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Gender roles in Agriculture and natural resources management in upper east region, Ghana

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Michael Mensah

aus Accra, Ghana

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Referent: Prof. Dr. Paul L. G. Vlek

Korreferent: Prof. Dr. Jan Börner

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ABSTRACT

The Upper East region is one of the poorest regions in Ghana with an estimated 90% of the people living in rural areas being peasant farmers. In many instances, farmers use their land unsustainably thus worsening the already poor soil condition. Women in the region contribute substantially to food production. However, the lack of access to land and other farm inputs are major challenges that reduce their potential production levels. Climate change is another challenge which is expected to worsen the already food insecure situation of the region. Management decisions and choice of management practices have implications for the natural resource base. The study sought to investigate the livelihood typologies and the factors that differentiate household types and determine the gender specific agricultural roles in the upper east region of Ghana. Similarly, gender differentials in the adoption of inorganic fertilizer and factors that influence gender-specific adaptation strategies to climate change and variability were studied. Finally, role-playing games were used to guide management of natural resources from a gender perspective.

A household survey was conducted from August to December 2014 using a pre-tested questionnaire where 150 males and 150 female farmers were randomly sampled from 14 communities within the Bolgatanga Municipality and Bongo district. Subsequently, a total of 44 grazing games comprising 22 games for male headed household (HH) and 22 games for female HH were played.

Results show that male farmers have access to and cultivate larger land areas than females in the study area due to the patrilineal system of inheritance. In addition, male farmers cultivate cash crops such as legume compared to women who kept a higher percentage of their lands under the cultivation of traditional cereal crops to improve household food security. Furthermore, male HH generate relatively higher income from the sale of their farm produce than their female counterparts. Women generally have limited access to land. Women are involved in all stages of farming activities and more particularly in physically demanding activities such as planting crops, weeding, planting trees, fertilizer application, watering, tree and crop harvesting and hauling of farm produce. The only role women play in the financial administration of the farm is selling of crops. Men on the other hand are engaged in land preparation, feeding of livestock, seedling production and pruning of trees. They are the main actors in the financial administration such as purchasing of farm inputs, farm financing and maintenance of farm records. The study also shows that male headed households are more likely to adopt fertilizer application than female HH. The factors that significantly influenced male HH adoption of inorganic fertilizer were household size, marital status, area of land allocated for maize and rice production and perceptions about fertility status of the soil. Factors that influence adoption of inorganic fertilizer for female headed HH were, farming experience, household size and dependency ratio, farm area for maize and rice and family remittance. A majority of both gender groups perceived an increase in temperature, a decrease precipitation and an increase in drought spells. However only 49% male and 40% female HH have adopted strategies to cope with increasing temperatures while 56% male and 49% female have adapted to decreasing precipitation. Similarly, 62% male and 60% female HH have adapted to increasing drought spells. The main difference between the two groups are that males prefer to migrate and seek employment in other parts of the country whereas females prefer to engage in off-farm jobs such as trading, basketry and shea-butter processing. The age of farmers, access to extension services, access to credit facility, farming experience between 11- 21 years, and perceived

loss of soil fertility, among other factors, are more likely to lead to the adoption of practices that reduce the impact of decreasing and erratic precipitation.

In the games, males produced higher numbers of cows but created the largest desert patches. Females were identified as better managers of natural resources as they created fewer desert patches. Strategies such as reducing the number of cows to allow for re-growth of vegetation in periods of feed scarcity, ploughing for each other using bulls, and family support using income from the sale of livestock were employed by both gender groups. Policies which target maize and rice producers will be relevant to increase fertilizer adoption. In addition, policies that target experienced farmers, farmers with large household size among female-headed households will be relevant for adoption of fertilizer. To promote climate change adaptation, policy should target farmers who have access to credit, extension services, land and access to weather information. The involvement of female farmers in decision-making is crucial to improve natural resource management.

Geschlechterrollen in der Landwirtschaft und im Management natürlicher Ressourcen in der Upper East Region Ghanas

KURZFASSUNG

Die Upper East Region ist eine der ärmsten Regionen Ghanas. Dort sind schätzungsweise 90 % der Landbevölkerung Kleinbauern. In vielen Fällen nutzen die Bauern ihr Land nicht nachhaltig und verschlechtern so den ohnehin bereits schlechten Zustand des Bodens. Die Frauen in der Region leisten einen erheblichen Beitrag zur Nahrungsmittelproduktion. Jedoch ist der fehlende Zugang zu Land und zu anderen landwirtschaftlichen Produktionsmitteln eine große Herausforderung, die das Produktionspotential der Frauen verringert. Der Klimawandel wird voraussichtlich die Notlage der Nahrungsmittelsicherung verschärfen. Die Entscheidungen und Praktiken mit den Folgen des Klimawandels umzugehen haben Auswirkungen auf die natürlichen Ressourcen. Zum einen hat diese Studie das Ziel die Lebensgrundlagen und die Faktoren zu bestimmen, welche die unterschiedlichen Haushalte ausmachen. Zum anderen geht es darum, die geschlechterspezifischen Rollen in der Landwirtschaft der Upper East Region in Ghana zu ermitteln. Ebenfalls untersucht werden die Geschlechterunterschiede in der Einführung von anorganischem Dünger und die Faktoren, welche den geschlechterspezifischen Anpassungsstrategien an den Klimawandel beeinflussen. Dabei wurden Rollenspiele eingesetzt, um den Umgang mit natürlichen Ressourcen aus geschlechtsspezifischer Sicht zu ermitteln.

Von August bis Dezember 2014 wurde eine Haushaltsumfrage mit einem vorab getesteten Fragebogen durchgeführt, bei der 150 Bauern und 150 Bäuerinnen aus 14 Gemeinden des Bolgatanga Municipal District und des Bongo District nach dem Zufallsprinzip befragt wurden. Anschließend wurden insgesamt 44 sogenannte *grazing games* durchgeführt, 22 in von Männern geleiteten Haushalten (HH) und 22 in weiblichen geleiteten Haushalten.

Die Ergebnisse zeigen, dass Männer im Untersuchungsgebiet aufgrund des patrilinearen Vererbungssystems Zugang zu größeren Landflächen haben als Frauen. Darüber hinaus bauen Männer Cash Crops wie Hülsenfrüchte an, Frauen hingegen nutzen einen höheren Prozentsatz ihrer Anbauflächen für traditionellen Getreideanbau, um die Ernährungssicherheit ihrer Haushalte zu verbessern. Männliche HH erzielten daher ein höheres Einkommen aus dem Verkauf ihrer landwirtschaftlichen Erzeugnisse als ihre weiblichen Kollegen. Frauen haben in der Regel nur begrenzten Zugang zu Land. Frauen sind in allen Bereichen der Landwirtschaft tätig und verrichten insbesondere harte körperliche Arbeit wie das Pflanzen von Nutzpflanzen und Bäumen, Jäten, Düngen, Bewässern, Ernten und das Tragen der Ernte. Die einzige Rolle, die Frauen in der Verwaltung der Finanzen spielen, ist der Verkauf der Ernte.

Die Männer hingegen beschäftigen sich mit der Bodenbearbeitung, der Fütterung von Vieh, der Produktion von Setzlingen und dem Beschneiden von Bäumen. Sie sind die Hauptakteure in der Verwaltung der Finanzen und kümmern sich um den Kauf von Produktionsmitteln, um die Finanzierung und um die Buchführung. Die Studie zeigt auch, dass von Männern geführte Haushalte eher auf Düngemittel zurückgreifen als weibliche HH. Die Faktoren, welche die Einführung von anorganischem Dünger bei Männern maßgeblich beeinflussen, sind die Haushaltsgröße, der Familienstand, die für

die Mais- und Reisproduktion zugewiesene Fläche und die Beurteilung der Fruchtbarkeit des Bodens. Faktoren, welche die Einführung von anorganischem Dünger bei von Frauen geführten HH beeinflussen, sind landwirtschaftliche Erfahrung, Haushaltsgröße und Abhängigkeitsgrad, landwirtschaftliche Nutzfläche für Mais und Reis und Rücküberweisung von Familienmitgliedern.

Die Mehrheit beider Geschlechtergruppen konnte einen Temperaturanstieg, sowie einen Rückgang der Niederschläge und einen Anstieg der Dürreperioden beobachten. Allerdings haben nur 49% der männlichen und 40% der weiblichen HH Strategien entwickelt, um mit den steigenden Temperaturen umzugehen. An die abnehmenden Niederschläge haben sich 56% der Männer und 49% der Frauen angepasst. Zudem haben sich 62% der männlichen und 60% der weiblichen HH auf die zunehmenden Dürreperioden eingestellt. Der Hauptunterschied zwischen den beiden Gruppen besteht darin, dass Männer es vorziehen, in andere Teile des Landes zu migrieren und eine Beschäftigung zu suchen, während Frauen es bevorzugen, Tätigkeiten außerhalb der Landwirtschaft auszuüben wie Handeln, das Herstellen von Korbwaren und die Verarbeitung von Shaebutter. Faktoren für die Einführung von Praktiken, welche die Auswirkungen abnehmender und unregelmäßiger Niederschläge verringern, sind: das Alter der Bauern, der Zugang zu Beratung und Krediten, landwirtschaftliche Erfahrung im Alter von über 10 Jahren und den augenscheinliche Fruchtbarkeit des Bodens.

In den Spielen produzierten die Männer eine höhere Anzahl von Kühen, aber auch die größten Wüstenflächen. Frauen wurden als bessere Verwalter von natürlichen Ressourcen ausgemacht, da sie weniger Wüstenflächen schufen. Beide Gruppen setzten die folgenden Strategien ein: sie reduzierten die Anzahl der Kühe, damit sich die Vegetation in Zeiten der Futterknappheit erholen kann; sie unterstützen sich gegenseitig beim Pflügen der Felder mit Bullen; und nutzten familiäre Netzwerke für den Verkauf von Vieh.

Politische Maßnahmen, die sich an Mais- und Reisproduzenten richten, werden relevant sein, um die Nutzung von Düngemitteln zu erhöhen. Ebenfalls relevant für die Einführung von Düngemitteln sind Richtlinien die sich an erfahrene Bauern richten, sowie an große von Frauen geführte Haushalte. Um die Anpassung an den Klimawandel zu fördern, sollte die Politik auf Bauern ausgerichtet sein, die Zugang zu Krediten und Beratungsdiensten, sowie zu Land- und Wetterinformationen haben. Die Einbeziehung von Bäuerinnen in den Entscheidungsprozess ist ausschlaggebend für eine bessere Bewirtschaftung von natürlichen Ressourcen.

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LIST OF ABBREVIATIONS

FAO	Food and Agriculture Organization
EU	European Union
HH	Headed household
ICT	Information and Communication Technique
RPGs	Role Playing Games
UER	Upper east region
SES	Social Ecological Systems
CDKN	Climate and Development Knowledge Network
IPCC	Intergovernmental Panel on Climate Change
ISSER	Institute for Social Science and Economic Research
MoFA	Ministry of Food and Agriculture
NGOs	Nongovernmental Organizations
EPA	Environmental Protection Agency
ICOUR	Irrigation Company of Upper Region
PCA	Principal Component Analysis

1 INTRODUCTION

1.1 Background to the study

Agriculture is an important driver for economic growth and poverty alleviation in countries where the main occupation of the poor is agriculture (Stamoulis 2007). However, agricultural production alone is not enough for reaching food security as defined by the FAO (2001) as the availability of food, access and affordability of safe and nutritious food always to meet the dietary needs of people and preferences for a healthy life. Globally, an estimated 854 million people are under or malnourished (Lambrecht el at., 2017) because of lack of access to food of the right quality, quantity and timeliness

In most developing countries, women contribute substantially to food production (Ogunlela and Mukhtar, 2009; Lal and Khurana 2011; Doss, 2014; Palacios-Lopez et al., 2017). The FAO (2011) indicated that women in sub-Saharan Africa make up about 50% of the agricultural labor force. However, these women, who represent a crucial resource in agriculture and the rural economy, are facing several challenges such as access to land and inputs among others, which are crucial in ensuring food security. In many instances, the roles of women in agriculture are not recognized or seen in terms of economic value because they mostly help their husband on the farm without charging a fee. When the farm is their own, the produce is mostly for subsistence with little or no surplus for the market. To boost agricultural production and thus economic growth and food security, it is important to recognize women's' contribution in food production and increase their access to the essential resources such as land and farm inputs. Even though the role of women in agriculture cannot be overlooked, these roles vary considerably between countries and regions. Koirala et al. (2015) stated that an empowered woman who makes decisions about planting materials and inputs is more productive in agriculture than one who is not empowered. Rural women can manage complex household duties and pursue multiple livelihood strategies.

While food insecurity is a major development problem in sub-Saharan Africa, poor and declining soil fertility, climate change and variability are added challenges that exacerbate the food insecurity situation of small-holder farmers and the urban poor. Climate change has become a major global issue which affects all sectors of human society, including all ecosystems including agriculture, water supply and health, with implications for smallholder farmers and their families, poverty and food security (IPCC, 2014; Schlenker, Lobell, 2010 and Rurinda 2014). These negative impacts are already felt and expected to increase in the future (IPCC 2007b; EU Commission 2009). To reduce the impact of climate change on the agricultural sector, especially on crop and livestock production there is a need to adapt to climate change. Boko et al. (2007) indicated that the low adaptive capacity of Sub-Saharan Africa to climate change makes the region most vulnerable. Similarly, Christensen et al., (2007) reported that West Africa is projected to have severe droughts resulting in drier conditions in the region hence increasing the incidence of food insecurity. The vulnerability of the region to climate change is a result of the reliance of the rural economies on rain-fed agriculture (FAO 2003; Commission for Africa 2005; Thornton et al., 2011). Hence, food insecurity and wide-spread poverty among smallholder farmers is worsened (Lobell et al., 2008), which will go hand in hand with a further depletion of the natural resources in the region.

Current projections are still challenged by uncertainties e.g. from the amount of greenhouse gas emissions, downscaling of climate projections and incomplete climate models (IPCC 2007c). These uncertainties make adaptation decisions to climate change difficult and many farmers are not sure whether to adapt or not. Climate change adaptation is however crucial to reduce the negative impact on food production and increase resilience of the agriculture sector. Heubes et al. (2011) reported that by 2050, about 2 million km² area of grassland in West Africa will be converted into desert area. This projection has serious implication for crops and livestock production.

Stakeholders, including farmers make decisions about climate change adaptation when they are aware of the time of the event, how the event will evolve, and to what extent risks from climate events can be reduced (Refsgaard et al., 2013 and Rurinda 2014). In this regard, developing and implementing plans commonly designed with the local populations and using an adaptive management approach (Holling 1978) is one of the suggested strategies to climate change adaption (Pahl-Wostl 2007). To increase the adaptive capacity of stakeholders, participatory approaches or active learning is recommended. Berkes and Folke (1998) reported that increasing adaptive capacity of stakeholder requires an in-depth study of their perceptions and reactions. There is however limited research looking at uncertainty in the context of social constructions and perception of affected Research shows inadequate learning materials exploring anticipation adaptation of stakeholders especially in areas of low adaptive capacity like West African countries (Tschakert and Dietrich 2010, d'Aquino and Bah 2013, 2014).

Unsustainable use of natural resources such as land by farmers to achieve agricultural growth is a major problem globally, but especially in Sub-Saharan Africa. This has been the major driver of natural resource degradation or desertification. Bernard et al. (2014) reported that unsustainable management of natural resource is a result of farmers' management decisions, choice of management practices, and their incapacity to act appropriately to current and future threats. In any given ecosystem, there are many actors with different interests that sometimes may be contrasting or competing (Villamor et al. 2014). For example, farmers competing for land for crop production and the grazing of animals of pastoralists. Conflict prevention as a result of land-use can be achieved when stakeholders learn among themselves through participatory approaches to observe how their decisions on land use impact on their livelihoods (Cundill et al. 2012) and how to manage the natural resource for the benefit of all. Reed et al. (2010) stated that social learning takes place when a change in understanding is beyond that of the individuals and is established within broader social units or communities as a result of interactions among the social actors through networks.

Role playing games (RPGs) are an important tool for participatory and joint learning. The RPGs are Information and Communication Technique (ICT) tools aiming at providing support for learning, teaching, planning, analysis and negotiation processes, among others. As a learning tool among other uses, RPGs aim at providing either players or game organizers with better knowledge of a given situation (Barreteau, 2003). Games are also seen as appropriate tools for stimulating active participation of stakeholders in a collective process with regards to resource management. Speelman, et al. (2014) for instance employed RESORTES, a land use board game and showed that, game sessions created an open and active discussion on land-use among participants where farmers expressed their actual views on and responses to multifunctional agricultural landscape planning and the land sharing vs. land sparing dilemmas. In another study, Washington-Otombre et al (2010) integrated an RPG with several modelling approaches (multi-criteria evaluation model and a machine learning base tool) to observe the complex land-dynamics influencing a land-adjudication process.

RPGs help stakeholders understand how to manage resources well without conflict. It is equally useful to reveal the heterogeneity of farmers and other factors that are responsible for land-use change to stakeholders. The dynamics of land-use is a complex process largely determined by human decisions. Thus, human agents are major determinants of land-use change and major drivers of any social environmental system. Heterogeneity amongst a human population can be determined through a characterization of human agents. A growing body of literature has demonstrated that human agent decisions are determined by several and different factors including resource endowment, cultural preferences and knowledge about the resources (Parker et al., 2008; Villamor et. al., 2011) with a direct link to the natural systems or environment. In recent years, there has been a dramatic increase in global attention to gender differentials in development, agricultural activities and contribution to food security. Yet, there remains a paucity in tangible actions that can lead to greater impacts on the ground. In this context, this study investigated the effectiveness of RPGs, in identifying coping strategies in response to climate variability and as a learning tool in understanding social ecological systems. The study also examines gender-specific determinants of land use decisions (using fertilizer adoption as a proxy) in order to enhance food production in the Upper East Region of Ghana.

1.2 Problem statement and justification

In Ghana, about 77% of the total labor force is engaged in subsistence farming making agriculture the most important sector for employment (FAO 2012). Out of these, 50% are women (FAO 2012). In the upper east region (UER) of Ghana, which is known to be one of the poorest regions in the country, about 90% of the rural population are subsistence farmers and women play an important role in economic growth and poverty reduction through their active engagement in all agricultural activities. A number of studies in other parts of the world have examined the changes in gender-specific roles in agricultural activities and their contribution to food security (DeFries et al., 2010; Villamor et al.; 2014a, Villamor et al., 2015). In general, these revealed that men and woman differ in their interest, mechanisms, roles and strategies for dealing with changing agricultural conditions due to environmental impacts. There is however, little information on gender roles in changing agricultural activities in the UER of Ghana, hence the need for this study.

Although farmer's adoption and use of fertilizer has been analyzed in several developing nations, including Ghana, there is still little work on gender differentials in fertilizer adoption in the country and most especially in the semi-arid part of Ghana where UER is located. Lower yields have been reported for female than for male farmers (Larson et al., 2015; Cadzow, 2016) which is caused by limited access to resources such as farm land, credit, information about modern technologies, extension services and education on the part of women (Doss, 2015; Bravo-monroy et al., 2016; Oluwasusi and Okanni 2014). Also, women are most likely to be constrained in their access to productive inputs, resulting in lower levels of fertilizer application (Oseni et al 2015). Female headed households in Ghana are less likely to adopt new crop varieties and fertilizers than female farmers in male headed households (Doss and Morris, 2001). However, little is known about gender differentials in decisions to use or adopt fertilizer in the study area.

In most parts of the semi-arid regions of Ghana, socio-cultural norms and practices forbid women to inherit key resources such as land, as well as access to formal credits. Access to land by women farmers in this region is constrained by the patrilineal system of inheritance. Yet, access to land is vital since land is a key factor of production in economic terms. Furthermore, ownership of land also would provide women status, power and wealth in many communities (FAO, 2011).

The patrilineal system of inheritance in the UER of Ghana favors men over women when it comes to ownership of assets including land, thus increasing tenure insecurity of females. Women culturally gain access to land only through male members of their household i.e., husband, brothers or sons (Tsikata and Yaro, 2011; Apusigah, 2009; Sarpong, 2006). In addition, women are normally given small and marginal pieces of land, usually unsuitable for the cultivation of vegetables and other staple crops, which reduces their potential to create wealth and contribute to food security of the household and the region at large (Tsikata and Yaro (2011).

The region is known to be one of the major producers of livestock in the country. Livestock keepers rely on the natural rangeland to graze their animals. In many instances, pastoralists are not able to manage their common land and water resources well, resulting in degradation (especially land) and in some cases conflict between crop farmers and livestock keepers. Role-playing games are an important tool for participatory learning and can help participants to analyze and negotiate natural resource use. The tool also helps the researcher to understand the decision-making processes of the farmers and the factors that they consider. Furthermore, the role of heterogeneity of the farming family in land use-change is not well understood at the household level.

1.3. Main research question

Does gender of a farmer affect the efficacy and sustainability of food production under climate change? Is this due to a differential understanding of the social ecological systems?

1.3.1 Specific questions

1. To what extent can role-playing games help in understanding natural resource management in the upper east region of Ghana?
2. Is there gender differentiation in land use decision?
3. What role do men and women each play in food production and food security in the upper east region of Ghana?
4. To what extent does land access explain the gender differential in food production in the upper east region?

5. Is there a gender differentiation in climate change adaptation strategies in the upper east region of Ghana?

1.4 Main objective

The overall objective is to assess the degree of gender differentiation in climate-change adaptation through role-playing games and evaluate their efficacy in generating insights in the social-ecological systems of farming communities in the Upper East Region, Ghana.

1.4.1 Working objectives

The specific objectives are to:

i. Understand and identify how role-playing games can be used to help manage natural resources from a gender perspective.
ii. Investigate the gender specific agricultural roles in the upper east region of Ghana.
iii. Identify the livelihood typologies and endogenous factors that differentiate household types.
iv. Determine the factors that influence gender-specific adaptation strategies to climate change.
v. Investigate the gender differentials in the adoption of innovation (inorganic fertilizer) among farmers.

1.5 Null- Hypotheses

i. Gender does not matter in the adoption of inorganic fertilizer
ii. Gender does not play a role in how a farmer deals with climate change adaptation
iii. Gender does not play a role in natural resource management

1.6 Outline of thesis

This thesis is structured into six chapters. This first chapter provides an introduction and defines the context of the research. It also includes the problem statement, justification, research questions and objectives of the study. Chapter 2 presents a review of relevant literature. Chapter 3 provides a description of the study area and the materials and methods used in the research. Chapter 4 provides results of the study. Chapter 5 presents discussion of the results. Chapter 6 gives a summary of the major findings of the research and related policy implication and recommendation for further research.

2 LITERATURE REVIEW

2.2 Understanding Social Ecological Systems (SES) in the VEA catchment, Ghana

2.2.1 Concept of social ecological systems

Social-ecological systems which is a linkage of nature and people are considered in most disciplines as complex adaptive systems controlled by information within and between social and biophysical changes. This system emphasizes on the need for humans to be seen as a part of nature (Berkes & Folke, 1998). Also, SES are dynamic systems that continuously change, showing high spatial variations in response to internal or external pressures (Filatova et al 2013). It is important to understand the driving forces of the dynamism of the SES and develop a sustainable management approach that sustains societal development (Constanza et al., 2000; Lambin, 2005; Schlüter et al., 2014).

It has been a daunting problem to develop a comprehensible approach in evaluating complex social ecological systems. Levin et al., (2012) stated that modeling SES poses a challenge due to the complex and multiple nature of the system. Similarly, Miller et al., 2008 cited in Rissman et al. (2017) indicated that different approaches have been adopted over the years to understand the relationships between the different qualitative and quantitative variables in SES. The variables varied with the methods used hence, impacting on the findings. For example, Ostrom (2007) proposed a framework which is social science base for SES that uses variables from different theories and models of SES from diverse fields. A common set of variables were provided for understanding an isolated SES and for drawing inferences from related SES. The framework aided scientist and policy makers to better understand their empirical studies and assessment of previous reforms in enhancing their analytical capacity (McGinnis & Ostrom, 2014).

2.2.2 SES, resilience and adaptive capacity

SES resilience is said to have revolved from natural scientific research (Berkes et al., 2003; Cote & Nightingale, 2012; Folke, 2006) (Berkes et al., 2003) which is important in sustaining the system. Folke, (2006) indicated that the resilience approach focuses on non-linear dynamics, thresholds and uncertainty how periods of slow change interplay with periods of drastic change and how such changes affect temporal and spatial scales. Given the complex nature of the SES, research scientist are required to investigate and understand the critical variables that affect the resilience of the system(Gunderson & Holling, 2001) and these core variables are categorized into two major components namely bio-physical and socio-economics factors. These vital indicators are made up of biophysical as well as socio-economic elements (Washington-Ottombre et al., 2010).

Currently, several efforts have been made to merge the social findings of related social ecological systems which entails ''social learning and social memory, mental models and knowledge system, social networks, institutional and organizational inertia and change, adaptive capacity, transformability, and systems of adaptive governance that allows for managements of essential ecosystem services'' (Folke, 2006). Diverse SES research are likely to face numerous challenges including efforts to expound the interaction of interwoven social-ecological systems responsible for vulnerability and those in charge of resilience as well as adaptive capacity. (Folke, 2006). Adaptability and adaptive capacity are considered as the capacity of actors within a system to affect resilience in a positive manner (Speelman, 2014).

As a result, such research would will inform policy and management decisions differently and the applications of SES by policy makers. Although most SES frameworks are designed to improve sustainability (Ostrom, 2007) it is sometimes difficult to understand which problem it diagnose(Rissman & Gillon, 2017). Most often, these systems are analysed without taking into account the human decision-making process. Long term behaviour of social ecological systems shows that these systems act as complex adaptive systems where by human decision-making forms part of the system (Walker et. 2002; Speelman, 2014).

2.2.3 Stakeholder involvement and social learning

Given the complexity in understanding social ecological systems, there is the need for a collective effort by the scientific community to consider the capacity to adapt to change (Robinson and Berkes, 2011). Collaboration between scientist from diverse disciplines and stakeholders is required to understand and improve the adaptive capacity of the actors of complex social ecological system (Page 2008). This partly explains why stakeholder participation has become a key strategy in problem solving and solution exploration (Scholz et al 2013; Angelstam et al., 2013). The growing scarcity of natural resources coupled with the competing interest and high demand is creating tension among stakeholders and therefore require social learning and negotiation processes for a better understanding (Barnaud et al., 2010; Villamor and van Noordwijk 2011). Stakeholder participatory approaches to problem solving and solution exploration dates back to 1960s (Participatory Rural Appraisal, Rapid Rural Appraisal, Participatory Action Research: e.g. Pretty 1995, Reed 2008). However, participatory approaches that focus on local decision making and negotiation processes are limited.

A better understanding of the resilience and adaptive capacity of any given system requires participatory learning (Tschakert and Dietrich 2010). There is a direct relationship between learning and the cognitive process of acquiring knowledge according to classical views on learning (Sfard 1998). Different perspectives of learning evolved over the years and these include social learning (Bandura 1977) and experiential learning (Kolb 1984). Experiential learning is achieved through experience (Kolb 1984). Kolb discovered two critical dimensions in experiential learning which involves grasping and transforming experience (Fig. 2.1). Learning by grasping is through concrete experience and abstract conceptualization whereas learning by transforming experience is through reflective observation and active experimentation. Often people focus on one or two phases of the Kolb cycle of learning. Social learning on the other hand is done through observation and interaction with others by placing more emphasis on reframing ideas and adjusting perspective (Pahl-Wostl et al., 2008 and 2013). Social learning leads to consensus building and conflict reduction among stakeholders (Lebel et al., 2010).

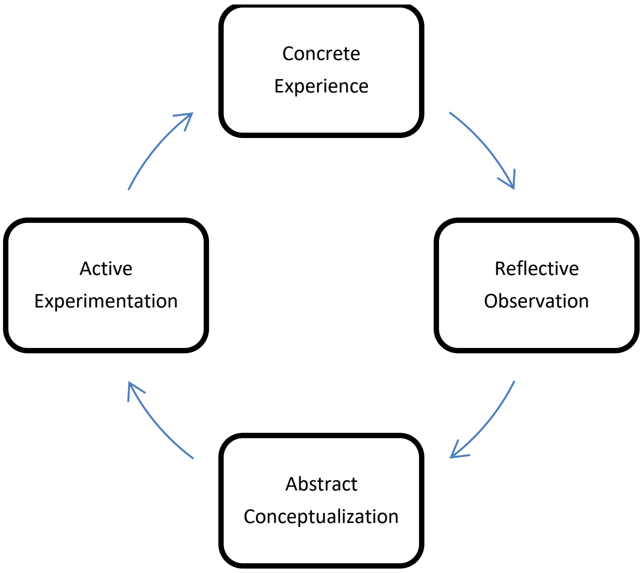

Figure 2.1 Kolb's cycle of experiential learning (Kolb 1994)

2.2.4 Role-playing games (RPGs) and complex SESs

Role-playing games (RPGs) is used as a modelling tool in social sciences. It is referred to as ''the performance of an imaginary or realistic situation played by people with given roles in order to analyse behavioural patterns" (Shafel & Shaftel, 1967). Barreteau, (2003) defines RPGs is an Information and Communication Technique (ICT) tool which enable negotiation processes analysis and support for. As learning tools RPGs aim at providing either players or game organizers with better knowledge of a given situation. Primarily, RPG deal with empirical approaches that control behavioural patterns through the setting of rules and roles. Furthermore, RPG study players behaviour as well as their opinions.

Games are widely used to study climate change, land use change, land cover change and management of fisheries. Games are effective tools to facilitate active engagement of stakeholders in collective processes. Speelman, et al., (2014) for instance employed RESORTES, a land-use board game in a study which indicate that, games promote open and active discussion on land-use among players. Also, Washington-Otombre et al., (2010) integrated RPG with other modelling methods to study complex land-use dynamics that affect land dispute resolution. The study shows that RPG can be integrated with other modelling approaches to analyse complex land-use dynamics.

Games are also used in other jurisdiction to study and understand gender inequality among some targeted societies and urban forestry.

2.2.5 Why Socio-ecological System (SES) games

Socio-ecological System games are more appropriate for theoretical concepts that provide complex system environment for players. Creating such a complex system environment for learning engages people's minds and emotions as well as promote long term learning. Games attract people from different backgrounds including policy maker's students and the general public. Therefore, SES games build trust and empathy, stimulate research into SES challenges and provide solid simulation of SES management decisions through an atmosphere of collaboration and mutual understanding. Further, SES can identify innovations in addressing SES challenges that cannot otherwise be solved by traditional methods. SES games provides the opportunity for testing of hypothesis through experiments.

2.2.6 Features of SES games

1. Motivated by a specific case study
2. Include some type of uncertainty and stochasticity
3. Accurately represent the decision-making goals and strategies
4. Link game outcomes to specific ecological processes
5. The game should be played under different scenarios

2.2.7 Attributes of games

Ranchhod et al., (2014) identified five specific essential attributes of educational games:

- **Players:** These are individuals who make decisions based on certain roles with the game.
- **Goals**: they are the intended objectives of the games that influence the decision and behaviour of players
- **Rules**: They are a set of guidelines that describe and shape the interaction between players and the game environment.

- **Conflict**: Players engage in competitive confrontation in order to attain their goals.
- **Artificial character**: Games normally suggest a fictitious situation that has nothing to do with reality. (See also Brown and Rychtar 2013).

Behind a game is a set of principles known as “game theory” which explains the decision-making process of rational individuals in an interdependent state. In game theory, some of the basic theoretical constructs that are determined by the players’ behaviour and dispositions are individualism, interdependency and rationalism (Romp 1997). O’Neill et al., (2005) (cited in Connolly et al., 2012) identified five “cognitive demands” in relation to games: these included understanding the content of a specific subject and how related challenges can be addressed. These are specific skills relating to the content and teamwork. Communication and self-regulation are considered as skills pertaining to the content. Wouters et al., (2009) identified four types of results as far as playing games are concerned and these entails; effective learning outcomes, cognitive learning outcomes, (divided into knowledge and cognitive skills, motor skills), and communicative learning outcomes (Wouters et al., 2009).

2.2.8 Challenges and limitations of games and participatory game design as learning tools

A key challenge of implementing RPGs is the unavailability of experienced game moderators and willing participants to engage in game play. RPGs requires experienced facilitators to design and conduct games that contain adequate and accurate information of the topic of study. Participation should also be based on the free will of participants. In developing countries, the participatory design is currently gaining attention but is hampered by lack of experienced facilitators and game designers (Khaled et al., 2014). RPGs are also often based on open-ended and loosely structured formats that require flexibility and social interactions, constituting a barrier for participants. Power distance, cultural/language differences, low literacy levels (Oyugi et al., 2008), poor telecommunication infrastructure and high travel cost from dispersed geographical distance also challenge the successful implementation of the participatory game design.

2.3 Grazing game as a learning tool for climate change adaptive strategies in response to climate variability.

2.3.1 Climate variability and adaptation

Climate change has many implications for different aspects of human societies including all ecosystems. Negative impacts on major areas, namely agriculture, water supply and health, are already felt and these are expected to increase in the future (IPCC 2007b; EU Commission 2009). Projections from the present climate show uncertainties due to the uncertainty in greenhouse gas emissions, downscaling of climate projections and incomplete climate models (IPCC 2007c). These uncertainties make adaptation decisions to climate change difficult since decision are usually based on climate projections; hence many actors are not sure whether to adapt or not. Climate change adaptation is however crucial to reduce the negative impact and increase resilience. In West Africa, climate change projections show that the region is one of the most vulnerable to climate change because of high variability of the climate, heavy reliance on rainfall as the main source of moisture for plant growth, weak institutional and economic capability to deal with climate change and variability. Heubes et al., (2011) reported that by 2050, about 2 million km^2 of grassland will be converted into desert area. There is however, great uncertainty due to the wide range of model- estimates and projections about the amount, intensity and pattern of future rainfall in the region (Adger et al., 2003). Climate change adaptation decision making considers climate events and how this event can be minimised considering the interest of the general society. (Refsgaard et al., 2013). These decision-making processes involve the development and implementation of a strategic plan with the involvement of the local population where an adaptive management strategy is employed (Holling 1978; Pahl-Wostl 2007). In order to increase adaptive capacity of stakeholders, participatory approaches or active learning are recommended. Berkes and Folke (1998) reported that increasing adaptive capacity of stakeholders involves the study and understanding of stakeholder's perceptions and responses. There is, however, limited research looking at uncertainty in the context of social constructions and perception of affected people (Pahl-Wostl 2006 cited in Villamor and Badmos 2015). Bernard et al. 2014 reported that unsustainable management of natural resource are a result of farmers' management decisions, their choice of management practices, and their capacity to act appropriately to current and future threats. In any given ecosystem, there are many actors with different interests that sometimes may be contrasting or competing (Villamor et al., 2014). Conflict prevention due to land-use can be achieved when learning among stakeholders is done through a participatory approach (Cundill et al., 2012). Reed et al. (2010) stated that social learning takes place when a change in understanding is beyond that of the individuals and is established within broader social units or communities because of interactions among the social actors through networks.

2.3.2 Anticipatory learning and climate change adaptation

According to Shostak (2009) anticipatory learning is the cycle of discovery, integration, and renewal that make actors keep thinking ahead in a changing environment. The use of RPGs, particularly board games are especially important as they reflect real life situation and help simulate and make the actors see and respond to future uncertainties based on their experiences and knowledge (Vieira Pak and Castillo Brieva (2010), Villamor and van Noordwijk (2011); Villamor and Badmos (2015)). The use of RPGs in land-use decisions enable stakeholders to identify adaption strategy options in order to build resilience to extreme climate change impacts. In RPGs, there is collective interaction of players in a way, which enhances their appreciation of the linkage between social ecological systems (Bousquet et al., 2001, 2003, Barreteau et al., 2007). Players often rely on past experiences while gaining new knowledge through the interactions. RPGs also help to create more awareness and emphasis on climatic uncertainty, hence helping local farmers to identify adaptation strategies to reduce the impact of climate change and variability on their livelihoods. RPGs help to see the behaviour and response of farmers to a likely negative effect of climate change and variability on their livelihood.

