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Adaptation opportunities and maladaptive outcomes in climate vulnerability hotspots of northern Ghana

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ABSTRACT

How climate change adaptation practices can constrain development and deliver maladaptive outcomes in vulnerability hotspots is yet to be explored in-depth using case study analyses. This paper explores the effects of climate change coping and adaptation responses in three case study villages across the Central Gonja district of northern Ghana. The study addresses the following research questions: i) What are the key climatic and non-climatic stressors confronting households in northern Ghanaian communities? ii) How are households adapting to climatic and non-climatic stressors? and iii) What are the outcomes of these coping and adaptation responses on development? The study employs a mixed-method approach including key informant interviews, focus group discussions and household questionnaire surveys. Data identified socioeconomic stressors including a lack of access to (and high cost of) farm inputs, labour shortages and population growth. Climatic stressors include erratic rainfall, high temperature, droughts and floods. Climatic and non-climatic stressors interact to affect agricultural practices and related livelihoods. The study identified various adaptation measures including extensification and intensification of agriculture, temporary migration, planting of drought resistant varieties, irrigation, and livelihood diversification. We show that many coping measures (e.g. livelihood diversifications activities such as selling of firewood and charcoal production) and adaptation responses (including intensification, extensification and irrigation) currently deliver maladaptive outcomes, resulting in lock-ins that could exacerbate future climate vulnerabilities. The paper contributes to the growing literature on adaptation and climate risk management by providing empirical evidence showing how coping and adaptations measures can deliver maladaptive outcomes in vulnerable communities.

1. Research problem and justification

Sub-Saharan Africa is highly vulnerable to the adverse impacts of climate change and variability (Niang et al., 2014). Increased temperatures coupled with erratic rainfall and uncertainties about the onset of the rains have significant implications for the livelihoods of hundreds of millions of people (Dube et al., 2016). Without appropriate adaptation, climate change will exacerbate current vulnerabilities and present significant challenges for many rural households (IPCC, 2014). This paper examines how local coping and

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adaptation opportunities can provide multiple development benefits in an identified vulnerability hotspot region of northern Ghana. The paper provides empirical evidence to examine the typologies of maladaptation proposed by Juhola et al. (2016), where adaptation action may deliver negative outcomes that: (i) affect target groups or sectors (*rebounding vulnerability*); (ii) compromise the ability of different groups or sectors to respond to climate change (*shifting vulnerability*); and, (iii) fail to promote sustainable development and result in environmental degradation (*eroding sustainable development*).

A rise in temperature and extreme weather events has been projected across all ecological zones of Ghana (EPA, 2007). Based on General Circulation Models and using 1960s as the baseline, the country's temperature has been projected to increase by 2.0 °C, whilst rainfall is projected to decrease by 10.9%, by 2050 (EPA, 2007). Such changes will shorten the growing season with implications for the agricultural and fisheries sectors as well as hydropower generation (Williams et al., 2017, Asante and Amuakua-Mensah, 2015; Kabo-Bah et al., 2016). The agriculture sector is the mainstay of the Ghanaian economy, contributing significantly to Gross Domestic Product and providing a source of livelihood to many low-income families (GSS, 2010). Yet, the agricultural sector is dominated by poor small-scale farmers and remains one of the most climate sensitive sectors. Ghana's economic growth and poverty reduction efforts are centred on the modernisation of the agricultural sector. Therefore, unless carefully managed, climate change could have adverse impacts on the country's poverty reduction, economic growth and social development efforts. Northern Ghana has been identified as a particularly vulnerable region to the changing climate (Antwi-Agyei et al., 2012).

The IPCC defines adaptation 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 involves medium- to long-term adjustments in socio-ecological systems (Smit and Pilifosova, 2001). Alternatively, coping strategies relate to short-term measures taken by households to moderate the adverse impacts of climate variability on their livelihoods over a time frame usually less than one year (Engle, 2011). In some cases, coping and adaptation strategies may exert greater pressure on households' abilities to withstand future vulnerabilities (Brown 2007), and this can lead to maladaptation.

Maladaptation is used to describe "actions or inactions that may lead to increased risk of adverse climate-related outcomes, increased vulnerability to climate change, or diminished welfare, now or in the future" (Noble et al., 2014; p. 857). Maladaptation either increases the vulnerability of the target group or another group to existing or future climate variability (Barnett and O'Neill, 2010). Magnan et al. (2016) presented case studies from the Maldives, Ethiopia, South Africa, and Bangladesh and highlighted four main dimensions in assessing the risk of maladaptation – i) process, ii) multiple drivers, iii) temporal scales, and iv) spatial scales. Juhola et al. (2016) advanced the scholarship by providing a typology for assessing maladaptation. This paper extends the literature on adaptation and maladaptation by providing empirical evidence to enhance understanding of how coping and adaptation practices can deliver maladaptive outcomes in vulnerability hotspots using in-depth case study analyses in northern Ghana.

