	20
Avanu Youth Farms Association	Anloga	31	19	50
Avume Co-op Vegetable/farm & Market Society	Avume	13	9	22
Avume Co-operative Vegetable Marketers Society	Avume	13	9	22
Blessing Co-op Vegetable Farmers/marketers Society	Benadzi	10	15	25
Dekaworwor	Bawe	19	16	35
Devoo Farmers Association	Avume	8	5	13
Dome Co-op Pump Users Association	Dome	34	16	50
Dormenyo Vegetable Farmers Society	Anyanui	18	17	35
Dornorgbor Co-op Farmers Society	Anloga	25	25	50
Doveme Co-op. Food Crops Farmers/marketing Soc.	Doveme Anloga	17	6	23
Dzidepo Vegetable Farmers Co-op Society	Anloga	35	15	50
Dzidodo Farmers Asscociation	Anloga	38	12	50
Dziewornu Co-op farm/market Association	Avume	21	8	29
Edudzi Co-op Vegetable farmers /marketers society	Tegbui	28	21	49
Forward Ever Youth Vegetable farmers Association	Woe	35	15	50
Goodwill Co-op Vegetable//Farm & Market Society	Avume	22	13	35
Honesty Vegetable farm & Markets Association	Anloga	28	14	42
Keta District Vegetable Farmers & Marketer Assoc.	Atietipe	20	10	30
Keta District Vegetable Farmers/Marketers Association	Tegbi-Ashiata	20	6	26
Keta District Vegetable Farmers/Marketers Association	Setsinu	28	22	50
Kpormornayeho Co-op Vegetable Farmer/Market Soc.	Tegbi	25	25	50
Lebene Co-op Multipurpose Society	Agbatsivi	10	11	22
Lorlorli Co-op Vegetable Farmer/Market Society	Abotsigbor	11	12	23
Lorlornyo Co-op Food Crop Farmers/Market Assoc.	Tsiame	14	6	20
Lorlornyo Co-op Vegetable Society	Dzita	26	24	50
Maranatha Co-op Farm/Market Association	Avume	24	9	33
Maranatha Co-op Farm/Market Association	Agorve	24	9	23
Mawuenyo Co-op Sugarcane Farm/Market Society	Azanu	30	14	34
Mawuli Vegetable Growers Association	Afiadenyigba	30	20	50
Melemawushi Co-op.Fish/Marketing Society.		18	15	33
Mieworge Vegetable Growers Association	Agorve	17	6	23
Nenyo Co-op Vegetable Farmers/Market Society	Dzelukope	20	12	32
Nolibilibi Farmers Association	Anlo-Afiadenyigba	31	17	48

Nutifafa Co-op Vegetable Farmers & Marketers Soc.	Avume	34	16	50
Nyatefe Youth in Agriculture	Woe	36	11	47
Progressive Farmers Association	Abolove	16	16	32
Sromawuda Co-op Farmers	Atiavi	17	16	33
Strong Arm Farmers Society	Anloga	24	16	40
Tsiame-Asadame Agblede Haborbor	Tsiame			
Tsormenanyo Co-op Farmers/marketers Union	Agorve	13	5	18
Unity Farmers Group	Atorkor	13	7	20
Veviedodo Co-op Sugarcane Farm/Market Society	Benadzi	23	10	33
Victory Shallot Farm Association	Anloga	10	8	18
Woe Multipurpose Co-op Society	Woe	30	20	50
Youth Farmers Co-op Society	Whuti	38	12	50

