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Smallholder farmers' livelihood adaptation to climate variability and ecological changes in the savanna agro ecological zone of Ghana

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Abstract

Climate variability and ecological changes have consequently altered life and natural livelihood-sustaining systems leading to socio-cultural, economic and environmental challenges and vulnerabilities. The risk factors are very high and the impacts will raise the developmental impediments of safeguarding livelihood security and poverty eradication in Sub-Saharan Africa. Adaptation to climate and ecological variation, though recognized as pressing and necessary, operates in the context of numerous uncertainties and unknowns. Previous studies on climate adaptation tried to identify universal patterns of coping rather than differentiating between agro ecological zones, villages and types of households. This paper uses case studies from two rural communities in the Savanna agro ecological zone of Ghana to explore smallholder farmers' responses to climate and ecological variation effects on their livelihood activities that have emerged since the mid-1980s. Results suggest that smallholder farmers use various coping, on-farm and off-farm adaptation strategies to ameliorate the negative impacts of climate and ecological changes on their livelihood. Coping measures such as selling household assets, migration of the entire households and

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decreasing food consumption/changing diets can be damaging. On −farm adaptation strategies such as varying planting dates, use of drought tolerant crop varieties, soil conservation strategies are based on farmers indigenous knowledge passed down from generations. To ensure sustainability of local adaptation strategies, there is the need for exchange of knowledge between and among smallholder farmers and formal institutions through the recognition and empowerment of local residents and collective actions.

Keywords: Environmental science, Ecology, Geography

1. Introduction

Climate variability is now acclaimed as one of the most arduous and complicated problem confronting the globe (IPCC, 2014). The risk factors are very high and the impacts would raise considerably the developmental impediments of safeguarding livelihood security and poverty eradication in most Sub-Saharan African (SSA) nations in general (IPCC, 2014) and Northern Ghana in particular (Dumenu and Obeng, 2016). Climate and ecological change have intensified and consequently altered life and livelihood-sustaining natural systems, leading to socio-cultural, economic and environmental disruptions (Thornton et al., 2014). Current climate change projections by climate experts indicate progressively severe negative impacts on many countries across the world. However, the most severe impacts are affecting the world's poorest countries with the weakest capacity to adapt (IPCC, 2014).

The agriculture sector in Ghana employs about 57% of the population and it is the major source of income for the majority of low-income Ghanaian families' most especially rural households (GSS, 2014). Not all, the sector also contributes appreciably to the foreign exchange earnings of the country and enhance development by means of providing raw materials to local industries (MOFA, 2007). Although agriculture contributes significantly to the country's GDP, the sector is exposed to climate change due to its reliance on rain-fed cultivation and as such variations in the climate are notably projected to lower agricultural productivity in the less developed countries (Antwi-Agyei, 2012). Since the volume and pattern of rainfall determine, to a large extent, agricultural productivity (Haile, 2005), crop yields in Ghana are estimated to reduce by 7% by 2020 due to projected decline in rainfall and upsurge in temperature (Antwi-Agyei et al., 2014). Food and livelihood security will be severely affected (EPA, 2008; Yaro, 2010; Antwi-Agyei et al., 2014).

For the past 30 years, Ghana has encountered increasing prevalence of extreme events such as droughts, floods and bush fires which are linked to climate change (Yaro, 2010) and these events have often resulted in severe food and livelihood

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insecurity (MOFA, 2007). Ghana suffered droughts in 1968−73, 1982−84, 1990−1992, but the drought of 1983/84 is among the most severe droughts in the country's history as it triggered major hydrological imbalances that affected crop production throughout the country (Yaro, 2010). Particularly, Ofori-Sarpong (1986) observed a great decline in cereal production as a result of the major drought in 1983 that led to extensive food and livelihood insecurity.

Adaptation to climate change is recognized as pressing and necessary (Nyantakyi-Frimpong and Bezner-Kerr, 2015). The strong imperative to ascertain a suitable adaptation pathway belies the difficulty of describing what adaptation is, who should carry out adaptations, who should benefit from the adaptation, and what that adaptation should be (Adger et al., 2009; Conway, 2009; Pelling, 2011). Livelihood adaptation to climate and ecological change operates in the context of numerous uncertainties and unknowns: we don't know precisely what the impact of ecological and climate change at the local level is or will be, or how stresses associated with it will overlap with other dynamic processes operating across multiple scales (Watson et al., 2016). In the midst of these complications and uncertainties, localized case studies have a lot to offer through their examination of "the lived experiences" of resource dependent smallholder farmers and communities in the less developed countries in coping and adapting to climate and ecological change (Berrang-Ford et al., 2015).

This study is not the first wave of interest in climate change adaptation in Ghana. Most of the studies conducted so far have tried to identify general patterns of coping rather than differentiating between agro-ecological zones, villages and types of households (Brockhaus et al., 2012). For example, Yaro (2010), Antwi-Agyei (2012), Antwi-Agyei et al. (2014) have identified diverse adaptation approaches which are very general and with larger spatial recommendation domain. Due to variations and diversities in the agro-ecological zones, adaptation strategies are peculiar to localities and ecological zones and usually centers on the specific climatic characteristics of the area. This paper, however, is different in that, households' adaptation measures are differentiated based on agro-ecology. The paper makes significant contribution to the body of literature on the possible role of adaptation by farmers in Ghana particularly the fragile savannah ecological zone (see Schipper and Burton, 2009; Antwi-Agyei et al., 2014; Bawakyillenuo et al., 2016; Antwi-Agyei et al., 2018).