An increasing body of work has focused on identifying and assessing specific adaptation and coping strategies employed by farming households to reduce the adverse impacts of drought linked to climate change on livelihoods of households (see examples Bawakyillenuo et al., 2016; Antwi-Agyei et al., 2014; Codjoe et al., 2012). Other studies including Yaro et al. (2014) and Berman et al. (2012) have explored how local institutions can be strengthened to facilitate climate change adaptation in dryland farming systems. Further studies have focused on the role of local indigenous knowledge in reducing the adverse impacts of climate change on the livelihoods of farming households (see Codjoe et al., 2014; Speranza et al., 2010; Nyong et al., 2007). Whilst these studies document a growing body of knowledge on appropriate adaptation strategies, studies relating to how these adaptation practices can be framed to deliver development benefits and improve adaptive capacities of households to respond to future climatic vulnerabilities remain limited.

Some adaptation/coping strategies potentially compromise the ability of households to respond to existing and future climate change and lead to lock-in effects, which can "shoehorn communities into positive or negative pathways of change" (Wilson, 2014, p. 1). Using a social resilience framework, Wilson (2014, p.11) identified structural lock-in effects such as moral codes that "define the philosophical basis upon which community actions take place and usually find expression through traditions and specific rites". Political lock-ins relate to power structures and decision making within a community and reflect the political pathways of individuals or groups in the community, which can lead to implementation of superior alternative community pathways (Davidson, 2010). Economic lock-in effects are directly linked to economic capital within the community and the effects of globalisation on a community's resilience (Wilson, 2014). Socio-psychological lock-ins are closely associated with "community-level endogenous social and psychological factors" (Wilson, 2014, p. 16). As yet, there is a lack of empirical evidence about how and to what extent farming households' livelihood responses to climate change provide development benefits and avoid potential lock-in effects. This dimension of adaptation decision-making is considered in this study.

This paper addresses the identified research needs by exploring the effects of climate change adaptation responses in three case study villages across northern Ghana. Specifically, it addresses the following research questions: i) What are the key climatic and non-climatic stressors confronting households in northern Ghanaian communities? ii) How are households adapting to climatic and non-climatic stressors? and iii) What are the outcomes (or effects) of these coping and adaptation responses on development?

2. Research design and methods

2.1. Research design and study area

The study was conducted in the northern region of Ghana, where previous studies have identified agricultural livelihoods as vulnerable to the adverse impacts of climate change (e.g. Acheampong et al., 2014; Antwi-Agyei et al., 2012). Northern Ghana is a region where relatively minor rainfall variability or perturbations can lead to significant impacts on crops yield, because of limited