2.3.3 Grazing game as pedagogical tools and eliciting behaviour

Games have become part of humankind over time as a source of entertainment and educational tools for eliciting behaviour in diverse disciplines. They are essential and attractive methods of teaching (de Freitas, 2006) with a long usage in anthropology (Villamor et al. 2015). Boyle, et al., (2011) reported that learning is more effective and attractive when it is experiential, active, situated, problem based and provides immediate results. Games are categorized into games for entertainment, games - based learning and serious games (Connolly et al., 2012).

Games and simulations provide an important learning tool for active, experiential and problem-based learning (Connolly et al., 2012; de Freitas 2006). Lindley (2004) defined games as "a goal-directed, competitive activity (against the computer, another player, or oneself), conducted within a framework of agreed rules or a simplified and contrived situation that contains sufficient verisimilitude or illusion of reality to elicit practical responses by those participating in the exercise". Games help in learning human behaviour, diverse interest and reasons for certain life choices. Natural resources management may be assisted by computer - based simulation and games (Barreteau et al., 2007).

2.4 GENDER SPECIFIC DETERMINANTS OF FERTILIZER ADOPTION

2.4.1 Agriculture growth and fertilizer use in Ghana

Agriculture is a major source of livelihood in Ghana and employs almost 70% of the total population. It generates about 30% of the Gross Domestic Product (GDP) and accounts for about 60% of ghana's foreign exchange earnings through export (Ayisu, 2008. The semi-arid region of Ghana, which comprises of the Northern, Upper West and Upper East regions is one of the intensely used agrarian part of the country. These three regions together are considered the food basket of the country as they account for more than 40% of agricultural lands (MoFA, 2010). Much labour is invested in agriculture in this area; however, it is characterized by high levels of insecure agricultural livelihoods, food insecurity, malnutrition and diminishing agricultural returns. According to MoFA (2010), about 80% of the population in this area depends on subsistence agriculture, which is marked by very low productivity and income. Over-reliance on rain-fed agriculture and local methods of farming, severe land degradation, declining soil fertility and low use of soil fertility inputs including fertilizers or rare use of modern farm practices are some of the factors responsible for low yields or low levels of productivity, and high poverty in this area.

Generally, there has been ample discussion and demonstration to increase productivity and sustainability in agriculture in the semi-arid region of Ghana, towards ensuring food security, reducing poverty, and protecting the environment, but little has been achieved. To meet expected rising demands however, increasing agricultural productivity becomes critical and as such, it is important to adopt and examine the performance of modern agricultural technologies such as fertilizer use. Inorganic fertilizers applied to soils have the potential to increases soil fertility, raise crop productivity and enhance household income and food security. For example, various studies have shown that fertilizer use improves crop yields in Africa (Duflo et al., 2008; Beaman et al., 2013). In Ghana, the relevance of inorganic fertilizers has been emphasised as the country tries to increase production and employment through the planting for food and jobs programme. in national development plans. According to Fuentes et al., (2012) higher fertilizer application rates have been observed in countries such as is Malawi and Kenya (22 and 32 kg/ha) compared to Ghana with application rate of less than 8 kg/ha. Generally, it has been recognised that concentrations of fertilizer applied are highest for cash crops such as cotton, cocoa, palm oil and vegetables whereas moderate concentration is applied to crops such as maize with very small concentration applied on crops like cassava, millet, sorghum and yam. (FAO, 2005). On average less than 20% of most farming households apply fertilizer to their crops even though variation exist cross the country (Kolavalli & Vigneri, 2011). In the view of Breisinger et al., (2011), several factors hinder farmers' access and use of fertilizer in various areas in the country; distance from the farm to the nearest agro-dealer selling fertilizer is one major factor. The long-distance increases farmers cost of production through transport and labour cost. To promote fertilizeruse in the country, the government in partnership with private sector introduced fertilizer subsidy which used the voucher system to identify the smallholder farmers who are the beneficiaries (Banful, 2009). This provided a fixed price for the sale of fertilizers including NPK 15:15:15, NPK 23:10:05, urea and ammonium sulphate (AS) and traders had no flexibility to adjust prices. In 2008-2009 smallholder farmers that cultivated mainly for subsistence were the beneficiary of the fertilizer subsidy program. In 2010, there was a new shift in fertilizer policy, which brought about the 'blanket subsidies '(waybill system) as a way to increase the number of farmers that uses fertilizer to drive the demand for fertilizers. (Fuentes et al., 2012). In the current intervention, farmers bought subsidized fertilizer directly from agrochemical dealers Unlike the old system where vouchers were used by farmers to buy the fertilizers. Other cost such as handling costs, clearing charges and incidentals for importers, transport cost, and dealers were refunded. Dizengoff (Subsidiary of Balton CP Ltd.), Wienco, Yara Ghana (a partner of Yara International ASA), Chemico, Golden Stork (a partner of SCPA Sivex International), AfCot (OLAM, Singapore) are the major players in fertilizer importation in the country and determine the availability and price of fertilizer.

2.4.2 Effects of gender on fertilizer use

Although various studies have analysed farmer's adoption and use of fertilizer in several developing nations including Ghana, works on the effects of gender on fertilizer adoption in the country and most especially in the semi-arid part of the country are scarce. Several studies for instance have established that lower yields are associated with female farmers (Larson et al., 2015; Cadzow, 2016). This has been attributed to limited access to resources such as farmland, credit, information about modern technologies, extension services and education on the part of women (Doss, 2015; Bravo-monroy et al., 2016). According to Oseni et al. (2015) women are most likely to face more challenges and be intimidated in accessing farm inputs thereby affecting their ability to apply the right levels of inorganic fertilizer. Doss and Morris (2001) found that female famers in female-headed households in Ghana were less likely to adopt new crop varieties and fertilizers than female farmers in male-headed households. In most parts of the semi-arid regions of Ghana, socio-cultural norms and practices forbid women to inherit productive resources such as land and to obtain credit among others. The allocation of land for household members is based on how members are connected to patriarch. Generally, plats are allocated to both unmarried sons married sons. Married sons of the patriarch and some unmarried sons are often allocated their own plots. Smaal portions of land is given to women who are married to sons of patriarch in order to need household food security (Ndiritu et al., 2014). An elderly widow who belongs to a male household may also be allocated plots to engage in farming for her sustenance (Saenz and Thompson, 2017; Ali et al., 2016).

Women are less likely to use fertilizer on their farms. In rural communities in Africa, it is an acceptable norm for men to decide for their women. This opens the opportunity for male farmers to think about their own farms first. NGOs and governments that support farmers with fertilizer and other farm inputs would have to leave these resources in the hands of the male farmers (Theriault et al., 2017; Oseni et al., 2015). The reason being that men are the heads of the family and that what is supposed to be giving to the woman must be subjected to the man's approval. Women may face punishment from husbands if they receive anything from a person or entity without the consent of the husband. The likelihood of male-headed households engaging in fertilizer application is therefore higher than for female-headed households. Generally, females in female-headed households in Ghana and Burkina Faso were observed to be disadvantaged and adopted fertilizer less frequently than those in male-headed households (Theriault et al., 2017;). At the individual farm level, female plot managers and male plot managers' use of fertilizer vary differently. Female plot manager's exhibit enthusiasm and readiness to use fertilizer on their plots, however, the rate of usage is impeded by males (Peterman et al., 2013). In contrast, Kazianga and Wahhaj (2013) found no difference between plots managed individually by males and females regarding fertilizer use in Burkina Faso.

2.4.3 Gender specific knowledge on soil conservation practices

In sub-Saharan Africa, soil conservation is essential in protecting the environment and helping increase farmers harvest for improved and sustained living standards (Druschke and Secchi 2014). According to Ghazani and Bijani (2016) environmental sustainability can be achieved when efforts are put in place to stop or reduce land degradation. Similarly, Azizi Khalkhili et al. (2012) reported that improper use of land is a vital factor impacting negatively on national security and food production. Most soils in developing countries are impacted negatively and rendered unproductive following the high levels of land degradation (Mahboobi and Sepehrara 2013)

Climate change is affecting agriculture and farmers' activities play a central role in global warming (Rurinda, 2014). Farmers who are aware of the negative impacts of some practices on the environment are more likely to be cautious in the farming activities they adopt (Makate et al., 2017; Nyangena & Juma, 2014). Building awareness can therefore motivate action for sustainable agriculture practices that present win-win scenarios. Local conservation knowledge stems from farmers experience in terms of their relationship with the environment and the observation of ecosystem services they depend on (Fazey et al., 2006 and Naah Ngmaadaba 2016). Farmers perception and knowledge about the natural resources are influenced by factors such as age and gender.

The gender of people for instance may influence their relationship with the environment and their perceptions and knowledge. Men usually have the most contact with the environment. Older farmers can more easily give information on environmental issues as compared to the younger generation. Peterman et al., (2010 and 2011) also observed that women have relatively low rates of adoption of drought tolerant maize varieties and other agricultural technologies due to low level of knowledge.

2.5 Heterogeneity of factors influencing land use change in the VEA catchment

2.5.1 Land use change dynamics

Land-use dynamics are a complex process that is largely determined by human decisions. Thus, human agents are major determinants of land-use change and major drivers of any social environmental system. The livelihood structure of human agents is worth investigating to identify heterogeneity and factors that are responsible for land-cover change. Heterogeneity in human population as determined through characterization of human agents causes the diversity in land-use decisions. A growing body of literature has demonstrated that human agent decisions are determined by several and different factors including resource endowment, cultural preferences and knowledge about the resources (Parker et al., 2008; Villamor et. al., 2011) with a direct link to the natural systems or environment. Understanding the background of the human agents is crucial, as it influences the pattern of land-use decisions by these agents (Soini 2006). It is therefore imperative to consider the key capitals such as social, human, natural, financial and physical capital when analyzing the heterogeneity in any human agent.

The principal components of multi agent system (MAS) modeling are the human decision makers, their physical environment and their interaction (Koomen and Stillwell 2007). The main difficulty is capturing the heterogeneity of the agents and their environment to depict the true heterogeneity of the “real world” (Brown and Robinson 2006). Farmers with varied livelihood typologies under diverse policy and environmental situation show diverse behavioral patterns concerning their land-use choices if there is a direct relationship between the socio-economic characteristics of farmers, biophysical environment and land-use choices.

2.5.2 Socio-economic characteristics

2.5.2.1 Livelihood and income

About 30% of the poorest population in Ghana comes from Northern Ghana (Upper West, Upper East and Northern). About 70% of the inhabitants in these regions are poor according to the definition of the national poverty line whereas the national average is estimated at 27% (GSS 2000). About 58 % of the population in the Bongo district and 51 % of the population of the Bolgatanga municipality depend on agriculture as their main source of livelihood in the region (GSS, 2007 and Sissoko et al.,2011) Guinea corn scientifically referred to as *Sorghum spp* and Millet known as *Pennisetum spp* are the major cereal crops found in Upper east region (Gyasi et al., 2008). The millet cultivars (short season "Naara" and long season "Zia") adapt well to the climatic conditions of the area and are usually ready for harvesting (Figure 2.2) in July, November or December (Stanturf et al., 2011). Millet is the least risky crop in terms of climate induced fluctuations in yield followed by sorghum (Stanturf et al., 2011), hence their contribution to food security is enormous.

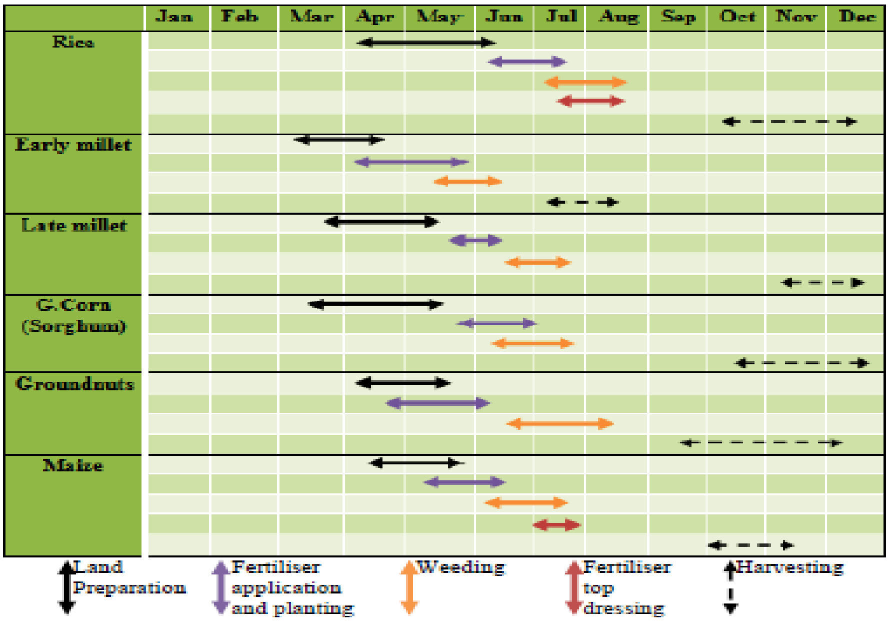

Figure 2.2: Cropping calendar of selected food crops in UER, adopted from Gyasi *et al.*, 2006.

The season for crop production starts in May and ends in October. This is followed by the dry season where there is a limited amount of irrigation farming around the Vea dam and other small dams in the catchment. The farm products are mainly for household consumption with a limited amount sold to generate income for the household. The income is put into various uses such as purchasing of farm inputs for the following season, for household expenses or other non-farming activities. High crop failure and income losses result from erratic rainfall, frequent droughts/floods and to some extent from poor access to markets (Sissoko *et al.* 2011 and Antwi-Agyei *et al.* 2012).

Livestock production is one of the livelihood strategies adopted to guard against crop failures (Barrett *et al.* 2001). Animals that are commonly reared include cattle, sheep, goats, poultry and guinea fowl. The Environmental Protection Agency (EPA 2003) reported that in the three regions (Northern, Upper East and Upper West), which constitute the northern savannah zone of Ghana, 43.4%, 36.4% and 74.4% of the national cattle, sheep and goat stocks, respectively, are to be found. Livestock serves as additional food for the families and are also used for rituals especially in the case of fowl (Callo-Concha et al. 2012). Deng (2007) reported that the cow dung serves as a rich source of manure for improving the fertility of soils on the farms in the area.

Migration to other parts of the country in search for jobs during the lean season is a common livelihood option in the region. Accra and Kumasi are the major destinations of the migrants where they provide labor in cocoa farms or engage in manual jobs (Adepoju 1977, Cordell *et al.* 1996). The rate of outmigration in 2000 was estimated at 22.2% (Ghana Statistical Service, 2005). Although permanent migration is considered a disadvantage as it leads to shortage of labor during the farming season, such migrants send remittances to support their families (Wouterse and Taylor 2008).

2.5.2.2 Cropping systems

Farmers in the Vea catchment practice rain-fed and to a small extent irrigated agriculture. They are mostly small-scale operators. Food production is carried out in nearby bush areas and around the hamlet (Laube, 2007). On average, each household has more than one field with one situated close to the house and the other some kilometers away from the hamlet. The land area for food production is generally small due to the use of rudimentary tools for farming and the low level of mechanization (Nin-Pratt *et al.,* 2011). About 70% of the farms in northern Ghana range between 0.5 ha and 2 ha in size (Eguavoen 2008). Yields in the study area are generally low, partly due to the low level of investment in inputs such as pesticides and fertilizers (Ouédraogo *et al.* 2001).

The traditional cropping system in West Africa is shifting cultivation (Callo-Concha et al., 2012). This is a system where a piece of land is put under fallow for a period of time to replenish the fertility of the soil. This is then followed by a period of cultivation. Igue *et al. (*2000) and Kanchebe (2010) reported a reduction in the fallow period in areas where shifting cultivation is practiced due to fragmentation and scarcity of land. Intercropping, a system where multiple crops are cultivated by farmers on the same piece of land on an annual basis, has become more common than shifting cultivation owing to the rapid population growth and increasing pressure on land (Ouedraogo *et al.,* 2010; Bado *et al.,* 2012). The unpredictable nature of the rainfall pattern coupled with the farmers' insurance against crop failure by cultivating multiple crops on a piece of land are two of the reasons for intercropping (Owusu *et al.,* 2008 and Ibrahim *et al.,* 2014).

Intercropping is the main cropping system in the study area. The various types of intercropping include cereal-legume (e.g. sorghum, cowpea), legume-legume (e.g. Bambara beans and groundnut) and cereals (e.g. sorghum and millet). The maturity period for crops grown in the region is between 120 and 180 days (Dixon et al., 2001). The main staple foods are sorghum, millet, rice and maize. Rice and maize are normally sold to generate income for the household whereas sorghum and millet are produced mainly to meet the household consumption needs. In order to meet the food requirement of households, early-maturing millet, which takes only two months to mature, is usually intercropped with sorghum and in some cases with late-maturing millet. Rice production is carried out close to the Vea dam and in inland valleys with irrigation due to its high-water requirement. Upland rice cultivation is also common in the catchment. The main cash crop is groundnut, which is mostly intercropped with bambara beans and cowpea. The cost of producing groundnut is low because it does well in all kinds of soil and does not require fertilizer. The Irrigation Company of Upper Region (ICOUR) is the organization responsible for the Vea and Tano irrigation facilities for farmers who want to carry out irrigation farming. It is mandated to provide farmers with land and inputs on credit, and the money is repaid at the end of the production season.

2.5.2.3 General land-use composition of male- and female-headed households

The characteristics of land cultivated by male-headed households and female-headed households vary, especially in areas where property ownership is the responsibility of the man (Fisher and Kandiwa, 2014). On average, the land cultivated by a male-headed households are larger than for female-headed households. Female farmers cannot compete with men for land because the land given to them is voluntary and mostly of low fertility. In some areas, the land available to male farmers is thrice the size than that of female farmers. This has compelled females to resort to certain categories of cropping systems (Ndiritu et al., 2014). For instance, in many parts of Africa, cash crop farming is mostly associated with male farmers. This is because the females are only supposed to farm for their sustenance (Alwang et al., 2017; Mishra & Sam, 2016; Kiptot et al., 2014). Access to credit is also a challenge due to the need for a collateral security and land is mostly used as collateral especially in rural communities. Female farmers cannot use their land because of lack of ownership.

Male-headed households also cultivate more lands than female headed households. Access to labour is a contributing factor. In rural communities, the common way to access labour is through communal activities. This involves local farmers coming together to work and rotate farms to ensure everybody benefits (Nyantakyi-Frimpong, 2017). It is observed that community people come out in their numbers to work for male farmers but not for their female counterparts. In northern Ghana, male-headed households cultivate most of the rice, millet, groundnuts and sorghum rather than female farmers. This is because these crops are categorized as cash crops in the area and access to labour and land give men the opportunity to cultivate such crops in larger quantities (Abdul-Razak & Kruse, 2017; Nyantakyi-Frimpong, 2017; Kuivanen et al., 2016).

2.6 Gender roles and access to agricultural resources

In the UER of Ghana, women play an important role in economic growth and poverty reduction through their active engagement in agricultural activities. However, little is known about the extent of their productive roles in agricultural livelihood activities in the region. A few studies have examined the changes in gender-specific roles with respect to changing agricultural activities in other parts of the world (DeFries et al., 2010; Villamor et al.; 2014a, Villamor et al., 2015). There is, however, little information on gender roles with respect to changing agricultural activities in the UER of Ghana.

2.7 Gender-specific productive roles

In general, productive tasks in rural households are classified under three main categories: 1. Productive roles that give rise to the goods and services used by the households 2. Reproductive roles that deal with bringing up children and upkeep of the family 3. Social/community roles that cater for social and community responsibilities and basically has to do with the general well-being of the people (Peter 2006; Villamor et al., 2015). Table 2.1 presents the various roles base on the above three categories.

2.7.1 Customary gender-differentiated roles in agriculture- related activities

Women are compelled to combine their reproductive and domestic roles such as cooking, fetching water, collection of fuel wood, child care, sale of cooked food and cooking with their regular farming activities (Duncan 2004). In effect, women tend to be more burdened than men whose workload is mostly restricted to their productive roles.

The contribution of women in the UER and Ghana to agricultural production for the household and the rural economies cannot be overemphasized. Over the years, women's roles have evolved due to the change in demand as well as in the rural economies in which they are situated. Traditionally, different roles are ascribed to men and women in the rural agrarian economy of Ghana, where women used to be seen merely as wives of farmers, and their contribution to agriculture was ignored. Furthermore, the multiplicity of women's roles, which include child birth and taking care of the children and the husband while at the same time processing the spouse's farm produce for the market, makes them overburdened and impoverished (Grieco 1997). In addition, activities such as fetching water and firewood are the sole responsibility of women making it impossible for them to attain their productive potentials. However, women, especially in female-headed households, are now assuming greater responsibilities in terms of providing for their children's educational and material needs when their husbands migrate to urban centers in search of greener pastures. In general, female-headed households in rural Ghana constitute about 20 % of all households with 11 % of the female-headed households located in the UER in Ghana (FAO 2012).

2.7.2 Traditional agricultural systems and gender-specific roles

Agro-pastoralism is the main practice in the UER of Ghana (Eguavoen 2013; Yembilah and Grant 2014). The farming system is predominantly subsistence oriented. Rain fed agriculture is the main source of livelihood in the area although dry-season (irrigation) farming is also common in communities that are located close to the Vea dam. Traditional cereals such as sorghum (*Sorghum vulgare)* and millet (*Pennisetum americanum*) are the basis for the agricultural system in the farmers' environment (Villamor & Badmos, 2016). Cultivation of traditional cereals is normally carried out around the compound and is continuous with soil enrichment through the application of crop residues, animal manure and compost (Gonzälez-Estrada et al., 2008). Groundnut (*Arachis hypogea*), either mixed or as monoculture, is grown within the compound or at some distance away from the homestead (Villamor & Badmos, 2016). Groundnut is the major leguminous crop cultivated together with other crops and is important in meeting the protein and financial requirements of the farmers as well as serving as fodder for livestock (Marfo 1992; Slingerland 2000; Ntare et al., 2007). Poisonous aflatoxins are the main challenge in groundnut production due to their harmful effect on human health. Cowpea (*Vigna unguiculata* L.) and Bambara beans (*Vigna subterranean)* are other common legumes cultivated in the area with the latter being used to define farm boundaries (Marfo 1992). Millet is the main staple food crop in the study area and has two common varieties namely early millet (*Pennisetum spicatum*) and late millet (Pennisetum glaucum). Both cultivated by farmers to reduce the risk of crop loss as a result of bad weather during a growing season. Sorghum (*Sorghum bicolor*) is another cereal that is commonly cultivated by many farmers due to its ability to withstand drought and can survive in areas that are too dry for maize cultivation. Maize (*Zea maize*) is an important part of the traditional agricultural production system in the region. It is mostly intercropped with leguminous crops such as cowpea and groundnut in order to improve soil fertility through nitrogen fixed by the legumes.

Livestock and poultry production also constitute an important component of the livelihood structure of the farmers to supplement both income and nutritional needs of the households. The most common livestock and poultry in the area include goats, sheep, cattle, guinea fowls, pigs, ducks, chickens and donkeys. Cattle ownership is considered in the region as a measure of wealth and social status (Yilma 2005) and is often used to pay bridal dowries (Villamor & Badmos, 2016).

In general, the nature of the cropping systems in the region is characterized by low output and decreasing productivity, labor constraints, low use of inputs such as improved hybrids and fertilizers, poor communication and transportation systems, and poor extension services (Ntare et al., 2007; Kpongor 2007; Schindler 2009).

Table 2.1: Three main categories of gender roles

1. Productive role	2. Reproductive role	3. Community role
Clearing land	Collecting firewood	Community meetings
Planting crops	Fetching water	Church meetings
Planting trees	Preparing meals	School buildings, bridges, etc.
Feeding livestock	Taking care of children	Cleaning public spaces
Weeding	Washing clothes	Afforestation
Fertilizer application	Cleaning house	Community beautification
Applying pesticides/herbicides	Children's expenses	Adopting conservation measures
Watering/irrigation	Household budgeting	
Producing seedlings	House construction/maintenance	

Pruning trees	Child bearing
Harvesting crops	
Harvesting fruit trees	
Hauling crops	
Selling crops	
Farm finances	
Purchasing farm inputs	
Maintaining farm records	

2.8 Gender and land tenure linkages in adaptation to climate change

Climate change has become a major issue globally with reported projection of serious impact on all sectors especially the agriculture sector, with implications for smallholder farmers and their families, in terms of poverty and food security (IPCC, 2014; Schlenker and Lobell, 2010). A report by Boko et al. (2007) indicated that the low adaptive capacity of Sub-Saharan Africa to climate change makes the region very vulnerable. Christensen et al., (2007) reported that West Africa is projected to have severe droughts resulting from drier conditions in the region. The vulnerability of the region to climate change is attributed to over-reliance of rural economies on rain-fed agriculture (FAO 2003; Commission for Africa 2005; Thornton et al., 2011), thus worsening food insecurity and poverty conditions of smallholder farmers (Lobell et al., 2008). A report by the Environmental Protection Agency (2007) of Ghana indicated a general increase in temperature and decrease in precipitation across all agro-ecological zones in Ghana. Apart from climate change, political, environmental, economic and social factors all have implications on Ghana's development and thus can support or undermine the fight on eradicating hunger and poverty (O'Brien and Leichenko, 2000).

Access to land is vital and one key factor of production in economic terms. Ownership of land also shows one's status, power and wealth in many communities (FAO, 2011). Research in this area is therefore crucial especially for West Africa and particularly Ghana where land is controlled under a complex customary system (Toulmin and Quan, 2000; Fenske, 2011). In Ghana, two main types of land tenure arrangement exist, being, the state/public and customary/private. Public lands can be compulsorily acquired by the state through the invocation of the necessary legislation (Lands Commission Act, 2008, (Act 767) and the State Lands Act, 1962 (Act 125). The Head of state is the only one who can exercise the right to compulsorily acquire certain lands for public use (Obeng-Odoom, 2014). On the other hand, customary lands are managed by Heads of families who double as traditional rulers with Lands Commission having an oversight responsibility over them (Yaro, 2010).

Acquisition of land for farming and other activities in the region is basically through the customary system (Antwi-Agyei et al., 2015). The different forms of acquiring land in the study area for farming activities include the following:

a. Family land - Family male heads are recognised as the custodian of lands under the customary land tenure system. The family heads ensure that every member of the family receives a fair share of land for their livelihood activities. Lineage, membership/ community, the first occupants of the land, ownership through continued use, status (nobles/commoners/captives; founders/allies/outsiders), age and gender are factors that guide customary land access (Kasanga, 2003).
b. "Leasehold- These are user rights granted to farmers to use land over a specified period based on an agreed rent" (Ministry of lands and forestry 2003). Leasehold title varies between 1 and 99 years.
c. Community/skin land- These are lands that belong to a community with skin as the traditional emblem of the souls of ancestors who originally owned the skin and therefore the land (Gambrah 2002). Accordingly, this land is administered based on the principles of customary or native law where the chief of the community administers the land on behalf of his subjects (Gambrah 2002).
d. Rent: A form of customary tenancy where an agreed amount of money is paid to the landlord in order to obtain use rights usually for a short period (1-5 years) after which the land revert to the owner if no further agreement is made.
e. Land from the chief: apart from community lands that are managed and administered by the chief on behalf of his subjects, the chief grants other share cropping contractual agreements. Lands with such tenancy agreements are

owned and managed by the chief in his own interest. The proceeds are therefore used for the upkeep of his immediate family.

f. Land from friends: This is a customary tenancy agreement in the form of share-cropping granted by friends. The farm produce is shared based on a contractual agreement.

The type of land ownership arrangement that exist may influence the type of management systems associated with different tenants (Kleemann et al., 2017; Antwi-Agyei *et al*., 2015). Farmers who own family land are more likely to engage and invest in agro-forestry as an adaptation strategy (Etongo et al., 2015).

Access to land by female farmers in the region is a major challenge due to social-cultural discrimination. The inability to secure tenure security has implication for agricultural development, climate change adaptation as well as food security in the region. According to Ibnouf (2011), women contribute substantially to food security and household income. For example, a report by the Social Watch Coalition in 2010 cited by Glazerbrook (2011) states the contribution of women to household food security is about 87% of the total food produced especially at the household level in Ghana. This is so because traditionally the burden of household management is largely shouldered by women who mostly provide food for the household.

2.9 Conceptual framework

Most landscapes provide several functions (de Groot, 2006) and have multiple functional uses. These functions (production, habitat, regulation) provide the goods and services that support mankind (Costanza et al 1997; Daily et al 2000; Millennium Ecosystem Assessment 2003). According to Norberg and Cumming (2008), decisions on how to manage these natural resources are closely linked to system dynamics. The diverse components within the socio-ecological systems are important for its overall functioning and performance. Figure 2.3 present a basic social ecological system framework. Empirical examples of how diversity matters in ecological systems are well documented and growing. However, very few examples in the literature are available that exemplify diversity in social systems including its possible feedback to both systems (diverse human behaviour affecting biophysical processes). In social systems, the steps involve in making alternative decisions entail analysing information about the outcomes of various alternatives (i.e., preferred or valued goods and services). Decisions, as the outcome of processing information involve (as simplification): 1) available options; 2) potential outcomes; and 3) experiences. What makes the decision making so complex is that there often are many available options and potential outcomes, and varying experiences of different decision makers. Multi-functionality of landscape may depend on the differentiated roles between males and females (Villamor et al. 2014), for example of gender differentiated preference of goods and services.

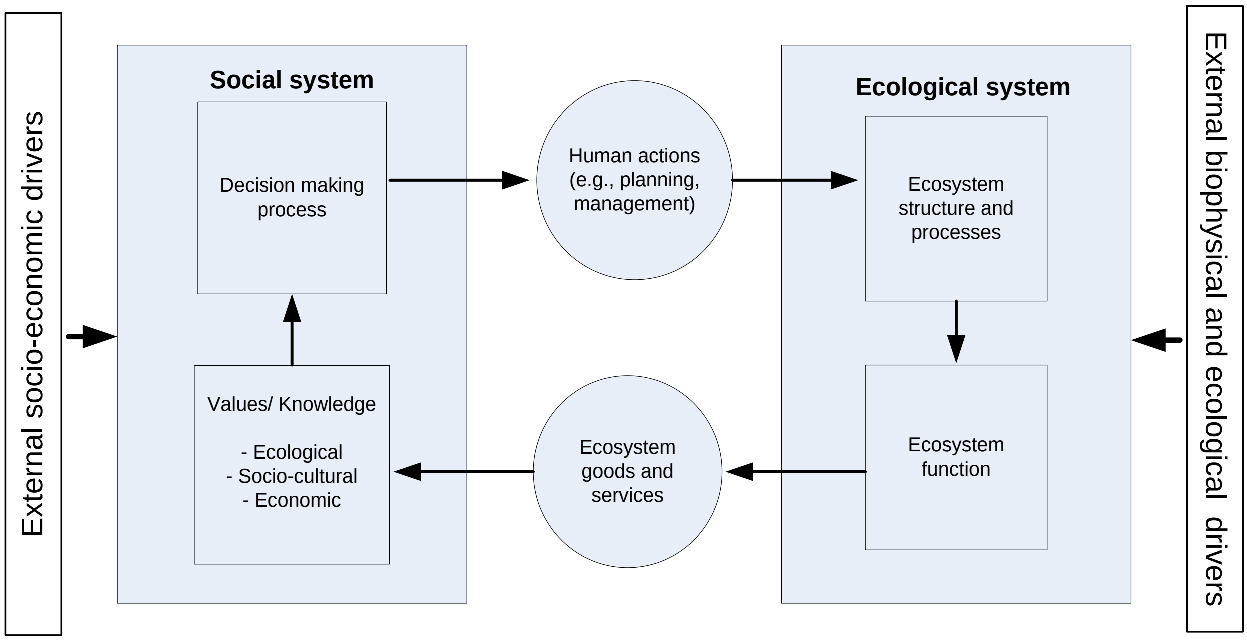

Figure 2.3 Basic socio-ecological systems framework

The socio-ecological system framework is to assist in understanding how gender influences the efficacy and sustainability of food production under climate change. The growth and development of the social system depends on the natural resources (ecological system) and vice versa. Thus, there is an interrelationship between social and ecological systems. The decision on sustainable use of natural resources can be influenced by the control of resources (land and income) and gender. The decision and management processes of male and female landholders on sustainable use of natural resources while engaging in food production may be different and these decisions may have consequence for the environment. The framework thus helps to understand this relationship.

3 MATERIALS AND METHODS

3.1 Introduction

This chapter discusses the materials and methods of data collection and analysis that were used for the study. Specifically, it discusses the study area, research approach and data collection procedures. It further presents the conceptual models and data analysis procedure for the specific objectives independently.

3.2 Study area

The study was carried out in the Vea catchment located within Bolgatanga municipality and Bongo district of the UER of Ghana (Figure 3.1). The Vea Catchment which has a total land area of about 301 km^2 is bordered to the north by Burkina Faso and to the east by Togo. The catchment is bounded by latitudes 10^0 45’ 44” to 11^0 0’ 49” and longitudes 1^0 0’ 3” to 0^0 45’ 17”. A larger portion of the region is situated within the semiarid West African savannah belt except for a small stretch of land in the north-eastern part of the catchment that belongs to the Sudan savannah (Adu, 1972). The UER falls within the White Volta basin with an estimated land area of about 8,842 km^2 which represents 3.7% of the entire land mass of Ghana (GSS, 2012). The region is made up of nine administrative districts namely: Kassena-Nankana East, Kassena Nankana West, Bawku Municipality, Talensi-Nabdam, Bawku West, Bongo, Garu Tempane, Bolgatanga municipality and Builsa Districts (GSS, 2012).