The study explored smallholder farmers' responses to climate and ecological change effects on their livelihood activities that have emerged since the mid-1980s within the savanna agro ecological zone of Northern Ghana using an ethnographic approach.

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2. Theory

Adaptation is described by the IPCC as a "process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate harm or exploit beneficial opportunities" (IPCC, 2014, p. 118). Adaptation usually comprises medium to long-term adjustments in social ecological systems (Smit and Pilifosova, 2003). Coping measures on the other hand refers to short-term strategies employed by households to lessen the negative repercussions of climate and ecological change on their well-being and livelihood over short period of time normally less than one calendar year (Engle, 2011). In general, adaptation entails modifications in processes, practices and structures to lessen likely damages or to profit from occasions related to ecological change. Burton et al. (2002) refers to adaptation as the capacity of environmental and social systems to adjust to variation in order to endure the repercussions of such alteration. Adaptation equally relates to the decision-making process and the set of actions undertaken to maintain the capacity to deal with current or future predicted change (Nelson et al., 2007). Eriksen et al. (2011) are of the view that adaptation refers to the process or adjustment by which households lessen the adverse impacts of ecological change on their livelihood and well-being and also take opportunity to profit from the ecological change.

There are several convergencies from the myriad of definitions offered by several authors. The emerging convergencies underlines the inherent linkage of the adaptation concept to the theory of diffusion of innovations (Rogers, 1995), which underpins this study. Although a variety of analytical approaches to adaptation exist, this study finds the adoption of innovations relevant for this study. The theory of diffusion of innovations (Rogers, 1995) allows this study to gain insights into decision making process by which smallholder households or farmers adaptations strategies are implemented and diffused among farming villages and communities. Underpinned by the theory of innovation adoption, this study has recognized that adaptation is a multi-faceted decision-making process. It is a function of individual and situational (climate and ecological change risks) circumstances of the decision maker and the characteristics of the innovation under consideration which occurs within a context of changing economic, social, political and biophysical conditions (Rogers, 1995; Smith and Skinner, 2002). The innovation of diffusion theory has elucidated understanding of the varied processes and mechanisms by which adaptation measures are implemented and their probability of adoption.

The theory of diffusion of innovations (Rogers, 1995) identifies four critical fundamentals that significantly influences the diffusion of innovation. These critical foundations are: the innovation itself, communication channels, time and the nature of the social system. The adoption or rejection of an innovation (an idea, a practice or an object) will depend on the opinion of possible adopters and the attributes of the

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innovation itself. Rogers theory of diffusion of innovation suggests five (5) crucial attributes of an innovation that will determine its adoption or rejection. These attributes include the relative benefit of the innovation, its compatibility, complexity, trialability and observability. Regarding the second critical element (channels of communication), Rogers suggest that mass media channels like radio, Televisions and the print media are very effective and efficient in spreading information rapidly to its audience. Personal communication (one on one interaction) among farmers is nevertheless an important way of communication and spreads innovation faster among farming communities. Time as the third element influences innovation adoption. Individuals predisposed to an idea are more likely to adopt such an idea (innovation) faster than those less predisposed. Roger, on the element of time, categorized individuals as innovators, early adopters, early majority, late majority and the laggards. Lastly, the social system comprises individuals, social networks, communal groups, associations among others. The opinions, values and roles of members of the social systems also influence, to a great extent, the rate at which innovations are adopted.

In like manner, adaptation to climate and ecological change passes through similar thought processes by smallholder households. Farmers need to realize first of all that there is the need to implement adaptation measures to reduce the risk of climate and ecological change impacts on their livelihoods. Second, farmers will then scrutinize the available options, with the goal to identify what and why (adaptation measures) to adopt or implement. It must however be noted that many factors such as age, farming experiences, information, economic resources, education and institutions determines the adaptive capacity of households (Bawakyillenuo et al., 2016; Osumanu et al., 2017). The choice or decision to implement adaptation measures (adopt innovations) more often depends of the accessibility of adequate information, education, institutional support and asset base of vulnerable households (Bawakyillenuo et al., 2016).

3. Materials and methods

3.1. General characteristics of the study area

The savanna agro ecological zone of Ghana consists of the Upper East, Upper West, North East, Savannah and Northern regions located in the northern-most extent of Ghana. The Savanna agro ecological zone of Ghana is known to be highly vulnerable to climate and ecological changes due to their semi-arid climate and physical characteristics (Boafo et al., 2016).

The savanna agro ecological zone is dominated by grassland and trees with low density, it is warmer than the rain forest, and has a unimodal rainfall season with 600−1500 mm/year alternated with pronounced dry seasons. Agriculture focuses

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on grain crops and livestock production. The limited availability of water and nutrients makes the zone highly fragile and prone to poverty (Callo-Concha et al., 2012).

Much of the landscape of the savanna agro ecological zone of Ghana has been shaped by human activities; areas with natural flora have been converted into other land uses and the fauna has been depleted by intensive hunting. However, few small forest patches remain as sacred groves where part of the original biodiversity is conserved (Aniah & Yelfaanibe, 2016, 2017). Triggered by demographic changes, the farming systems of the savanna zone of Ghana have evolved from the interaction of indigenous migratory systems to sedentary systems based on exotic crop species in diverse arrangements, in accordance with the environmental and socio-economic circumstances of the farmers (Callo-Concha et al., 2012). In the savanna zone of Ghana, the predominant cropping system is the 'cereal-root crop mixed' cropping systems based on a combination of cereals, leguminous and root crop species (Callo-Concha et al., 2012). The key challenges to agriculture production include insufficient moisture due to the high rainfall variability and frequent droughts (Challinor et al., 2007) and poor soil fertility (Sanchez, 2002). These challenges have been identified as the main ecological constraints to smallholder farmers' adaptive capacity (Callo-Concha et al., 2012). The area is highly rural and inhabited by smallholder farmers (GSS, 2013) whose poverty levels range between 68% and 88% (Boafo et al., 2016).