APPENDIX IV - FOUR MAIN EXTENSION APPROACHES IN GHANA

Approach	Farmer Field School/ IPM	T&V (Traing and Visit)	Participatory Approaches (PRA, PTD&E, SLA, etc.)	Commodity based, Nucleus farmer and out-grower focused
How it is used (Characteristics)	1. Technology is transferred through experiential learning 2. It covers enture season of the commodity 3. Farmer centered expansion 4. Use of TOT 5. Use of farmer groups 6. Aspects of FSR&E incorporated	1. Requires large No. of staff & regular training 2. Interaction between farmers, research and Extension must exist 3. Focus on training technical staff for training farmers 4. Uses TOT 5. Emphasis on single line command 6. Activities are time bound 7. Fixed visiting schedules 8. Uses Farmer groups 9. Aspects of FSR&E incorporated	1. Client centered 2. Indigenous knowledge base 3. Usually a bottom up approach 4. Requires good moderation or facilitation 5. Uses farmer groups 6. Uses TOT for facilitation 7. Aspects of FSR&E incorporated	1. Target specific commodities (Cocoa, Oil Palm, Rubber & Cotton) 2. Covers relatively small beneficiaries 3. Provides embedded services (land preparation, inputs, credit, farmer training, & marketing) 4. Highly technology dependent 5. Proft oriented 6. Highly skilled personnel 7. Deals with the entire value chain 8. Aspects of FSR&E incorporated
Who uses it	MoFA projects (RTIP & SPFS), NGOs, FAO, COCOBOD,	MoFA projects (URADEP, VORADEP, NAEP), Country-wide	NGOs, Projects (SPFS) Brong Ahafo and Northern regions	COCOBOD, TOPP, BOPP, GREL, GCCL, Farmapine
Strengths	1. Participatory and hands-on 2. Result oriented 3. Enhances technology adoption 4. Joint decision making 5. Creation and sharing of knowledge 6. Builds confidence of participant 7. Competence in crop health 8. Extension officers get trained	1. Capacity building of staff and farmers 2. Increased Extension coverage 3. Adequate logistics for Extension delivery 4. Adequate monitoring and supervision 5. Reporting was automated and regular for decision making 6. Field demos widely spread	1. Client empowerment 2. Enhances sustainability 3. Enhances adoption of technologies 4. More judicious use of resources 5. Mutually supportive relationship 6. Improve farmer to farmer technology transfer 7. Enhances communication	1. High use of technologies 2. Ready market for produce 3. Availability of other services (credit, inputs, etc.)
Weaknesses	1. Expensive 2. Difficulty assembling participants at all times 3. Implementation of approach is limited due to inter-personal differences 4. Not suitable for commodities with	1. Rigid in terms of framework 2. High cost dependent 3. High dependence on research knowledge	1. Time consuming 2. Time conflicts with other activities of clients	1. Inputs may not be used for the purpose intended 2. Service provider can dictate all contractual agreement 3. It ignores non-target commodities

	long gestation periods			
Institutional arrangement	1. Facilitating entity in place 2. Adequate logistics should be provided 3. Demonstration sites in place	1. Single line of command 2. Monthly training 3. Forthnighly staff meeting 4. Bi-monthly technical review meeting 5. RELC planning and reveiew sessions 6. Subject matter specialist	1. Link up with local leadership to mobilise clients/ participants 2. Stakeholder fora/ networking	1. Contract farming for the companies 2. Intensive monitoring system and supervision 3. Nucleus farmer/ organization prives funding
Ho to improve it	1. Sensitise participants to participate fully 2. Cost reduction 3. Govt funding needed	1. T&V should be modified for adoption (provision of adequate transport, fuel, and other logistics to enhance supervision) 2. RELC should be strengthened 3. SMS centers should be revived 4. Improve staff strength 5. Redesign demos for use	1. Link up with local leadership to mobilise clients/ participants 2. Stakeholder fora/ networking	1. There must be a strong FBO to negotiate 2. Extension service providers should extend services to other enterprises of clientele to minimize diversion of inputs and produce.

Source: Adapted from GECCPAN, 2015

APPENDIX V – PROFILE OF KETA MUNICIPAL

Profile of Keta Municipal

Keta Municipal Assembly

November, 2013

1.1 Introduction

This document provides information on the Keta Municipality. The issue discussed include the background, physical features, political administration, social structure, economy and demographics.

1.2 Background

Keta Municipal, with Keta as the capital is one of the 25 administrative districts of the Volta Region of Ghana. It was carved out of the former Anlo District, which comprised Akatsi and Ketu Districts. The Keta Municipal Assembly was established by the Establishment Instrument (L.I.) 1868 of 2007.

1.3 Physical Features

1.3.1 Location and Size

The Municipality lies within Longitudes 0.30E and 1.05E and Latitudes 5.45N and 6.005N.

It is located east of the Volta estuary, about 160km to the east of Accra, off the Accra-Aflao main road. It shares common borders with Akatsi South District to the north, Ketu North and South Districts to the east, South Tongu District to the west and the Gulf of Guinea to the south. Out of the total surface area of 1,086km^2, approximately 362km^2 (about 30 per cent) is covered by water bodies. The largest of these is Keta Lagoon, which is about 12 km at its widest section and 32km long.