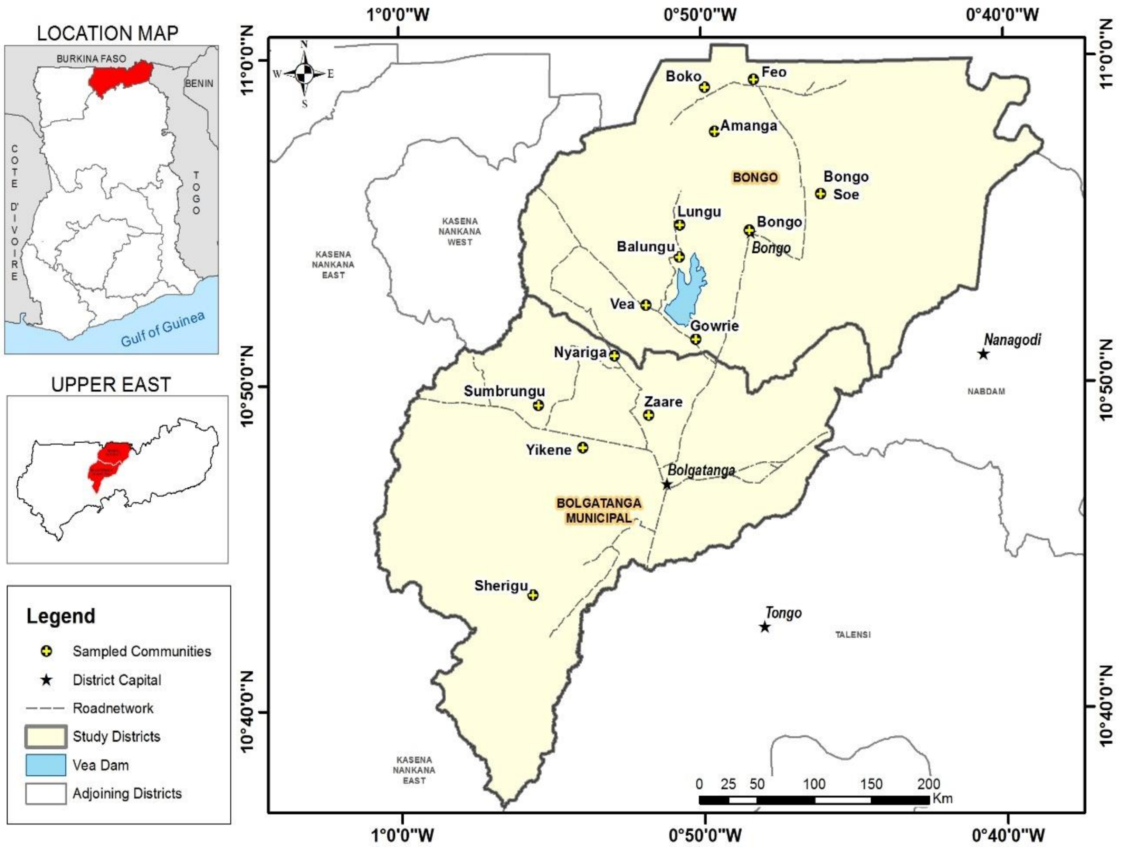

Figure 3.1: Map of the study area

3.2.1 Demography

According to GSS 2012 report, the population of UER is estimated to be 1,046,545 (506,405 males and 540,140 females), representing 4.2 % of Ghana's population with a density of 118 km^{-2} and an annual growth rate of 1.2 %. The region is about 79 % rural with an average household size of 5.8 people (Figure 3.2). Population density of the region exceeds the country's average population of 103.4 km^{-2} (GSS, 2012).

There are diverse ethnic groups in the study area (Bolgatanga and Bongo district) (Naah Ngmaadaba, 2016). These comprise of Akan, Ga-Dangme, Ewe, Garu, Gurma, Mole-Dagbon, Grusi and Mande. Table 3.1 presents the ethnic composition in the study area according to Ghana 2010 population and housing census. Mole-Dogbon is the predominant ethnic group (86.3% in Bolgatanga municipality and 98.1% in Bongo district) with the least being Ga-Dangme (0.3% in Bolgatanga municipality and 0% in the

Bongo District). According to the GSS (2010) there are more females (51.6%) than males (48.4%) in the region.

Table 3.1: Major ethnic groups by District (%)

Ethnic group	Bolgatanga Municipality	Bongo District
Akan	2.2	0.3
Ga-Dangme	0.3	0.0
Ewe	0.9	0.0
Garu	0.7	0.0
Gurma	3.9	1.3
Mole-Dagbon	86.3	98.1
Grusi	3.0	0.1
Mande	0.6	0.1
Total population	126,620	82,611

Source: Ghana Statistical Service, 2010 Population and Housing Census

3.2.2 Socio-economic activity

According to GSS (2010), the main economic activities in the region are agriculture, forestry and hunting. Agriculture is the predominant economic activity employing about 80% of the economically active population. Cereals production (maize, guinea-corn and sorghum) is the main crop cultivated however, groundnuts, beans and dry season tomatoes and onions are also cultivated. There are two main irrigation projects in the region for dry season farming. These are the Tono and Vea irrigation projects with catchment area of 850 and 2,490 hectares respectively. Small scale agro processing (rice and groundnut) and handicraft are income generating for the active population. Similarly, farmers are also into the production of livestock (sheep, goats, cattle and pig) and poultry, which serves as source of security, income and nutritional needs of the household. In most cases, livestock are kept under three main management system, which comprise of intensive, extensive and semi-intensive. However, the greater percentage of the livestock are kept under extensive system of management. In 2013, the nominal GDP (Per capita) of the region was $2,500.

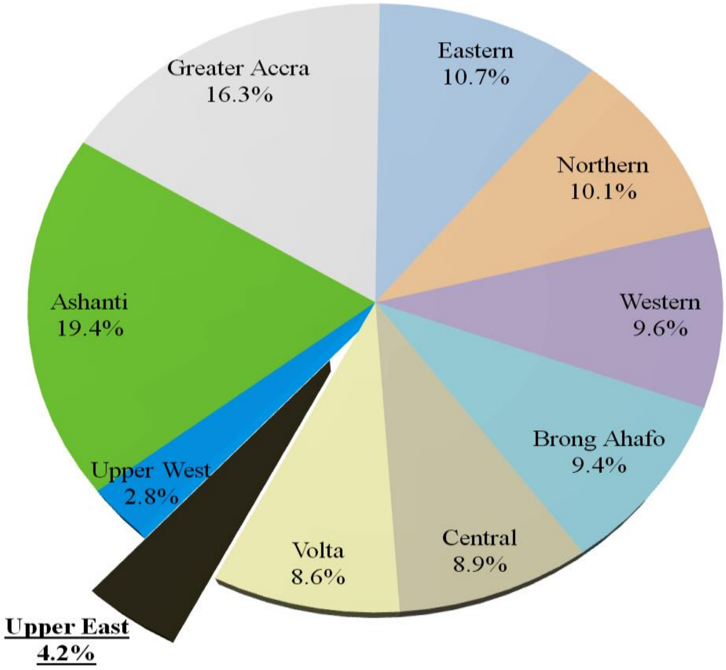

Figure 3.2: Percent population of Ghana by region (GSS 2012)

3.2.3 Climate of the study area

Vea catchment is located within the Sudan-Savannah climate zone, which has high temperatures and a mono-modal rainfall distribution (Fig 3.3) (Forkour 2014). The rainy season has a duration of 5 months (May – September) when most farming activities take place whereas the dry season last for 7 months (October – April) (Martin 2005; Schindler 2009;). South – west monsoon winds from the Atlantic Ocean during the rainy season produce humid and wet conditions that approach their maximum northern extent in the month of August whereas the north-east trade winds from the desert ('Harmattan') which occur in the dry season produce warm, dusty and dry conditions with their maximum southwards extent January (Yaro 2000; Schindler 2009). Over the last 30 years (1985 – 2014), the hottest dry period is experienced between March and April and the coolest rainy season in August (Figure 3.3). The mean annual rainfall over the 30-year period was 1031 (±144.63) mm and 29.0 (±0.34) ^{0}C for temperature.

The relatively short duration of the rainy season coupled with the highly variable onset and intensity results in high inter annual variation in farming outcomes (IFAD, 2007).

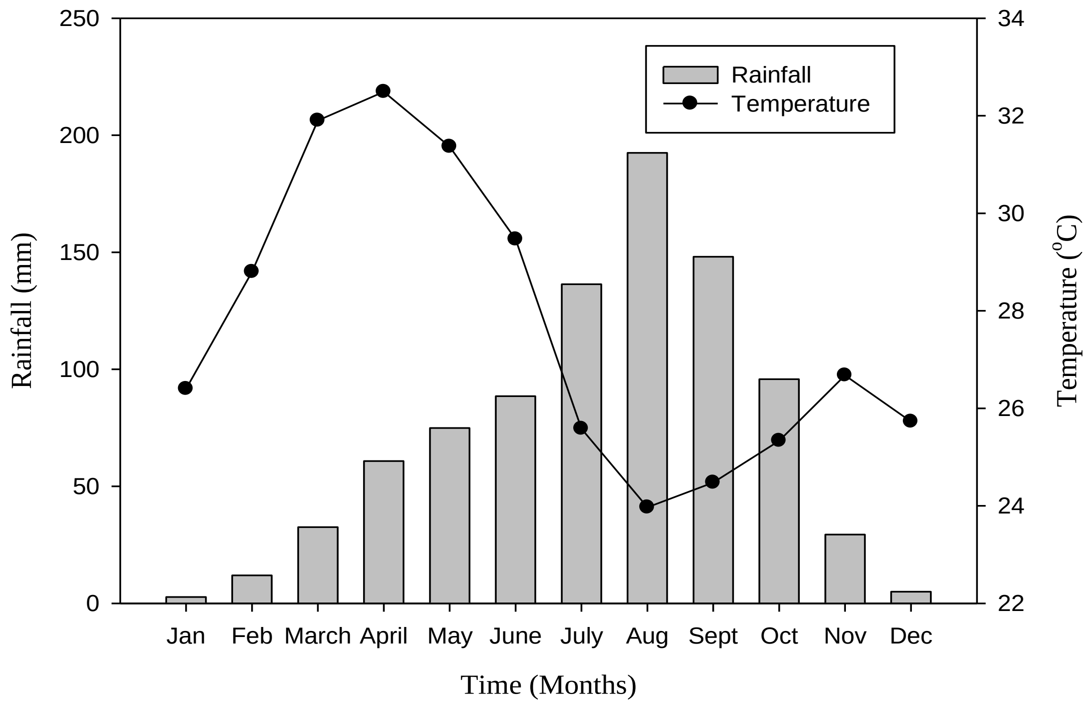

Figure 3.3 Annual mean temperature and rainfall pattern in Upper East Ghana over a 30-year period (1985 – 2014). Source: Ghana Meteorological services Department

3.2.4 Topography

Farr and Kobrick (2000) indicated that the elevation of the Vea catchment is relatively flat and less than 300 m with a slope of about five degrees and characterized by inland valleys. Rock outcrops are found in the eastern (known as Bongo granite) side of the study area (Forkour 2014)

3.2.5 Geology

The geology of the area (Vea catchment) is made up of Birimian rocks of Paleoproterozoic age, which is common for the West African craton (Wright et al. 1985, Forkour 2014). These rocks cover the larger part of the country and are made up of schist, gneiss, phyllite, migmatite and granite (Gyau-Boakye and Tumbulto 2006).

3.2.6 Soils

There are four soil classes (lixisol, fluvisol, leptosol and luvisol) in the study area (Badmos 2015). Lixisol and leptosol are further divided into three sub categories making a total of eight soil classes (Figure 3. 4). Soils that developed over granites and sandstones consist of subsoils that vary from coarse sandy loams to clays with a variable quantity of gravel, and top soils that are different in texture ranging from coarse sand to loam. The soils over basic rocks including the valley bottoms consist of heavier top and subsoils (Adu 1969)

Lixisols are characterised by low organic matter content with a sandy loam to sandy clay loam composition and are highly weathered. According to WRB (2006), lixisols have a high amount of clay in the subsoil but with a lesser amount in the topsoil and a low level of available nutrient for plant growth, hence the need for chemical fertilizer to improve crop yield. Organic matter content in West African soils are generally low mainly due to the culture of burning vegetation coupled with crop residue removal for other domestic uses (Batiano *et al*. 2011).

Fluvisols are found around inland valleys and are prone to water logging during the wet season as a result of high clay content but are suitable for rice production (Forkour 2014). Leptosols are in the upland areas of the catchment and are generally shallow with a large proportion of gravel (Martin 2006). This type of soils is suitable for crops such as millet.

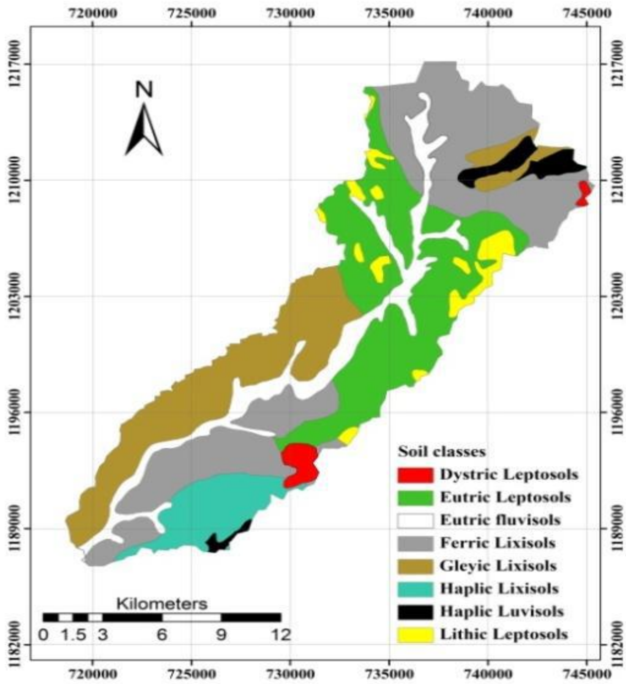

Figure 3.4: Soil classes in Upper east Ghana (Badmos 2015)

3.2.7 Vegetation

The vegetation falls largely within the Sudan-Savannah agro-ecological zone of Ghana with short, drought and fire-resistant deciduous trees that are interspersed with open savannah grassland (Inusah et al., 2015). The region along the southern limits falls within the guinea savannah and grades to Sudan savannah at the upper part of the escarpment (Blench 2005). Figure 2.5 shows the seven ecological regions of Ghana. EPA (2003) indicated that guinea savannah covers an estimated land area of 14,900 km^2 consisting of northern two thirds of Ghana whereas Sudan savannah covers an area of 1, 900 km^2. Common tree species in the region include kapok (*Ceiba pentandra*), shea (*Vitellaria paradoxa*), and locust-bean 'dawadawa' (*Parkia biglobosa*) (Naah Ngmaadaba 2016). Indigenes keep these trees for their economic and social values (Schindler, 2009). Perennial grass such as `Elephant Grass` (*Pennisetum purpureum)* that are very sparse and serve as ground cover can also be found with most areas looking bare and seriously eroded (Quansah et al., 2015). White thorn (*Faidherbia albida*) and baobab (*Adansonia* *digitata*), mango (*Mangifera indica*) and neem (*Azadirachta indica* are other dominant tree species in the study area (Blench 2005).

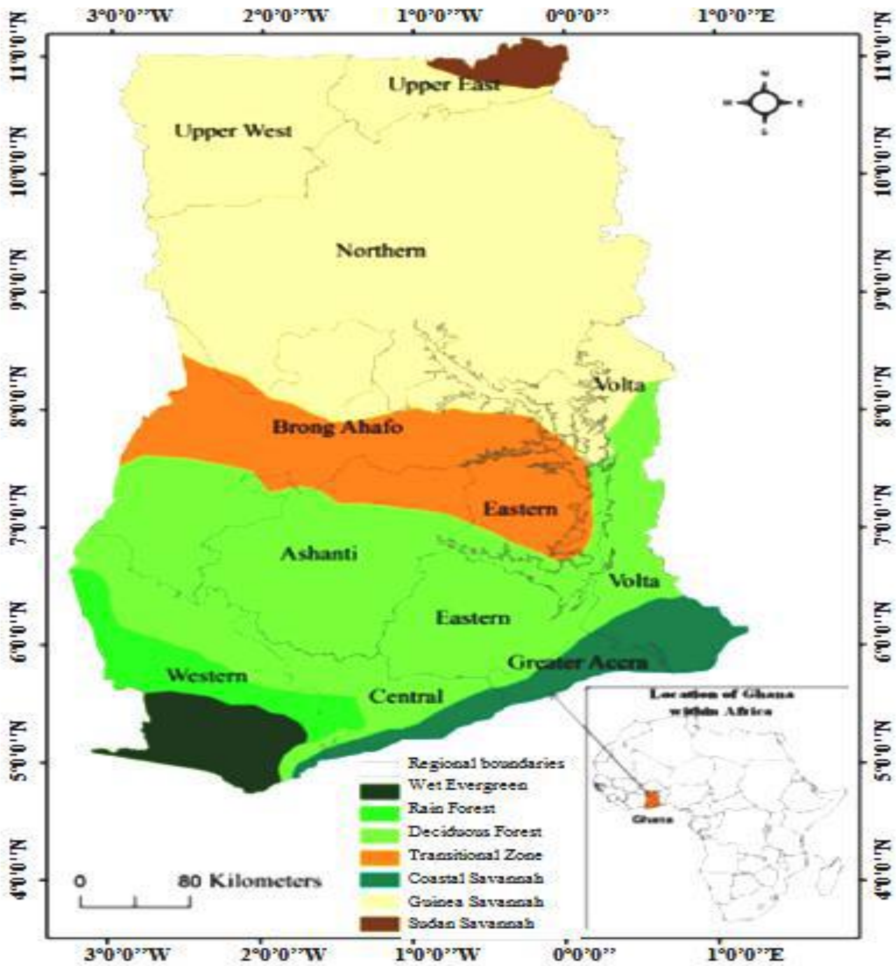

Figure 3.5: Regional map of Ghana indicating the seven Eco - regions of the country (Antwi et al. 2014)

3.3 Data collection procedure

A household survey was conducted between August and December 2014 using a pre-tested questionnaire where 150 males and 150 female farmers were randomly sampled from Bolgatanga Municipality and Bongo district of the Upper east region of Ghana using the random sampling method. A total of 14 communities were randomly selected out of which seven (Sumbrungru, Sherigu, Yikene, Zaare, Nyarega, Vea and Gowrie) were located in Bolgatanga municipality and seven (Lungu, Bongo, Balungu, Bongo Soe, Amanga, Feo and Boko) in the Bongo district. Data on male- and female-headed households were obtained from the Ministry of Food and Agriculture offices at both Bolgatanga municipality and Bongo district. Farmers were interviewed by trained research assistants under supervision to guarantee accuracy of information gathered. The two districts were selected to represent agricultural activities in the catchment given the presence of Vea dam that allows farmers to produce crops all year round. Structured and unstructured questionnaires were employed for the survey. Data collected during the survey covered farmers' socio-economic and demographic attributes, cropping and livestock production as well as their accessibility to climate information. Temperature and rainfall data were obtained from Ghana Meteorological service department in the region.

Information on farmers' household characteristics and their perception of climate change were gathered during data collection. The household questionnaire was divided into four parts: 1) social relationship and family condition (i.e., household size, educational level, age, labour availability, gender, etc.); 2) land access/tenure, and situation of farmlands; 3) perception of climate change and variability, observed changes, drivers and impact of the change on livelihood activities according to gender; and 4) adaptation strategies to mitigate the impact of the climate changes and challenges.

Furthermore, soils were randomly sampled at different depth (0-15 cm and 15 – 30 cm) from farmers' fields for laboratory analysis. Farmers' fields with organic fertilizer, inorganic fertilizer and fields where no fertilizers were applied during the research period were selected for the following physical and chemical analysis (parameters): total N (%), available P (ppm), available K (mg kg^{-1}), pH, CEC (cmol (+) kg^{-}, Organic C (%), EC (μScm^{-1}), OM (%), Sand (%), Silt (%), Clay (%). Farmer knowledge on soil conservation practices were also determined through interviews.

3.3 Grazing game as a learning tool for adaptive strategy in response to climate variability by gender specific groups

3.3.1 Conceptual model of the role-playing game (grazing game)

The “over-grazing game” which was developed in 1984 by Van Noordwijk with the main purpose of teaching university students was modified and used for the study. The game aimed to expose activities of local farmers that result in land degradation through overgrazing and desertification as well as to better understand the indigenous knowledge, farmers’ behaviour and adaptive strategies in the study area (Vea catchment). The game was modified to understand the coping strategies of individual farmers and to reflect the existing situation of the upper east region. The modified version of the grazing game combines conditions of low rainfall on which agriculture production is highly dependent with other determinants that bring flexibility and complexity into the game (Villamor and Badmos 2016). The key assumptions were based on prior research carried out in the study area in terms of the erratic rainfall, inter-annual variability distribution and amount (Villamor and Badmos 2016, Van der Geest and Diez 2004; Amikuzino). The game was modified by disaggregating participants according to gender and creating more rooms to accommodate additional crops and a simplified score sheet.

The modified version of the conceptual model adopted from Villamor and Badmos (2016) is presented in Figure 3.6. It represents the actors such as farmers and markets; processes such as reproduction and regrowth of grass; resources such as grass, patches of land and rainfall; and strategies such as keeping cows, selling cows, or relocating the animals to a valley where more feed is available during the dry season or to an upland in the rainy season. Crop production and cattle rearing on subsistence basis within the area is a major source of economic activities for the local farmers (Villamor and Badmos 2016). The game process entails grass development cycles based on rainfall: i.e. more rainfall promotes grass, shrubs or bush development/growth and increases cow reproduction and less rainfall inhibits grass growth, thus reducing cow reproduction. The indicators in the conceptualized model that are monitored include total number of cows produced, total number sold, and the increase in the number of herds after reproduction. Arrows shown in figure 3.6 represent decision strategies regarding grazing management, marketing and maintenance of cows. The term “cows” was used throughout the game with the assumption that bulls were always available for reproduction purposes.

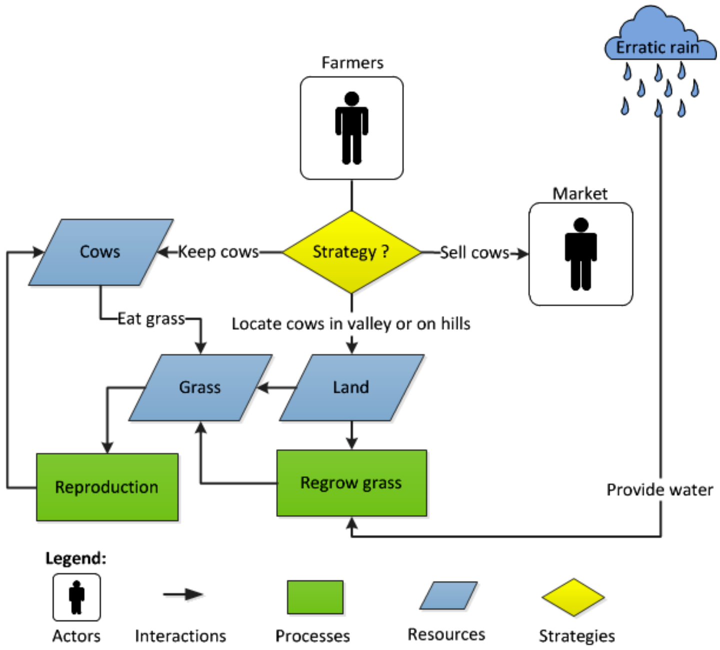

Figure 3.6: Conceptual model of the grazing game adopted from Villamor and Badmos (2016).

3.3.2 Specifications of the Ghana RPG (Grazing game)

A total of 44 games were played by 245 male headed households and 237 female headed households. The participants were selected based on interest to participate in the game and gender without taking into consideration other demographic characteristics. Participants of the game were subdivided into 22 women and 22 men in the catchment. The game employed an 8 × 8 grid board with each patch measuring 5 cm × 5 cm representing the entire farming landscape. The centre of the game board denoting a valley constitutes a total of 16 patches and this is assumed to contain water all year round. The amount of rainfall and grass growth is determined prior to every round of the game using the dice as shown in (Figure 3. 7). The amount of grass and crop available were represented by coloured pins. Three pebbles were used to represent herds. The Land patches were differentiated using coloured codes according to the type of land cover with green patches representing bush and red patches denoting desert (Figure 3.7). Score sheets were used to document the performance of individual players. The number of cows produced at the end of the season as well as the number sold were recorded using the score sheets.

3.3.2.1 Vegetation and rainfall

The amount of rainfall and thus the availability of grazing land in every year for each land patch in the game is determined using the dice. The amount of grass growth ranges between 1 and 6 marker (units). In an instance where a dice thrown shows five (5), every patch on the game board will be represented with 5 units of grass in that particular year of play. Every round of the grazing game constitutes a year. Each year comprised of dry and rainy seasons (two seasons per year).

3.3.2.2 Grazing rules

The game commences with one herd of cows which is made up of a total of 5 cows. Every cow requires 1 unit of pasture every month for good growth, development and reproduction. Herds can pass through 2 neighbouring fields each month. Grazing of animals usually starts in April and takes place in the middle (valley) of the board being used for the game which denotes a naturally moist environment in the study area. The next grazing takes place between the month of May and October in the upland area and grazing on crop lands are allowed only in November. Grazing in the dry season last from November to April. Cows could be fed on half ration if the grazing requirement is not met but reproduction will be impeded as well as the sales value. Crop residues such as groundnut, millet, rice and maize could be used to supplement the ration after harvesting.

3.3.2.3 Reproduction and sale

Cows that receive full ration for at least 6 months reproduce a new calf when the dry season is over. Players are allowed to sell cows when the rainy season is over and are willing to do so. The value of cows that have not been fed on one unit of grass in the past 6 months depreciate by half or 50 %.

Cows that are not fully fed over the previous 6 months have their value diminished by one half. Herds having 6 cows or more could be split into 2 sub herds to enable them to graze independently. If sub herds are reduced to less than 3 cows, they must be regrouped.

3.3.2.4 Regrowth of vegetation

At the end of first year, new rules were introduced to determine how the vegetation is influenced by rainfall:

- There is no growth of vegetation on a patch if no vegetation remains after every round of the game played
- Patches of land with 1 unit of vegetation at the end of the round grows slowly and takes time to recover. The value of every available grass under this circumstance is depreciated by half or 50 %. For example, 1 is equivalent to 0 markers or unit, 2 and 3 are equated to 1 marker, 4 and 5 are equated to 2 markers and 6 equals to 3 markers. These units or markers of grass are determined by the throw of the dice.
- The vegetation changes from grass to bush if 6 units of vegetation already exist on a land patch and the next throw of the dice records another 6

3.3.2.5 Players

There was no fixed number of participants for each game but the number per game was based on availability of participants. However, each game was played by a minimum of 5 and a maximum of 15 players. The game requires support from three people for effective and successful management. They include a game master, an observer who takes notes of the conversation of each round (one year) of the game and a game recorder to keep records of the event and serve as a moderator. Three research assistants who were native speakers and came from the area were engaged to facilitate the game, two men for monitoring the male-headed games and one woman for the female-headed games.

3.3.2.6 Session, steps and reflection of the game

A game session constitutes one year. At the onset, farmers could select 4 patches of land with respect to their choice of crops. This entails for example 1 unit of groundnut, 1 unit of maize, 1 unit of millet and 1 unit of rice. Players can graze animals on the other patches of their choice apart from the 4 selected patches for crops. The animals are only allowed to feed on the stover after harvesting in November. The purpose is to increase cow production through good management practices while avoiding desertification. The rules and objectives of the game were spelt out by the game master before the beginning of each session (one year). Each game was pretested to educate players and familiarize them with the rules.

Grazing of cows begins inside the valley for the first month of the year or round one and subsequently moves to the uplands. The game master announces the start and the end of both seasons (rain and dry season) of each game. The game master also announces the scores of all players to account for the number of bush and desert patches as well as the number of young cows reproduced. Players are given the opportunity to sell cows when the year ends as in many instances there is scarcity of feed at this period.

Players were asked to carry out an overall assessment of the game through a reflection exercise designed to understand the strategies and decisions made. The questions asked entailed the suitability of the game, if the game depicts a real-life situation, what local ecological knowledge can be acquired, the responsibility of the government toward farmers and how to improve on the game to reflect reality.

3.3.2.7 Game scenarios

The game scenarios which were introduced by the game master included the following: Introduction of additional household with on herd which has a total of 5 cows at the beginning of the third year in order to increase the population of the cows. This is to understand their responses to increasing population in an environment with limited natural resources couple with negative impact of climate change. According to the rule of the game, the additional household was expected to choose 4 new units out of 64 for rice, millet, maize and groundnut cultivation. The population-increase scenario was aimed at investigating farmers' responses to competition for scarce resources (i.e. patches of grass).

A fertilizer subsidy was introduced at the start of year 4 to rejuvenate the grass in the desert patches on condition that farmers reduce their stock (number of cows) by at least one cow. The purpose of the fertilizer subsidy was to explore farmers' responses (accessing the subsidized fertilizer) to local government initiative (fertilizer subsidy) of increasing crop productivity in a sustainable way and to reduce the pressure on the grass to allow for re-growth. According to Angelucci (2012), the fertilizer subsidy in the region was introduced in 2008 to motivate local farmers in adopting improved maize varieties. The game reverts to the original scenario (just like rounds 1and 2) at the start of year 5 where no subsidy is given (like round 1 and 2) and all farmers (both old and new comers) are allowed to participate in the game.

Figure 3.7: Game board and dice with the local farmers

3.4 Data analysis procedure for specific objectives

3.4.1 Analysis of survey data

3.4.2 Categorization of household agents

Household classification

The concept of sustainable rural livelihood framework was used to classify the households within the Vea catchment. This framework captures five core types of capital, which entail physical, social, financial, natural and human capital (Ellis, 2000; Campbell et al., 2001). These constitute all assets for determining sustainable development and poverty alleviation (Siegel, 2005). The reason for using this framework is to eliminate to a large extent the bias associated with the choice of indicators (Le, 2005; Villamor, 2012). The livelihood capital selected for the socio-economic survey include:

a. Natural capital: Land area cultivated, land area owned and land area per capita
b. Financial capital: Gross income per capita, gross income per annum, percentage crop income, livestock and off-farm jobs.
c. Human capital: Dependency ratio, education, age, household size and family labor.
d. Physical capital: The distance of farms from the road.
e. Social capital: Group membership and ethnicity.

3.4.3 Statistical analysis for household agent groups

Principal Component Analysis for statistical description of households

Principal component analysis (PCA) was employed to gather information from several variables. This type of statistical analysis is a data reduction technique used to condense information from the large set of variables considered during the field survey (more than 20 variables) with minimal loss of information (Campbell *et al*., 2001).

K-mean cluster analysis using Principal Component scores

K-mean cluster analysis (KCA) was chosen for easy interpretation of grouping results. It was run using the standardized component scores obtained from the PCA to determine the household agent groups. KCA is a data grouping technique aimed at partitioning *n* observations into *k* clusters where each observation is identified with the closest average value (Villamor 2012). The k-means algorithm is a set of rules used to select specific characteristics into k partitions by ensuring that one partition features close characteristics of variables and partitions that are not similar (Schindler 2009). The purpose of the algorithm is to reduce the total intra-cluster variance V, as shown below:

$$V = \sum_{i=1}^{k} \sum_{x_{i-s_i}} (x_{i-\mu_i})^2$$

where *Si*, *i* = 1, . . . , *k* refer to *k* clusters (agent groups), *xj* ∈ *Si* the elements of each cluster (household agents), and μ*i* refer to centroids or averages of every cluster. Every *xj* and *μi* has as different dimensions as the data set, i.e. one dimension for every indicator. Thus, $(xj - \mu i)^2$ refers to the distance of the agent *xj* to the group centroid *μi* (Schindler 2009).

3.5 Data analysis of gender roles and access to agricultural resources

During the data collection, household heads answered questions relating to their community, productive and reproductive activities by employing a gender role framework which is also referred to as the Harvard analytical framework (Razavi and Miller 1995). The framework addresses the major community, productive and reproductive roles. A statistical software (STATA 13) was employed to determine the correlation between male and female headed household's responses in terms of agreement and disagreement in their roles. The analysis was based on the Fisher's exact test (Fisher 1922; Agresti 1992). Significant difference in activities explain a clear 'distinct' opinion between genders.

Testing of the following null-hypothesis were carried out:

(H1) *Reproductive roles for men and women are similar*

(H2) *Men and women hold similar opinions on individual or joint productive roles*

3.6 Gender specific determinants of land use decision (fertilizer adoption)

Binary probit model

Linear regression models with binary dependent variables poses some basic challenges such as heteroscadasticity of the error term, non-normality, low efficiency of determination and the probability of the outcome falling outside 0 – 1 range (Gujarati

2003; Asante et al., 2011 and Tesfaye et al. 2014). The probit model ensures that the estimated probability will fall within the logical limit of 0 and 1 (Tesfaye et al. 2014). Some challenges associated with functional forms in relation to linear probability model are addressed with an s-shape relationship between the probability of an event and the independent variable. (Pindyck and Rubinfeld 1991 and Martey et al., 2014)

The data was analysed using the probit model because the dependent variables were binary in nature (Martey et al., 2014) The assumption of the model is that there is a latent unobserved continuous variable Y_i^* that determines the value of Y_i while only the value 0 and 1 for the dependent variable; Y_i are observed (Sebopetji and Belete 2009).

Assuming the response variable Y_i is binary with only two possible outcomes (1 = adoption and 0 = no adoption). Suppose also that dependent variable Y_i is influenced by a vector of the independent variable x_i, the model can be specified as follows:

$$Pr(Y_i = 1|x_i) = F(\beta' x_i) = \Phi(\beta' x_i) \qquad (1)$$

Where Pr represents probability, Y_i is the binary choice variable denoting willingness to adopt and Φ represents the cumulative distribution function (CDF) of the standard normal distribution. β denote a vector of unknown parameters (Martey et al., 2014).

The latent variable Y* is specified as follows:

$$Y_i^* = \beta_0 + \sum_{n=1}^{N} \beta_n x_{ni} + u_i \qquad (2)$$

And

$$Y_i = \begin{cases} 1 & if\ Y_i^* > 0 \\ 0 & otherwise \end{cases} \qquad (3)$$

Where x_i denotes a vector of explanatory variables, u_i represents random distance term, N total sample size, and β denotes a vector of unknown parameters to be estimated by the maximum likelihood approach. The parameters may not necessarily represent the marginal effects of the independent variables due to the non-linearity of the probit model. The coefficients of the marginal effects are very useful for policy decision-making. The marginal effect is estimated by differentiating equation (1) with respect to x_i (Greene 2008).

$$\frac{\delta Y_i}{\delta x_i} = \emptyset(\beta' x_i)\beta_i \qquad (4)$$

Where φ refers to the probability density function of the standard normal distribution.

The empirical specification for the Vea catchment is as follows:

$$y_i = \beta_0 + \sum_{n=1}^{N} \beta_n \, x_{ni} + v_i \qquad (5)$$

where Y_i = adoption of fertilizer (1 if farmer adopted fertilizer, 0 otherwise). $X_{(1\text{-}20)}$ comprises: X_1 = gender; X_2 = age; X_3 = education; X_4 = household size; X_5 = farming experience; X_6 = marital status; X_7 = dependency ration; X_8 = percent income from non-farm income sources; X_9 = group membership; X_{10} = remittance; X_{11} = land ownership; X_{12} = access to agriculture extension; X_{13} = access to credit; X_{14} = access to climate information; X_{15} = access to market; X_{16} = soil fertility; X_{17} = maize area; X_{18} = rice area; X_{19} = slope; X_{20} = livestock holding.

3.7 Data analysis of gender and land tenure linkages in adaptation to climate change

Farmer's perception on climate change was analysed from a gender perspective using descriptive statistics. The logit model was employed to determine factors influencing the decision to adopt adaptation strategies in the face of climate change (increasing drought, increasing temperatures, decreasing precipitation) using STATA 13. Due to the nature of the decision variables, the logit model was deemed appropriate: whether farmers perceive climate change and have adopted strategies to cope with the challenge. The logit model is the most suitable analysis tool for such a dichotomous outcome (Fosu-Mensah et al., 2012) and takes into account the link between a set of independent variables and a binary dependent variable be it binary or continuous variable. The logistic model for '*k*' independent variables (X_i, X_2, X_3,…,X_k) is given by

$$\text{Logit } P(\times) = \alpha + \sum_{i=1}^{k} \beta i, xi$$

Where, Exp (*βi*) denotes the odds ratio for a person with characteristics *i* versus not having *i,* while *βi* refers to the regression coefficient, and α is a constant.

3.8 Data Analysis of role-playing games (grazing game)

The data was analysed using Microsoft spread sheet. The following indicators were considered:

(I) The total number of livestock produced (II) the number of degraded patches (III) the number of cropland patches (IV) the number of fallow or bush patches (V) income from the sale of livestock (VI) total number of livestock lost.