This study selected two rural communities, Gowrie Kunkua and Soe Kabre as case study sites for in-depth survey (Fig. 1). The selected communities are located within the Bongo district, which spans a total land area of 488 km^2 representing approximately 5.52% of the total landmass of the Upper East Region. The selected communities have about 400 households each. The average household size in the selected communities/Bongo district is 6 persons per household. The Bongo district has a total population of 84, 545 people which represents 0.34% of the Ghanaian population. Approximately 48.8% of the total population is males and 72% live in rural areas (GSS, 2013). About 80% of the economically active population engages in rainfed agriculture. The main produce is millet, guinea-corn, maize, groundnut, beans, sorghum and tomatoes and onions which are usually cultivated in the dry season. Livestock and poultry production are also important sources of livelihood for the people (GSS, 2013). The population density as of 2009 was projected to be 217 persons per km^2 over a land size of 459.5 km^2. This compounded by the rocky landscape of the area, which covers about 40% of the land surface of the district, undermines agricultural activity (Sow et al., 2014).

The Bongo district shares borders with Burkina Faso to the North, Bolgatanga Municipal to the South West, Nabdam District to the South East and Kassena-Nankana West District to the West (Fig. 1). It lies between longitudes 0.45°W and latitude 10.50°N to 11.09°N. According to the Institute of Local Government

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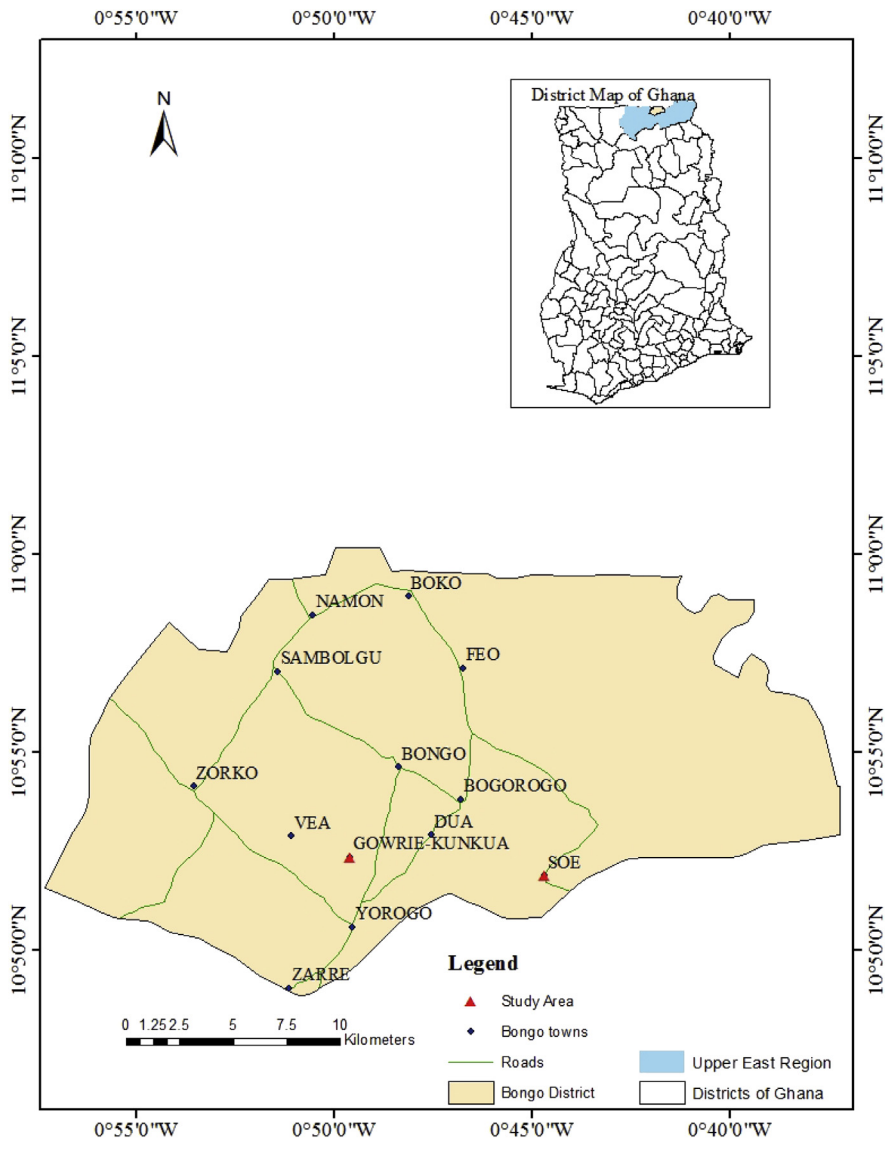

Fig. 1. Study communities in Bongo District, savanna ecological zone of Ghana.
Source: Author's construct.

Studies (2010), a district in Ghana represents a second-level administrative subdivision below the level of region.

The Bongo District was selected based on a scrutiny of rainfall and crop yield (production) data. The scrutiny identified the Bongo district as the most vulnerable district to climate and ecological change in the Savanna agro ecological zones of Ghana. Expert and stakeholder interviews were used to select study communities (Bryman and Bell, 2007) based on the following criteria: (i) the community should have been or is being exposed to some sort of climate anomaly (particularly drought); (ii) it should have characteristics that could be researched in line with

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the study's aim; and (iii) the community must be prepared to partake in the study during its entire period.