Figure 1 Administrative Map of Keta Municipal

1.3.2 Relief and Drainage

Keta Municipality is a low-lying coastal plain with the highest point of only 53 metres above sea level around Abor in the north of the Municipality. The lowest point is approximately between 1 to 3.5 metres below sea level along the coast around Vodza, Kedzi and Keta townships. Three main geographic belts may be identified namely the Narrow Coastal Strip, the Lagoon Basin of the middle belt and the Plains of the North.

(i) The coastal Strip

The generally low-lying nature has exposed particularly the eastern parts of the coastal strip to intense sea erosion and occasional flooding. Notwithstanding, a great irrigation potential exists. The Coastal Strip is marked by sand bars with a few sea cliffs bordering the coast. This belt is affected by severe sea erosion, the previously worst hit areas include Keta, Kedzikope, Vodza, Kedzi and Horvi which have been saved by the Keta Sea Defence Project. Currently Srogboe-Dzita stretch is under severe sea erosion resulting in damages to properties and loss of livelihoods to about twelve communities which are periodically cut off during high tidal waves.

(ii) The Lagoon Basin

The general elevation of the lagoon basin is also below sea level. It is made up of lagoons and islands such as Atiavi, Alakple, Seva, Anyako and Dudu. The basin is generally marshy due to the underlying sandy-clay geological formation. The main drainage basins are the lagoons, which together constitutes about 362km^2. The major lagoons include Keta, Angaw Agbatsivi, Logui, Nuyi and Klomi. Into this basin drains some streams and distributaries of the Volta River. These include such streams as Angor, Avida, (near Hatorgodo), Awafla (near Awaflakpota), Nukpehui (in the north-western part of the Municipality), Tordzie and Kplikpa. Many of the creeks are dwindling in size due to low rainfall, excessive evaporation and siltation. As a result, the volume of water in the lagoon has drastically declined and tends to fluctuate seasonally, leading to the emergence of several islands in the Keta, Angor and Agbatsivi lagoons. The biggest among the Islands are Seva and Dudu, which are partially inhabited.

(iii) The Northern Plains

The Northern plain is generally gently undulating with a relatively higher elevation of about 50 metres above sea level.

1.3.4 Soils

(i) Oyibi-Muni Association

Along the coastal strip are the Oyibi-Muni and Keta Associations characterized by sandy soils often without any top layer of humus. Naturally, it supports coconut cultivation. When manured, it supports shallot, okro, pepper and other vegetables. In fact, this strip is the leading shallot producing area in Ghana though it covers only about 11 per cent of the Municipality (excluding lagoons).

(ii) Ada-Oyibi Association

The Soil in the lagoon basin (Ada-Oyibi Association) is very shallow, overlying a hard and compact clay formation. The soil is generally alkaline and supports mangrove vegetation, sugar- cane, and grass for pasture. Due to the underlying clay, this area is liable to flood and not suitable for arable farming though it covers over 75 per cent of the total dry land of the Municipality.

(iii) Toje-Alajo Association

The Toje-Alajo Association covers the Northern plain around Abor and constitutes about 14 per cent of the Municipality (lagoon excluded). It is relatively deep and supports crops like cassava, maize and legumes.

1.3.5 Climate

1.3.5.1 Rainfall

The Municipality falls within the Dry Coastal Equatorial Climate with an annual average rainfall of less than 1,000mm. The amount of rainfall reduces as one travels from the north to the coastal parts where only about 800mm per annum may be recorded. The Municipality is thus one of the driest along the coast of Ghana. The Municipality experiences a double maximum rainfall pattern. The major rainy season is between March and July while the minor one begins in September and ends in November. Thus the total amount of rainfall is relatively low. Hence all year round cropping is severely constrained and the vegetable farming around Anloga which depend largely on irrigation.

1.3.5.2 Temperature

The high average temperatures (about 30°C), couple with low relative humidity, promote high evapo-transpiration. The high evapo-transpiration also exacerbates the general water deficient conditions and a potential for salt production.

1.3.6 Vegetation

The entire Municipality falls within the coastal savanna zone which is categorized into four (4) vegetational Zones.