The average rainfall generated by the dice per year were categorized into: very dry, dry, wet and very wet where very low values represented very dry and high values denote very wet conditions.

4 RESULTS

4.1 Introduction

The results of the study are presented in this chapter. Results were examined in line with the objectives, i.e. heterogeneity of factors responsible for land use change, gender roles and access to agricultural resources, gender specific determinants of fertilizer adoption, linkages between gender and land tenure in climate change adaptation and the grazing game as a learning tool for adaptive strategy in response to climate variability by gender specific groups.

4.2 Heterogeneity of factors influencing land use change in the VEA catchment

4.2.1 Household characterization by household agents

Table 4.1 presents the summary results of the demographic characteristics of the household agents (respondents). Generally, female-headed households were older than male-headed households. In the female-headed households, the farmers' age ranged from a minimum of 25 to a maximum of 97 years with an average age of 53 years while that of males ranged from 18 to 97 years with an average age of 55 years. This might be due to the labor-intensive nature of farming, which is less attractive for younger females.

Male-headed households had slightly larger household sizes than female-headed households. Male-headed household ranged from 1 to 15 persons with a mean of 7.8 whereas the female-headed households ranged from 1 to 15 with a mean of 7.7. Similarly, male-headed households availed of slightly more household labor than female-headed households. The male-headed household labor ranged from 1 to 12 with a mean of 5.1 while the female-headed households labor ranged from 1 to 11 with a mean of 4.7. There was no significant difference between the labor available to both household agents.

Female-headed households had slightly more household dependents compared to their male counterparts. Female-headed household dependents ranged from a minimum of 1 to a maximum of 10 with a mean of 2.9, whereas dependents for male-headed households ranged from a minimum of 0 to a maximum of 7 with a mean of 2.7.

There was no significant difference between the male and female dependency ratio. The dependency ratio for male-headed households ranged from 0 to 4 with a mean of 0.63, while that of female-headed households ranged from 0.1 to 4 with a mean of 0.77. Ages varied between male and female-headed households.

Table 4. 1 Household agent characteristics of male and female farmers (N=150 females; 150 males) in UER, Ghana ($n_{females}$= 150; n_{males}= 150)

Household agent	**Male**		**Female**	
characteristics	**Range**	**Mean± SD**	**Range**	**Mean**
Farm labor (#)	1-12	5.1±2.28	1-11	4.72±2.08
Household size (#)	1-15	7.8± 3.06	1-15	7.65±3.07
Dependency	0-7	2.7±1.62	1-10	2.88±1.85
Age (years)	18-97	55.3±17.98	25-97	53.37±14.88
Dependency ratio	0-4	0.63±0.52	0.1-4	0.77±0.71

4.2.2 General land-use composition of male- and female-headed households

The male farmers cultivated on average 50% more land than the female farmers (Table 4.2). The mean land area cultivated by the male-headed households is 18,712m^2, whereas that of the female-headed households is 12,081 m^2.

The total land area kept under cultivation for traditional cereals (TC) by male-headed households has a mean of 4,724 m^2 whereas the mean value for female-headed households is 3,918 m^2. Female-headed households allocated about 33 % of their farmland for the cultivation of traditional cereals compared to 25 % by the males.

Similarly, male-headed households allocated 28% (mean 5,218 m^2) of their total land area for the cultivation of traditional cereal legumes compared to 35% (mean of 4260m^2) for female-headed households. This suggest that female farmers dedicate a larger proportion of their land to subsistence crops, in part to meet the food needs of the family.

The land area put under cultivation of groundnut by male-headed households (mean 2,692 m^2) is almost twice that of female-headed households (mean 1,543 m^2).

With a larger holding, male-headed households are able to cultivate cash crops to supplement their financial income. However, the fraction of the land holding dedicated to groundnut production is only slightly higher for male-headed households (14.4%) than for their female counterparts (12.7%). The trend observed for groundnut area for male- and female-headed households is the same for groundnut-mixed areas, with male-headed households cultivating larger land areas (mean 3,224 m^2) than their female counterparts (mean 1,611 m^2). The percent land area dedicated to groundnut-mixed crops is 17.2% for males compared to 13.3% for females (Figure 4.1). The same was true for the cultivation of maize as a cash crop, where male-headed households were able to cultivate larger areas of land (5.7%) than female-headed households (2.6%). The difference was however not significant. The mean land area allotted by male-headed households for rice cultivation was 1,797 m^2 whereas that of their female counterparts was 437 m^2.

Table 4.2 Land-use type of male- and female-headed households ($n_{females}$= 150; n_{males}= 150)

Land use (m^2)	**Male**		**Female**	
	Range	**Mean± SD**	**Range**	**Mean± SD**
Total land holding	2833-23875	18712±1623	2023-13354	12081±4844
Farm area for traditional cereals	0-16187	4724±2890	0-8093	3918±1851
Farm area for traditional cereal legumes	0-20233	5218±3173	0-9712	4260±1953
Farm area for groundnut	0-12949	2692±2510	0-8498	1543±2063
Farm area for groundnut mixed	0-18210	3224±3100	0-8498	1611±2095
Farm area for maize	0-9712	1058±1947	0-5261	312±933
Farm area for rice	0-10117	1797±2277	0-5665	437±1038

Source: Field data (2014)

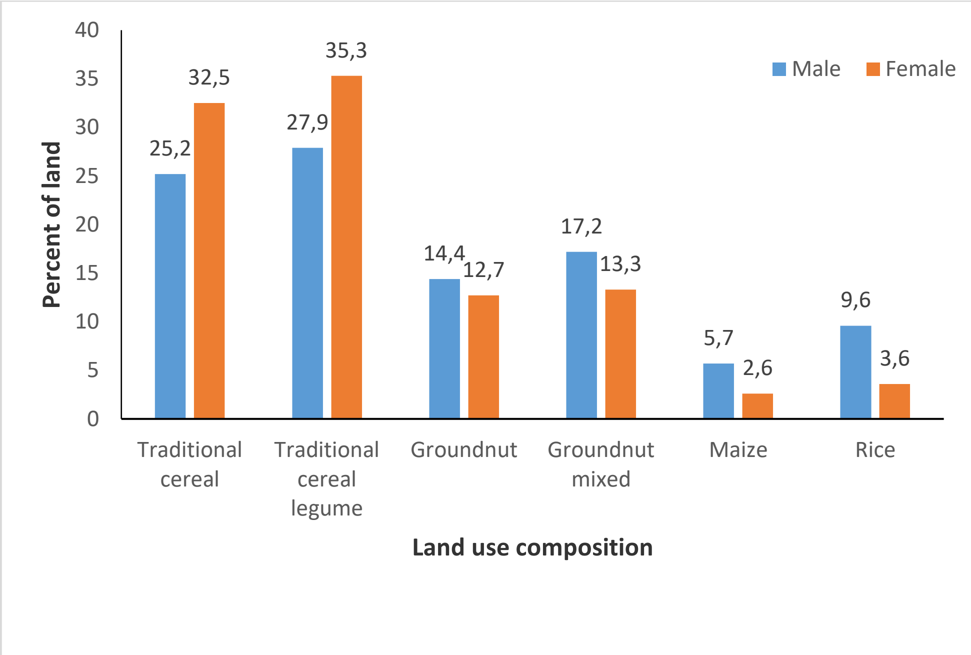

Figure 4.1: Percentage land-use type of male- and female-headed households ($n_{females}$= 150; n_{males}= 150)

4.2.3 Income from livelihood activities of male- and female-headed households

Income for various livelihood activities was estimated based on the quantity of surplus yield (number of bags or animals) that was reportedly sold by farmers multiplied by the unit price at the time of data collection (2014). The average total gross income for male-headed households was GHC 3,893.3 compared to GHC 2,407.6 for female-headed households (Table 4.3). Thus, male-headed households had GHC 1,485.7 more average gross income than their female counterparts, in line with their difference in land holdings. The average per capita income for male-headed households is GHC 499 and GHC 315 for female-headed households.

The sources of income were different for the different households. On average, traditional cereals (TC) generated 16.9% of the total income for male-headed households, whereas for female-headed households this was 24.2% (Table 4.3). Male-headed households' average percent income from the cultivation of traditional cereal legume (TCL) is estimated at 18.9 %, compared to 27.2 % by female-headed households. Groundnuts contributed 16% and 12%, respectively to incomes of the male and female-headed households and for the mixed crop/groundnut system, this was 19 and 12 % respectively. Maize and rice were twice as important in the income for male households than for female households.

The proportion of income generated by livestock was higher for the female-headed households (7.4 versus 5.3%). On the other hand, male-headed households made only 2 % of their average income from off-farm activities such as basket weaving, and road construction compared to 8.9% for female-headed households.

Table 4.3: Income from livelihood activities of male- and female-headed households ($n_{females}$= 150; n_{males}= 150)

Income from livelihood activities	**Male**		**Female**	
	Range	**Mean± SD**	**Range**	**Mean± SD**
% Traditional cereal income	0-50.0	16.9±10.8	0-50.0	24.2±13.3
% Traditional cereal legume income	0-59.4	18.9±11.8	0-53.3	27.2±14.7
% Groundnut culture income	0-45.3	15.7±12.0	0-43.2	11.7±14.2
% Groundnut mixed income	0-64.7	18.8±14.4	0-43.2	11.9±14.3
% Maize culture income	0-54.0	3.7±7.6	0-38.0	1.6±5.4
% Rice culture income	0-84.7	18.7±23.6	0-79.0	7.1±16.5
% Livestock income	0-23.8	5.3±5.5	0-45.4	7.4±9.1
% Off-farm income	0-52.0	2.0±4.7	0-49.9	8.9±10.5
Gross income (GHC)	668.9-9300.5	3893.3±1509.0	525.9-5597.9	2407.6±1159.7
Per capita income (GHC)	74.3-3243.2	499.1±435.4	52.60-2662.6	314.7±341.0

Source: Field data (2014)

4.2.4 Household characterization by gender of household heads

4.2.4.1 Female-headed households

To gain overall insight in the different characteristics of the households the survey information was subjected to a Principle Component Analysis (PCA), differentiated by the gender of the HH heads. For the female-headed households, sampling adequacy for PCA was first confirmed using the Kaiser-Meyer-Olkin measure of sampling adequacy (0.718) and the Bartlett's Test of Sphericity producing a Chi-Square of χ^2 = 1556.33 with 55 degrees of freedom at a significance of p< 0.001.

A total of three components with eigenvalues greater than 1 were extracted by PCA. These components contributed 73.4% of the total variance of original independent variables (Table 4.4). The rotated component matrix was used to determine specific components for categorizing the household agents (Table 4.5).

The first principal component (PC1) is strongly related to variables related to groundnut and traditional cereal cultivation; hence, it is named ´groundnut and traditional cereal factor´. These variables are made up of percentage income from groundnut (loading = 0.927), land area of groundnut (loading =0.969), land area of groundnut mixed (loading=0.966), income from traditional cereals (loading=0.737), gross income (loading =0.888) and land holdings (loading=0.647). This factor or component contributes 41.52% of the total variance of the original data set.

The second principal component (PC2) is highly correlated to the following variables: labor availability of the households (loading =0.815), land area per capita (loading =0.832) and household membership (loading =0.916). This factor or component accounts for 21.39% of the total variance of the original data set. Because all the variables are related to labor, this component is named ``labor factor``

The third principal component (PC3) is strongly related to distance of the farmers' houses to their respective farms, hence it is named ``distance factor``. This variable is made up of distance of house to farm (loading = 0.751) and the number of cattle owned by a household head (loading=593), which is assumed to be means of

Table 4.4: Total variance explained by extracted components using Principal Component Analysis for female-headed households ($n_{females}$= 150; n_{males}= 150)

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	4.667	42.427	42.427	4.667	42.427	42.427	4.567	41.518	41.518
2	2.307	20.971	63.398	2.307	20.971	63.398	2.353	21.387	62.905
3	1.100	10.001	73.399	1.100	10.001	73.399	1.154	10.494	**73.399**
4	.944	8.584	81.982						
5	.820	7.451	89.434						
6	.445	4.048	93.482						
7	.342	3.110	96.592						
8	.194	1.768	98.359						
9	.116	1.053	99.413						
10	.052	.470	99.882						
11	.013	.118	100.000						

Table 4.5: Rotated component matrix (i.e. loadings) using Varimax with Kaiser Normalization method (KMO=0.718) ($n_{females}$= 150; n_{males}= 150)

Variable	Component		
	1 Groundnut/traditional cereal factor (41.52%)	2 Labor factor (21.39%)	3 Distance factor (10.49%)
Groundnut culture area	**.969**	-.011	-.039
Groundnut mixed area	**.966**	-.005	-.027
% income from groundnut culture	**.927**	.018	-.089
Gross income	**.888**	-.152	.247
% income from traditional cereals	**-.737**	-.108	-.091
Total land holdings	**.647**	-.327	.342
Household membership	.076	**.916**	.040
Land area per capita	.230	**-.832**	.128
Labor availability	.056	**.815**	.157
House distance to farm	.067	.049	**-.751**
No. of cattle	.138	.116	**.593**

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transportation to the farm plots. This factor or component contributes 10.49% of the total variance of the original data set.

4.2.4.2 Livelihood typology of household agents

The standardized scores derived from the three principal components with k = 2 were used to run the K-cluster analysis (K-CA) resulting in two household agent types. The statistical difference between the various household agents regarding the most pressing livelihood variables are presented in Table 4.6. The livelihood indicators used in the research are made up of five core capitals, namely natural (i.e. total land holdings, traditional cereals, traditional cereal legume, groundnut, groundnut mixed, rice and maize areas), financial capital (i.e. gross income, percentage income from traditional cereals, traditional cereal legume, groundnut, groundnut mixed, maize, and rice culture as well as livestock and off-farm activities), physical capital (i.e., number of cattle owned by household, household distance to farm), human capital (i.e. labor availability, dependency ratio, dependents, education and age, etc.), and social capital (i.e. group membership). The radar diagrams depict the differences in the agents' typology and highlight the most important variables based on the livelihood capitals (Figs. 4.2 – 4.4).

Table 4.6: Descriptive statistics for female-headed households ($n_{females}$= 150; n_{males}= 150)

Variables	Type	N	Range	Mean ± SD
Labor	1	58	1-7	3.74±1.66
	2	92	1-11	5.34±2.09
Distance	1	58	1-30	9.05±7.24
	2	92	1-60	16.22±11.77
% Traditional cereals income	1	58	0-50	22.79±12.13
	2	92	0-50	25.14±13.93
% Groundnut income	1	58	0-43	11.20±12.87
	2	92	0-43	10.20±14.77
Gross income	1	58	1145-5598	3024.49±1128.45
	2	92	525-5503	2015.30±1004.32

Total land holdings	1	58	2833-13354	8672.45±2063.57
	2	92	2023-10926	5516.24±1984.69
Land area for traditional cereals	1	58	0-8093	4564.66±2261.30
	2	92	0-7689	3591.83±1507.24

4.2.4.3 Household type 1: Groundnut-based farmers

The spider diagrams of the standardized scores of basic livelihood indicators reveal that this group constitutes households that are relatively well-off by having larger land holdings and higher annual gross income (Figure 4.2). The average land holding in this group is around 8,672.45 m^2. The average annual gross income is GHC 3,024.49 representing an income difference with type 2 of GHC 1009.20 (Table 4.6). Another key factor distinguishing this group from household type 2 is the percentage income and land area from groundnut production, which constitutes 14.2% of the annual income. This is significantly higher than the income for household type 2. This group also has a smaller number of dependents but longer distances from house to farm (Figures 4.2 and 4.3). This household type constitutes about 38.7% of the total female population. Income contribution from mixed groundnut (14.3%), maize (3.6%) and rice production (8.1%) are important for their livelihoods.

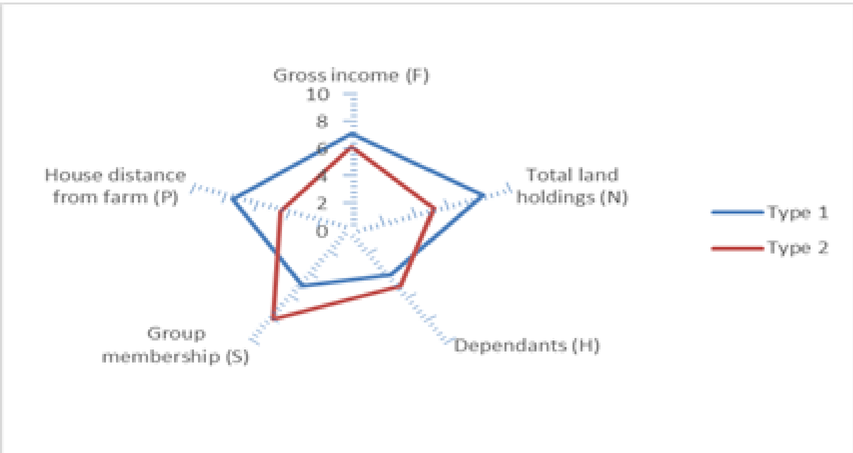

Figure 4.2: Variation between female-headed household types 1 and 2 in terms of gross income, total land holdings, dependents, group membership and house distance to farm. F=financial capital; N=natural capital; H=human capital; S=social capital; P=physical capital ($n_{females}$= 150; n_{males}= 150)

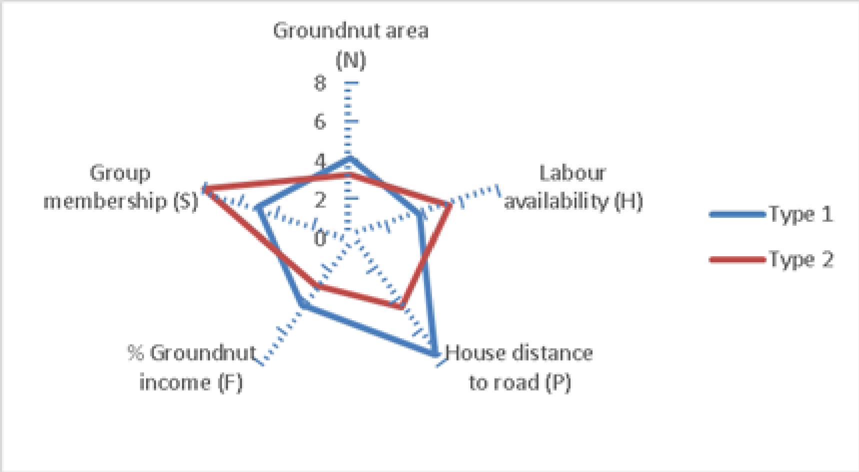

Figure 4.3: Variation between female-headed household types 1 and 2 in terms of groundnut area, labor availability, distance of house to farm, percentage groundnut income, and group membership. N=natural capital; H=human capital; P=physical capital; F=financial capital; S=social capital ($n_{females}$= 150; n_{males}= 150)

4.2.4.4 Household type 2: Traditional crop-based farmers

This group of female-headed farmers is considered the poorer household type in terms of total annual gross income and land holdings. The households earn on average a total annual gross income of GHC 2,015.30 (Table 4.6). The average total land holding is 5,516.24 m^2. Labor availability in this group is 3.74 persons per household. This group constitutes about 61.3% of the total female-headed household respondents.

Traditional cereals and a combination of traditional cereals and legume production are the main factors that differentiate this household from household type 1 (Figure 4.4 and 4.5). The histogram (Figure 4.5) shows that percentage income from traditional cereals (25.1%) and traditional cereal legume (29%) for this group is 2.3% and 4.5% higher than for household type 1, respectively.

Furthermore, land area proportion for traditional cereals (34%) and traditional cereal legume (38%) is higher than household type 1 (Figure 4.6). Also important in the livelihood structure of this group is income from livestock production and off-farm activities (Figure 4.5) that constitute 8.4% and 10.2%, respectively.

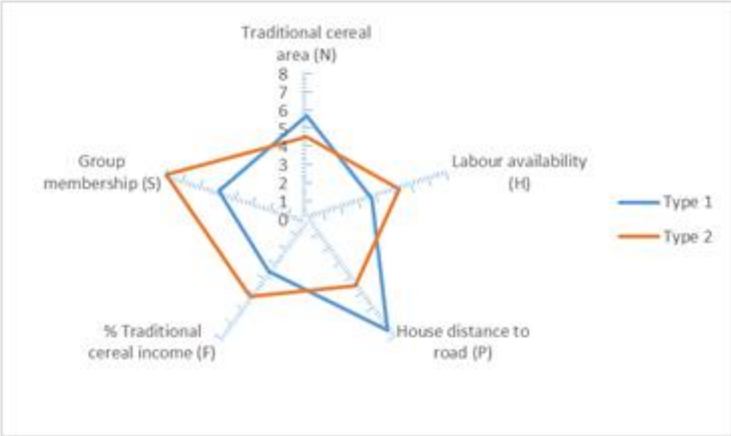

Figure 4.4: Variation between female-headed household types 1 and 2 in terms of traditional cereal area, labor availability, distance of house to farm, percentage income from traditional cereals and group membership. N=natural capital; H=human capital; P=physical capital F=financial capital; S=social capital ($n_{females}$= 150; n_{males}= 150)

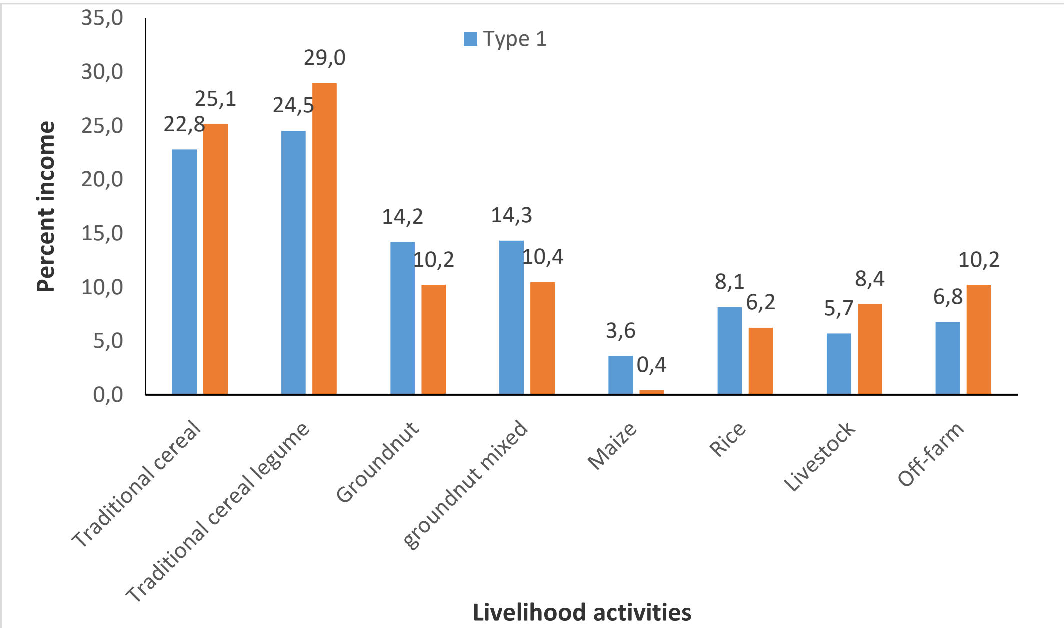

Figure 4.5: Income composition of female-headed household types 1 and 2 ($n_{females}$= 150; n_{males}= 150)

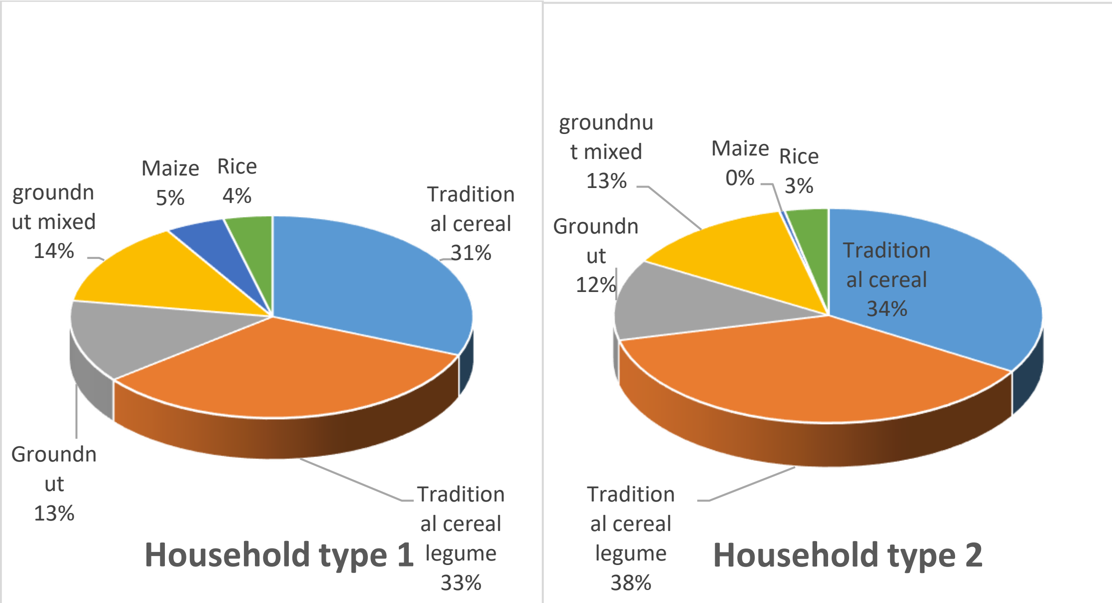

Figure 4.6: Land-use of female-headed household types ($n_{females}$= 150; n_{males}= 150)

4.2.4.5 Male-headed households

A total of three principal components with eigenvalues greater than 1 and Kaiser-Meyer-Olkin Measure of Sampling Adequacy of 0.716 were extracted by the PCA. A chi-Square of χ^2 = 1,439.983 with 55 degrees of freedom at a significance of $p < 0.001$ was obtained.

These components contributed 72.75% of the total variance of original independent variables (Table 4.7). The rotated component matrix was used to determine specific components for categorizing the household agents (Table 4.8).

The principal component 1 (PC1) is strongly related to groundnut and traditional cereal variables, hence it is named ´groundnut and traditional cereal factor´. These variables are made up of groundnut area cultivated (loading = 0.959), mixed groundnut area cultivated (loading =0.929), and percentage income from groundnut (loading=0.848). This factor contributes 34.9% of the total variance of the original data set.

The second principal component (PC2) is highly correlated to labor availability of the households. This component is therefore named `labor factor`. The variables include land area per capita (loading=0.878), available family labor (loading=0.832), household size (loading=0.906), and per capita income (loading=0.851). This factor accounts for 28.20% of the total variance of the original dataset.

The third principal component (PC3) is different for the male-headed households and is strongly related to percentage income from livestock (loading=0.616) rather than farm distance. This livestock factor accounts for 9.62% of the total variance of the original data set.

Table 4.7: Total variance explained by extracted components using Principal Component Analysis for male-headed households ($n_{females}$= 150; n_{males}= 150)

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	**% of Variance**	**Cumulative %**	**Total**	**% of Variance**	**Cumulative %**	**Total**	**% of Variance**	**Cumulative %**
1	4.265	38.772	38.772	4.265	38.772	38.772	3.842	34.930	34.930
2	2.721	24.739	63.511	2.721	24.739	63.511	3.102	28.199	63.129
3	1.016	9.236	72.747	1.016	9.236	72.747	1.058	9.618	**72.747**
4	.857	7.787	80.534						
5	.740	6.724	87.258						
6	.659	5.986	93.244						
7	.383	3.483	96.727						
8	.163	1.484	98.211						
9	.125	1.141	99.351						
10	.043	.391	99.743						
11	.028	.257	100.000						

Table 4.8: Rotated component matrix (i.e., loadings) using Varimax with Kaiser Normalization method (KMO=0.716) for male-headed households ($n_{females}$= 150; n_{males}= 150)

Variable	Principal component		
	1 Groundnut/ traditional cereal factor (34.9%)	**2** Labor factor (28.2%)	**3** Livestock factor (9.62%)
Education of household head	.163	.169	**.794**
Groundnut culture area (m²)	**.959**	-.025	.004
Gross income (GHC)	**.807**	-.185	.068
Land area per capita (m²)	.244	**-.878**	-.055
% Traditional cereal income	**-.575**	.149	.131
Groundnut mixed area (m²)	**.929**	-.068	.011

Labor availability	.040	**.832**	.021
% Groundnut income	**.848**	.029	-.112
% Livestock income	-.352	-.051	**.616**
Household size	.092	**.906**	.093
Per capita income (GHC)	.371	**-.851**	-.025

4.2.4.6 Livelihood typology of household agents

The standardized scores derived from the three principal components with k = 2 were used to run the K-cluster analysis (K-CA) resulting in two household agent types. The statistical difference between the various household agents regarding the most pressing livelihood variables are presented in Table 4.9. The livelihood indicators used in the research consist of the five core types of capital employed for female-headed households. The spider diagrams show the differences in the agents' typology and highlight the most important variables based on the livelihood capital types.

Table 4.9: Descriptive statistics for male-headed households ($n_{females}$= 150; n_{males}= 150)

Variable	Type	N	Range	Mean ± SD
Labor	1	82	2-12	5.66±2.34
	2	68	1-10	4.56±2.13
% Livestock income	1	82	0-14	3.75±4.12
	2	68	0-24	6.53±6.2
% Traditional cereal income	1	82	0-25	11.94±6.01
	2	68	0-50	21.02±12.12
% Groundnut income	1	82	10-45	24.83±7.06
	2	68	0-33	8.10±9.84
Gross income (GHC)	1	82	2138-9300	4698.94±1481.37
	2	68	669-6398	3225.16±1173.4
Total land holdings	1	82	5665-23066	12639.92±4091.80
	2	68	2833-23875	10511.50±3960.83

Land area for traditional cereal (m^2)	1 2	82 68	0-14568 0-16187	4237.11±2443.53 5127.44±3172.40

4.2.4.7 Household type 1: Groundnut-based farmers

Table 4.9 shows that this group of male farmers are richer in terms of total annual gross income and the total land area cultivated. Total annual gross income for this group is GHC 4,699. Total land area cultivated per capita for this group is 12,640 m^2. The percent groundnut area cultivated is 14 % higher than for household type 2 (Figure 4.11).

Groundnut production is the key factor that differentiates this group from household type 2. The spider diagram (Figure 4.7) indicates that labor available in this group is much higher and a contributory factor for the high income realized. Also, these households have a higher group membership than household type 2

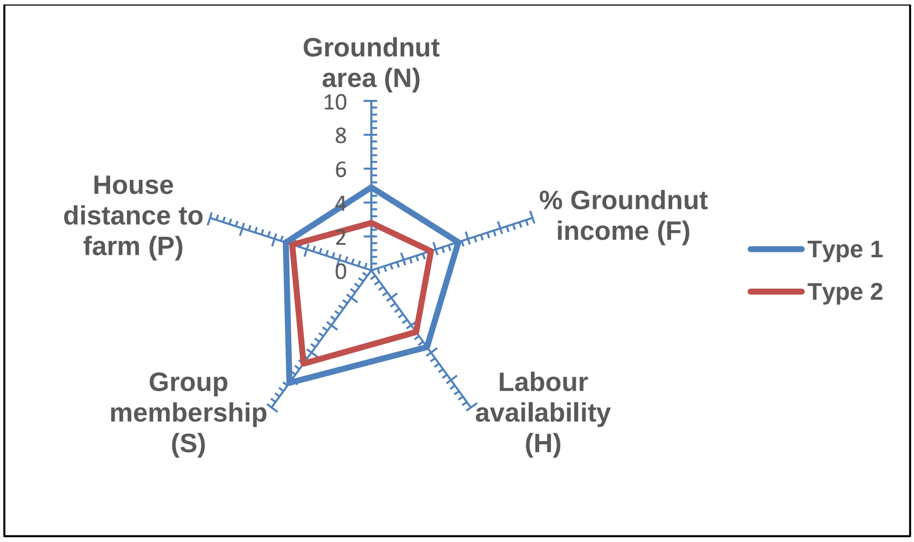

Figure 4.7: Variation between male-headed households type 1 and 2 in terms of groundnut area, income from groundnut, labor availability, group membership and house distance to farm. N=natural capital; F=financial capital; H=human capital; S=social capital; P=physical capita ($n_{females}$= 150; n_{males}= 150)

4.2.4.8 Household type 2: Traditional cereal-based farmers

Male-headed household type 2 is considered poor in terms of total land holdings and gross income. The average total land area per person in this group is 10512 $m^{2.}$. The average total annual gross income per person is GHC 3,225 (Table 4.9).

Also, these male-headed households have a relatively smaller number of available family labor per household as well as a lower number of group membership with 7.07 members compared to 8.7 in household type 1 (Figure 4.8). The average available family labor is 4.56 persons per household compared to 5.66 persons in household type 1.

Traditional cereal production is the main factor that differentiates this group from household type 1. The spider diagram (Figure 4.9) and the histogram (Figure 4.10) show that this group earns a relatively higher percentage of gross income (21%) from traditional cereal production, which is 9.1% higher than for household type 1. Land area for traditional cereals for this group is also significantly higher (9.5%) (Figure 4.11).