3.2. Research methods

The empirical data from this study spans six months of ethnographic fieldwork. A study of this kind, which seeks to examine the lived experiences of farmers affected by climate variability and ecological changes cannot properly be carried out with only quantitative methodology or analysis. Immersed ethnography is one of the best methodological approaches to use in exploring smallholder farmers lived experiences (responses to climate and ecological change effects on their livelihoods) (Nyantakyi-Frimpong and Bezner-Kerr, 2015). It is particularly vital in assisting us understand many dimensions of social relations (e.g., peer-to-peer learning, diffusion and adoption of innovation) that could not have been easily understood when the approach adopted was basically closed ended questionnaire surveys (Schroeder, 1999). Again, the ethnographic approach has the virtue of solidity (St. Martin and Pavlovskaya, 2009) and is precisely valuable when the researcher seeks to completely understand smallholder farmers' lived experiences in all its entirety and complexities (Schroeder, 1999; Watts, 2013; Nyantakyi-Frimpong and Bezner-Kerr, 2015). Roncoli et al. (2009) and Nyantakyi-Frimpong and Bezner-Kerr (2015) have especially stressed the utility of an ethnographic methodology and the need for participatory methods of data collection in obtaining farmer beliefs about climate change and their livelihood adaptation.

Generally, the sampling technique employed in this study was purposeful and aimed to select information rich cases for in-depth scrutiny. Information rich cases offered the researchers an opportunity to learn a great deal about important issues which yielded greater insights and in-depth understanding (Patton, 2002; Creswell, 2013). The study employed a combination or mixture of purposeful sampling strategies. This was necessary because triangulating or combining sampling strategies is flexible and enables the research findings to capture multiple perspectives, interest and needs (Patton, 2002; Creswell, 2013). First of all, the study employed criterion sampling to review and select all cases and/or districts that met a predetermined criterion (exposed to climate anomaly-drought). Inclusion criterion for this study are districts in Ghana that have been predisposed to climate and ecological change risks and abnormalities (erratic rainfall pattern, drought, high temperature). The Bongo district (study district) was tinted as the most vulnerable district in Ghana to climate change hence its selection. Due to limited resources and time, the study employed purposeful random sampling to select 75 households in each of the two (2) (Gowrie Kunkua and Soe Kabre communities) rural villages/communities in the Bongo district.

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From June to December 2015, we conducted village-level fieldwork by living and working with smallholder farmers in their farms and engaging in daily farming practices with the farmers. Daily farming practices such as land preparation, planting, sowing, weeding, soil and water conservation, contour construction, stone bonding, animal grazing/feeding, termites hunting, crop harvesting and crop residue management. Data collection integrated a sequential, multimethod triangulation technique (Creswell and Plano Clark, 2011). The fieldwork started with oral historical interviews with the community elders (clan heads, chief/earth priest, sectional/divisional heads/sub-chiefs) in the Gowrie Kunkua and Soe Kabre communities, and then continued with a survey of 75 households in each of the two communities. Households are defined "as constituting of a group of people who own the same productive resources, live together and feed from the same pot" (Yaro, 2006). Through transect walks and community institutional and resource mapping (CIRM), we randomly surveyed every fourth household until we obtained the required sample size. The 75 households represented approximately 48% and 42% of all households the Gowrie Kunkua and Soe Kabre communities respectively.

Based on initial analysis of the survey data, we used qualitative techniques including in-depth interviews, focus group discussions and participant observations to help position and offer profundity to the quantitative findings (Creswell and Plano Clark, 2011). The qualitative data gathering and analysis process was iterative. The kinds of additional information or informants required were usually decided as the data gathering and analysis evolved concurrently (Patton, 2002; Miles and Huberman, 1994). We conducted at least two focus group discussions in each community comprising about 5−10 farmers of different socio-economic backgrounds, to ensure triangulation of the key issues emerging from the household questionnaire. Following analyses and synthesis of these data sets, a total of 15 key informants (7 in each community) were chosen for in-depth interview into the issues raised at focus group discussions. Focus group discussants and Key Informants were purposefully selected based on their farming knowledge and experience of ecological/climate change as presented during the household questionnaire survey.

The interview time varied significantly from 3 hours 30 minutes to 5 hours 30 minutes. They were conducted on/near farms or homes of the respondents and in the local language (Gurune) which we understand and speak. We earlier on employed the services of the Gurune language department of the University of Education (Winneba) to assist in interpreting key English language terminologies and concepts such as vulnerability, adaptation and resilience which do not have exact translation or meaning in the Gurune language. Ethical approval for this study was obtained from the Ethical clearance committee of the University for Development Studies.

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3.3. Data analysis

Quantitative data from the household questionnaire were first inspected, cleaned, coded and then entered in a Microsoft Excel (Version 2010) and Predictive Analytic Software (formerly SPSS). Appropriate statistical analysis was then conducted using descriptive statistics and compared means, where possible.

Qualitative data from interviews and focus groups were coded and indexed through intensive content analysis in order to identify major themes (Krippendorff, 2004). Structuring themes permitted the categorization of the responses and identification of those that diverged from the common themes. Key informant interviews and focus group discussions were used to triangulate any contradictions observed in the data. As a way of ensuring that threats to qualitative data validity and reliability are eliminated (Patton, 2002), themes and sub-themes from earliest analyses were confirmed and validated by the research participants in the two study communities through the organization of 3 feedback community meetings in each of the communities. The feedback provided during these meetings enabled us to further refine the results.