- The northern part of the Municipality marked by tall grasses and interspersed with medium sized trees with relatively higher density.
- The mid-section of the Municipality with short grasses and short trees with occasional occurrence of “Pamira” palm and baobab trees.
- South-western part, characterized by mangrove plants along the Volta estuary and tall grasses used for fuel, and mat/hat weaving respectively.
- South-eastern part along the coast from Whuti with short grasses and many neem trees. Most of the coconut trees along the coast have been affected by the Cape St. Paul Wilt disease. This has had a major influence on the pattern of rainfall in the Municipality.

1.4 Political and Administrative Structure

The Keta Municipal Assembly is the highest administrative and political authority in the District. The legislative and deliberative organ of the Assembly is made up of Seventy-four (74) Assembly Members including One (1) Municipal Chief Executive and Two (2) Members of Parliament. Fifty (50) are elected members and Twenty-One (21) are government appointees. The Members of Parliament and the Municipal Chief Executive are non-voting members of the General Assembly. There are two (2) constituencies in the Municipality which are Anlo and Keta Constituency. There are 14 Zonal Councils and fifty (50) electoral areas. The Presiding Member is the leader of the General Assembly.

1.5 Social Structure

1.5.1 Traditional Administration

Keta Municipality is part of Anlo Traditional Council which has 36 states and headed by a paramount chief, the Awoamefia of Anlo who serves as a symbol of authority among all people in the Municipality. There are other chiefs with their own areas of influence who assist the Awoamefia in the promotion of peace and stability in the Municipality. Every year in the first week of November, the people gather at Anloga to celebrate Hogbetsotso Festival. Display of rich cultural values, resource mobilisation for development and peaceful co-existence are prominent issues considered during the occasion.

1.5.2 Religious Composition

The predominant religion is Christianity, which constitutes about 72.8 percent of the population followed by traditional religion 25.4 percent, Muslim 1.0 percent and others 0.8 percent. The fact still remains that Christianity dominates in the Municipality and some people practice it alongside traditional religion.

1.5.3 Ethnic Composition

The 2010 Population and Housing Census Report shows that the Ewes still dominate the Municipal population with about 98.7 percent while the other tribes constitutes the remaining 1.3 percent. This indicates that the population of the Municipality is highly homogeneous regarding ethnicity.

1.5.4 Festivals

The main festival is the Hogbetsotso, which symbolizes the great exodus of Ewes from their ancestral home, Notsie, to their present abode around the 15th Century. The Hogbetsotso Festival, which is celebrated at Anloga, the traditional home of the Anlos, attains a grand final with a durbar of Chiefs and people amidst pomp and pageantry on the first Saturday of every November.

1.6 Economy

Keta Municipality is mainly an agrarian economy, with the majority of the population engaged in crop farming, livestock keeping, fishing and other agric related activities and trading. A wide range of industrial activities has been identified in the Municipality. All the industries, which are small scale, are owned and managed mainly by sole proprietors. The Keta Municipality has great potential for some categories of industries. Some of these include Ceramics Industry and Salt Production.

1.6.1 Agriculture

(i) Crop Production

The Municipality is one of the major vegetable producers in the Volta Region. It is well known for its shallots, which are produced in the flood plains along the Angaw and Keta Lagoons and streams. The main shallot producing areas are Anloga, Anyanui, Agbledomi, Dzita, Atorkor, Srogboe, Whuti, Woe and Tegbi. Other vegetables such as okro, tomato and pepper are also extensively cultivated either as pure stands or as intercrops depending upon the season, with the alluvial soils along the lagoons providing very ideal sites for their production. The new developed technology of tube well irrigation has given a new impetus in the production levels of previously unknown crops and horticulture in the Municipality.

Maize and cassava are also grown as off-season crops, along the littoral but as main season crops in the northern parts of the Municipality. Coconut is also cultivated along the littoral even though it is no more the main source of income for the people as it used to be some years ago as a result of the Cape St Paul Wilt Disease, which appeared in the Municipality in the Woe area around 1932 and devastated large numbers of trees and still causing havoc. Coconuts are also grown in the inland parts of the Municipality around Afiadenyigba, Atiavi, Hatorgodo, Atsiame and Dorveme areas. Sugarcane is also a major crop extensively cultivated in the flood-prone mid-western parts of the Municipality, with the following major producing areas; Atiavi, Hatorgodo, Bleamezado, Agorbledokui and Tregui. Cowpea is also a major crop grown in the northern parts of the Municipality around Abor, Weme and other surrounding towns during the main cropping season. It is also grown along the littoral during off seasons as green manure. Sweet potato is one of the crops found all over the Municipality; however, the northern part of the Municipality grows it more extensively.