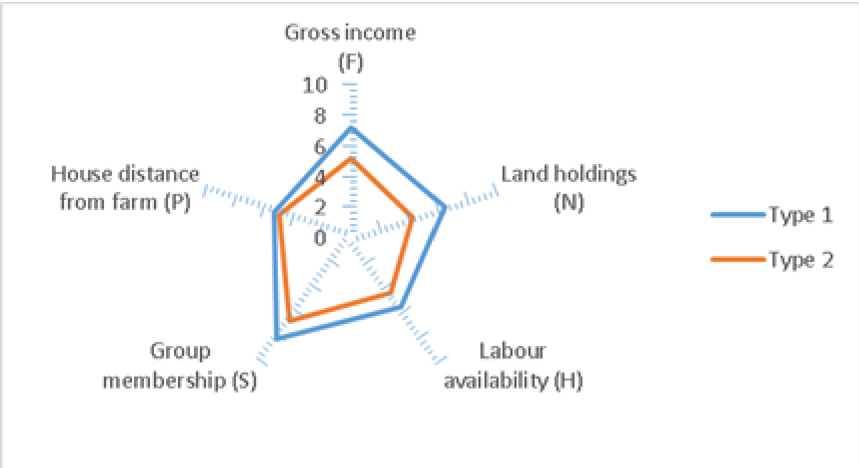

Figure 4.8: Variation between male-headed households type 1 and 2 in terms of, gross income, land holding, labor availability, group membership and house distance to farm. F=financial capital; N=natural capital; H=human capital; S=social capital; P=physical capital ($n_{females}$= 150; n_{males}= 150)

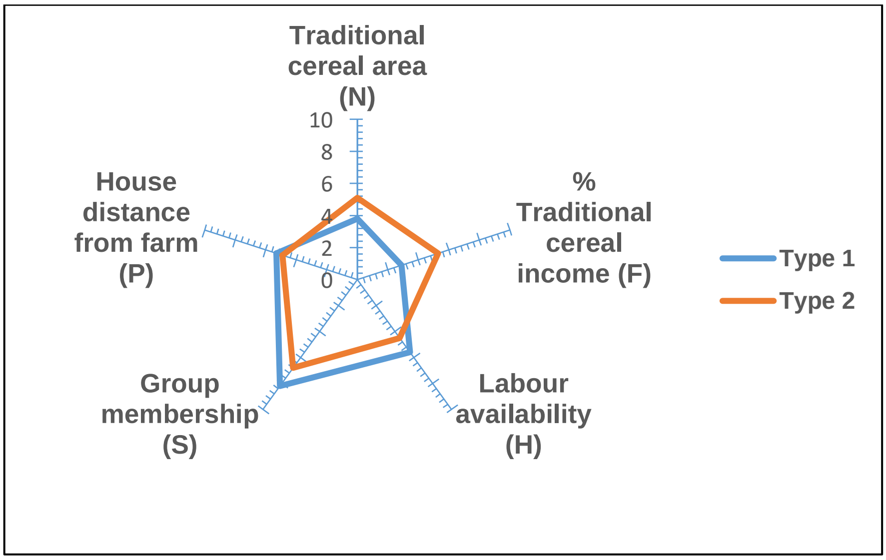

Figure 4.9: Variation between male-headed households type 1 and 2 in terms of rice area, income from rice, education, group membership and house distance to farm. N=natural capital; F=financial capital; H=human capital; S=social capital; P=physical capital ($n_{females}$= 150; n_{males}= 150)

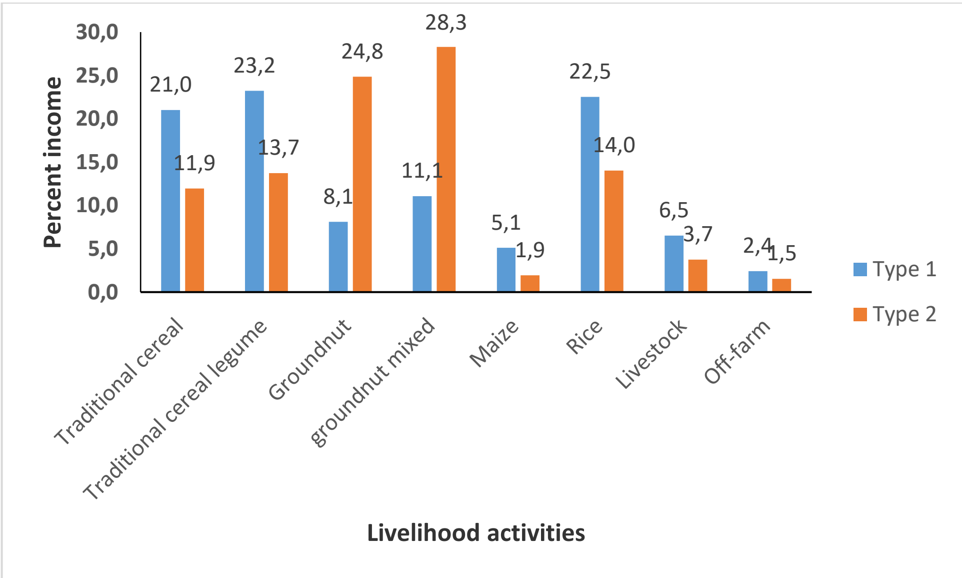

Figure 4.10: Income composition of male-headed households type 1 and 2 ($n_{females}$= 150; n_{males}= 150)

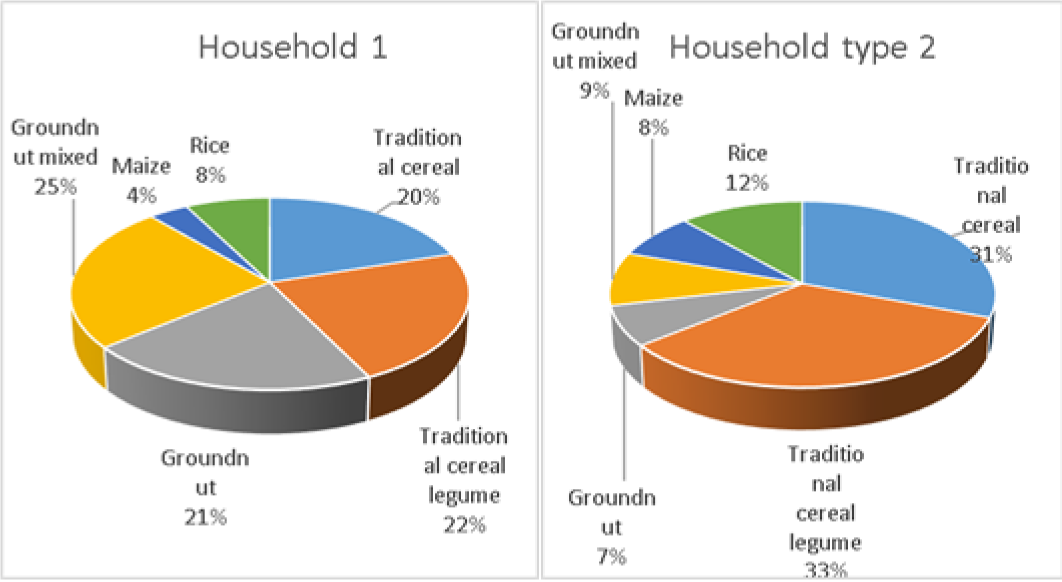

Figure 4.11: Land use of male-headed households type 1 and 2 ($n_{females}$= 150; n_{males}= 150)

4.3 Gender roles and access to agricultural resources

4.3.1 Who performs the specific productive roles in the main agricultural systems?

Figure 4.12 presents the distributional percentage of tasks performed by men and women in the region as reported by the surveyed individuals. The results suggest that women are involved in all levels of farming activities and more particularly in physically demanding activities with respect to planting crops, weeding the farm area, fertilizer application, irrigation or watering, tree and crop harvesting as well as hauling of farm produce. The only engagement women have in the financial administration of the household is selling of crops. Men on the other hand are responsible for physical activities in terms of land preparation, feeding of livestock, seedling production and pruning of trees. They are the main actors in the financial administration regarding purchasing of farm inputs, farm financing and maintenance of farm records. The work distribution is very similar for male and female-headed households except for tree-planting.

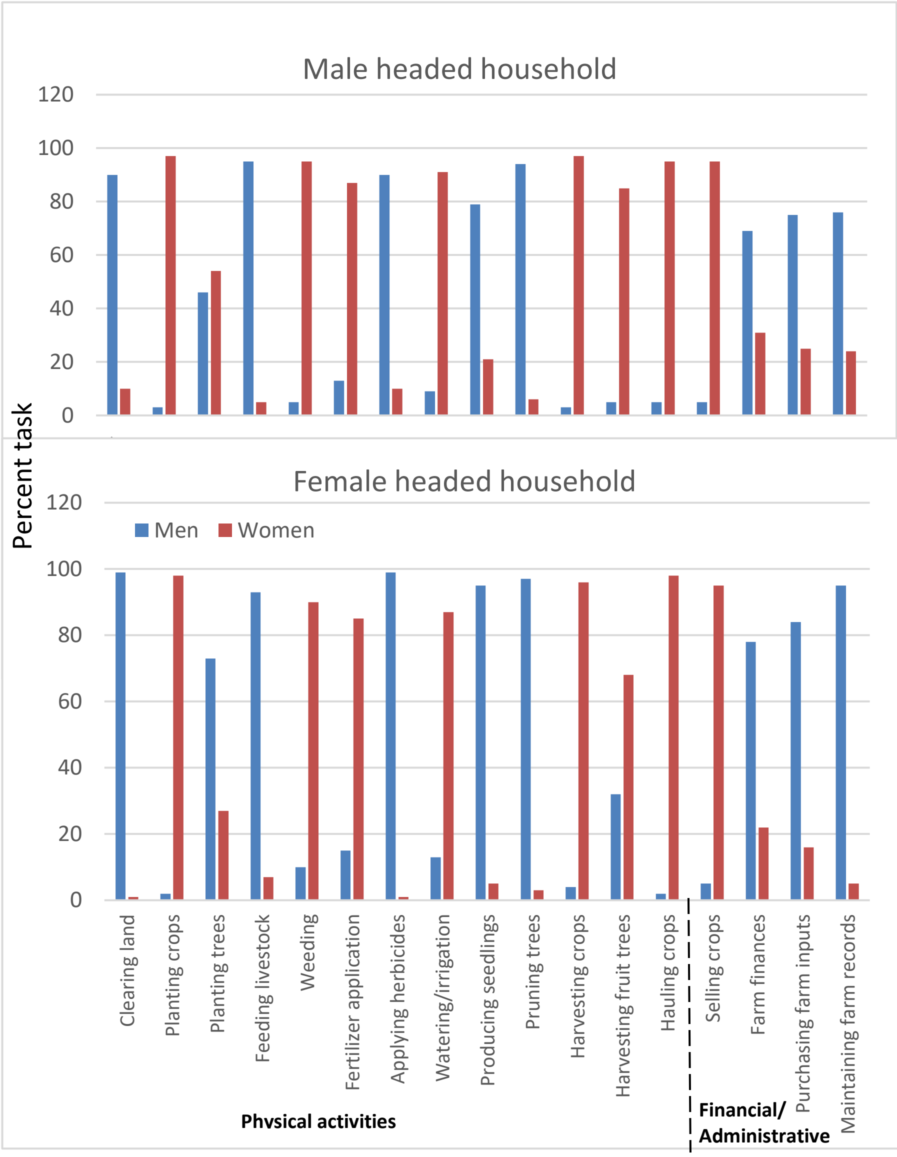

Figure 4.12: Distribution of gender-specific productive roles in the UER, Ghana, 2014 ($n_{females}$= 150; n_{males}= 150)

4.3.2 Perceived roles in male and female-headed households

There is remarkable consistency in the perceived division of labor between the male and female-headed households (table 4.10). According to the Fisher exact test, there is a strong agreement when *p-values* are high and vice versa. The results show significant differential between the household types in the labor inputs by men and women are clearing of land, planting of trees, pesticide or herbicide application, seedling production, and maintenance of farm records. About the reproductive chores, there is high agreement between male and female-headed households with women carrying the majority of this burden, irrespective of who heads the household. In contrast, there is a strong shift towards women engagement in social and community roles when a woman is the head of the household except when it comes to adoption of conservation measures.

Table 4.10: Perspectives of male- and female-headed households regarding ´who performs specific roles` in the UER, Ghana, in 2014 ($n_{females}$= 150; n_{males}= 150)

Roles	**Activity**	**Male headed household (%)**		**Female headed household (%)**		**Fischer exact test**
		"men"	**"Women"**	**"Men"**	**"Women"**	**(*p*)**
Productive	Clearing land	90	10	99	1	**0.002**
	Planting crops	3	97	2	98	0.718
	Planting trees	46	54	73	27	**0.014**
	Feeding livestock	95	5	93	7	0.441
	Weeding	5	95	10	90	0.152
	Fertilizer application	13	87	15	85	0.717
	Applying pesticides/herbicides	90	10	99	1	**0.001**
	Watering/irrigation	9	91	13	87	0.549
	Producing seedlings	79	21	95	5	**0.000**
	Pruning trees	94	6	97	3	0.251
	Harvesting crops	3	97	4	96	0.722
	Harvesting fruit trees	15	85	32	68	0.076
	Hauling crops	5	95	2	98	0.169
	Selling crops	5	95	5	95	1.000
	Farm finances	69	31	78	22	0.195
	Purchasing farm inputs	75	25	84	16	0.131
	Maintaining farm records	76	24	95	5	**0.000**
Reproductive	Collecting firewood	2	98	5	95	0.334
	Fetching water	0	100	2	98	0.114

	Preparing meals	1	99	2	98	0.612
	Taking care of children	4	96	6	94	0.368
	Washing cloths	2	98	3	97	0.712
	Cleaning house	2	98	6	94	0.204
	Children's expenses	10	90	20	80	0.102
	Household budgeting	15	85	19	81	0.560
	House construction/maintenance	64	36	79	21	0.050
Community	Community meetings	66	34	92	8	**0.000**
	Church meetings	46	54	68	32	**0.019**
	School building, bridges etc.	63	37	91	9	**0.000**
	Cleaning public spaces	47	53	70	30	**0.007**
	Afforestation	52	48	92	8	**0.000**
	Community beautification	46	54	71	29	**0.002**
	Adopting conservation measures	67	33	56	44	0.115

Note: Bold text depict significant results of male and female headed households

4.3.3 Collaboration between men and women in male and female headed households

The opinions of the male and female household heads about sharing in farming and household tasks is represented in Table 4.11. In general, there was great congruence in the perception of cooperation in performing most productive tasks between the different HH genders except for purchasing farm inputs and maintaining farm records. The results for instance, show that planting of crops and harvesting of fruit trees are performed jointly by men and women. About 86 % of the men and 94 % of the women perceived planting of crops to be a productive task that is performed jointly, whereas an equal percentage of both gender household heads (65 % men, 65 % women) expressed the same view on harvesting of fruit. There is a strong agreement in the perception of men and women that productive roles such as watering, weeding and selling of crops are undertaken individually. Among the male household heads responding, about 88 %

regarded watering or irrigation, 92 % weeding, and 90 % selling of crops to be performed individually by women.

In contrast, out of the 9 reproductive roles considered, for the various 3 activities (i.e., washing of clothes, children's expenses and household budgeting) it was discovered that men and women have different views on working together. Among the men respondents, 85 % regarded washing of clothes as roles that should be carried out particularly by women whereas among women respondents, 63 % regarded children expenses and 72 % regarded household budgeting as task that should be shouldered individually by men. A similar trend can be seen in the community task where women perceived afforestation (65 %), community beautification (59 %) and church meetings to be a sole responsibility and task to be performed by men.

Table 4.11: Perspectives of men and women head of households about collaboration in household activities 'joint roles' in the upper east region, Ghana, 2014 ($n_{females}$= 150; n_{males}= 150)

Roles	**Activity**	**Male headed households (%)**		**Female headed household (%)**		**Fischer exact test**
		"Joint"	**"Individual"**	**"Joint"**	**"Individual"**	**(*p*)**
Productive	Clearing land	20	80	12	88	0.107
	Planting crops	86	14	94	6	0.121
	Planting trees	20	80	12	88	0.107
	Feeding livestock	10	90	11	89	0.851
	Weeding	8	92	8	92	1.000
	Fertilizer application	10	90	12	88	0.704
	Applying pesticides/herbicides	7	93	12	88	0.115
	Watering/irrigation	12	88	12	88	1.000
	Producing seedlings	0	100	1	99	0.246
	Pruning trees	2	98	5	95	0.335
	Harvesting crops	16	84	15	85	0.748

	Harvesting fruit trees	65	35	65	35	1.000
	Hauling crops	17	83	16	84	0.875
	Selling crops	10	90	10	90	1.000
	Farm finances	37	63	32	68	0.394
	Purchasing farm inputs	33	67	22	78	**0.037**
	Maintaining farm records	33	67	22	78	**0.046**
Reproductive	Collecting firewood	14	86	14	86	1.000
	Fetching water	13	87	6	94	**0.042**
	Preparing meals	12	88	8	92	0.253
	Taking care of children	26	74	24	76	0.687
	Washing cloths	15	85	6	94	**0.011**
	Cleaning house	16	84	10	90	0.168
	Children's expenses	54	46	37	63	**0.005**
	Household budgeting	43	57	28	72	**0.011**
	House construction/maintenance	55	45	43	57	**0.037**
Community	Community meetings	56	44	42	58	**0.015**
	Church meetings	64	36	51	49	**0.033**
	School building, bridges etc.	55	45	49	51	0.354
	Cleaning public spaces	54	46	51	49	0.729
	Afforestation	57	43	35	65	**0.000**
	Community beautification	54	46	41	59	**0.028**
	Adopting conservation measures	26	74	37	63	**0.047**

Note: Numbers in bold text represent significant differences between HH types

4.4.1 Gender specific determinants of fertilizer adoption

Out of the 150 male-headed and 150 female-headed households interviewed during the survey, approximately 55% of the former and 21% of the latter reportedly applied fertilizer to their crops (Table 4.12). Majority of the respondents have no access to credit and extension services, lack education and are extremely dependent on agriculture for their livelihood. Only 2 % and 9 % of household income for male-headed and female-headed households are, respectively derived from non-farm sources. Only 15% and 33% of male and female-headed households, respectively, perceive that their soils are fertile. As shown in Table 4.12, livestock holding by male-headed households in the study area is about 5 times that of female-headed households and is estimated at 5.40 TLU (tropical livestock unit) for male heads and 1.0 TLU for female heads, reflecting their ability to generate cash for purchases such as fertilizer.

Table 4.12: Gender specific description of model variables for fertilizer adaptation ($n_{females}$= 150; n_{males}= 150)

Variables	Unit	Male		Female		Male and female combine	
		Mean	St Dev.	Mean	St Dev.	Mean	St Dev.
Dependent variable							
Fertilizer application	Dummy=1 if yes, 0 otherwise	0.55	0.50	0.21	0.41	0.38	0.49
Explanatory variables							
Household characteristics							
Gender	Dummy=1 if yes, 0 otherwise	1.00	0	0	0	0.5	0.50
Age	Years	55.31	17.97	53.00	14.88	54.34	16.50
Education	Years	2.78	3.28	1.36	3.59	2.07	3.51
Household size	Count	7.83	3.06	7.65	3.07	7.74	3.06
Farming experience	Years	25	5.38	23.72	4.58	24.36	5.03
Marital status	Dummy=1 if yes, 0 otherwise	0.90	0.30	0.047	0.212	0.47	0.50
Dependency ratio		0.62	0.52	0.78	0.71	0.70	0.63

Percent income from non-farm sources	(%)	2.02	4.67	8.87	10.45	5.45	8.78
Social capital							
Group membership (Agric. union/cooperative)	Dummy=1 if yes, 0 otherwise	0.267	0.44	0.31	0.47	0.29	0.46
Remittance	Dummy=1 if yes, 0 otherwise	0.63	0.49	0.40	0.50	0.56	0.50
Institutional and infrastructural variables							
Land ownership	Dummy=1 if yes, 0 otherwise	0.29	0.46	0.22	0.45	0.26	0.45
Access to Agric. Extension services	Dummy=1 if yes, 0 otherwise	0.47	0.50	0.35	0.48	0.41	0.49
Access to credit	Dummy=1 if yes, 0 otherwise	0.17	0.37	0.23	0.42	0.20	0.40
Access to climate information	Dummy=1 if yes, 0 otherwise	0.94	0.26	0.93	0.26	0.93	0.26
Access to market	Dummy=1 if yes, 0 otherwise	0.93	0.26	0.91	0.28	0.92	0.27
Plot characteristics							
Soil fertility	Dummy=1 if yes, 0 otherwise	0.15	0.35	0.33	0.47	0.24	0.43
Maize area	Hectares	0.11	0.19	0.31	0.09	0.07	0.16
Rice area	Hectares	0.18	0.23	0.42	0.10	0.11	0.19
Slope	Dummy=1 if yes, 0 otherwise	0.91	0.29	0.89	0.31	0.9	0.30
Physical and financial assets							
Livestock holding	Tropical livestock unit	5.40	4.02	1.01	1.28	3.20	3.70

4.4.2 Probit regression for fertilizer adoption

Table 4.13 presents results of pooled data of adoption of fertilizers for both genders. Farming experience, gender difference, access to climate information, size of rice and maize farms positively and significantly influenced farmers' likelihood to adopt fertilizer application. However marital status, land and livestock ownership negatively and significantly influence adoption of fertilizer application.

Table 4.13. Determinants of fertilizer adoption by both male and female headed households ($n_{females}$= 150; n_{males}= 150)

Explanatory variables	Marginal effect	St. Err	P - Value	(95 % confidence interval	
Age	0.002	0.001	0.110	-0.000	0.004
Education	-0.009	0.006	0.099	-0.021	0.002
Farming experience	0.006	0.004	0.067*	-0.000	0.013
Household size	0.010	0.006	0.124	-0.003	0.022
Marital status	-0.134	0.052	0.011*	-0.236	-0.031
Access to Agric. Extension	-0.020	0.38	0.597	-0.094	0.054
Access to credit	0.021	0.054	0.705	-0.086	0.127
Gender	0.005	0.003	0.046*	-0.014	0.001
Dependency ratio	0.036	0.030	0.233	-0.023	0.095
Maize area	1.111	0.128	0.000***	0.861	1.361
Rice area	1.115	0.098	0.000***	0.923	1.307
Market access	0.009	0.053	0.867	-0.096	0.114
Land ownership	-0.121	0.045	0.007**	-0.209	-0.033
Livestock holding	-0.011	0.006	0.076*	-0.022	0.001
Non-farm income	-0.004	0.003	0.151	-0.009	0.001
Slope	-0.021	0.070	0.762	-0.158	0.116
Soil fertility	0.034	0.049	0.487	-0.158	0.116
Group membership	-0.033	0.043	0.438	-0.118	0.051
Remittance	0.021	0.038	0.583	-0.054	0.0963
Access to climate information	0.111	0.064	0.086*	-0.016	0.237

NB: significance level, ***1%, **5%, *10%. Prob> chi^2 = 0.0000; Log pseudo likelihood = -102.488; Pseudo R^2= 0.481; Number of obs. =300

Table 4.14 presents results on determinants of chemical fertilizer adoption by male headed households. The results show that household size, marital status, area of land allocated to maize production, rice area and perception about fertility status of soil positively and significantly influenced male farmer's adoption of fertilizer application. In contrast, the results show that land ownership, non-farm income, and access to climate information negatively and significantly influenced fertilizer application by male farmers. However, the effects of age of farmers, education, farming experience, access to extension services, access to credit, dependency ratio, access to market, livestock holding, and slope of the land, group membership and remittance were not statistically significant.

Table 4.14 Determinants of fertilizer adoption by male headed households ($n_{females}$= 150; n_{males}= 150)

Explanatory variables	Marginal effect	St. Err	P - Values	(95 % confidence interval)	
Age	0.0004	0.0009	0.649	-0.0014	0.0023
Education	-0.0076	0.0062	0.216	-0.0197	0.0045
Farming experience	-0.0007	0.0035	0.851	-0.0075	0.0062
Household size	0.0141	0.0069	0.041**	0.0006	0.0276
Marital status	0.1880	0.0719	0.009***	0.0479	0.3281
Agric. Extension	-0.0219	0.0379	0.564	-0.0963	0.0525
Access to credit	-0.0532	0.0717	0.458	-0.1936	0.0873
Dependency ratio	0.0484	0.0316	0.125	-0.0135	0.1103
Maize area	0.9593	0.1682	0.000***	0.6297	1.2890
Rice area	1.2577	0.1694	0.000***	0.9257	1.5897
Market access	-0.0108	0.0592	0.855	-0.1268	0.1052
Land ownership	-0.0880	0.0464	0.058*	-0.1790	0.0031
Livestock holding	-0.0041	0.0030	0.176	-0.0101	0.0018
Non-farm income	-0.0162	0.0078	0.038**	-0.0314	-0.0009
Slope	0.0462	0.0482	0.338	-0.0483	0.1406
Soil fertility	0.1364	0.0458	0.003***	0.0466	0.2261
Group membership	0.0011	0.0369	0.976	-0.0713	0.0735
Remittance	-0.0543	0.0349	0.119	-0.1224	0.0139
Access to climate information	-0.1220	0.0560	0.029**	-0.2317	-0.0123

NB: significance level, ***1%, **5%, *10%. Prob> chi^2 = 0.0000; Log pseudo likelihood = -23.08; Pseudo R^2= 0.7766; Number of observations=150

Table 4.15 presents summary results of factors that influence female decision to apply chemical fertilizer to their farms. The results show that there is a positive association between fertilizer application by female headed households and farming experience, household size, and dependency ratio, farm area allocated for maize production, rice area and family remittance. Negative effects were observed between fertilizer application by female farmers and education and non-farm income. The age of female farmers, marital status, access to extension services, access to credit, access to market, land ownership, livestock holding, non-farm income, slope, soil fertility, group membership and access to climate information had no statistically significant effect.

Table 4.15: Determinants of fertilizer adoption by female headed households ($n_{females}$= 150; n_{males}= 150)

Explanatory variables	Marginal effect	St. Err	P - Values	(95 % confidence interval)	
Age	0.0025	0.0019	0.194	-0.0013	0.0062
Education	-0.0262	0.0124	0.034**	-0.0505	-0.0019
Farming experience	0.0141	0.0055	0.010**	0.0034	0.0249
Household size	0.0187	0.0088	0.034**	0.0014	0.0361
Marital status	0.2651	0.1621	0.102	-0.0525	0.5827
Access to Agric. Extension	-0.0044	0.0586	0.940	-0.1193	0.1105
Access to credit	0.0289	0.0701	0.680	-0.1084	0.1662
Dependency ratio	0.0710	0.0361	0.050*	0.0001	0.1418
Maize area	0.8900	0.2774	0.001***	0.3463	1.4338
Rice area	0.5007	0.2451	0.041**	0.0203	0.9811
Market access	0.0008	0.0885	0.993	-0.1727	0.1743
Land ownership	-0.0958	0.0712	0.178	-0.2353	0.0437
Livestock holding	-0.0064	0.0279	0.819	-0.0611	0.0483
Non-farm income	-0.0052	0.0030	0.085*	-0.0111	0.0007
Slope	-0.0298	0.1192	0.802	-0.2634	0.2037
Soil fertility	-0.0436	0.0673	0.517	-0.1755	0.0883
Group membership	-0.0676	0.0625	0.280	-0.1901	0.0549
Remittance	0.1113	0.0569	0.051*	-0.0002	0.2228
Access to climate information	0.0562	0.1433	0.695	-0.2247	0.3372

NB: significance level, ***1%, **5%, *10%. Prob> chi^2 = 0.0000; Log pseudo likelihood = -58.11; Pseudo R^2= 0.2526; Number of observations=150

4.4.3 Gender specific knowledge on soil conservation practices

The farmers' knowledge on soil conservation practices is presented in Table 4.16. Both gender groups have sound knowledge on soil conservation practices. Approximately 95 % and 97 % of male and female-headed households are well aware of soil conservation practices in terms of crop residue retention, soil fertility management using organic matter, zero tillage, seed bed preparation, crop rotation and the use of cover crops. However, the main challenge faced by farmers is lack of financial resources as shown in the adoption rate of chemical fertilizer. Farmers were of the view that interest rates on credit were so high that the probability of default was high hence their inability to take credit.

Table 4.16: Gender specific knowledge on soil conservation practices ($n_{females}$= 150; n_{males}= 150)

Variable	**Male (%)**		**Female (%)**		Average true total (%)
	True	**False**	**True**	**False**	
Residue retention					
Crop residues are sources of soil organic matter	98	2	99	1	98
Soil organic matter improves water capacity	88	12	89	11	89
Soil fertility management					
Organic manure is as strong as chemical fertilizer	98	2	99	1	98
Manure improves water holding capacity of the soil	71	29	87	13	79
Tillage					
Planting can be done without ploughing	100	0	99	1	99
Tillage improves water infiltration	98	2	98	2	98
Seed bed					
Improves water holding capacity	99	1	100	0	99
Improves soil aeration	99	1	99	1	99
Rotation					

Rotating cereals and legumes improve soil fertility	99	1	99	1	99
Rotation prevent some plant disease	99	1	99	1	99
Cover crops					
Reduce soil erosion	95	5	99	1	97
Increase soil microbes	93	7	93	7	93

4.4.4 Soil chemical and physical characteristics of farmers` fields

The results of physical and chemical analyses of the soil from farmer's fields are presented in Table 4.17. The result indicates that soils are slightly more acidic on farms where some fertilizers were applied than on farms where no fertilizers were applied. Similarly, soil phosphorus was higher on farms using organic manure compared to farms which only received chemical fertilizer and farms where no fertilizer was applied. In addition, CEC and soil organic carbon (SOC) were generally higher in soils where organic manure was applied.

Table 4.17: Soil characteristics of the study area as at 2014 (N=30)

Parameters	Organic Fertilizer (farms)		No Fertilizer application		Fertilizer	
Soil depth (cm)	**0 - 15**	**15 - 30**	**0 - 15**	**15 - 30**	**0 - 15**	**15 – 30**
Total N (%)	0.48	0.33	0.15	0.16	0.21	0.19
Available P (ppm)	9.54	7.50	5.96	5.53	7.36	6.97
Available K (mg kg^{-1})	2.47	2.90	1.77	1.91	1.61	2.08
pH	7.23	7.0	6.67	6.45	6.12	6.39
Mg (cmol (+) kg^{-1})	0.60	0.98	1.22	0.86	0.91	0.97
CEC (cmol (+) kg^{-1})	12.74	10.6	9.23	7.10	10.8	9.87
Organic C (%)	4.08	2.20	1.53	0.47	2.69	1.73
EC (µS/cm)	96.2	113	68.89	74.4	62.8	81.3
Sand (%)	65.6	65.4	66.4	63.6	58.3	66.0
Silt (%)	11	12.8	11.43	12.86	15.75	11.25
Clay (%)	23.4	21.8	22.14	23.6	25.0	22.8

4.5 Gender and land tenure linkages in adaptation to climate change

4.5.1 Descriptive characteristic of farmers by gender

The socio-economic characteristics of respondents are summarized in Table 4.18. The mean age of sampled male and female-headed households is approximately 55 years. On average, males have relatively more farming experience, dependents and income relative to females. The male-headed households have slightly more farmland than females. In general, there is a high illiteracy rate among farmers especially with female-headed households where about 85 % have no form of education (Table 4.19). Out of the total farmers interviewed, only 3% had tertiary education. Ninety-two per cent of the female respondents were widowed. In contrast, 90% of males were married at the time of the survey. The widowed were largely women who assumed headship of their households following the demise of their spouses and to a small extent when their spouses travel to other parts of the country in search of off-farm jobs. About a third (29%) of the male respondents obtained their farmlands through inheritance, a customary practice in the study area where a piece of land is transferred from a father to a male child (Table 4.19). On the other hand, 28% of farmland cultivated by female respondents were obtained through family members, in part following the demise of their husbands or during periods when their spouses travel to other part of the country to engage in off-farm jobs. Other equally important sources of farmland for both gender groups were gained through leasehold with use right up to 99 years, or through rent having a use right that ranges between1 to 5 years. In terms of labour, both gender group engaged the services of family and hired labour with male-headed households having slightly more family labour compared to female counterparts.

Table 4.18: Descriptive statistics and socio-economic information of respondents by gender (2014)

Variables	Gender	Mean	Standard deviation	Min	Max
Age	Men	55.31	17.98	17	97
	Women	53.37	14.88	25	97
	N	54.34	16.43	21	97

Family labor	Men	5.06	2.28	1	12
	Women	4.72	2.08	1	11
	N	4.89	2.18	1	11.5
Farming experience (yrs.)	Men	25	5.38	19	40
	Women	23.72	4.58	18	40
	N	24.36	4.98	18.5	40
Total area of landholdings (ha)	Men	1.94	0.73	0.53	4.13
	Women	1.24	0.47	0.32	2.59
	N	1.59	0.6	0.43	3.36
Number of dependents (#)	Men	3.65	1.62	0	7
	Women	2.88	1.85	1	10
	N	3.27	1.74	0.5	8.5
Income (US$/Year)[1)]	Men	1210.97	469.37	208.05	2892.83
	Women	748.22	360.91	163.59	1741.19
	N	979.60	415.14	185.82	2317.01

1) This is based on an exchange rate of USD 1 = GHS 3.215; N_{total} *= 300*

Table 4.19: Demographic and land ownership characteristics of respondents by gender (2014)

Key variables		**Men (n=150)**		**Women (n=150)**	
		#	(%)	#	(%)
Marital status	Married	135	90	7	4.7
	Single	12	2	5	3.3
	Widowed	3	8	138	92
Educational Level	Primary/Secondary	65	43.3	16	10.7
	Tertiary	1	0.7	7	4.6
	No education	84	56	127	84.7
Land ownership	Inherited	44	29.3	28	18.6
	Leasehold (99yrs)	27	18	12	8
	Rented (1-5yrs)	39	26	33	22
	Community	10	6.7	16	10.7
	Chief	7	4.7	18	12
	Friends	3	2	1	0.7
	Family	20	13.3	44	28

4.5.2 Perception of climate change and variability

Table 4.20 shows a general trend in terms of perception of male and female respondents on climate change and variability particularly to temperature, decreasing rainfall, and frequency of drought. Both gender groups indicate that temperatures have risen over the past decades resulting in rapid reduction in soil moisture and affecting crop development.

They both share the perception that precipitation is decreasing, and the rainy season is shortening. According to them, the start of the rainy season has shifted from April to May and sometimes stops in the early part of September leading to loss of crop. The rainfall pattern is increasingly unpredictable making it difficult for farmers to mitigate their losses. Furthermore, both male and female respondents (80%) indicated that the frequency of drought has increased over time resulting in acute water shortages during the dry season. The result indicates that there is no significant difference in climate change perception between gender groups.

Table 4.20: Gender-specific perspective of climate change and variability based on survey results (2014) ($n_{females}$= 150; n_{males}= 150)

Indicator	**Men (%) (n=150)**			**Women (%) (n=150)**		
	Decreasing	Increasing	No change / Do not know	Decreasing	Increasing	No change / Do not know
Changes in temperature	15	74	11	7	80	13
Changes in rainfall distribution	81	11	8	87	5	8
Changes in drought frequency	7	86	7	5	89	6

Actual data on trends of temperature recorded during the last 30 years (Figure 4.13) shows that farmer's perception of increasing temperature was confirmed by climatological evidence. On the other hand, figure 4.14 shows that there is no clear evidence of decreasing rainfall. Instead, the rainfall data (between 1985 and 2013) have a marginal increase contrary to the respondents claim, with irregularity in rainfall in the years 1989, 1991, 1995, 1999, 2007 and 2011. The respondents might be confusing the unreliable and ineffective nature of the rainfall (heavy storms with excessive run-off) with decreasing precipitation. The historical rainfall anomaly between 1985 and 2014 shown in figure 4.15 rather shows dry periods in 1990, 1995, 2004 and 2005 contrary to farmers' perception of more recent drier years. Years below the zero line are periods with low rainfall when compared to the average of the entire period whereas years with the bar at or below -1.5 are considered drought years.