4. Results and discussion

4.1. Smallholder farmers coping and adaptation measures

The study revealed diverse strategies for coping and adapting to ecological and climate changes (declining soil fertility, degrading forests and droughts) peculiar to the savanna agro ecological zones of Ghana. Coping measures were employed by smallholder farmers when confronted with a climate or ecological threat. Smallholder farmers reported discarding these reactive measures when the threat is over. Table 1 shows that smallholder farmers at the micro-level employ several coping, on-farm and off-adaptation strategies. Key coping measures identified include, but not limited to, relying on family and friends, receiving assistances from government, income from off-farm jobs, harvesting wild fruits and game, selling household assets and buying of food. The results also revealed vital on-farm adaptation strategies such as changing planting times, planting drought tolerant crops, crop diversification, use of indigenous knowledge in agronomic practices and dry season cultivation (irrigation). Other important adaptation strategies (off-farm) reported include: migration, reducing their food consumption and changing diets. These coping and adaptation strategies have been documented by other studies (e.g. Nyong et al., 2007; Speranza et al., 2010; Laube et al., 2012; Antwi-Agyei et al., 2014).

4.2. Coping measures

As shown in Table 1, smallholder farmers sold their assets (livestock and/or poultry) to cope with food shortfalls as indicated by 24.6% and 26.6% of respondents in

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Table 1. Smallholder Farmers coping and adaptation Measures.

Coping measures	Gowrie Kunkua (N = 75)		Soe Kabre (N = 75)	
	Percentage	Frequency	Percentage	Frequency
Sale of livestock	24.6%	19	26.6%	19
Buy food	24.6%	19	26.6%	19
Appropriate agronomic practices	15.2%	11	7.4%	6
Rely/harvest forest/wild products/fruits	0.4%	1	26.6%	20
Livelihood diversification	21.9%	16	5.4%	4
Rely on family/friends and other	3.1%	2	4.9%	4
Others (e.g. social support systems/CCT, LEAP, GSOP	10.2%	8	6.9%	5
On-farm adaptation measures				
Planting late or early to avoid drought	93.3%	70	69.3%	52
Planting drought tolerant/resistant crops	76%	57	49.3%	37
Planting various crops at different times	89.3%	67	90.6%	68
Use of indigenous knowledge/strategies	78.7%	59	56%	42
Off-farm adaptation				
Migration	50.7%	38	40%	30
Decreasing food consumption and altering diets	67%	50	64%	48

Source: Field Survey, July 2015.

Gowrie Kunkua and Soe Kabre communities respectively. Whenever households sell the livestock/poultry and other assets, they buy food from the market to supplement the food shortage. All respondents who indicated selling their livestock/poultry and other assets bought food (grains and cereals) to cope with the food shortfall. It was however realized that, 80% of smallholder farmers that sold their key productive assets failed to rebuild (restock) the assets after the catastrophe (drought, food shortfall) had halted. Continuous selling of productive assets such as livestock, poultry and land is a source of dwindling tangible assets and endangers households to chronic livelihood and food insecurity. An interviewee indicated that, "*the erratic rainfall regime which has resulted in food shortfalls exhausted (poor and vulnerable) smallholder farmers coping strategies making them fall back on the consumption of seed and sale of key assets (farm implements, land, livestock/poultry) for their survival*". These events have significantly reduced the coping ability (or adaptive capacity) of smallholder farmers and endangered future food production and availability. For this reason, majority of smallholder farmers (92%), believe that severe food and livelihood insecurity will result from depletion of assets through continuous use of coping strategies.

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Employing appropriate agronomic practices such as depending on wells and dugouts for cultivating vegetables (and also for animals to drink), harvesting immature food crops and performing traditional cultural sacrifices (to reverse the calamity e.g. drought) were reported by 15.2% and 7.4% of smallholder farmers in the Gowrie Kunkua and Soe Kabre communities respectively during this study. The use of agronomic practices as coping measures was also documented by (Dovie, 2010), he observed that, farmers plant early, use drought tolerant crops and revive old traditions as the main coping strategies of rural farmers.

About 0.4% and 26.6% of smallholder farmers in the Gowrie Kunkua and Soe Kabre communities respectively, reported relying on forestry products, wild fruits and wildlife as coping measures to ecological and climate change. The great disparity between Gowrie Kunkua and Soe Kabre reliance on wild/forestry products is due to the fact that, the Soe Kabre community is located very close to a forest, hence they have access to a whole range of forest products/wild fruits in contrast to the Gowrie Kunkua community which is located in between two urban towns without forest.

Approximately 21.9% and 5.4% of smallholder farmers in the Gowrie Kunkua and Soe Kabre communities respectively, reported diversifying their livelihoods into craftsmanship viz a viz weaving baskets/hats, smocks and paid non-farm jobs viz tailoring, masonry, etc. The results indicate that, over 60% of smallholder farmers in the savanna ecological zone undertake several non-arable farming livelihood activities in reaction to ecological/climate change (particularly droughts). An interviewee asserted that, "*livelihood diversification is practiced more at the moment than three (3) decades ago; it enables us to buy food for our families during the dry season*". A further scrutiny of livelihood diversification revealed that, off-farm livelihood activities such as petty trade, shea nut picking and butter processing, pito brewing and malt processing and basket and hat weaving are mainly female livelihood activities. Male non-farm livelihood activities were selling livestock and poultry, stone quarrying, sand mining, fishing, masonry, carpentry, motor/bicycle fitting/repairs among others. Livelihood activities such as weaving, charcoal production and petty trade were practiced by both men and women. These findings are in tandem with (Berlie, 2013).