(ii) Fishing

The Municipality is endowed with numerous water bodies, and has a high potential for fisheries development. Among the available resources are the Atlantic coastline, lagoons and creeks. Fishing is carried out in the sea, lagoons and rivers. Several types of fishing gears are used for fishing in the sea. These include beach seine, Ali, Polo, Watsa, Set nets and Drift gill nets. Some of these fishing gears have proved to be inappropriate and efforts are being made to regulate them.

(iii) Livestock

Livestock production is a secondary vocation to most farmers in the Municipality. The Municipality is very popular for rearing ducks and geese. Local poultry (fowls) are also kept on free range. A few women keep turkeys, while pigeons are pastimes for the wealthy men in the society. A few farmers keep improved poultry. Poultry is abundant in commercial towns along the littoral where the demand is highest. Sheep and goats are also found in most homes and are fed on household waste. They are kept mainly on free range and therefore become a nuisance in the community. Pigs used to be common in most villages but with the devastation of the coconuts and the subsequent disappearance of waste from its processing, their feeding has become a problem resulting in decrease in their numbers. Few numbers are being kept around Salo, Agortoe and Afiadenyigba areas. Exotic breeds are however being kept by a few commercial farmers around Keta and Dzelukope. Cattle and small ruminants are mostly found in the middle belt of the Municipality where pasture is available.

1.6.2 Industry

The industrial activities of the Municipality has been categorised into six major areas depending on the raw material base and production orientation.

The categories are:

- Agro-based: Fish processing, cassava processing, sugar cane juice distilling, and coconut-oil extraction
- Mining: Quarry, exploitation of salt and sand winning.
- Wood-based: Carpentry, Standing brooms.
- Textile: Tailoring/Dressmaking ,Kente Weaving,
- Service: Hairdressing, Vehicle repair/fitting mechanics, Radio/TV mechanics, masonry.
- Ceramics: Pottery.

1.6.3 *Services*

There are three major financial institutions in the Municipality namely Ghana Commercial Bank, Keta and Abor and Anlo Rural Bank Limited, Anloga. However, there are microfinance and other small scale financial institutions popularly called 'Susu Collection' which are available across the District.

1.7 Tourism Potential

As a low lying coastal plain with the highest point only 53 metres above sea level interspersed with lagoons, creeks and mangrove forests, the Keta Municipality offers a great potential for tourism development in the country. With the recent expansion in tourist receptive facilities, one expects a corresponding increase in tourist attractions like the development of water sports, coconut groves, cultural tourism and many others.

1.7.1 Lagoons:

The lagoons also provide calm water bodies for cruising and other water sports. Three major lagoons are found in the Municipality, namely Keta, Angaw and Avu. The Keta Lagoon is the largest in the country and has several islands such as Seva, Dudu and Xevi Kpodzi (bird sanctuary). The lagoons offer opportunities for angling since they are rich in tilapia, mudfish and others such as crabs, shrimps and scallop.

1.7.2 Mangrove Swamps

Along the main Angaw, Avu and part of Keta lagoon are very extensive stretches of mangrove swamps. Opportunities exist for visitors to cruise through the mangrove forest or to study its ecology.

1.7.3 Ramsar Site

The Anlo- Keta wetlands have been designated Ramsar Site, because it provides sanctuaries for several birds including migratory and resident ones, especially water fowls. It is said that the Anlo- Keta Ramsar Site is at the crossroad of several thousands of migratory birds that fly the Mediterranean and the South-Atlantic flyway. Some of the birds which nest, rest, feed and breed there include the various types of terns, gulls and pelicans. There is, therefore, the great need for the construction of bird watching towers to attract more tourists into the Municipality.

1.7.4 Sandy Beaches:

The Keta Municipality is blessed with several kilometres of very clean and unique golden beaches in the country which can offer places of relaxation to tourists. The beaches drenched in brilliant sunshine have sands ranging from fine to coarse grained types. The coconut clad sandy beaches are interspersed with bare sandy surfaces stretching from Azizanu to Dzelukope near Keta.