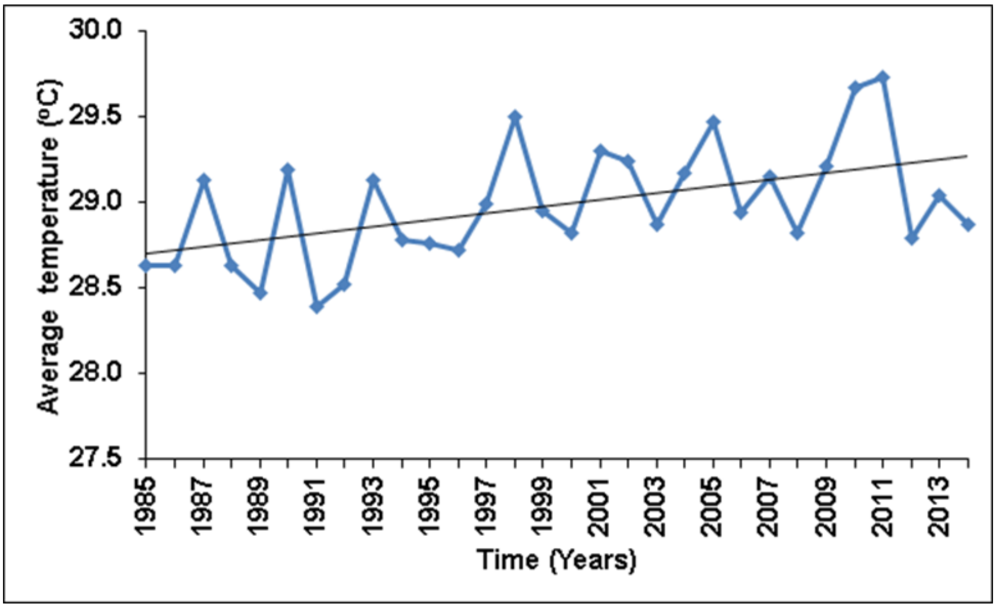

Figure 4.13: Historical average annual temperature (ºC) of Bolgatanga municipality, Ghana (Source: Ghana Meteorological Agency 2014)

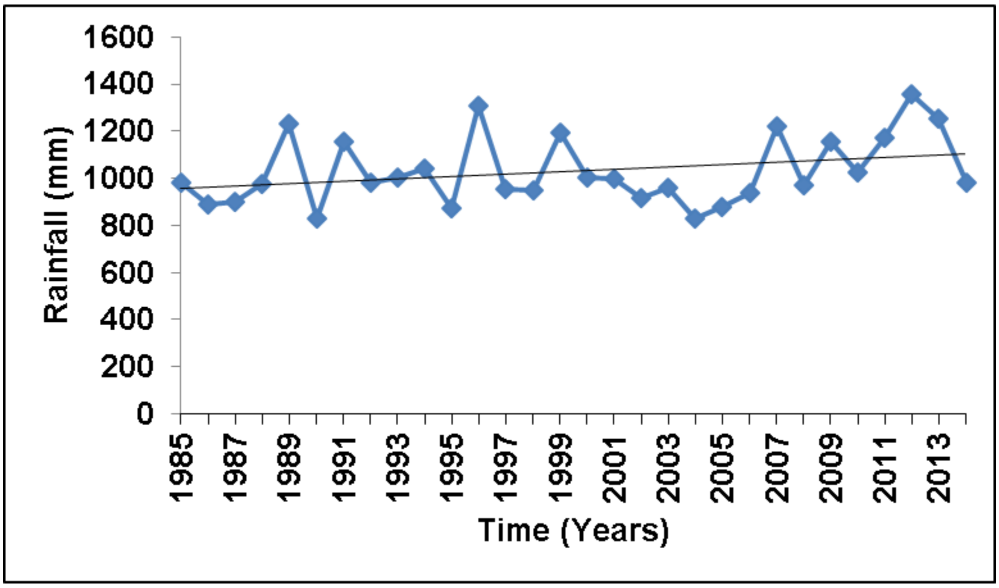

Figure 4.14: Historical annual rainfall (mm) of Bolgatanga municipality, Ghana (Source: Ghana Meteorological Agency 2014)

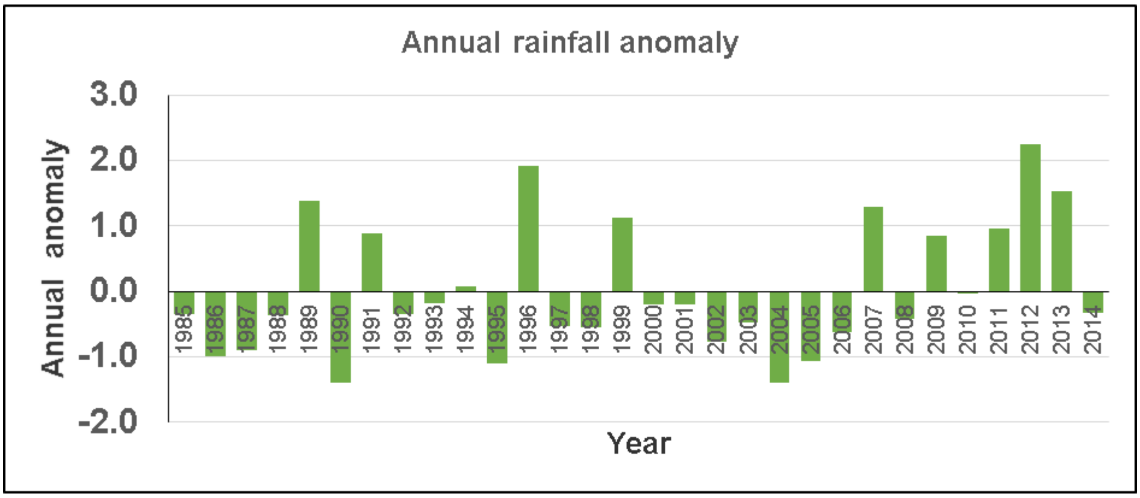

Figure 4.15: Annual rainfall anomaly derived from historical rainfall data of Bolgatanga municipality (Source: Ghana Meteorological Agency 2014) Anomaly=(X – mean of X)/standard deviation.

A majority of the respondents (84% and 80% male- and female-headed households) attributed the rise in temperature to deforestation following the high demand for firewood and charcoal. Others blamed the annual ritual of bush burning and increasing human population whereas some believe that it is a natural course. There is also a common view that decreasing precipitation is as a result of indiscriminate felling of trees in the study area (83 % male- and 72% female-headed households). Similar reasons were adduced for the increasing incidence of drought in the area.

In general, both male and female respondents share the perception about the negative impacts of climate change and variability especially the erratic rainfall, which affect their overall farm productivity (Figure 4.16). According to them, erratic rainfall has direct detrimental impacts on crop and animal production whereas high temperature is responsible for loss of soil moisture. The early cessation of the rainy season and severe drought leads to low crop yield. They have also associated climate change to the reduction in soil fertility due to inadequate organic matter production from vegetation growth. The farmers consider organic matter to be an essential factor in ameliorating physical properties of the soil.

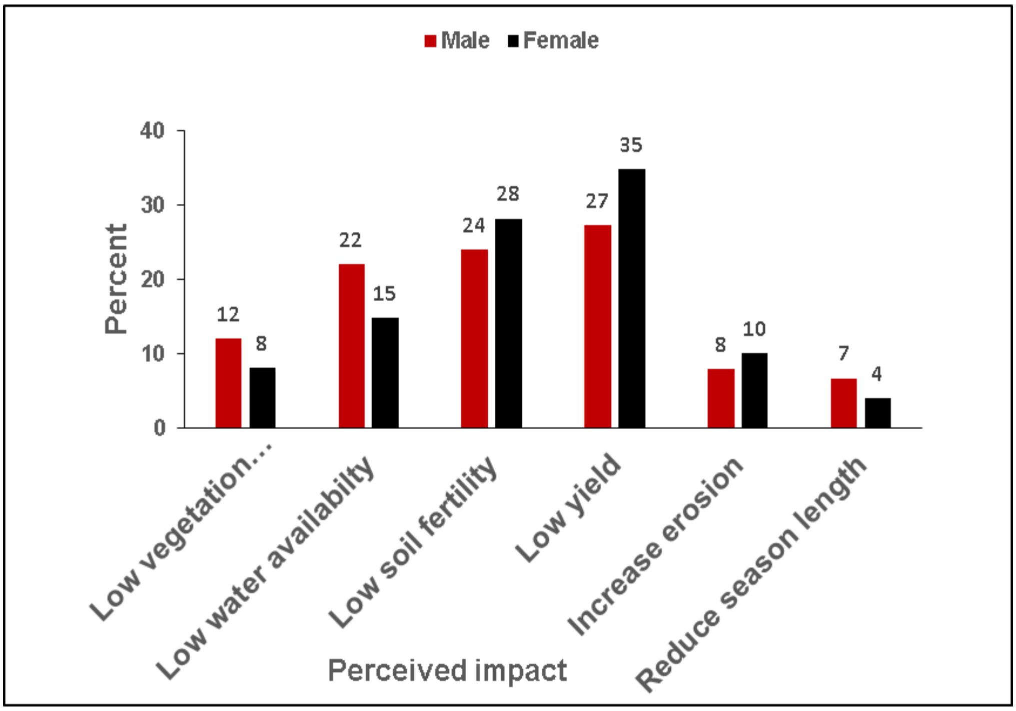

Figure 4.16: Perceived impact of climate change on farming in UER, Ghana ($n_{females}$= 150; n_{males}= 150)

4.5.3 Adaptation strategies to cope with climate change

Table 4.21 indicates that farmers employ different strategies to deal with three major climate change scenarios. A total of ten strategies were identified to adapt and mitigate the impact of climate change. Male and female respondents have almost similar top adaptation strategies for both scenarios of increasing temperature and decreasing or ineffective precipitation. Among the top two are changing planting dates (ranging between 14% and 22% of respondents), and crop diversification (ranging between 12% and 17% of respondents). On the other hand, under the increasing drought scenario, male and female respondents have different strategies. For female-headed households, the top strategies are engaging in off-farm jobs (46%) and migration to other parts of country (20%). In contrast, for male-headed households, the top strategies are migration to other parts of country (43%), followed by engagement in off - farm activities.

Table 4.21: Adaptation strategies used by farmers in the Vea catchment of Ghana by gender ($n_{females}$= 150; n_{males}= 150)

Adaptation strategies	**Scenario**					
	Increasing temperature		Decreasing precipitation		Increasing frequency of drought	
	Male %	Female %	Male %	Female %	Male %	Female %
Crop diversification	**17.3**	**14.7**	**13.3**	**12.7**	0	0
Change in crop type	8.7	5.3	4	6	0	0
Reduction in farm size	0.7	1.3	0	2.7	0	0
Change planting date	**16.7**	**14**	**22**	**15.3**	0	0
Engage in off-farm jobs	1.3	1.3	1.3	0	**19.3**	**46.6**
Plant short season varieties	1.3	0.7	9.3	9.3	0	0
No adaptation/ do nothing	50.7	61.3	44	50.7	28.7	30.7
Migration to other parts of the country	3.3	1.4	4.7	2	**43.3**	**20**
Apply less fertilizer	0	0	0.7	0	0	0
Produce more livestock	0	0	0.7	1.3	5.3	0
Ritual ceremony	0	0	0	0	3.4	2.7

4.5.4 Determinants associated with the decision to adopt adaptation strategies

a) Increasing temperature

Seven variables were significantly associated with the decisions to adopt adaptation strategies to cope with increasing temperature (Table 4.22). Gender is a significant determinant associated with the decisions to adopt; male-headed households are more likely to adopt strategies than female-headed households. Access to extension ($p < 0.000$) and credit services ($p < 0.000$) signified that the more access to these services, the higher the likelihood of the farm households to adopt coping strategies. The households whose land tenure are in the form of family land, rented or provided by chiefs are significantly more likely to adopt adaptation strategies.

Table 4.22: Determinants associated with the decision to adopt adaptation strategies to cope with increasing temperatures ($n_{females}$= 150; n_{males}= 150)

Variable	Coefficient	Std. err	Sig	(95% confidence interval)	
Gender (dummy)	0.698	0.333	0.036*	0.045	1.351
Household size (#)	0.087	0.054	0.105	-0.018	0.193
Land tenure					
Family	0.814	0.421	0.053*	-0.011	1.639
Leasehold	0.731	0.456	0.109	-0.162	1.624
Rented	0.759	0.388	0.050*	-0.001	1.520
Community	0.414	0.570	0.467	-0.703	1.530
Chief	1.292	0.562	0.022*	0.187	2.398
Friends	0.671	1.039	0.519	-1.366	2.708
Extension access (dummy)	1.428	0.285	0.000***	0.870	1.987
Credit access (dummy)	1.631	0.379	0.000***	0.888	2.374
Soil fertility (dummy)	-0.674	0.320	0.035*	-1.300	-0.047
Household cattle (#)	-0.046	0.040	0.245	-0.125	0.032
Per capita income (US$)	0.001	0.000	0.197	-0.000	0.001
Constant	-3.288	0.834	0.000***	-4.923	-1.653

*** $p \leq 0.05$; ** $p \leq 0.01$; *** $p \leq 0.001$. Prob> chi^2 = 0.0000; Log likelihood = -170; Pseudo R^2 =0.1743**

b) Decreasing precipitation

Table 4.23 shows that ten variables were significantly associated with the decisions to adapt to perceived decreasing precipitation. The most significant factor is soil fertility ($p < 0.000$) suggesting that the more fertile the soil, the higher the likelihood of both male and female headed households to implement adaptation strategies. Age, land tenure (rented), credit access, farming experience (11-20 years), land area for traditional cereal legume, mixed groundnut, maize yield and total crop yield also significantly increased the willingness of farmers to take coping action.

Table 4.23: Determinants associated with the decision to adopt adaptation strategies to cope with decreasing or erratic precipitation ($n_{females}$= 150; n_{males}= 150)

Variable	Coefficient	Std. err	Sig	(95% confidence interval)	
Age	0.024	0.008	0.003**	0.008	0.040
Land tenure					
Family	0.145	0.422	0.730	-0.682	0.973
Leasehold	0.536	0.463	0.247	-0.372	1.443
Rented	0.811	0.397	0.041*	0.033	1.589
Community	-0.138	0.498	0.782	-1.113	0.837
Chief	-0.472	0.533	0.376	-1.518	0.574
Friends	-0.686	1.497	0.647	-3.621	2.248
Extension access (dummy)	0.643	0.303	0.034*	0.048	1.237
Credit access (dummy)	1.131	0.383	0.003**	0.381	1.881
Farming experience (6-10yrs)	0.477	1.128	0.673	-1.735	2.688
Farming experience (11-20yrs)	3.343	0.884	0.008**	0.611	4.075
Farming experience (21-30yrs)	1.693	0.850	0.046	0.027	3.359
Farming experience (> 30yrs)	0.866	0.883	0.327	-0.865	2.596
Soil fertility (dummy)	-1.869	0.368	0.000***	-2.589	-1.148
Traditional cereal legume area (ha)	1.498	0.646	0.020*	0.232	2.765
Mixed Groundnut area (ha)	1.562	0.566	0.006**	0.453	2.672
Maize yield (kg/ha)	0.002	0.001	0.011*	0.000	0.003
Total crop yield (kg/ha)	-0.001	0.000	0.016*	-0.001	-0.000
Constant	-3.234	1.0.085	0.003**	-5.361	-1.107

* $p \leq 0.05$; ** $p \leq 0.01$; *** $p \leq 0.001$. Prob> chi^2 = 0.0000; Log likelihood = -166; Pseudo R^2= 0.2017

c) Increasing frequency of drought

A total of eight variables were significantly associated with the decisions to adopt adaptation strategies under increasing frequency of drought (Table 4.24). Gender is significantly associated with the decisions to adopt; suggesting that male-headed households are more likely to adopt strategies than female-headed households. The better the access to extension ($p < 0.000$) and credit services ($p < 0.000$) the higher the likelihood of the farm households to adopt coping strategies. The households whose land tenure are in the form of family land, leased, rented or provided by chiefs are significantly more likely to adopt adaptation strategies. Furthermore, the more fertile the soil, the higher the likelihood of both gender group to implement adaptation strategies.

Table 4.24: Determinants associated with the decision to adopt adaptation strategies to cope with *increasing drought* ($n_{females}$= 150; n_{males}= 150)

Variables	Coefficient	Std. err	Sig	(95% confidence interval)	
Gender	0.696	0.289	0.016*	0.130	1.263
Fertilizer subsidy	0.726	0.398	0.068	-0.548	1.506
Groundnut yield (kg/ha)	0.010	0.007	0.121	-0.003	0.023
Family land	0.873	0.429	0.042*	0.032	1.712
Leasehold	1.057	0.469	0.024*	0.138	1.977
Rented land	0.988	0.397	0.013*	0.210	1.766
Community land	0.362	0.552	0.512	-0.719	1.444
Land from chief	1.242	0.531	0.019*	0.201	2.284
Land from friends	0.446	1.222	0.715	-1.949	2.842
Extension access (dummy)	1.430	0.290	0.000***	0.862	1.997
Credit access (dummy)	1.562	0.370	0.000***	0.836	2.288
Soil fertility (dummy)	-0.681	0.334	0.042*	-1.336	-0.025
Groundnut area(ha)	-7.188	5.111	0.160	-17.206	2.830
Constant	-2.729	0.567	0.000***	-3.841	-1.618

* $p \leq 0.05$; ** $p \leq 0.01$; *** $p \leq 0.001$. Prob> chi^2 = 0.0000; Log likelihood = -170; Pseudo R^2 = 0.1799

4.6 Grazing game as a learning tool for adaptive strategies in response to climate variability by gender groups in semi-arid Ghana

4.6.1 Overall gender specific response

Figure 4.17 and 4.18 presents rainfall and average number of cows produced by both gender groups from 44 grazing games. From the results, the distribution of very dry, dry, wet and very wet years as determined by the throw of the dice was different for the male and female-headed households. The male players simulated wet and very wet years whereas the female group simulated more dry and very dry years.

For cow production, males produced higher number of cows than females under all rainfall categories except for very wet category. The highest number of cows (75) produced by males was observed under the wet category while females had the highest number of cows (72) under the very wet category. However, the difference in the number of cows produced by both gender group was significant only under the 'very dry' and 'very wet' categories where males produced 46% more cows and female 26% more respectively.

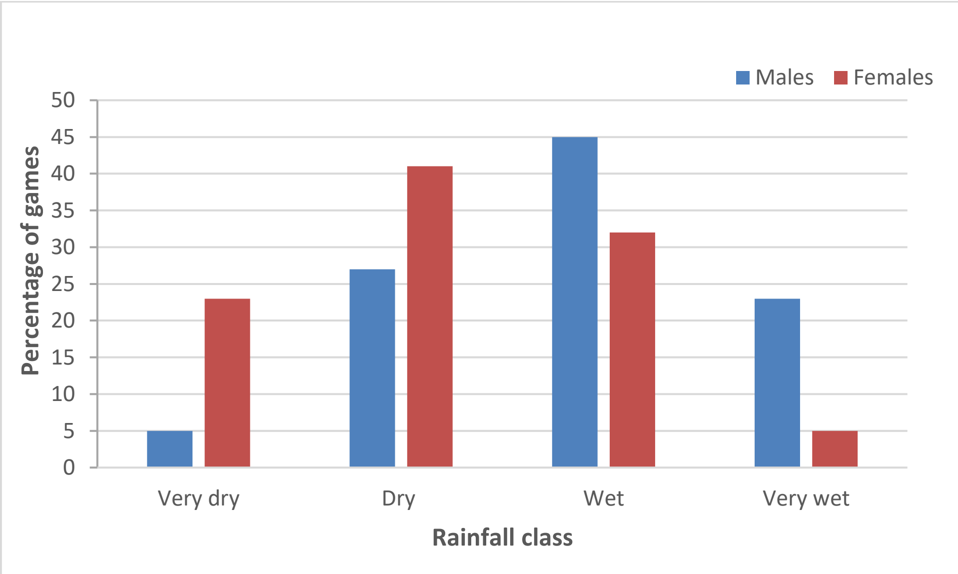

Figure 4.17: Percentage of games in annual rainfall categories among male and female headed household grazing game players in UER ($n_{female\ games} = 22$; $n_{male\ games} = 22$)

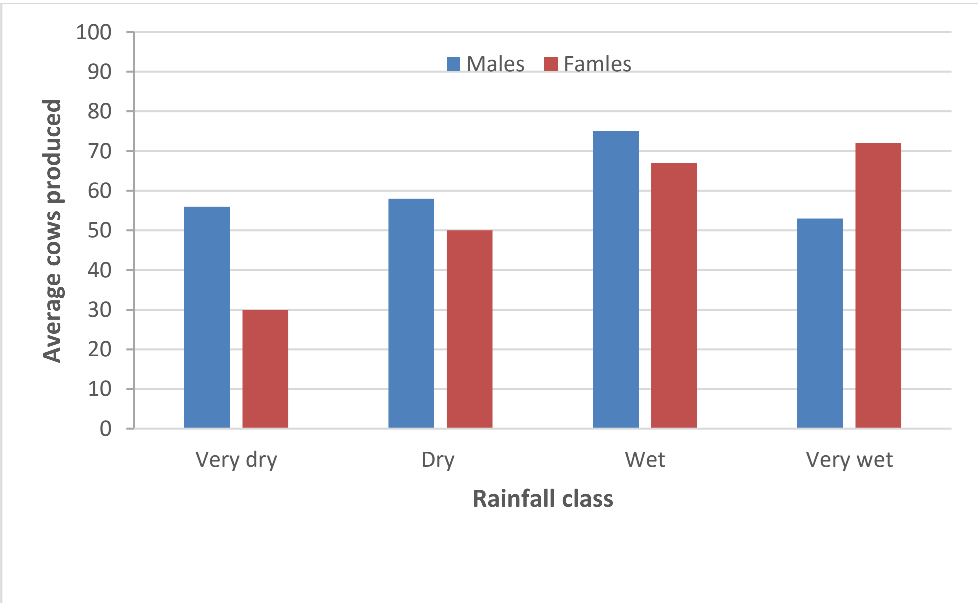

Figure 4.18: Annual average yield of cow produced by male and female headed household grazing game players in UER ($n_{female\ games}$ = 22; $n_{male\ games}$ = 22)

Figure 4.19 presents the number of desert patches created under various rainfall categories. Males created desert condition under all rainfall categories whereas females recorded no desert patches under the wet and very wet rainfall categories signifying that they are more conscious about the state of their lands. Males recorded high percentage of desert patches despite the high amount of rainfall recorded during the game suggesting that desertification can also be caused by factors other than climate.

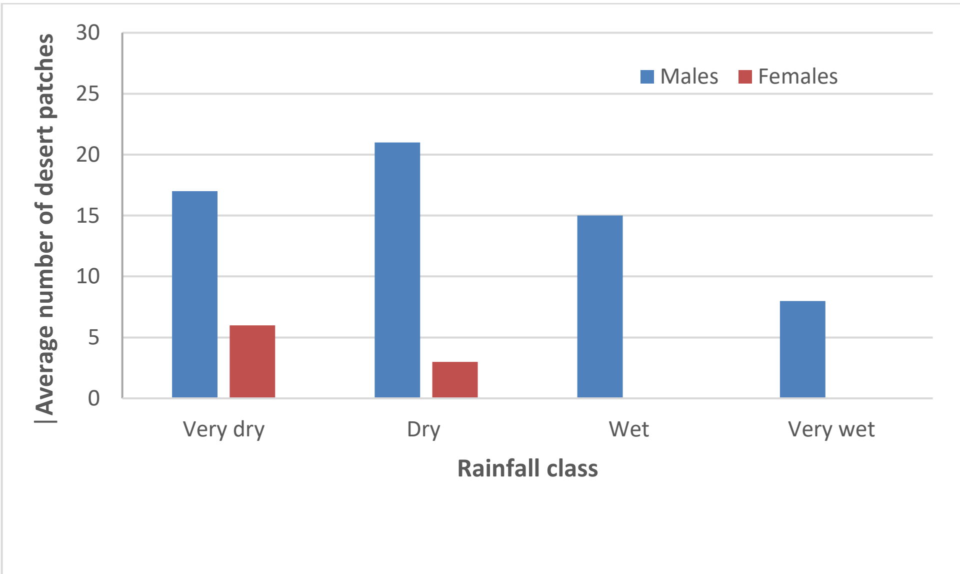

Figure 4.19: Prevalence of desertification among male and female grazing game players in UER ($n_{female\ games}$ = 22; $n_{male\ games}$ = 22)

Figure 4.20 presents the annual average production of cows and the amount of desert patches created. From the results males produced the highest number of cows and created the largest number of desert patches (degradation) compared to females. Males produced 10% more cows than females but created about 85% desert patches (degradation) more than females for the number of cows produced. Results from figure 4.21 and 4.22 (case 3 of both figures) shows that some of the games played by both gender groups ended with high percentages of desert patches in spite of the high amount of rainfall recorded during the game, which again suggests that desertification could also be caused by factors other than climate.

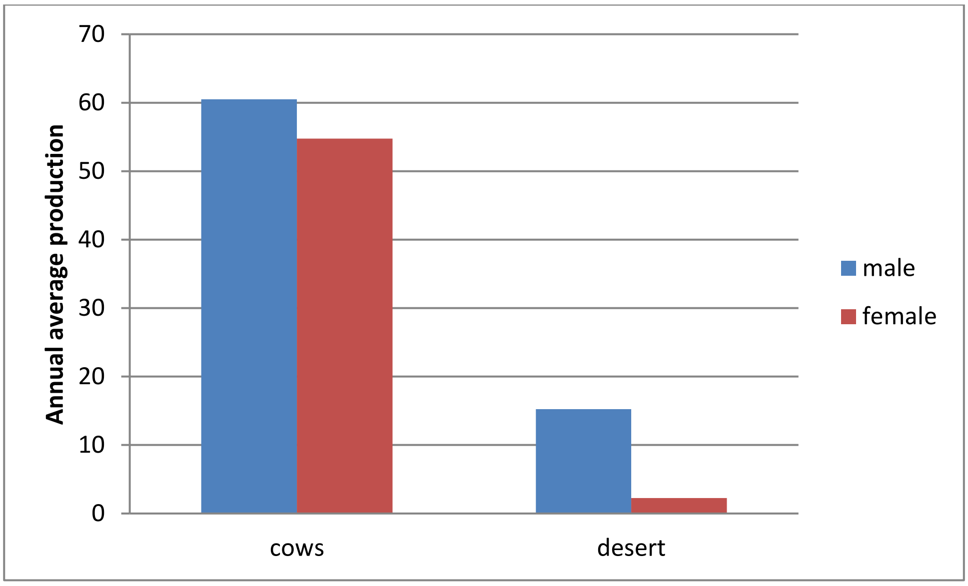

Figure 4.20: Average number of cows produced, and desert patches created by male and female-headed households ($n_{female\ games}$ = 22; $n_{male\ games}$ = 22)

A total of 3 games each from male and female headed households showing the rainfall pattern in the Vea catchment were selected. Figure 4.21 and 4.22 depict land use pattern in response to rainfall in the game (Figure 4.21B and 4.22B) and cow production levels (Figure 4.21C and 4.22C). Case 1 of both genders reveal a concave shape following the decreasing trend in rainfall pattern (Figure 4.21A and 4.22A) whereas case 2 shows a moving average rainfall but a convex shape with a decreasing rainfall pattern and case 3 depicts a galloping moving average rainfall pattern. The land use pattern and cow production trend in cases 1 and 2 reveal that a reduction in rainfall increases the rate of desertification and decreases cow production due to low amount of feed. On the contrary, in case 3 the amount of desert patches went up marginally despite the increasing trend of rainfall, which might be due to over grazing.

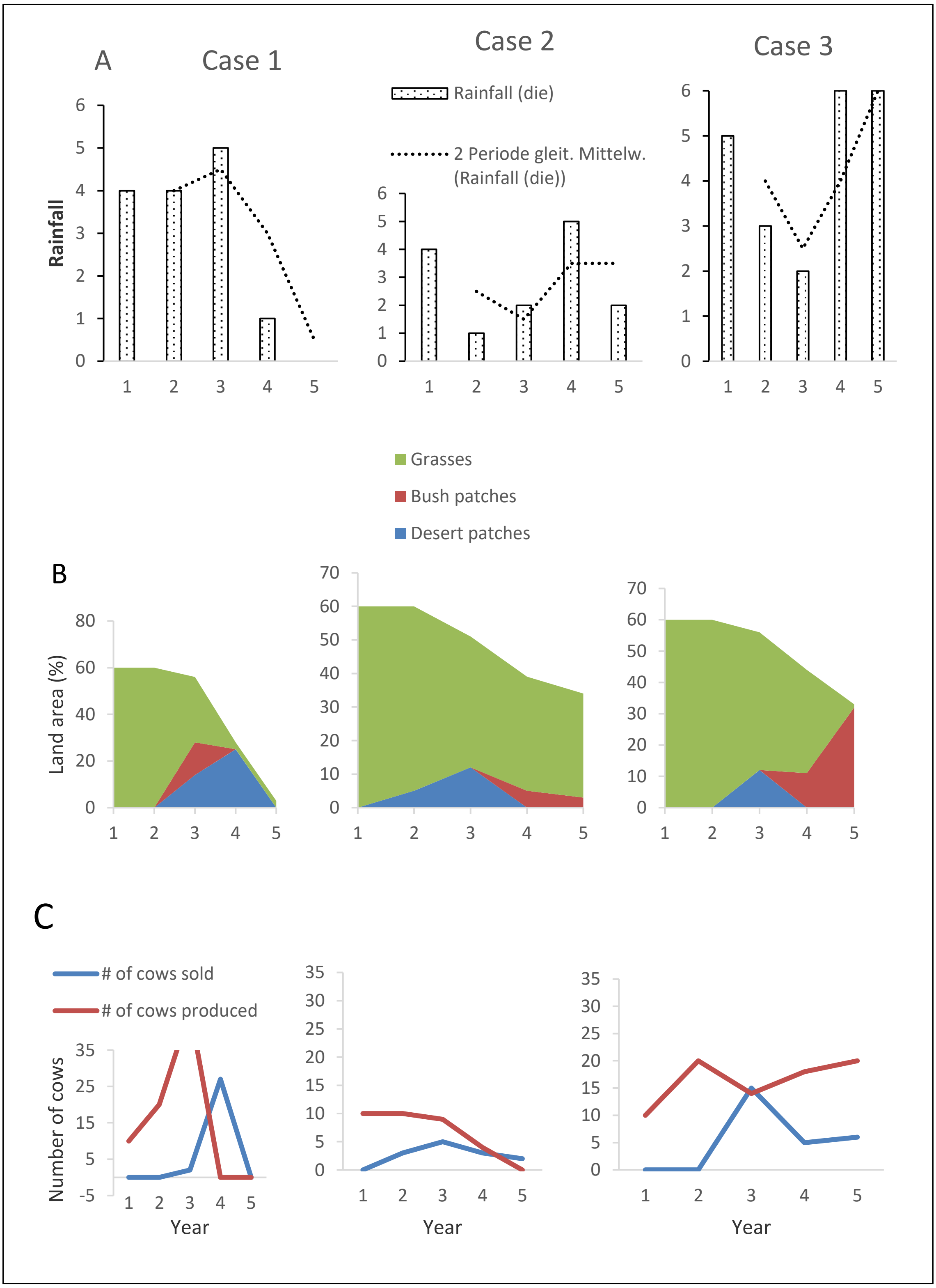

Figure. 4.21: Results of female grazing game depicting rainfall patterns under dry conditions with decreasing rainfall (case 1), dry conditions with ascending rainfall (Case 2) and wet conditions with ascending rainfall (case 3): (A) pattern of average rainfall, (B) Land use pattern and (C) cow production trend ($n_{female\ games}$ = 22; $n_{male\ games}$ = 22)

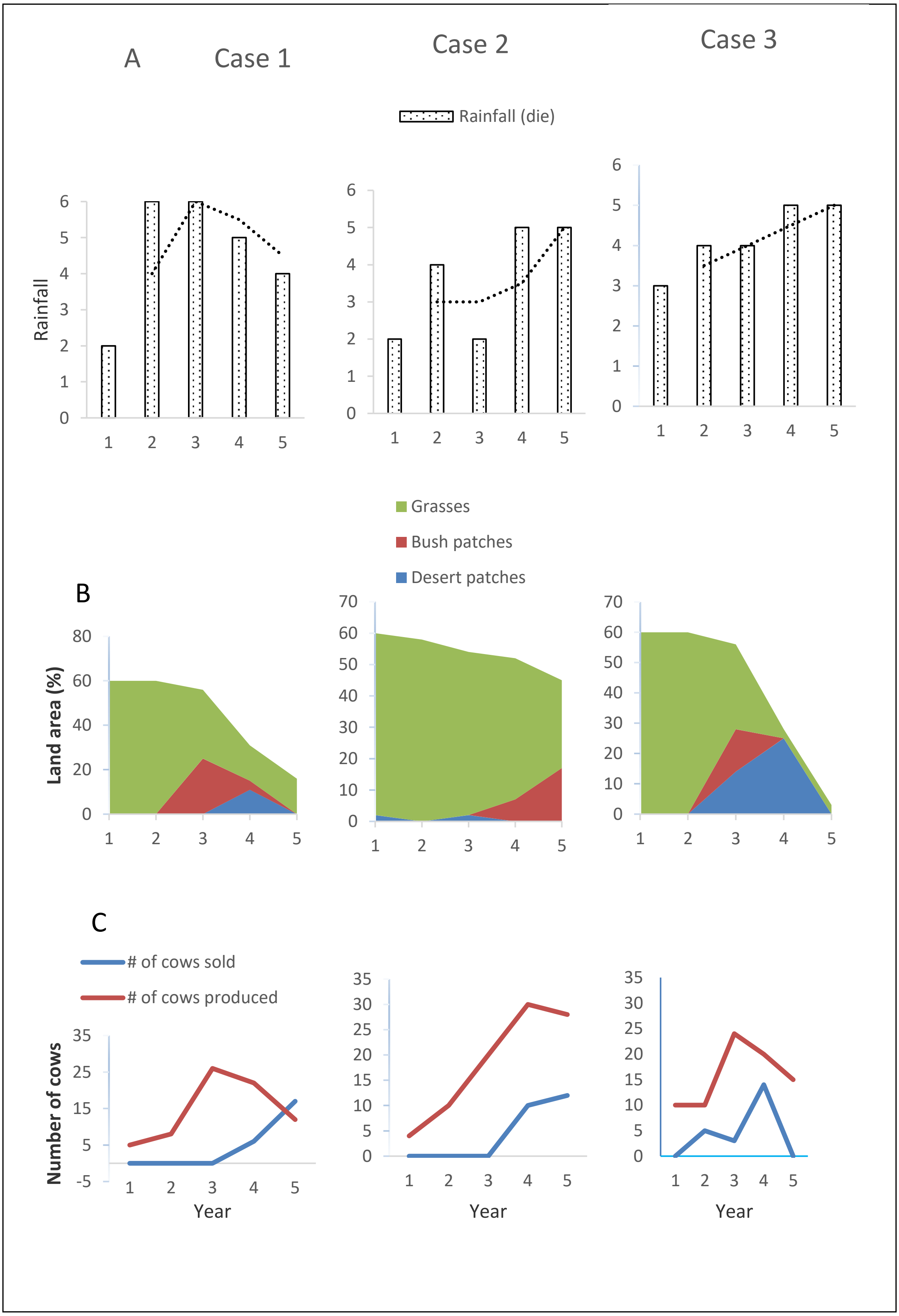

Figure 4.22: Results of male grazing game depicting rainfall patterns under dry conditions with decreasing rainfall (case 1), dry conditions with ascending rainfall (Case

2) and wet conditions with ascending rainfall (case 3): (A) pattern of average rainfall, (B) Land use pattern and (C) cow production trend ($n_{female\ games} = 22$; $n_{male\ games} = 22$)

4.6.2 Coping strategies and the nature of the game

Various strategies adopted by male and female players under erratic rainfall conditions during the game were observed. Similar strategies were adopted by male and female players. The decision to sell or keep a cow is taken after the rainfall amount is determined by the dice and is thus an informed decision (Table 4.25). The most common coping strategy by both gender groups against unpredictable and erratic rainfall was selling of cows (30% men and 22% women) to minimize losses (Table 4.26). The study also revealed that a majority of the farmers opted for the cultivation of early maturing crop (millet) and to some extent maize due to their ability to withstand drought conditions. The above choice is partly because early millet and maize mature before the ceasing of the rainy season. The main difference between the men and women strategies is the preference to migrate to other parts of the country for menial jobs by men and engagement in off-farm jobs such as basketry, trading and labour for road and house construction by women.

Table 4.25: Strategies identified from observations of the best performers of both gender group during the grazing game ($n_{female\ games} = 22$; $n_{male\ games} = 22$)

Strategies of Best Performers during Low Rainfall by both gender group
Cows are fed on half ration
A dice is thrown before a decision is taken to sell a cow
Cattle are only sold in the dry season when there is shortage of feed
Fertilizer is purchased to ameliorate soil fertility
Herds are usually divided and sent to feed on different patches
Cooperation among players to maintain a limited number of cattle

Table 4.26: Gender specific coping strategies to cope with rainfall variability during the grazing game ($n_{female\ games}$ = 22; $n_{male\ games}$ = 22)

Coping strategy	Men (%)	Women (%)
Off-farm jobs	8	20
Application of inorganic fertilizer to degraded land	3	3
Migration	15	4
Cultivate early maturing crops	20	17
Renovate irrigation canals	4	8
Ask for government support	10	11
Sell the cows	30	22
Move close to fallow and forest areas	2	3
Cultivate more trees	5	6
Move close to dam	4	6

4.6.3 Observed gender specific behaviour and perception

About 97% and 96% of the male and female players indicated that the game is a true reflection of reality. The game board was designed to reflect the exact landscape of farmers' fields. The patches at the centre of the game board represent the valley where there is available water throughout the year and the outer patches denote the uplands. Rice cultivation in a valley is a normal practice of farmers in the study area due to the water sensitive nature of the plant. Other crops such as Millet, Maize and Groundnut are located at the uplands since their water requirement is not very high. The reason for inter-cropping cereals with groundnut is to improve the nitrogen level of the soil through the nitrogen fixing ability of the groundnut. The size of the valley on the game board is 4 centimetres square and 8 centimetres for the upland area. Players could position their crops on the game board based on their traditional practices in order to reflect reality.