Another 3.1% and 4.9% of households in the Gowrie Kunkua and Soe Kabre communities respectively reported depending on support from family and friends. In total, approximately, 8% of smallholder farmers in this study indicated they have sought assistance or depended on their family and/or friends for the past five (5) years (2011−2015) as a coping strategy to climate/ecological change and its negative effects on their livelihood activities. An interviewee asserted that, "*Smallholder farmers depend on social capital (alliances and networking) including Community Based Organizations, Susu/savings association, religious associations etc that offer*

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support to its members in the form of labor on farms, food, credits and animals". More households (40%) in the Gowrie Kunkua belonged to social networks than the Soe Kabre community (36%).

Smallholder farmers do not only receive assistance from family/friends but also government and Non-governmental organizations. Approximately, 10.2% of smallholder farmers in the Gowrie Kunkua community and 6.9% of households in the Soe Kabre community reported receiving remittance from both government and non-government social projects in the form of Conditional Cash Transfers (CCT) such as the Ghana Social Opportunity Project (GSOP), the Livelihood Empowerment Against Poverty Program (LEAP) as well as other Conditional Cash Transfer (CCT) or social intervention programs. In total, 34.7% of smallholder farmers in this study confirmed that they have received assistance from government and NGOs at least once in the last five (5) years (2010−2015).

4.3. Smallholder farmers adaptation strategies

Smallholder farmers' adaptation strategies used to manage ecological and climate changes (particularly meteorological droughts, socio-economic droughts, poor soil fertility and food shortfalls) in the savanna agro ecological zones of Ghana are categorized generally into *on-farm* adaptation strategies and *off-farm* adaptation strategies. On-farm adaptation strategies comprise a chain of practices or strategies carried out by agricultural dependent smallholder farmers on their farm intended to offset the negative effects of ecological and climate change/variability particularly droughts. *Off-farm* adaptation strategies comprise strategies or actions that smallholder farmers carry out which are outside the farm, intended to moderate their vulnerability to negative effects of climate and ecological change/variability such as food/livelihood insecurity.

4.4. On-farm adaptation strategies

This study obtained a wide inventory of on-farm adaptation strategies peculiar to the savanna agro ecological zone of Ghana. These strategies reported by smallholder farmers can be exported and applied elsewhere by households in Ghana and SSA at large. It must however be noted that, these adaptation strategies are implemented at different times.

4.4.1. Planting late or early to avoid drought

The study revealed that an overwhelming majority of smallholder farmers alter their planting schedule in reaction to the late start of precipitation for the past three (3) decades. Approximately 93.3% and 69.3% of smallholder households in the Gowrie Kunkua and Soe Kabre communities respectively indicated they altered their sowing

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period as a strategy to manage the late arrival of the rains. A discussant at an FGD corroborated that, "*the planting season used to start in March/April four decades ago, but now farmers have to postpone planting until May/June since onset of the rainfall pattern is now late and has become highly variable*". Another participant indicated that "*the rainy season has become short (starts late and stops early), as a result of the late start of the rainfall regime, we constantly alter our planting dates (sometimes we plant late, other times, we plant early) to avoid droughts*". This is an indication that the onset of the rains, which decides or regulates the beginning of the farming season has changed. The growing season, which used to begin in March/April in the 1940s through to the 1970s has changed since 1980s/1990s to late May and early June and more recently (2014/2015) from late June to early July. Farmers, due to uncertainties, now plant their crops late to avoid droughts which wither crops and high temperature which kills seedlings.

4.4.2. Planting drought resistant crops and early maturing crops

Smallholder farmers have resorted to the use of drought tolerant or resistant crop varieties as one of the chief adaptation strategies to ameliorate the negative effects of climate and ecological change (particular droughts) on their livelihoods. The study revealed that 76% and 59.3% of smallholder farmers in the Gowrie Kunkua and Soe Kabre communities respectively use crop varieties that can resist droughts and also matures early. Examples of some of these crops in the study area include maize, groundnut, and cowpea. An interviewee asserted that "*these crops (maize, groundnut and cowpea) require a smaller number of moisture days (65−90) to mature, measured against indigenous crop varieties such as guinea corn, late millet which require between 125-145 moisture days to mature*". The use of drought tolerant crops has been indicated as one of the main recommended adaptation strategies in food systems (Campbell et al., 2011). An official of MoFA explained that, "*the crops that mature early are also drought resistant because during their flowering which requires adequate moisture comes early enough such that by the time droughts set in, the crops would have matured fully*". This is very significant in decreasing climate and ecological change risks. The crops that mature early are also vital in supporting or augmenting household food shortfalls especially during the stress periods. This corroborates (Antwi-Agyei et al., 2014) who suggest that households respond to climatic and non-climatic drivers through the adoption of crop varieties that matures early and requires less moisture.

4.4.3. Planting various crops at different times

The study discovered that, smallholder farmers in the Sudan and Guinea Savanna ecological zone of Ghana are progressively employing or planting various crops at different times as an adaptation strategy to climate and ecological change in order

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to increase their yields and minimize the risk of total crop failure. The survey disclosed that, 89.3% and 90.6% of smallholder farmers in Gowrie Kunkua and Soe Kabre communities respectively testified to employing crop diversification as an adaptation strategy to reduce the negative effects of climate and ecological change on their livelihoods. Experts at the office of the District Department of Agriculture noted that, "*diverse crops have distinct biological dynamics and therefore their susceptibility to ecological change; erratic rainfall and high temperature vary considerably"*. A key informant explained that, "*as a way of distributing our risks in times of uncertainties, we (farmers) plant different crops at different times*". An FGD participant noted "*we plant various crops at different times because, when one particular crop fails, we (farmer/household) will be compensated by the yield from the other crops hence helps us avoid total crop failure*". Another FGD participant reiterated that, "*planting more than one crop on the same parcel of land grants some form of insurance for the household against crop failure"*. Discovery by Bryan et al. (2013) which suggests that households are constantly employing crop diversification as an adaptation strategy to climate change, confirms this study.