1.7.5 Festivals:

The main festival is the Hogbetsotso, which symbolizes the great exodus of Ewes from their ancestral home, Notsie, to their present abode around the 15th Century. The Hogbetsotso Festival, which is celebrated at Anloga, the traditional home of the Anlos, attains a grand final with a durbar of Chiefs and people amidst pomp and pageantry on the first Saturday of every November. During such festivals, religious cults are displayed through some magical performances. Such cults include the Korku and Yewe cults. One interesting feature is to see the members of Korku cult cut themselves without effect with sharp knives.

1.7.6 Fort Prinzenstein

This Danish Fort build in 1784 at Keta is one of the most spectacular relics of colonialism in the Municipality. It played a key role in the infamous triangular slave trade involving West Africa, England and North America. Efforts need to be made to save this important historical monument from total destruction by sea waves and to preserve it as an important tourist resort. The Keta Sea Defense Project has greatly saved the Fort from further destruction and still has a story to tell.

1.7.7 Atorkor Slave Market

In addition to Keta, Atorkor was the second slave market in the Municipality. The trade was masterminded by one Ndorkutsu. A monument was raised in the area where this wicked activity took place. The Keta Municipal Assembly intends to convert the place into an important tourist resort. A beginning has been made with the construction of a sculpture showing a slave dealer giving orders to slaves with a whip.

1.7.8 Anlo Military Headquarters, Tsiame

This is yet another important tourist spot where the Anlos during their historical wars gathered to plan war strategies against their enemies. It is located at Tsiame, north of Keta and at that very spot today, stands a grove, which tourists can visit.

1.7.9 Cape St. Paul Light House-Woe:

This is an ancient light house located at Woe near Keta. While it is still functioning, this light house directs ships at night away from what is believed to be a big submerged mountain just off the coast of Woe.

1.7.10 Abutia Guest House:

Located at Woe-Abutia near Keta, this facility has nineteen rooms, which are well kept. There is a security car park and a spacious drinking bar.

1.7.11 Keta Beach Hotel:

The Keta Beach Hotel, a one-star hotel, is situated within the serene residential area of Keta. Its facilities include self-contained rooms with TV/Fans, Air Conditioners and a restaurant and bar service in addition to a conference hall and communication facilities.

1.7.12 Lorneh Lodge Tegbi:

Situated at Tegbi, is an ultra modern hotel facility with an extra-ordinary scenic beauty. It has twenty self-contained rooms with TV/video, split-unit air conditioners, soft-carpet, fridge and telephone facilities. Complementary facilities include beach resort, swimming pool and a conference hall among others.

1.7.13 Agblor Lodge is rather a small but compact hotel with five rooms each well-furnished with TV, fan. A small bar is run to enhance visitors' comfort.

1.7.14 Happy Corner Restaurant:

This facility which is located at Woe offers congenial environment for tourists and residents for comfort and relaxation. Speciality in mouth-watering grilled tilapia and *Akple* or other combination varieties.

1.7.15 Breeding Sea Turtles

The Beach or the Coastline between Anloga and Dzita and much especially around Dakordzi and Akplorwotorkor records a lot of Seasonal Sea Turtles which come on-shore to lay eggs for hatching. The scene is so interesting attractive to watch during the months of August, September and October.

1.7.16 Others

The under listed Receptive Centres are of recent but modern developments in the Municipality. These includes Hotel de White House at Anloga, Twine Lodge Hotel at Tegbi, Larota Guest House at Tegbi, Pin Drop Hotel at Anloga, Dzigbordi Lodge at Anloga and Meet Me There at Dzita.

1.8 Social Infrastructure/Amenities

1.8.1 Education

Keta Municipality has various educational institutions which cater for different categories of the school going population. These include institutions for pre-school, basic, primary and secondary education in the Municipality and grouped into the 10 educational circuits for effective supervision. These are Abor-Tsiame, Anloga, Anyako-Afiadenyigba, Atiavi-Hatorgodo, Dzelukope-Vui, Dzita-Anyanui, Keta, Shime, Srogboe-Kome and Tegbi-woe. Of these 10 circuits, Keta, Dzelukope-Vui, Tegbi-Woe, Anloga and Abor-Tsiame are urban oriented while the rest are rural.

There are 320 schools in the Municipality which was made up of 126 Pre-schools (84 public and 42 private), 103 Primary schools (90 public and 13 private), 77 Junior High schools (73 public and 4 private), 12 Senior High/technical Schools (10 public and 2 private) and 4 Technical/Vocational (1 public and 3 private).