The introduction of the population and fertilizer subsidy scenario in years 3 and 4 of the game was meant to observe farmers reaction and coping strategies to change. Both male and female players were uncomfortable due to the fear of the unknown future. In reaction to the addition of a new household with a new herd to the game players began to compete for the limited resources as the case might be in a real-life situation when there is scarcity of resources. In response to the increase in player's population, they were willing to cooperate with each other for a better solution. Some of the statements made by the male farmers include:

> *To rejuvenate the pasture, we can reduce the number of cows so the grazing area can regenerate. We can plough for each other using our bulls*

Some of the direct statements made by the female players were:

> *We can support each other with money and food.*
>
> *We can assist each other in planting and harvesting of crops.*
>
> *We could appeal to government to repair irrigation canals to allow us to cultivate crops all year round.*

Similarly, both gender groups alluded to the fact that the erratic rainfall simulation in the game reflects the existing rainfall pattern in the study area. According to them, rainfall is unpredictable and usually delayed, leading to shortening of the season. Farmers perceived desert conditions during the game as a major threat to food production and their livelihood. Also, male and female farmers fed their animals with crop residues to allow for regrowth of the grass. Table 4.27 present similar behavioural responses to rainfall variability among male and female farmers in the Vea catchment.

Table 4.27: Gender specific observed coping strategies identified under extreme rainfall variability in UER ($n_{female\ games} = 22$; $n_{male\ games} = 22$)

Observed behaviour	**Situation**	**Men's strategies**	**Situation**	**Women's strategies**
Competition	Less available grass	Clearing of entire patches to prevent the new household from grazing animals	Less available grass	Clearing of all patches
Leadership	Insufficient grass	Grazing pattern determined by more experience farmers.	Inadequate grass	Grazing pattern determined by experience farmers
Cooperation	Limited rainfall	Agreement to plough land for each other using bulls.	Irregular rainfall	Strong agreement to sell equal number of cows by all players
Ecological awareness	Wet seasons	Abundance of guinea fowl signifies more available grass. Land fallow to ameliorate soil.	Wet seasons	More guinea fowl is an indicator for fresh grass. Regrowth of vegetation to ameliorate soil fertility. Application of organic residue to improve soil.
Ego and reputation	Pressure from colleagues	Older farmers exhibited strong dominance. Desert creation is considered bad luck.	Pressure from other farmers	Older farmers had more influence.

4.6.4 Gender specific indigenous ecological knowledge for coping with climate change and variability.

The study revealed the indigenous ecological knowledge of farmers. Both gender groups held similar ecological knowledge, which helps them to cope with climate change and variability. The ecological knowledge identified during the game included the following (Table 4.28):

1. Availability and behaviour of guinea fowl:

Most of the male and female respondents indicated that the presence and behaviour of guinea fowl is a true reflection of the environment. Guinea fowl, also known as "original fowl" belong to birds of the family *Numididae* in the order of *Galliformes*. These birds are insects and seed – eating ground nesting birds that are native to sub-Sahara Africa and are kept on free-range. The birds are very sensitive to rainfall conditions affecting their nature and feeding habits. Both male and female respondents revealed that their presence is a strong indicator of the amount and distribution of rainfall in a season. Higher amount and quality of insects during the onset of the rainy season promotes good growth and development of guinea fowl and vice versa. Reproduction of the birds is greatly impeded during irregular rainfall patterns as their eggs are usually laid during that period. Guinea fowls are also said to play an important role in the biological control of ticks and flies in cattle.

2. Multi-canopy layers of vegetation:

The presence of multi-canopy layers of vegetation serves as protective habitats for the birds against predators in the dry land ecosystem. This reduces the incidence of bird loss and hence more income to the farmers as these birds are seen as a good source of income to both male and female farmers. Guinea fowls are sold mostly in the dry season for payment of children's school fees or medical expenses.

3. Importance of vegetation in improving soil fertility:

Vegetation plays an important role in soil conservation and soil erosion. Litter fall or dead plant of vegetation when decomposed adds humus to the soil thereby enhancing the fertility status of the soil. Similarly, vegetation also helps in nutrient recycling where deeper-rooted plants bring up nutrient from deep layers of the soil to the surface of the soil as litter, which then decomposes to add organic matter to the soil. Furthermore, vegetation helps improve the moisture content of the soil hence creating favorable conditions for microbial activity in the soil. Some vegetation species such as Acacia are nitrogen fixing plants and can enhance soil fertility.

4. The importance of water bodies:

Water bodies serve as an important resource and habitat in an ecological system. Water bodies serve as source of drinking water for humans and livestock such as cattle and goats. Both gender groups emphasized the importance of the Vea dam in animal and crop production especially during the dry season when water is scarce.

Table 4.28: Grazing game as a social learning tool for all gender groups ($n_{\text{female games}} = 22$; $n_{\text{male games}} = 22$)

Forms of learning	**Case: Grazing game**	**Examples**
Instrumental: Does the game promote knowledge and skill acquisition among farmers and game facilitators?	The game helps them to gain knowledge and skills on good farm management practices.	Upland and lowland patches represented on the game board reflects a real-life situation in the study area
Communicative: Does the game promote exchange of ideas through communication	Game promote exchange of information and ideas on best farming practices.	Male and female players together with game facilitators share ideas on team work and how to solicit external support from government

Transformative: Acquisition of new skills based on reflection. Single loop: New knowledge based on personal actions and reflection. Adopt new ideas to enhance productivity.	New ideas to improve Existing farming practices	Both male and female players agree to sell some number of cows during the dry season where there is scarcity of feed.
Double loop: Reflecting on the assumptions behind certain actions	Review of policies and farming practices to enhance farming practices and systems.	Use of improved crop varieties (early maturing millet and maize)
Triple loop: Advance learning based on assumptions and specific actions capable of improving some values and norms.	This calls for integrated landscape planning	

Adopted and modified from Villamor and Badmos (2016)

5 DISCUSSION

5.1 Heterogeneity of factors influencing access to land and land use change

Male farmers cultivated on average 50% more land than the female farmers. This might be due to the fact that men in this part of the country traditionally control physical assets, especially land (Anang et al. 2013), attributed to the patrilineal system of inheritance and succession which is bias against women (Kasanga1994; Sarpong 2006). Better access to credit and inputs could also account for the relatively larger area of land cultivated by males compared to females, as farmers sometimes use their land as collateral to obtain credit facilities to engage more labor and input. This is in line with the finding of Lambrecht (2017) who compared 20 years data trend of land holding of males and females in Ghana and stated that females generally are less likely to hold land and hold 50% less plots size compared to males. They added that the gap in land size between males and females is larger in the forest and savannah than in coastal areas in Ghana. The trend analysis of land holding of rural male and female also shows that land holding of rural males have decreased over time while that of females remained constant

The male HH with larger holdings are able to cultivate more cash crops (groundnut, groundnut mixed and rice) to ensure financial income whereas female-headed HH are more interested in crops such as traditional cereals and traditional cereal legumes to meet their household food needs.

Male HH were endowed with more land area (6,631 m^2 more) than female HH resulting in higher gross (GHC 1,486 more) and per capita (GHC 184 more) income. This confirms the findings by many scientist including Anang et al. (2013); Kasanga (1994); and Sarpong (2006), who suggested that the patrilineal system of inheritance and succession in the region is biased against women. The relatively lower income earned by women could also be due to lower quality of farm land owned by women (Goldstein and Udry 2008). However, female HH are multi-tasking and have more entrepreneurial skills as evidenced in their income share from off-farm activities and livestock production, which are higher than for their male compatriots.

The higher land holdings coupled with preference for cash crops made male-headed households' better-off farmers than female HH for the livelihood type 1 (groundnut based farmers) as this resulted in higher gross income. A similar trend was observed for household type 2 (traditional cereal based farmers) where male farmers are more endowed in terms of gross income and land holdings.

5.2 Gender-specific productive roles in agricultural production and marketing systems

Male and female farmers play significant roles in agricultural production throughout the world. According to Auta et al 2000 and Damisa et al. (2007), women contribute about 60 to 90 percent of the total farm work in Nigeria. Furthermore, Koyenikan & Ikharea (2014) reported that women constitute about 70 percent of the total workforce involved in agricultural production, processing and marketing activities across the whole of sub-Sahara Africa.

From this study, the physically demanding activities such as planting crops, weeding, planting trees, and fertilizer application that were traditionally male dominated activities are now performed by women, which indicates a shift in their productive roles. This is in line with the findings of Koyenikan & Ikharea, (2014) who reported that productive roles of Nigerian women include physically demanding activities such as planting crops, weeding, harvesting crops, marketing of food produce among others with little or no involvement in the financial administration of farming and marketing activities. This observation could be due to increased need of women to act independently of men in order to improve their household food security and resilience to poverty.

Despite the increasing visible role of women in agricultural production, they have limited control over physical and financial resources thereby increasing their vulnerability to food insecurity and constraining their efforts in reducing poverty. The core reproductive roles of women have not changed despite their increasing involvement in farming activities (Table 4.20).

5.2.1 *Do men and women play the same roles in male and female-headed households?*

The hypothesis (H1) that 'Men and women have similar opinions about productive roles in the upper east region is rejected. The disagreement in some productive roles (i.e. clearing of land, planting of trees, pesticide or herbicide application, seedling production, and maintenance of farm records) of men and women in male and female-headed households as indicated in the fisher exact test (Table 4.10) is due to additional responsibilities or task performed by women which were originally men dominated. Thus, women are taking up more labor-intensive roles which were traditionally meant for men hence over-burdening them. This result is contrary to the findings of Villamor et al., (2015) who reported that in lowland areas in Sumatra, Indonesia, women are primarily responsible for less labor-intensive farming activities in monoculture rubber production whereas men engage in a more labor-intensive farming activity. The shift in the productive roles of women could be due to increase desire to improve household food security in order to reduce their vulnerability and poverty.

5.3 Gender specific determinants of land use decision (fertilizer adoption)

5.3.1 Probit regression for fertilizer adoption

HYPOTHESIS I: We reject the null-hypothesis "Gender does not matter in the adoption of inorganic fertilizer". The results on the contrary shows that gender does matter.

In the past few years, the global rural development agenda has strongly emphasized the significance of mainstreaming gender as a focus of policy development and analysis (UN 2002). Gender disaggregated evidence has helped facilitate the implementation of rural development policies more effectively. However, agricultural information divergent on gender has been highly inadequate in many parts of Ghana. This has limited the targeting of extension and policy towards women for a more sustained and efficient agricultural production by female-headed households (Oluwasusi and Okanni 2014).

Most studies conducted on the determinants of fertilizer adoption and rate of application by farmers used pooled data without differentiating for gender (e.g. Akpan et al., 2012; Fufa and Hassan 2006; Martey et al., 2014; Yu and Nin-Pratt 2014). However, in this study analysis was done by splitting the data according to gender. The study is based on the presumption that male- and female-headed households are subjected to different binding constraints with females presumably worse off with regards to access to information, land tenure security and finance (Oluwasusi and Okanni 2014). The low application rate of fertilizer in the study area is a major constraint to crop production and accounts for low crops yields. High cost of fertilizer coupled with lack of access to credit are the main reason for low application rate in the study area (Fosu et al., 2004; World Bank, 2008; Fosu-Mensah 2012). Similarly, the lower rate of fertilizer adoption by females can be attributed to the fact that females in general lack access to productive resources such as credit and land hence making males more likely to adopt new technology such as fertilizer (Bamire et al., 2012). The finding of this study is in line with the report by Kehinde et al., (2016) who stated that female cocoa farmers in southwestern Nigeria applied 9.1% less fertilizer to their farms compared to males. The lower percentage of income (2% and 9 %) for male-headed and female-headed households, respectively derived from non-farm livelihood- sources suggest high dependency on agriculture.

As shown in Table 4.16, experienced farmers were more likely to adopt fertilizer application confirming in the finding of Gracious et al (2015) in Uganda, Nkonya et al., (2005) in Tanzania and Abdoulaye and Sanders (2005) in Niger. Women were apparently more constrained than men in adopting fertilizers (Oluwasusi and Okanni 2014). The positive influence of climate information on fertilizer adoption suggests that farmers with knowledge of the availability of moisture for their crops, reducing the risk of loss of investment that might result from crop failure, will be more willing to adopt fertilizer application. Climate information is vital in the face of climate change, informing farmers about the onset, amount and duration of the season. This information allows farmers to plan strategies in which crop loss is minimised (Fosu-Mensah et al., 2012). The negative and significant influence of land and livestock ownership on fertilizer adoption suggest that owners of livestock use the droppings of their animals as manure on their farms. Compound farming is commonly practiced by farmers in this area where animal manure from poultry and animal droppings are applied to land close to homesteads (Kpongor et al., 2007). Although the build-up of plant nutrients from manure is a gradual process, the ownership of the land makes the farmer benefit from the long-term build-up of these nutrients through manure application. This finding is in contrasts to the finding of Beshir et al., (2012) in Ethiopia who found a positive association between livestock ownership and fertilizer adoption.

The positive association between fertilizer adoption by male-headed households and household size and marital status suggest that increase in crop yield is very vital to prevent malnutrition and poverty alleviation. The adoption of fertilizer and its application will increase crop yield to meet household food demand. This is in line with the finding of Gracious et al. (2015) who found association of family size and adoption of fertilizer in Uganda. Generally, maize and rice crops are fast growing crops and require nutrients for effective growth, hence farmers who have large acreage of maize and rice fields are more likely to adopt fertilizer to boost crop yields. In addition, farm size and off-farm income suggest the social status of the farmer enhances the ability to invest in the fertility of the land. This result is in line with the finding of Doss and Morris (2001) in Ghana and Beshir et al., (2012) in Ethiopia.

Female-headed households who earn relatively more income from non-farm sources are less likely to adopt and apply fertilizer. More educated, female heads are less likely to apply fertilizer. This could be attributed to increased access to alternative employment, which make these farmers less reliant on agriculture and demotivate them from investing in fertilizer. A year increase in the level of education leads to a 2.62% decrease in the probability of fertilizer application by the household she heads.

5.4 Gender and land tenure linkages in adaptation to climate change

5.4.1 Gender differentiated outcomes

HYPOTHESIS II: We reject the null – hypothesis “Gender does not matter on how a farmer deals with climate change adaptation” as findings from the study indicate that gender matters

Male and female-headed households are aware of climate change and its impacts in terms of increasing temperatures, erratic rainfall and frequent drought. Both gender groups feel equally vulnerable to the impact of climate change and variability. This result is consistent with earlier findings by Thornton et al., (2006), Fosu-Mensah et al., (2012), Amadou et al., (2015) and Sanogo et al., (2016) who reported that farmers are aware of climate change in Africa, sub-humid Ghana, upper east region of Ghana and southern Mali respectively.

Farmer's opinion about climate change is affected by context-specific power structures in relation to social categorization (Kaijser and Kronsell 2013). Our finding suggest that women are disadvantaged in the area of land ownership and property right due to the patrilineal system of inheritance and succession. Unequal access to relevant productive resources such as land by women does not only hinder their ability to access credit facilities but also their decision to use land and the amount of food produced. A growing body of literature shows that, most women in Sub-Saharan Africa (SSA) can only access and use land through men under the customary land tenure system (Farnworth et al. 2013). Furthermore, when women are given access to and control over crucial productive resources in terms of land, credit and social support (inputs), this will lead to an improved family well-being such as food security, education and health (OECD 2012 and FAO 2011).

5.4.2 Gender matters in the decision under specific climate change scenarios

With increasing temperature, female-headed households prefer to reduce farm size as a way of reducing risk of loss of income in case of crop failure. Women most often engage in off-farm activities such as trading, basketry and shea-nut gathering to supplement household income from farming activities. Thus, women make smaller investments in farming under an increasing temperature scenario than men, and so appear to be financially more risk averse. This result is in line with a similar study carried out by Charness and Gneezy, (2011) in Boston, north America who reported that women invest less and seem to be more financially risk averse than men.

Similarly, under decreasing precipitation, female-headed households adapt by crop diversification and change in crop type. This supports the earlier finding that women are more risk averse and will prefer to diversify to reduce the risk of crop loss in case of climate disaster. Traditionally, women in this part of the country are responsible for the day-to-day food needs of the family and so, will adopt strategies that will improve the food and nutrition needs of the family. In addition, under drought conditions, female- headed households turn to off-farm jobs to supplement their income. Thus, women in this region have more income-generating options than men due to their diverse cultural and gender roles (i.e. cooking, watching water caring for children among others).

On the other hand, male-headed households are more likely to take adaptive measures to cope with climate change than female-headed households. This might be due to ownership and control over basic physical and financial resources that are crucial for improving food security and resilience to climate change and variability. Tenge et al., (2004) and Abaje et al., (2014) reported that the traditional social barriers of female-headed households negatively impact on adaptation due to their limited access to information, land and other social resources. Female-headed households are generally under-resourced and with higher illiteracy rates thereby limiting their ability to increase agricultural investment to improve their resilience to climate change and variability (Nabikolo et al., 2012).

Temesgen et al., (2008) reported that male- headed households are more likely to adapt to climate change by implementing high-capital strategies than their female counterparts. However, male-headed households in the Vea catchment prefer to adapt to increasing temperatures through crop diversification, change of crop type and change in planting dates. In addition, male-headed households will migrate to the southern part of the country when impacted by climate change. Seasonal labour migration to the southern part of Ghana has been an on-going phenomenon for a long time (Arthur, 1991) among male-headed households in the region, with migration rates of 22.2 % in 2005 (GSS, 2005). The main reason for the seasonal labour migration is to seek jobs to supplement household incomes. In the process, females are compelled to assume headship roles of the family. Local off-farm jobs such as basket weaving, and trading (46.6% respondents) are the most preferred adaptation strategy for female - headed households.

5.5 Grazing game as a learning tool for adaptive strategy in response to climate variability by gender specific groups in semi-arid Ghana

HYPOTHESIS III: We reject the null-hypothesis "Gender does not play a role in natural resources management" as results from this study show that women are better managers of natural resources than men, hence gender matters in natural resources management.

The grazing game as a social learning tool was played in the context of lacking and erratic rainfall to understand the resilience of the environment and the human system to climate change and variability from a gender perspective. Thus, the game seeks to understand how different gender groups manage their natural resources (land) and cope with population pressure and climate change. It also helps to understand the behaviour of farmers when confronted with issues relating to climate change, desertification and coping strategies.

The grazing game facilitates social learning especially for the researcher as it helps to understand the motive behind farmers response' and at the same time evaluate their behavior and their perceptions during the game (Villamor and Badmos 2016). The most relevant aspects for assessing the degree to which the grazing game is an effective tool for facilitating social learning is as shown in Table 4.28. The higher number of cows produced by males compared to females could be attributed to the fact that males generally have more access to factors of production (land, labour, capital, fertilizer, etc). Due to women's limited access to land, they are less likely to access credit facilities as land is most often used as collateral to secure credit (Tsikata and Yaro, 2011; Apusigah, 2009; Sarpong, 2006). This result is in line with the finding of Doss, 2015 and Bravo-Monroy et al., (2016) who reported that women generally have limited access to resources such as farm land, credit, information about modern technologies, extension services and education in Sub-Sahara Africa. The high number of cows produced under wet and very wet conditions by males and females reflects the abundance of feed for the animals due to vigorous grass growth. Animals in the region are normally in an extensive system of production, hence abundance of feed is crucial to increase production.

The development of a large number of desert patches by males in all categories of rainfall was due to the excessive production of cows. This suggest that there is a strong correlation between cow production and land degradation, or creation of desert patches as shown in figure 4. 20. In some instances, farmers employed their local knowledge in decision making whether to sell off their animals based on some indicators such as abundance of guinea fowls at the onset of the rainy season. This is in line with the finding of Sanni et al. (2012) who carried out a study in northern Nigeria on traditional knowledge for predicting rainfall variability and reported that local farmers use guinea fowl as an indicator for climatic conditions. A better understanding of the local ecological knowledge such as the case of the guinea fowl might be useful for proper planning and management of an ecosystem (Villamor and Badmos 2016; Stringer and Reed 2007). Similarly, the creation of desert patches under wet and very wet conditions by male headed households suggest that land degradation can be caused by factors other than climatic condition. In addition, the difference in cow production and desert patches created by males suggest that, there is a threshold of cow production that can be accommodated on a piece of land above which significant diminishing returns set in. The results suggest that women are generally good managers of natural resources compare to their male counterparts (World bank 2008)., Women are conscious of their environment and will more readily reduce stock (number of cows) to prevent degradation. The game was very realistic, exposing the inability of farmers to predict the outcome of their decisions in relation to the unpredictable nature of rainfall patterns.

6 CONCLUSION AND RECOMMENDATIONS

6.1 General conclusion

Based on the results the following conclusion are drawn;

Male farmers have access to and cultivate larger land areas than their female counterparts in the study area due to the patrilineal system of inheritance. In addition, male farmers prefer to cultivate or put more land into the cultivation of cash crops such as legume compared to women who kept a higher percentage of their land in the cultivation of traditional crops to improve on food security for the household. Furthermore, the male-headed households generate higher income from the sale of farm produce than the female headed households. Women generally have little access to land but mostly put their lands into the cultivation of crops that will help improve on household food security status.

Women are involved in all stages of farming activities and more particularly in physically demanding activities with respect to planting crops, weeding the farm area, planting trees, fertilizer application, irrigation or watering, tree and crop harvesting as well as hauling of farm produce. The only engagement women have in the financial administration of the household is selling of crops. Men on the other hand are responsible for physical activities in terms of land preparation, feeding of livestock, seedling production and pruning of trees. They are the main actors in the financial administration regarding purchasing of farm inputs, farm financing and maintenance of farm records. Both gender groups perform the same activities such as planting of crops and harvesting of fruits. However, irrigation, weeding, and selling of crops were perceived as roles to be performed by women. Thus, the role of women is changing from reproductive roles to multi-purpose roles. Rural women are getting over-burdened with this additional work as it adds to their reproductive roles including caring for children, fetching of water, cooking and fetching of fuel wood which are not usually paid for. The contribution of women to agriculture and household food security is significant. The role of women in farming activities and marketing of farm produce clearly shows the difference between gender groups with females mostly using their farm produce for household consumption.

Factors that influence male and female farmers' decision to apply inorganic fertilizer are different and varied. The study shows that male-headed households are more likely to adopt fertilizer than female-headed households. The factors that significantly influenced male-headed households' adoption of inorganic fertilizer were household size, marital status, area of land allocated for maize production, rice area and perception about fertility status of soil. In contrast, land ownership, non-farm income access to climate information negatively but significantly influenced fertilizer application by male farmers. The factors that influence adoption of inorganic fertilizer for female-headed households include, farming experience, household size, dependency ratio, farm area allocated for maize production, rice area and family remittance while negative association were observed between fertilizer application by female farmers and education and non-farm income.

Majority of both gender groups perceived an increase in temperature, a decrease in precipitation and increasing drought spells in the study area. However only 49% male and 40% female have adapted to increasing temperature while 56% male and 49% female have adapted to decreasing precipitation. Similarly, 62% male and 60% female-headed households have adapted to increases in drought spells. The main adaptation strategies that both gender groups are adopting include changing planting dates and crop diversification. However, the main difference between the two groups are that males prefer to migrate to other parts of the country in search of greener pastures wheras females engage in off-farm activities such trading, basketry and shea-butter processing. Adaptation to decreasing and erratic precipitation is enhanced with age of farmers, access to extension services, access to credit, farming experience. Farmers who perceive their soil to be fertile, farmers who farm on rented land, cultivate traditional crop, maize and mixed groundnut are more likely to adopt farm management practices that will reduce the impact of decreasing and erratic precipitation.

The grazing game depicted real-live situations. It showed farmers how to cooperate with each other in the management of natural resources (land, grassland or pasture). The game is thus a good learning tool as it helped farmers to understand the consequence of lack of cooperation in natural resource use and management. The game also helped the farmers to come up with management strategies of their rangelands for sustainable use. Males produced the highest number of cows but created the largest number of desert patches reflecting land degradation. Females were as better managers of natural resources as they created fewer desert patches throughout the games played. Strategies such as reducing the number of cows in order to allow for re-growth of vegetation in periods of less feed, ploughing for each other using their bulls and family support using income from the sale of livestock were identified for both gender groups. Similarly, farmers saw the erratic rainfall scenarios as a real situation and a threat to food security in the region. The game also helped to identify some indigenous ecological knowledge for coping with climate change and variability. Farmers use the abundance of guinea fowl at the onset of the rainy season as an indicator for good year in terms of the amount and distribution of rainfall.

6.2 Recommendations

There is the need to eliminate cultural discrimination against women by restructuring and improving the land tenure system in the study area and promote equal rights to land ownership. To achieve this, intensive education programs are required to sensitize all stakeholders especially tendanas (chief makers), chiefs and family heads who oversee farmlands to recognise women in their decision-making process especially with regard to land tenure. The government should also put some measures in place to enable banks to provide flexible credit terms to farmers especially women. Block farming, where the government acquires a large area of farmland and distributes it among households to improve food security and livelihood, might be an option to enhance land tenure security among women in the study area. Female farmers should be empowered by government to go into cash crop farming such as groundnut and cowpea

There is a need for institutional support in the form of fertilizer subsidy to improve fertilizer adoption in the catchment. More education on the use of compost and or manure to improve the soil organic carbon and general nutrient content of the soil is recommended. Different policy instruments are required to increase the adoption of inorganic fertilizer application for both gender groups. Policies which target -maize and rice producers will be relevant to increase fertilizer adoption by male and female-headed households. In addition, policies that target experienced farmers, farmers with large household size among female-headed households will be relevant for adoption of fertilizer.

Policy decisions and programs to promote adaptation strategies to climate change and variability should be targeted at farmers who have access to credit, extension services, land and access to weather information. In addition, agriculture extension officers should be given regular training on modern farming techniques (climate smart agriculture) in the face of climate change. Government should also train more extension officers to increase the extension-farmer ratio in the study area. There is also an urgent need to train more female extension officers to improve female farmer's extension ration.

The concept of role-playing games should be extended to other areas of research and adopted by the government for use in understanding and implementing climate change adaptation and mitigation strategies in various communities in Ghana. This is relevant because the study established that participatory learning enhanced in-depth understanding of cooperation in sustainable natural resources management and coping strategies of climate change among farmers. The involvement of female farmers in decision-making is crucial to improve natural resource management.

7 REFERENCES

Abdoulaye, T., and Sanders, J. H. (2005). Stages and determinants of fertilizer use in semiarid African Agriculture: the Niger experience. Agricultural Economics, 32: 167-179.

Abdul-Razak, M. and Kruse, S. (2017) The Adaptive Capacity of Smallholder Farmers to Climate Change in the Northern Region of Ghana. Climate Risk Management, 17, 104-122. https://doi.org/10.1016/j.crm.2017.06.001

Adepoju, A. (1977). Migration and development in tropical Africa: Some research priorities. *African Affairs*, *76*(303), 210-225.

Adger, W. N., S. Huq, K. Brown, D. Conway, and M. Hulme. (2003). Adaptation to climate change in the developing world.*Progress in Development Studies* 3:179-195. http://dx.doi.

Akpan, S. B., Udoh, E. J. and Nkanta, V. S. (2012). Factors influencing fertilizer use intensity among small-holder crop farmers in Abak Agricultural Zone in Akwa Ibom State, Nigeria. Journal of Biology, Agriculture and Healthcare, 2:54-65.

Ali, D.A., Deininger, K., Duponchel, M., (2016). Using Administrative Data to Assess Impact and Sustainability of Rwanda's Land Tenure Regularization. Policy Research Working Paper, World Bank, Washington DC.

Alwang, J., Larochelle, C., and Barrera, V. (2017). Farm decision making and gender: results from a randomized experiment in Ecuador. *World Dev.* 92, 117–129. doi: 10.1016/j.worlddev.2016.11.015.

Amikuzino, J., and S. A. Donkoh. (2012). Climate variability and yields of major staple food crops in Northern Ghana. *AfricanCrop Science Journal* 20:349-360.

Angelstam, P., Andersson, K., Annerstedt, M., Axelsson, R., Elbakidze, M., Garrido, P., Grahn, P., Jönsson, K.I., Pedersen, S., Schlyter, P., Skärbäck, E., Smith, M., Stjernquist, I., (2013). Solving problems in social-ecological systems: definition, practice and barriers of transdisciplinary research. AMBIO 42 (2), 254-265.

Angelucci, F. (2012). *Analysis of incentives and disincentives for maize in Ghana*. Technical Note Series. Monitoring African Foodand Agricultural Policies, Food and Agriculture Organization ofthe United Nations, Rome, Italy.

Anriquz., G. and Stamoulis., K (2007). Rural development and poverty reduction: is agriculture still the key?. Journal of agricultural and development economics. Vol.4, pp 5-46

Antwi-Agyei, P., Fraser, E. D. G., Dougill, A. J., Stringer, L. C., & Simelton, E. (2012). Mapping the vulnerability of crop production in Ghana using rainfall, yield and socioeconomic data. *Applied Geography, 32*(2), 324–334.

Apusigah, A. A. (2009). The gendered politics of farm household production and the shaping of women's livelihoods in Northern Ghana. *Feminist Africa*, *12*(12), 51-67.

Auta, S.J., S. Abubakar, Z. and R. Hassan, 2000. An assessment of the contribution of women to family farming in North Eastern Nigeria. A Research Report Submitte to Nears/Abu Zaria, September 2000.

Asante, B. O., Afari-Sefa, V and Sarpong, D. B. (2011). Determinants of small-scale farmers decision to join farmer-based organizations in Ghana. Africa journal of agriculture research. 6(10),2273-2279. Retrieved from http://ugspace.ug.edu.gh/handle/123456789/2572?show=full

Ayisu, S. (2008). An analysis of factors influencing credit default, a case study of maize farmers in Agogo. (Unpublished Masters Thesis), Department of Agricultural Economics, Agribusiness and Extension, Faculty of Agriculture, Kwame; Nkrumah University of Science and Technology, Kumasi, Ghana.

Azizi-Khalkhili, T., Bakhshi Jahromi, A., & Bijani, M. (2012). Soil conservative behaviorof farmers: The role of information and communication media. Iranian AgriculturalExtension and Education Journal, 7 (2), 51–61.

Badmos, B. K. (2015). Multi-agent simulation approach on the impact of agricultural land-use change adaptation towards the effect of changing climate in semi-arid Ghana. Dissertation. Kwame Nkrumah University of Science and Technology, Kumasi, Ghana.

Bamire, A. S., Abdoulaye, T., Sanogo, D. (2012). "Determinants of improved maize adoption in Nigeria: Are they the same for poor and well-endowed households?" Ife J. Agric. 25: 83-100.

Bandura, A., 1977. Social learning theory. Prentice-Hall, Englewood Cliffs.

Banful, Afua Branoah (2009) Operational Details of the 2008 Fertilizer Subsidy in Ghana – Preliminary Report. GSSP Background Paper 18, Washington D.C., IFPRI.

Barnaud, C., Le Page, C., Dumrongrojwatthana, P., Trébuil, G., (2010). Exploring synergies between farmer's livelihoods, forest conservation and social equity. Participatory simulations for creative negotiation in Thailand Highlands. Innovation and Sustainable Development in Agriculture and Food.

Barreteau, O. (2003). The joint use of role-playing games and models regarding negotiation processes: characterization of association. *Journal of Artificial Socieities and Social Simulations*, *6*(2).

Barreteau, O., C. Le Page, and P. Perez. (2007). Contribution of simulation and gaming to natural resource management issues: an introduction. *Simulation & Gaming* 38:185-194. http://dx.doi.org/10.1177/1046878107300660

Barrett, C. B., Reardon, T., & Webb, P. (2001). Nonfarm income diversification and household livelihood strategies in rural Africa: concepts, dynamics, and policy implications. *Food Policy, 26* (4), 315–331.

Beaman, L., Karlan, D., Thuysbaert, B., & Udry, C. (2013). Profitability of Fertilizer: Experimental Evidence from Female Rice Farmers in Mali. *American Economic Review*, *103*(3), 381-386. https://doi.org/10.1257/aer.103.3.381

Berkes, F., & Folke, C. (1998). *Linking Social and Ecological Systems: Management Practices and Social Mechanisms for Building Resilience* (Eds.). Cambridge, UK: Cambridge University Press.

Berkes, F., Colding, J., & Folke, C. (2003). Navigating Social-Ecological Systems: Building REsilience for Complexity and Change (eds.). Cambridge, UK: Cambridge University Press.

Bernard, F., van Noordwijk, M., Luedeling, E., Villamor, G.B., Sileshi, G.W., and Namirembe, S. (2014). Social actors and unsustainability of agriculture. *Current Opinion in Environmental Sustainability* **6**, 155-161

Beshir, H., Emana, B., Kassa, B., and Haji, J. (2012). Determinants of chemical fertilizer technology adoption in North eastern highlands of Ethiopia: the double hurdle approach. J. Res. Econ. Int. Finance. Page 39 – 49.

Boko, M., Niang, I., Nyong, A., Vogel, C., Githeko, A., Medany, M., Osman-Elasha, B., Tabo, R., & Yanda, P. (2007). Africa. *In*: Parry, M. L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J., & Hanson, C. E. (Eds.), *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge: Cambridge University Press, 433–467.

Bousquet, F., O. Barreteau, P. d'Aquino, M. Etienne, S. Boissau, S. Aubert, C. Le Page, D. Babin, and J.-C. Castella. (2003). Multiagent systems and role games: collective learning processes for ecosystem management. Pages 248-285 *in* M. Janssen, editor. *Complexity and ecosystem management: the theory and practice of multi-agent approaches*. Edward Elgar.

Bousquet, F., R. Lifran, M. Tidball, S. Thoyer, and M. Antona. (2001). Agent-based modelling, game theory and natural resource management issues. *Journal of Artificial Societies and Social Simulation* 4(2). [online] URL: http://jasss.soc.surrey.ac.uk/4/2/0.Html

Boyle, E. A., Connolly, T. M., and Hainey, T. (2011). The role of psychology in understanding the impact of computer games. Entertainment computing. 2, 69-74

Bravo-Monroy, L., Potts, S. G., & Tzanopoulos, J. (2016). Drivers influencing farmer decisions for adopting organic or conventional coffee management practices. *Food Policy*, *58*, 49-61. https://doi.org/10.1016/j.foodpol.2015.11.003

Breisinger, C., T. Zhu, P. Al Riffai, G. Nelson, R. Robertson, J. Funes, and D. Verner (2011). Global and Local Economic Impacts of Climate Change in Syrian Arab Republic and Options for Adaptation. IFPRI Discussion Paper 1071. International Food Policy Research Institute, Washington, D.C.

Brown M. Rychtar J. (2013). Game-theoretical models in biology. Chapman and Hall/CRC mathematical and computational biology series. Pp 14.

Brown, D. G., & Robinson, D. T. (2006). Effects of heterogeneity in residential preferences on an agent-based model of urban sprawl. *Ecology and Society*, *11*(1), 1-22.