4.4.4. Using indigenous knowledge and appropriate agronomic practices

One of the key adaptation strategies employed by smallholder farmers which have been passed on from the ancestors (old generation) and is now being modified was the use of appropriate indigenous agronomic practices and knowledge. About 78.7% and 56% of smallholder farmers in the Gowrie Kunkua and Soe Kabre communities, respectively, adopted a range of appropriate indigenous agronomic practice which has been developed by local knowledge. The appropriate agronomic practices used by households include manuring, composting, organic manure application, crop residue management and the use of animal droppings. In managing post-harvest loss, smallholder farmers use plant extract (*dabokoka*) in the storage and preservation of grains, others use groundnut shell to control striger and other hygienic practices to prevent animal diseases. Again, some farmers use shea-butter residue (molded and dried) as fuel for cooking and also for plastering walls to prevent cracks and/or collapsing of buildings and reptiles from entering the premises of the house. Households also reported using pito residue for fishing and feeding animals such as pigs.

4.4.5. Planting trees and alley cropping

Tree planting and agro-forestry is widely recognized as one of the adaptation strategies that can potentially mitigate climate change in the long-term. An official of the Forestry Commission indicated that, "*tree planting has the ability to help reduce high temperature, increase rainfall amounts, provide farmers with animal feed*

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and improve microorganism on the farm". About 29% and 24% of smallholder farmers in the Gowrie Kunkua and Soe Kabre communities respectively indicated they have planted trees on their farms in the past and this assisted them to get fruits to eat, fuel wood and feed for their animals. These findings confirm previous studies by (Jama et al., 2006; Kebebew and Urgessa, 2011; Antwi-Agyei, 2012) that suggest tree planting provides opportunity for low-income farmers to enhance their livelihoods activities by selling the wood products as small timbers, medicines and food.

4.4.6. Dry season gardening and irrigation

Rain water harvesting techniques (ponds and dugouts) and large-scale irrigation services are progressively being used by smallholder farmers in the Sudan and Guinea Savanna Ecological Zone as a long-term planned adaptation strategy to climate and ecological change risks. Many farmers are gradually engaged in dry season vegetable cultivation (particularly tomatoes) during the off-season. Approximately 42% and 6% of households in the Gowrie Kunkua and Soe Kabre communities respectively reported practicing dry season farming. The Gowrie Kunkua community is located close to the Vea irrigation dam, approximately, 72 % of smallholder farmers have been allocated land at the irrigation site for farming by ICOUR. Although it has been widely agreed that the use of irrigation facilities can significantly reduce food and livelihood insecurity caused by crop failure (due to droughts), an interviewee indicated that, "*the Vea irrigation facility has become obsolete or unused in recent times. The canals feeding water to the irrigated farms are currently damaged; hence water cannot pass through to the farms*". FG discussant asserted that, "*the inability of ICOUR (government) to repair the Vea irrigation facility has hindered our ability to cultivate vegetables in the dry season hence our current vulnerability (food and livelihood insecurity) to climate and ecological change*". As a result of this current challenge, farm households in the Gowrie Kunkua community with assistance from an NGO (e.g. Sustainable Family Agricultural and Education Support Program-SUFAEP), in the form of inputs (seeds, chemicals, fertilizer, water pump, donkey cart) and training (water harvesting techniques, nursing, planting, weeding, soil conservation, pest and disease control etc.), have helped farmers to cultivate vegetables in the dry season. According to an interviewee, "*using irrigation (Vea irrigation facility) as a way of managing with drought (food shortfalls) yielded significant benefits from the 1960s to early 2000 when the dam was effectively operational, in recent times, farming is limited to only one rainy season (June−October) since the irrigation facility is obsolete*". The vital importance of dry season farming as a planned adaptation strategy was reiterated by a key informant that, "*cultivating vegetables such as tomatoes, onions, and other leafy vegetables in the dry season is very critical in enhancing my livelihood, the income I earn from the sale of produce*

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(vegetables) is used to support my children's health and education, buy food and it also prevents any member of my household from migrating to the cities (Southern Ghana) for work". Dry season farming is a vital adaptation strategy to climate and ecological change. This assertion is supported by (Antwi-Agyei, 2012) that farm households rely greatly on irrigation to cope with climate change, especially during the dry season when there are no farming activities.