1.8.2 Health

The Municipality has been divided into six (6) health sub-municipal namely Keta, Anloga, Tegbi, Anyako, Anyanui and Shime for effective management. Health activities are carried out in the Municipality by Ghana Health Service, Private and Christian Health Association of Ghana which operates a catholic hospital at Abor Weme, and a E.P. Church Health Centre at Hatorgodo.

Distribution of health facilities in Municipality

Facility	Number	Location
IC Hospital	**1**	Dzelukope-Keta
Health Centre	**12**	Tegbi, Kodzi, Tregui, Atiavi, Tsiame, Galosota, Afiadenyigba, Anloga, Anyako, Anyanui ,Asadame
RCH centres	**2**	Dzelukope, Agbledomi
CHPS zones	**2**	Sasieme, Trekume,Atorkor
ATE	**4**	Tegbi, Anyanui, Abor and Anloga

Private Clinic		
Maternity Home	**5**	Vui, Woe, Anyanui, Abor and Anloga
Mission Health centre	**1**	Hatorgodo
Mission Hospital	**1**	Abor

Source: Municipal Health Management Unit, 2013

1.8.3 Transport, Telecommunication and Banking Services

Transport infrastructures in the Municipality are mainly road and water. In the case of water transport the services are privately owned. There are good roads in the Municipality which is about 74.8km, traverses the coast from Havedzi through Keta-Anloga-Dabala to join the main Accra-Aflao road. The Municipality is well served with communication networks and some financial services providers such Commercial Bank, Rural Bank etc.

1.8.4 Electricity and Water

The Electricity Company of Ghana District Office is located at Keta with bulk supply station at Anloga. Almost all the major towns in the Municipality have access to electricity.

The main sources of water are pipe schemes, boreholes, rivers, hand-dug wells, dams and dugouts. Pipe borne water forms the major sources of domestic water supply to the people.

1.8.5 Transport Services

1.8.5.1 Road Network

The First class road (74.8km) traverses the coast from Havedzi through Keta-Anloga-Dabala to join the main Accra-Aflao road. The northern section of the Municipality between Abor and Anyako is accessible by second class road. The Keta-Aflao stretch of road which was completely destroyed by sea erosion between Keta and Horvi has now been constructed under the Keta Sea Defence Project by the Central Government. Settlements in the north of the Municipality (Abor-Atiavi-Hatorgodo axis) are linked mostly by second class roads and are complemented by feeder roads. The middle and south western sections of the Municipality (Angaw and Klomi lagoon basin) are poorly accessible mainly by third class roads and footpaths. Generally, the Municipality is relatively more accessible as indicated by a relatively high road density of 194.7 meters/km^2.

This mode of transport is used for passenger and cargo services, passenger buses and mini-buses with a seating capacity of between 16-40 are used for these services. Truck services are used to carry mainly tomatoes, shallots, salt and fish to outside the Municipality while manufactured goods and foodstuffs like rice, yams, maize and building materials are imported.

1.8.5.2 Water Transport

Lagoon transport, though important is poorly developed In the case of water transport the services are privately owned. Non-motorized local canoes are used to transport goods and people across the lagoons. Another setback is the seasonal fluctuations in the water level, which render movement very slow and even cumbersome. The siltation of the lagoon has also generally reduced the water level.

The major routes are Anyako/Seva-Anloga, Afiadenyigba-Keta-Anloga, Atiavi-Keta-Anloga, and Alakple/Kodzi/Fiahor-Keta-Anloga. The seasonal drying up of the lagoon makes water transport unreliable and time consuming as opposed to road transport (over 90 per cent of the population use road transport regularly).

1.9 Demographic Characteristics

The 2010 Population and Housing Census put the total population of the Municipality at 147,618 which forms 7.0 percent of the Regional total population. The population constitutes 53.6 percent females and 46.4 percent males with an annual growth rate of 1.10 percent. The Municipality is the most urbanised district in the region with more than half 53.3 percent of the district's population living in the urban areas with 46.7 percent of the population living in the rural areas.

(i) Spatial Distribution of Population

The Municipality is relatively more urbanized based on the criterion that any settlement with a population of 5000 or more represents an urban centre. The numerous rural settlements scattered over the whole Municipality make efficient service provision difficult.