Cadzow, H. (2016). Empowering Freetown's women farmers. A Doctoral dissertation, University of Otago, New Zealand.

Callo-Concha, D., Gaiser, T., & Ewert, F. (2012). *Farming and cropping systems in the West African Sudanian Savanna. WASCAL Research Area: Northern Ghana, Southwest Burkina Faso and Northern Benin.* ZEF Working Paper Series, No. 100, Center for Development Research (ZEF), University of Bonn.

Campbell B, Sayer J. A, and Frost P. (2001) Assessing the performance of natural resource systems. Conservation Ecology 5(2):22

Charness, G., and Gneezy, U., 2011. Strong evidence for gender differences in risk taking. Journal of economic behaviour and organization. 83(2012), 50-58.

Christensen, J. H., Hewitson, B., Busuioc, A., Chen, A., Gao, X., Held, R., Jones, R., Kolli, R. K., Kwon, W. K., Laprise, R., Magana Rueda, V., Mearns, L., Menendez, C. G., Räisänen, J., Rinke, A., Sarr, A., Whetton, P., Arritt, R., Benestad, R., Beniston, M., Bromwich, D., Caya, D., Comiso, J., de Elia, R., & Dethloff, K. (2007). Regional Climate Projections. In *Climate Change, 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, University Press, Cambridge, Chapter 11* (pp. 847-940), Cambridge University Press, Cambridge.

Commission for Africa (2005). Our common interest: report of the commission for Africa. Commission for Africa, London, 464 p.

Connolly, T. M., Boyle, E. A., MacArthur, E., Hainey, T and Boyle, J. M (2012). A systematic literature review of empirical evidence on computer games and serious games. Computer and education. 59, 661-686. Edmonds and R. Meyer, editors. *Simulating social complexity: a handbook*. Springer, Berlin, Germany. http://dx.doi.org/10.1007/978-3-540-93813-2_10

Constanza, R., Daly, H. E., Folke, C., Hawken, P., Holling, C. S., McMichael, T., and Rapport, D. J. (2000). Managing our environmental portfolio. *BioScience*, *50*, 149–155.

Cordell, D. D., Gregory, J. W., & Piché, V. (1996). *Hoe and wage: A social history of a circular migration system in West Africa*. Boulder, Colorado: Westview Press.

Cote, M., & Nightingale, A. J. (2012). Resilience thinking meets social theory: Situating social change in socio-eoclogical systems (SES) research. *Progress in Human Geography*, *36*(4), 475–489.

Cundill, G., G. S. Cumming, D. Biggs, and C. Fabricius (2012). Soft systems thinking and social learning for adaptive management. *Conservation Biology* 26:13-20. http://dx.doi.org/10.1111/j.1523-1739.2011.01755.x

Cundill, G., G. S. Cumming, D. Biggs, and C. Fabricius. (2012). Soft systems thinking and social learning for adaptive management. *Conservation Biology* 26:13-20. http://dx.doi. org/10.1111/j.1523-1739.2011.01755.x

d'Aquino, P., and Bah A. (2014). Multi-level participatory design of land use policies in African dry lands: a method to embed adaptability skills of dry lands societies in a policy framework. *Journal of Environmental Management* 132:207-219. http://dx. doi.org/10.1016/j.jenvman.2013.11.011.

Damisa, M. A., Samndi, R., and Yohanna M. (2007). Women participation in agricultural production: A probit analysis. Journal of applied sciences. Vol.7(3), 412-416.

de Freitas, S. & Oliver, M. (2006). How can exploratory learning with games and simulations within the curriculum be most effectively evaluated? Computers and Education, 46 (2006) 249-264.

de Freitas, S. (2006). Using games and simulations for supporting learning, Learning, Media and Technology 31 (4), 343-358.

DeFries, R. S., Rudel, T., Uriarte, M., & Hansen, M. (2010). Deforestation driven by urban population growth and agricultural trade in the twenty-first century. *Nature Geoscience*, *3*(3), 178–181.

Deng, Z. (2007). *Vegetation Dynamics in Queme Basin, Benin, West Afrika*. Göttingen, Germany: Cuvillier Verlag Göttingen.

Diiro, G. M., Alan, P. K. and Abdoul, G. S. (2015). The role of gender in fertiliser adoption in Uganda. African Journal of Agricultural and Resource Economics. 10: 117- 130.

Doss, C. (2014). If women hold up half the sky, how much of the world's food do they produce? In Gender in Agriculture (pp. 69-88). Springer Netherlands.

Doss, C. R. (2015). *Women and Agricultural Productivity: What Does the Evidence Tell Us?* Yale University Economic Growth Center Discussion Paper No. 1051.

Doss, C. R., and Morris M. L. (2001). How does gender affect the adoption of agricultural innovations? The case of improved maize technology in Ghana. Agricultural economics. Vol. 25, 27-39.

Druschke, C. G., and Secchi, S. (2014). The impact of gender on agricultural conservation knowledge and attitudes in an Iowa Watershed. Journal of soil and water conservation. 69 (2), 95-106.

Duflo, E., Kremer, M., & Robinson, J. (2008). How High are Rates of Return to Fertilizer? Evidence from Field Experiments in Kenya. *American Economic Review*, *98*(2), 482-488. https://doi.org/10.1257/aer.98.2.482

Eguavoen, I. (2008). *The political ecology of household water in Northern Ghana*. Social Anthropology. Munster, Germany: LIT Verlag.

Ellis F (2000) Rural livelihoods and diversity in developing countries. Oxford University Press, Oxford.

Etongo, D., Djenontin, I.N.S., Kanninen, M., Fobissie, K., KorhonenKurki, K., Djoudi, H., (2015). Land tenure, asset heterogeneity and deforestation in Southern Burkina Faso. Forest Policy and Economics, 61: 51–58.

European Commission (2009) White Paper. Adapting to climate change: Towards a European framework for action. Downloaded January 2015 from http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri0COM:2009:0147: FIN:EN:PDF

Filatova, T., Verburg, P. H., Cassandra, D., & Ann, C. (2013). Environmental Modelling & Software Spatial agent-based models for socio-ecological systems : Challenges and prospects q. *Environmental Modelling and Software*, *45*, 1–7. http://doi.org/10.1016/j.envsoft.2013.03.017

Fisher, M., Kandiwa, V. (2014). Can agricultural input subsidies reduce the gender gap in modern maize adoption? Evidence from Malawi. Food Policy 45, 101–111.

Folke, C. (2006). Resilience: The emergence of a perspective for social-ecological systems analyses. Global Environmental Change, 16, 253–267.

Food and Agricultural Organization (2003). Responding to agricultural and food insecurity challenges mobilizing Africa to implement Nepad Programmes FAO. Maputo, Mozambique.

Food and Agricultural Organization (2011). *Gender differences in assets*. ESA Working Paper No. 11-12, Agricultural Development Economics Division, Food and Agricultural Organization of the United Nations, Rome, Italy.

Food and Agriculture Organization (2001). *FAO's State of Food Insecurity 2001.* Rome: FAO

Food and Agriculture Organization (2001). *FAO's State of Food Insecurity 2001.* Rome

Food and Agriculture Organization (2005). The state of food and agriculture. Rome

Food and Agriculture Organization (2006). *The State of Food Insecurity in the World 2006: Eradicating World Hunger—Taking Stock Ten Years after the World Food Summit.* Rome: FAO. Also available at www.fao.org/sof/sofi.

Food and Agriculture Organization (2011). *The state of food and agriculture 2010–2011: Women in agriculture, closing the gender gap for development.* 2011th ed., Rome, Italy: Food and Agriculture Organization of the United Nations.

Food and Agriculture Organization (2012). Gender inequalities on Rural Employment in Ghana. An Overview.

Fosu, M., Ronald, F. K. and Vlek, P.L.G. (2004). Improving maize yield in the Guinea savannah zone of Ghana with leguminous cover crops and PK fertilization. Journal of Agronomy 3 (2): 115-121

Fosu-Mensah, B. Y., Vlek, P. L. G., & MacCarthy, D. S. (2012). Farmers' perception and adaptation to climate change: A case study of Sekyedumase district in Ghana. *Environment, Development and Sustainability*, *14*(4), 495–505. doi:10.1007/s10668-012-9339-7.

Forkour, G (2014). Agricultural land use mapping in West Africa using multi-sensor satellite imagery. PhD thesis. University of Würzburg. Germany.

Fuentes., M. M. P. B., Fish, M. R., and Maynard, J. A. (2012).Management strategies to mitigate the impacts of climate change on sea turtle's terrestrial reproductive phase. Mitigation and Adaptation Strategies for Global Change 17(1):51-63.

Fufa B. and Hassan RM. (2006). Determinants of fertilizer use on maize in Eastern Ethiopia: A weighted endogenous sampling analysis of the extent and intensity of adoption, *Agrekon*, 45:38-49.

Fazey, I., Fazey, J. A., Salisbury, J. G., Lindenmayer D. B., and Dovers, S. (2006). The nature and role of experiential knowledge for environmental conservation. *Environmental Conservation* 33 (1): 1–10.

Ghana Statistical Service (2005). *Socio-Economic and Demographic Trends Analysis; Population Data Analysis Reports;* GSS: Accra, Ghana.

Ghana Statistical Service (2007). *Patterns and Trends of Poverty in Ghana: 1991–2006*. Accra: Ghana Statistical Service.

Ghana Statistical Services (2002). *Population and Housing Census, Summary Report of Final Results.* Ghana, Accra 2002.

Ghazani, E., & Bijani, M. (2016). Application of environmental attitudes towardanalyzing farmers pro-environmental behavior in order to soil conservation (thecase of rice farmers in the central part of Sari Township). Iranian Journal of Agricultural Economic and Development Research, 2–47 (1), 81–91 (In Persian).

Gujarati, D. N. (2003). Basic econometrics. 4th edn. TATA McGraw-Hill, Inc.: New York, NY

Gunderson, L., & Holling, C. (2001). Panarchy; Understanding Transformations in Systems of Humans and Nature. Washington, D.C, USA: Island Press.

Gyasi, E. A., Karikari, O. & Dugan, E. (2008). Climate Change impacts on land management. In: Allotey, J., & Mensah, L., (Eds.), Ghana climate change impacts, vulnerability and adaptation assessments, under the Netherlands climate assistance programme. Accra, Ghana: *Environmental Protection Agency*, 110-168.

Gyasi, E. A., Karikari, O., Kranjac-Berisavljevic, G., & Vordzogbe, V. V. (2006). *Study of Climate Change Vulnerability and Adaptation Assessment Relative to Land Management in Ghana.* University of Ghana, Legon, Accra, 1 - 91.

Heubes, J., I. Kühn, K. König, R. Wittig, G. Zizka, and K. Hahn (2011). Modelling biome shifts and tree cover change for 2050 in West Africa. *Journal of Biogeography* 38:2248-2258. http://dx.doi.org/10.1111/j.1365-2699.2011.02560.x

Holling, C. S. (1978). *Adaptive environmental assessment and management*. Wiley-Interscience, Chichester, UK.

Intergovernmental Panel on Climate Change (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. Cambridge University Press, Cambridge.

Intergovernmental Panel on Climate Change (IPCC). (2007).The physical science basis. Contribution of Working Group I to the Fourth Assessment Report of the IPCC.

Intergovernmental Panel on Climate Change (IPCC). (2014). Climate Change 2014: Impacts, Adaptation and Vulnerability: Contribution of Working Group II to the IPCC Fifth Assessment Report. Cambridge University Press, Cambridge.

IPCC (2007b) Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution ofWorking 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, 976pp.

IPCC (2007c) Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 996pp

IPCC (2007c) Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 996pp

IPCC, (2014). Climate Change 2014: Impacts, Adaptation and Vulnerability: Contribution of Working Group II to the IPCC Fifth Assessment Report. Cambridge University Press, Cambridge.

Rurinda, J. (2014) Vulnerability and adaptation to climate variability and change in smallholder farming systems in Zimbabwe. PhD thesis. Wageningen University.

Kaijser, A. and Kronsell, A. (2013) "Climate change through the lens of intersectionality", Environmental Politics , Vol. 23 No. 3, pp. 417-433. [ISI], [Google Scholar] [Infotrieve]

Kazianga, H. and Z. Wahhaj (2013) "Gender, Social Norms, and Household Production in Burkina Faso", Economic Development and Cultural Change, Vol. 61, No. 3, pp. 539-576.

Kehinde, A. D., Adeyemo, R., Amujoyegbe, B. J., Bamire, A. S., and Idrissou, L. (2016). Gender differentials and fertilizer adoption among small holder farmers in cocoa based farming system of Southwestern, Nigeria. International Journal of Agricultural Policy and Research Vol.4 (12), pp. 276-281,

Keys, B., & Wolfe, J. (1990). The role of management games and simulations in education and research. Journal of management, 16(2), 307-336.

Kiptot, E., Franzel, S., and Degrande, A. (2014). Gender, Agroforestry and Food Security in Africa. *Current Opinion in Environmental Sustainability* **6**, 104-109.

Kleemann, J., Gülendam, B., Bulley, N. N. H. and Fürst. (2017). Assessing driving forces of land use and land conver change by mixed-method approach in North Eastern Ghana, West Africa. Journal of Environmental Management (196) 411-442.

Koirala, K., Mishra, A., and Mohanty, S. (2015). The role ofgender in Agrcultural productivity in the Philippines; Average treatment effect. Apaper presented at Southern Agricultural Economics Association 2015 Annual meeting, Allanta, Georgia, January 31 to February 3, 2015.

Kolavalli, S., and Vigneri, M. (2011). Cocoa in Ghana: shaping the success of an economy. In: Chuhan-Pole P, Angwafo M (eds) Yes, Africa can: success stories from a dynamic continent. The World Bank, Washington DC, p 201–217.

Kolb, D.A., 1984. Experiential learning: experience as the source of learning and development. Prentice Hall.

Koomen, E., & Stillwell, J. (2007). Modelling land-use change. *GeoJournal 90*,1-22.

Koyenikan, M. J., & Ikharea, V. E. (2014). Gender Access to and Control of Agricultural Resources in South Zone of Edo State , Nigeria, *1*(7), 138–145.

Kpongor, D. (2007). Spatially explicit modeling of sorghum (Sorghum bicolor L) production on complex terrain of a semi-arid region of Ghana using APSIM. A Published PhD thesis, Ecology and Development Series 51. Center for Development Research (ZEF), University of Bonn. Bonn, Germany. 132 p.

Kuivanen, K.S., Alvarez, S., Michalscheck, M., Adjei-Nsiah, S., Descheemaeker, K., Mellon-Bedi, S., Groot, J.C.J., (2016). Characterising the diversity of smallholder farming systems and their constraints and opportunities for innovation: a case study from the Northern Region, Ghana. NJAS-Wagening.J. LifeSci.78,153–166.https:// doi.org/10.1016/j.njas.2016.04.003.

Lal, R., and Khurana, A. (2011). Gender issues: The role of women in agriculture sector. Zenith International Journal of Business Economics and Management Research, 1(1), 29-39.

Lambrecht, I., Schuster, M., Asare, S., & Pelleriaux, L. (2017). Changing Gender Roles in Agriculture? Evidence from 20 Years of Data in Ghana, (March).

Lambrecht, I., Schuster, M., Asare, S., and Pelleriaux, L. (2017). Changing Gender Roles in Agriculture? Evidence from 20 Years of Data in Ghana) Discussion Paper 01623, page 1 – 40.

Lambrecht, I., Schuster, M., Asare, S., and Pelleriaux, L. (2017). Changing Gender Roles in Agriculture? Evidence from 20 Years of Data in Ghana) Discussion Paper 01623, page 1 – 40.

Larson, D. F., Savastano, S., Murray, S., & Palacios-López, A. (2015). *Are women less productive farmers? How markets and risk affect fertilizer use, productivity, and measured gender effects in Uganda*. World Bank Policy Research Working Paper No. 7241. Retrieved SSRN from https://ssrn.com/abstract=259692210.1596/prwp

Laube, W. (2007). *Changing Natural Resource Regimes in Northern Ghana. Actors, Structure and Institutions*. Münster: LIT Verlag.

Le Q. B (2005) Multi-agent system for simulation of land-use and land cover change: A theoretical framework and its first implementation for an upland watershed in the Central Coast of Vietnam. Center for Development Research. Bonn, University of Bonn. PhD in Geography: 268p

Levin, S., Xepapadeas, T., Crépin, A.-S., Norberg, J., de Zeeuw, A., & Folke, C., … Walker, B. (2012). Social-ecological systems as complex adaptive systems: modeling and policy implications. *Environment and Development Economics*, *18*(2), 111–132. http://doi.org/doi:10.1017/S1355770X12000460

Lindley C. A. (2004). Narrative, game play, and alternative time structures for virtual environments. In S. Göbel, U. Spierling, A. Hoffman, I. Iurgel, O. Schneider, J. Dechau & A. Feix (Eds.), Lecture Notes in Computer Science: Vol. 3105. Technologies for Interactive Digital Storytelling and Entertainment (pp. 183-194) Heidelberg: Springer Berlin.

Lobell, D. B., Burke, M. B., Tebaldi, C., Mastrandrea, M. D., Falcon, W. P., & Naylor, R. L. (2008). Prioritizing climate change adaptation needs for food security in 2030. *Science*, *319*(5863), 607-610. http://dx.doi.org/10.1126/science.1152339

Mahboobi, M. And Sepehrara, M. (2013). Farmers' professional ethics toward soil conservation Journal of Ethics in Science and Technology, *8* (*3*) (2013), pp. 25-35.

Makate, C., Wang, R., Makate, M. and Mango, N. (2017), "Impact of drought tolerant maize adoption on maize productivity, sales and consumption in rural Zimbabwe", Agrekon, Vol. 56 No. 1, pp. 67-81. [Crossref], [ISI], [Google Scholar] [Infotrieve]

Martin N (2005) Development of a water balance for the Atankwidi catchment, West Africa - A case study of groundwater recharge in a semi-arid climate. Dissertation, Georg-August-Universität, Göttingen.

Martin, N. (2006). Development of a water balance for the Atankwidi catchment, West Africa – A case study of groundwater recharge in a semi-arid climate. Göttingen, Germany: Cuvillier Verlag 176 pp.

Martey, E., Wiredu, A. N., Etwire, P. M., Fosu, M., Buah, S. S., Bidzakin, J., Ahiabor, B. D. K and Kusi, F (2014). Fertilizer adoption and use intensity among smallholder farmers in Northern Ghana: A case study of the AGRA soil health project. Sustainable agricultural research. Vol.3. No.1

McGinnis, M. D., & Ostrom, E. (2014). Social-ecological system framework : initial changes and continuing. *Ecology and Society*, *19*(2), 30.

Miller, A.C., Seymour, H., King, C., Herman, T.G. (2008). Loss of seven-up from Drosophila R1/R6 photoreceptors reveals a stochastic fate choice that is normally biased by Notch. Development 135(4): 707--715.

Ministry of Food and Agriculture (MoFA). (2010). Agriculture in Ghana: Facts and Figures (2009), Accra, Ghana, 53pp.

Mishra, K. and Sam, A. G. (2016). Does Women's Land Ownership Promote Their Empowerment? Empirical Evidence from Nepal. World Development 78: 360–371.

Naah Ngmaadaba, J-B. S. (2016) Towards an understanding and harnessing of local ecological knowledge of forage resources for sustainable rangeland management in West Africa's Sudannian Savannas. PhD thesis, University of Cologne.

Ndiritu, S. W., Kassie, M., & Shiferaw, B. (2014). Are there systematic gender differences in the adoption of sustainable agricultural intensification practices? Evidence from Kenya. Food Policy, 49, 117–127.

Nin-Pratt, A., Johnson, M., Magalhaes, E., You, L., Diao, X., & Chamberlin, J. (2011). *Yield Gaps and Potential Agricultural Growth in West and Central Africa*. Washington DC: International Food Policy Research Institute and World Resource Institute.

Nkonya, E. M., Pender, J., Kaizzi, K., Edward, K., and Mugarura, S. (2005). Policy option productivity and reducing soil nutrient depletion and poverty in Uganda. Environment Production Technology Division (EPTD). Discussion paper 134. International Food Policy Research Institute (IFPRI). Washington D.C.

Nyangena, W. and Juma, O. M. (2014). Impact of improve farm technology on yield. The case of improve maize varieties and inorganic fertilizer in Kenya. Environment for Development Discussion paper series 14-20.

Nyantakyi-Frimpong, H. R. B. K. (2017) Land grabbing, social differentiation, intensified migration and food security in northern Ghana. http://agris.fao.org/agrissearch/search.do?recordID=US201700044915. Accessed in 20th July 2018.

O'Neil H. F., Wainess, R., & Baker, E. L. (2005). Classification of learning outcomes: Evidence from the computer games literature. The Curriculum Journal, 16, 455–474.

Obeng-Odoom, F. (2014). Urban land policies in Ghana: a case of the emperor's new clothes? Rev. Black Polit. Econ. 41, 119–143.

Ogunlela, Y. I., and Mukhtar, A. A. (2009). Gender issues in agriculture and rural development in Nigeria: The role of women. Humanity & social sciences Journal, 4(1), 19-30. org/10.1191/1464993403ps060oa

Oluwasusi, O and Okanni, Y. O. (2014). Effectiveness of extension services among food crop farmers in Ekiti State, Nigeria. Journal of agricultural and information. Vol. 15 (I)4. https://doi.org/10.1080/10496505.2014.952175.

Oseni, G., Corral, P., Goldstein, M., & Winters, P. (2015). Explaining gender differentials in agricultural production in Nigeria. *Agricultural Economics*, *46*(3), 285-310.

Ostrom, E. (2007). A diagnostic approach for going beyound panaceas. *Proceedings of the National Academy of Science of America*, *104*, 15181–15187.

Ouédraogo, E., Mando, A., & Zombré, N. P. (2001). Use of compost to improve soil properties and crop productivity under low input agricultural system in West Africa. *Agriculture, Ecosystems & Environment*, 84 (3), 259–266.

Oyugi, C., Dunckley, L., and Smith, A. (2008) 'Evaluation methods and cultural differences: studies across three continents', In Proceedings of NordiCHI08, vol. 358. ACM, New York, pp 318-325.

Page, S.E. (2008). The Difference: How the Power of Diversity Creates Better Groups, Firms, Schools, and Societies (New Edition). Princeton University Press.

Pahl-Wostl, C. (2006). The importance of social learning in restoring the multifunctionality of rivers and floodplains. *Ecology and Society* 11(1):10. [online] URL: http://www.ecologyandsociety.org/vol11/iss1/art10/

Pahl-Wostl, C. (2007). Transition towards adaptive management of water facing climate and global change. *Water Resources Management* 21:49-62. http://dx.doi.org/10.1007/s11269-006-9040-4

Pahl-Wostl, C., G. Becker, C. Knieper, Sendzimir. J., (2013). How multilevel societal learning processes facilitate transformative change: a comparative case study analysis on flood management. Ecology and Society 18(4): 58.

Pahl-Wostl, C., Tabara, D., Bouwen, R., Craps, M., Dewulf, A., Mostert, E., Ridder, D., Taillieu, T., (2008). The importance of social learning and culture for sustainable water management. Ecological Economics, 64(3), 484-495.

Palacios-Lopez, A., Christiaensen, L., & Kilic, T. (2017). How much of the labor in African agriculture is provided by women? Food Policy, 67, 52-63.

Parker S, Tracey D, Mackay E, Mills S and others (2008) Classification guide for potentially vulnerable invertebrate taxa in the Ross Sea long-line fishery. Document WGFSA-08/19. CCAMLR, Hobart

Peterman, A., Behrman, J., and Quisumbing, A (2011). A review of empirical evidence on gender differences in non-land agricultural inputs, technology, and services in developing countries. ESA working paper No.11-11.

Peterman, A., Quisumbing, A., Behrman, J., and Nkonya, E. (2010). Understanding gender differences in agricultural productivity in Uganda and Nigeria. IFPRI Discussion Paper 01003.

Peterman, A., Janssens, W., & Van Cleempoel, K. (2013). A holistic framework for conceptualizing customer experiences in retail environments. *International Journal of Design, 7*(2), 1-18.

Pindyck, R and Rubinfeld, D. (1991). Econometric models and econometric forecast, 3rd edn. McGraw-Hill, Inc. New York, NY.

Pretty, J.N. (1995). A Trainer's Guide for Participatory Learning and Action. Iied, London, UK.

Quansah, E., Mauder, M., Balogun, A. A., Amekudzi, L. K., Hingerl, L., Bliefernicht, J. and Kunstmann, H. (2015). Carbon dioxide fluxes from contrasting ecosystems in the Sudanian Savanna in West Africa. *Carbon Balance and Management* 10:1

Ranchhod A., Gurau C., Loukis E. and Trivedi R. (2014). Evaluating the educational effectiveness of simulation games: A value generation model. Information sciences. (264) 75-90.

Reed, M.S. (2008). Stakeholder participation for environmental management: a literature review. Biological conservation 141 (10), 2417-2431.

Refsgaard, J. C., Arnbjerg-Nielsen, K., Drews, M., Halsnæs, K., Jeppesen, E., Madsen, H., Markandya, A., Olesen, J. E., Porter, J. R., Christensen, J. H. (2013). The role of uncertainty in climate change adaptation strategies—A Danish water management example. Mitig Adapt Strateg Glob Change (18) 337–359

Rissman, A. R., & Gillon, S. (2017). Where are Ecology and Biodiversity in Social – Ecological Systems Research ? A Review of Research Methods and Applied Recommendations. *Society for Conservation Biology*, *10*(February), 86–93. http://doi.org/10.1111/conl.12250

Robinson, L.W., Berkes, F. (2011). Multi-level participation for building adaptive capacity: Formal agency-community interactons in northern Kenya. Global Environmental Change 21 (4), 1185-1194.

Romp. G. (1997). *Game Theory: Introduction and Applications*, Oxford University Press, Oxford, UK.

Rurinda, J. (2014). Vulnerability and adaptation to climate variabilityand change in smallholder farming systems in Zimbabwe. PhD thesis. Wageningen university.

Saenz, M. and Thompson, E. (2017). Gender and policy roles in farm household diversification in Zambia. World Development 89, 152-169.

Sanfo, S. (2010). Politiques publiques agricoles et lutte contre la pauvreté au Burkina Faso: le cas de la région du Plateau Central. A Doctoral Thesis. University of Paris 1 Panthéon-Sorbonne.

Sanni, S. A., K. O. Oluwasemire, and N. O. Nnoli. (2012). Traditional capacity for weather prediction, variability and coping strategies in the front line states of Nigeria. *AgriculturalSciences* 3:625-630. http://dx.doi.org/10.4236/as.2012.34075

Sarpong, G. A. (2006). Improving tenure security for the rural poor. Ghana–Country case study. *Rome: Food and Agricultural Organization* (FAO). Workshop for Sub-Saharan Africa. (NO: LEP Working Paper No. 2). Retrieved from ftp://ftp.fao.org/docrep/fao/010/k0783e00.pdf

Schlenker, W., & Lobell, D. B. (2010). Robust negative impacts of climate change on African agriculture. *Environmental Research Letters*, *5*(1), 014010.

Schlüter, L**.,** Lohbeck, K. T**.,** Gutowska, M. A**;** Gröger, J., Riebesell, U**.,** Reusch, T. B. H**.** (2014). Experiment: Adaptation of a globally important coccolithophore to ocean warming and acidification. *PANGAEA*, https://doi.org/10.1594/PANGAEA.835341,

Scholz, G., Dewulf, A., Pahl-Wostl, C. (2013). An Analytical Framework of Social Learning Facilitated by Participatory Methods. Systemic Practice and Action Research, 1-17.

Sebopetji, T.O and Belete, A. (2009). An application of probit analysis to factors affecting small scale farmers' decision to take credit: A case study of greater letabo local municipality in South Africa. African Journal of Agricultural Research. 4(8):718723.

Sfard, A. (1998). On two metaphors for learning and the dangers of choosing just one. Educational researcher 27(2), 4-13.

Shafel, F., & Shaftel, G. (1967). *Role-Playing for the Social Values: Decision-Making in the Social Studies.* NJ: Prentice-Hall,.

Shostak, A. (2009). Four defining dimensions of anticipatory learning, by Marsha Lynn Rhea. *Educational Futuristics*. 19 July. [online] URL: http://www.educationalfuturistics.com/2009/07/19/ four-defining-dimensions-of-anticipatory-learning-by-marsha-lynnrhea/

Siegel P. (2005) Using an asset-based approach to identify drivers of sustainable rural growth and poverty reduction in Central America: a conceptual framework.

World Bank Policy Working Paper 3475. Washington, DC, World Bank.

Sissoko, K., Keulen, H., Verhagen, J., Tekken, V., & Battaglini, A. (2011). Agriculture, livelihoods and climate change in the West African Sahel. *Regional Environmental Change, 11*(1), 119–125.

Soini, E. (2006). Livelihood, land use and environment interactions in the highlands of East Africa. A Dissertation, Department of Geography, University of Helsinki.

Speelman, E. N., García-Barrios, L. E., Groot, J. C. J., & Tittonell, P. (2014). Gaming for smallholder participation in the design of more sustainable agricultural landscapes. *Agricultural Systems*, *126*, 62–75.

Stanturf, J., Warren, M., Charnley, S., Polasky, S., Goodrick, S., Armah, F., & Nyako, Y. (2011). Ghana climate change vulnerability and adaptation assessment. *Washington: United States Agency for International Development.*

Stringer, L. C., and M. S. Reed. (2007). Land degradation assessment in Southern Africa: integrating local and scientific knowledge bases. *Land Degradation & Development* 18:99-116. http://dx.doi.org/10.1002/ldr.760.

Temesgen Deressa, R.M. Hassan, Tekie Alemu, Mahmud Yesuf and C. Ringler (2008). Analyzing the determinants of farmers' choice of adaptation methods and perceptions of climate change in the Nile Basin of Ethiopia. IFPRI Discussion Paper, September, 2008.

Tesfaye, A., Negatu, W., Brouwer, R., and Zaag ,P. V. D. (2014). Understanding soil conservation decision of farmers in the Gedeb watershed, Ethiopia. Land degradation and development. 25. 71-79. DOI: 10.1002/Idr.2187.

Theriault,V. Smale, M. And Haider, H. (2017) How Does Gender Affect Sustainable Intensification of Cereal Production in the West African Sahel? Evidence from Burkina Faso. World Development 92, 177-191.

Thornton, P. K., Jones, P. G., Ericksen, P. J., & Challinor, A. J. (2011). Agriculture and food systems in sub-Saharan Africa in a 4 C+ world. *Philosophical Transactions of the Royal Society of London A: Mathematical, Physical and Engineering Sciences*, *369*(1934), 117-136. https://doi.org/10.1098/rsta.2010.0246

Tschakert, P., Dietrich, K.A., (2010). Anticipatory Learning for Climate Change Adaptation and Resilience. Ecology and Society 15(2): 11.

Tsikata, D., & Yaro, J. (2011). Land Market Liberalization and Trans-National Commercial Land Deals in Ghana since the 1990s. In *Paper presented at the International Conference on Global Land Grabbing,* Global Agricultures Consortium, IDS, Sussex Vol. 6(8), 1–34.

Tsikata, D., & Yaro, J. (2011). Land Market Liberalization and Trans-National Commercial Land Deals in Ghana since the 1990s. In Paper presented at the International Conference on Global Land Grabbing, Global Agricultures Consortium, IDS, Sussex Vol. 6(8), 1–34.

United Nations (2002). Gender mainstreaming: An overview. New York, NY 10017, USA

Van der Geest, K., and T. Dietz. (2004). A literature survey about risk and vulnerability in drylands, with a focus on the Sahel. Pages 117-146 in A. J. Dietz, R. Ruben, and A. Verhagen, editors. The impact of climate change on drylands: with a focus on West Africa. Kluwer, Dordrecht, The Netherlands. http://dx.doi. org/10.1007/1-4020-2158-5_11

Van Noordwijk, M. (1984). Ecology textbook for the Sudan. Grafische Kring Groningen, Amsterdam. The Netherlands.

Vieira Pak, M., and D. Castillo Brieva. (2010). Designing and implementing a role-playing game: a tool to explain factors, decision making and landscape transformation. *Environmental Modelling & Software* 25:1322-1333. http://dx.doi.org/10.1016/j. envsoft.2010.03.015

Villamor G. B. (2012) Flexibility of multi-agent system modelsfor rubber agroforest landscapes and social response to emerging reward mechanisms for ecosystem services in Sumatra, Indonesia. Ecology and development series no. 88.

Villamor, G. B. (2012). Flexibility of multi-agent system models for rubber agroforest landscapes and social response to emerging reward mechanisms for ecosystem services in Sumatra, Indonesia. Ecological and development series no.88.

Villamor, G. B., and B. K. Badmos. (2015). Grazing game: a learning tool for adaptive management in response to climate variability in semiarid areas of Ghana. *Ecology and Society* 21(1):39. http://dx.doi.org/10.5751/ES-08139-210139

Villamor, G. B., Dah-Gbeto, A., Bell, A., Pradhan, U., & Van Noordwijk, M. (2015). Gender specific spatial perspectives and scenario building approaches for understanding gender equity and sustainability in climate smart landscapes. In Minang, P., VanNoordwijk, M., Freeman, O., Mbow, C., de Leeuw, J., Catacutan, D. (Eds.), *Climate-Smart Landscapes: Multifunctionality in Practice*, WAC/ICRAF, Nairobi (2015), pp. 211-224

Villamor, G. B., Pontius, R. G., & van Noordwijk, M. (2014a). Agroforest's growing role in reducing carbon losses from Jambi (Sumatra), Indonesia. *Regional Environmental Change*, *14*(2), 825-834.

Villamor, G. B., Van Noordwijk, M., Le, Q. B., Lusiana, B., Matthews, R., & Vlek, P. L. (2011). Diversity deficits in modelled landscape mosaics. *Ecological Informatics*, *6*(1), 73-82.

Villamor, G.B., van Noordwijk, M., (2011). Social role-play games vs individual perceptions of conservation and PES agreements for maintaining rubber agroforests in Jambi (Sumatra), Indonesia. Ecology and Society 16 (3), 27.

Walker, M.P., Brakefield,T., Morgan, A., Hobson, J.A., Stickgold, R. (2002). Sleep and Motor Skill Learning. Neuron, 35 pp. 205-211.

Villamor, G. B., Noordwijk, M., Djanibekov, U., Chiong-Javier M . C., Catacutan, D. (2014). Gender differences in land-use decisions: shaping multifunctional landscapes? Current Opinion in Environmental Sustainability, **6**:128–133.

Washington-Ottombre, C., Pijanowski, B., Campbell, D., Olson, J., Maitima, J., Musili, A., … Mwangi, A. (2010). Using a role-playing game to inform the development of land-use models for the study of a complex socio-ecological system. *Agricultural Systems*, *103*(3), 117–126. http://doi.org/10.1016/j.agsy.2009.10.002.

Wouters, P., van der Spek, E., van Oostendorp H. (2009). Current practices in serious game research: A review from a learning outcome perspective. DOI: 10.4018/978-1-60566-360-9.ch014 · Source: OAI

Wouterse, F., & Taylor, J. E. (2008). Migration and Income Diversification: Evidence from Burkina Faso. *World Development, 36* (4), 625–640.

Yaro J. A (2000) Poverty and Land Degradation: A Case Study of the Gia-Kajelo Community, Kassena-Nankana District of Northern Ghana (MPhil. Thesis) Department of Human Geography, University of Oslo, Oslo, Norway.

Yu B. and Nin-Pratt A. (2014). Fertilizer adoption in Ethiopia cereal production. *Journal of Development and Agricultural Economics*, 6:318-337.

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