4.5. Off-farm adaptation strategies

4.5.1. Migration

Approximately 50.7% and 40% of households in the Gowrie Kunkua and Soe Kabre communities respectively indicated that they migrated at least once in the last five (5) years as a strategy to reduce the effects of climate and ecological change on their livelihoods. A discussant at a FGD asserted that, "*during the dry season, people migrate temporarily to Southern Ghana to work in the cocoa growing areas, chop bars and drinking spots and head portage in order to meet their basic needs and remit back home*". This study through an interview with a key informant revealed that, in recent times, people in the savanna ecological zone migrate to Southern Ghana to work on farms to earn income and accumulate food. This study further revealed that, some of the migrants in addition to working on people's farms, harvest vertiver grass straw for weaving baskets since the vertiver grass species are depleting in the savanna ecological zone. Findings of Awumbila and Ardayfio-Schandorf (2008) confirm this study. It is important to add that these activities that migrant farmers engage in are low income paid jobs and others pay with food produce not in cash. Smallholder farmers indicated that, the major trigger of their migration is the recurrent droughts coupled with inherent poor soil fertility in the savanna ecological zone, which have contributed significantly to reductions in agricultural productivity over the years. This finding is in tandem with (Rademacher-Schulz and Mahama, 2012; Van der Geest, 2011). For instance, data from MoFA suggest that average yields for millet and sorghum were 1.4 mt/ha and 1.2 mt/ha respectively, for 2010, compared with 0.8 mt/ha and 1.0 mt/ha for the same crops in 2012 and a further decline of 0.6 mt/ha and 0.9 mt/ha for 2014. Soils in the savanna ecological zone are deficient in nitrogen, phosphorus and sulphur (Antwi-Agyei, 2012). As indicated by an interviewee, "*the soil quality for crop production is very poor*". Studies by (McLeman; Smit, 2006; Myers, 2002; Gemenne, 2011) also confirm that people migrate in response to harsh climate conditions as a coping mechanism. Discussant at an FGD said "*We migrate to southern Ghana so that we can work and earn money to enable us buy food, pay our school fees and health insurance since we have a long dry season in which we sit and do nothing"*. These assertions all indicate that households migrate in anticipation of droughts and poor soil quality to secure a sustainable livelihood for themselves and their families. Migration (inter and intra

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village migration, rural-rural, rural-urban and regional migration) is a critical coping strategy employed by smallholder farmers in the study communities. A focus group discussant remarked that "*the rainfall problem in this community has become so bad that our harvest is always not enough to feed our families, so most people migrate to Tamale, Kumasi and Kintampo to work on people's farms to earn money or sometimes food. The youth also migrate to the big cities (Accra and Kumasi) to work as "Kayaye" (head potters), roasting kebabs, working in chop bars and restaurants to take care of their family needs"*. Damaging coping strategies such as out-migration of the entire households were practiced especially when elementary coping strategies are exhausted. From the interviews and group discussions, it is obvious that, smallholder farmers migrate due to ecological and climate change effects such as erratic rainfall, droughts, poor soil fertility and food shortfalls (Dovie, 2010; Antwi-Agyei, 2012). An interviewee commented that "*there are other factors aside the poor rainfall problem that makes people to migrate… lack of jobs and low infrastructure development are the other factors that compounds our already fragile environmental problems"*.

4.5.2. Decreasing food consumption and altering diets

Decreasing food consumption and altering diets is now a crucial coping strategy of smallholder farmers in the savanna ecological zone of Ghana. The results show that 67% and 64% of smallholder households/farmers in the Gowrie Kunkua and Soe Kabre communities respectively reduced/decreased their food intake or altered their diets as a coping strategy to climate and ecological change (livelihood and food insecurity). Vulnerable households indicated they usually depend on food provided by churches and social intervention programs of NGOs. A female remarked during a household interview: *"When my family's food is running low (food shortfall), the elderly people usually eat once a day so that the children can eat twice a day. We also sometimes eat food that is not our preference"*.

Connected to altering diet is the reduction in food consumption by the members of the households. Since the 1990s, when rainfall pattern became more erratic, households in the savanna ecological zone have been decreasing food consumption as a key coping strategy to ecological and climate change (droughts, food shortfall) and during the dry season (Antwi-Agyei, 2012). Decreasing food consumption and altering diets as a coping strategy requires crucial assessment since this strategy poses dangerous consequence on the health and well-being of affected households. This situation makes the affected more vulnerable to negative effects of climate and ecological change by predisposing such households to many diseases that will make them more susceptible to climate and ecological stress (Heltberg et al., 2009; Antwi-Agyei, 2012).

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5. Conclusion

The study highlights that local communities in the savanna agro ecological zone of Ghana are coping and adapting to climate variability and ecological changes. Due to the impacts of recurrent shocks (droughts, soil infertility, displacement, etc.), the ambiguity of the limited access to financial and technical resources and the lack of support to indigenous knowledge systems, local communities have often turn to short term coping strategies rather than long term sustainable adaptation strategies. Key coping strategies such as continuous selling of productive assets for example livestock, poultry and land is a source of dwindling tangible assets and endangers households to chronic livelihood and food insecurity. Out migration of the entire households identified as a key coping strategy can be damaging and therefore needs to be conceptually reconsidered in the savanna context. Decreasing food consumption and altering diets as a coping strategy also pose consequence on the health and well-being of households. To enable smallholder farmers shift from coping (reactive) to planned adaptation strategies, there is the need for exchange of knowledge (innovation adoption) on adaptation between local farmers and the formal institutions notably the NGOs and government agencies such as MoFA. Policy options need to be targeted at climate adaptation programmes and policies that are long term and sustainable and directly linked to livelihood diversification. For example, suitable livelihood enhancement programmes that foster asset building (craftmanship, training) should be mainstreamed into broader climate change adaptation programmes. There is also the need for smallholder households to be supported to establish communication channels for knowledge and information sharing. Community farmer groups and social networks could be initiated through farmers fora and workshops spearheaded by the extension officers of the Ministry of Food and Agriculture. The formation of these associations and farmer networks will enable smallholder households have access to social capital for effective sharing and adoption of innovations. This study contributes to scientific debates on the role of adaptation by farmers by elucidating our understanding of how smallholder households/farmers are adapting to the risks posed by climate and ecological change.

Declarations

Author contribution statement

P. Aniah: Conceived and designed the experiments; Analyzed and interpreted the data; Wrote the paper.

M.K. Kaunza-Nu-Dem: Contributed reagents, materials, analysis tools or data.

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J.A. Ayembilla: Performed the experiments.

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Additional information

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