The average density for the Municipality is 211.9 persons/km^2 (water bodies excluded), which is significantly higher compared with the national and regional figures of 65.7 persons/km^2, and 69.1 persons/km^2 respectively. This can be attributed to the presence of large water bodies, which occupy 1/3 of the total land area.

The main population density zones are the coastal areas comprising a narrow strip of sand bar between Anloga and Keta where the density rises to about 500 persons/km^2 compares favourably with densities in Greater Accra Region (609.7 persons/km^2 which is the highest in the country. It is the most serviced area and is also noted for intensive shallot farming.

Keta, the Land of varieties and tradition welcomes you with the *Warm* and *Unforgettable* Memories.

APPENDIX VI – EDUCATIONAL LEVEL AND PERCEPTIONS

Educational level and perceptions of climate change impacts

	Improving	Not sure/No change	Worsening	Total
None	2	6	50	58
(%)	0.48	1.45	12.11	14.04
Primary	0	7	22	29
(%)	0	1.69	5.33	7.02
JHS	12	26	141	179
(%)	2.91	6.3	34.14	43.34
SHS	1	27	58	86
(%)	0.24	6.54	14.04	20.82
Vocation	0	3	16	19
(%)	0	0.73	3.87	4.6
Training College	0	0	8	8
(%)	0	0	1.94	1.94
Polytechnic	0	4	12	16
(%)	0	0.97	2.91	3.87
Graduate/Tertiary	1	3	14	18
(%)	0.24	0.73	3.39	4.36
Total	16	76	321	413
(%)	3.87	18.4	77.72	100

APPENDIX VII – FACTOR LOADINGS OF BELIEFS ABOUT CLIMATE IMPACTS

Factor loadings of strong beliefs about climate change impacts

Variable	Obs	Mean	Std. Dev	Min	Max	Eigen-value	Pro-portion	Factor loading Factor 1	Factor loading Factor 2	Cron-bach's Alpha 0.726
Change in air & water temperature	427	3.923	1.431	1	5	2.528	0.5056	0.2178	0.8913	
Duration of drought	429	2.515	1.617	1	5	1.158	0.2316	0.8011	0.2769	
Incidence of pests	427	2.578	1.606	1	5	0.574	0.1148	0.8300	0.0003	
Crop damage & failure	428	2.654	1.619	1	5	0.398	0.0796	0.8609	-0.0913	
Size & intensity of waves	427	3.178	1.478	1	5	0.342	0.0684	0.6394	-0.5278	

APPENDIX VIII –SOCIO-ECONOMIC CHARACTERISTICS AND STAGE

Summary of logistic regression results between all socio-economic variables and stages of the transformational change process

Stage	Prob chi2	Gender	Age	Low-Edu	Mid-Ed	Hi-Edu	Edu	Hoh	Ext	Owner-ship	Fbo	MStat
PC	0.0054		0.064				0.086					
PC	0.0758						0.088					
C	.00001								0.000	0.017		
C	0.0059								0.001	0.034		
P	0.0048								0.037		0.096	0.056
P	0.1124								0.074			
A	0.0001								0.005	0.001		
A	0.0066								0.006	0.003		
M												
M	0.5125											
T	0.018								0.034	0.033		
T	0.1252			0.035	0.037		0.035		0.048			

*** p<0.01, ** p<0.05, * p<0.1

APPENDIX IX –SMALLHOLDER CLIMATE-SENSITIVE PRACTICES

Practices smallholders have adopted in response to the negative climate change impacts

Climate-sensitive practices	Obs	Mean	Std. Dev.	Min	Max	Scale
Using hybrid varieties	419	4.47	1.02	1	5	High
Change in planting dates	419	4.27	1.22	1	5	High
Intercropping	419	4.12	1.08	1	5	High
Using mulch/mulching	421	4.10	1.13	1	5	High
Change in slash and burn	416	3.94	1.26	1	5	High
Using same land but more chemical inputs	418	3.80	1.54	1	5	High
Carting soil from one area to another	421	3.71	1.35	1	5	High
Expansion of farms to new lands	414	3.67	1.53	1	5	High
Using tube-well irrigation	415	3.50	1.47	1	5	High
Weather forecasting	415	3.48	1.31	1	5	High
Integrated livestock and crop farming	409	2.73	1.40	1	5	High
Using crop insurance	416	2.66	1.35	1	5	High
Agro-forestry	419	2.49	1.40	1	5	Low