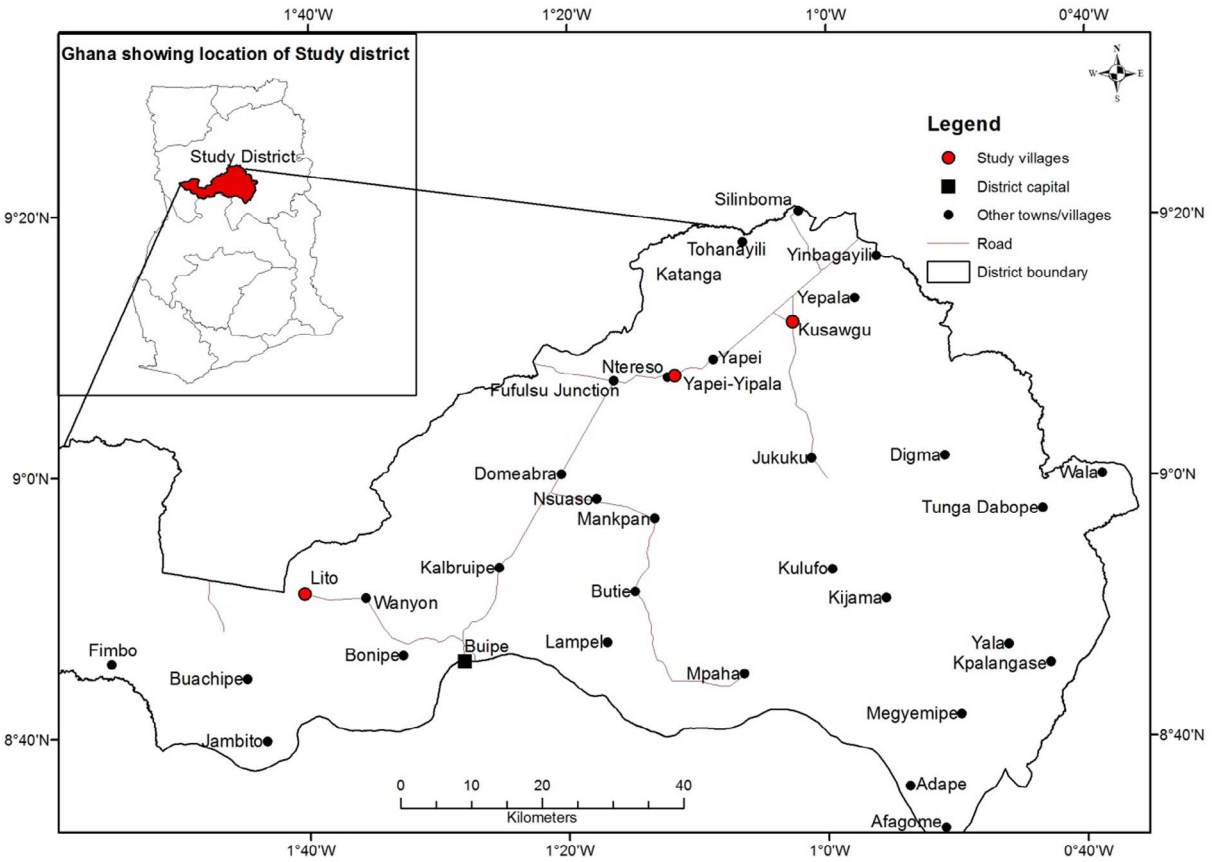

Fig. 1. Study district showing study villages.
Source: Antwi-Agyei et al. (2016)

adaptive capacity (Antwi-Agyei et al., 2012). The northern region has been characterised by extreme events such as floods and droughts and these have often resulted in extensive damage to crops and livestock leading to famine (EPA, 2007). These extreme events have been projected to increase due to climate change, particularly increasing temperature and erratic rainfall, and these are likely to further worsen livelihoods in this region (World Bank, 2010).

Three farming communities (Lito, Kusawgu and Yapei-Yipala) in the Central Gonja district of the northern region (Fig. 1) were selected based on consultation and advice from Agricultural Development Officers at the Central Gonja district of the Ghana's Ministry of Food and Agriculture. The Central Gonja district has a population of 87,877 people and lies in the tropical continental zone (GSS, 2010). The district experiences a uni-modal rainfall pattern that permits only one growing season. Rainfall generally starts in May/June and ends August/September (Nkrumah et al. 2014). Average household size for this district is 7.6; slightly above the national average of 4.5 people (GSS, 2010). Of the population above 15 years old, subsistence crop farming employs about 77.7% of the population, with only a few farmers engaged in livestock rearing (GSS, 2010).

These farming communities are exposed to rainfall variability which has already adversely impacted on the livelihoods of the households. These communities share common features regarding population, ethnicity and ecological problems. The ethnicity of the majority of people in these communities is mainly Gonjas and Dagombas. The average landholding (ha) is 1.93 ha, 2.26 ha and 2.25 ha for Lito, Kusawgu and Yapei-Yipala, respectively (Antwi-Agyei et al., 2016). Smallholder farmers rely on rudimentary agricultural technologies with rainfall determining crop productivity. Those lacking resources rely on natural soil fertility to support agricultural production, including the use of poultry manure (MoFA, 2007). Food crops of importance include maize, rice, groundnut, sorghum, millet, yam, soyabean and cowpea. The three study communities are served by the Buipe and Yapei markets, where households sell any excess farm produce. Bush burning and land degradation are widespread in this district (MoFA, 2007). Patterns of under-development, poor road networks, and lack of infrastructural development, have characterised these communities and the northern region in general (GSS, 2010).

2.2. Research Methods

Household data were collected during April–June 2015. A household is defined as "a group of people who own the same productive resources, live together and feed from the same pot" (Yaro 2006, p. 129). A mixed-method research design was used to

capture households' livelihood responses to changing environmental and climatic conditions in study villages. Methods including key informant interviews, focus group discussions and household questionnaire surveys were adopted to gain local insights into the complexity of climate variability and how it affects rural livelihoods.

In all, 219 household surveys were conducted in the three study communities, containing both open and closed ended questions. To ensure a representative sample in the study communities, households were selected through stratified random sampling based on age, gender and social standings. This stratification was based on observable social groups, informed by key informants in these communities. Data collection proceeded with a rapid rural appraisal using transect walks, providing an overview of the significant social and physical features, as well as household characteristics, in the study communities. The survey contained questions relating to livelihood strategies, stressors on livelihoods, coping and adaptation mechanisms as well as the type of farming and land tenure issues which are important in shaping resource access and livelihood option (Antwi-Agyei et al., 2015). Information on social networks, gender issues, values and belief systems, and traditional knowledge which may affect their capacity to adapt to climate change and variability were collected to enable assessment of any 'lock-in' effects. Questionnaire administration was face-to-face with respondents. Household respondents were asked to limit their answers to the last 40 years or since their childhood.

Six focus group discussions (FGDs) were also conducted (2 in each community) with an average of 14 participants drawn from different socio-economic backgrounds, considering age, gender and social standing. Selecting participants with different socio-economic backgrounds provided the opportunity to capture the different dimensions and complexity of climate change and livelihood challenges. Participants included some of the farmers who took part in the household surveys and demonstrated considerable knowledge on livelihood challenges. To improve participation of women, separate FGDs were held with female farmers and women's groups.

Nine key informant interviews were conducted with opinion leaders, purposefully selected based on their past experience and knowledge on environmental change and livelihood challenges. The key informants included chiefs, chief farmers, and youth and women's group leaders. The purpose of the key informant interviews was to capture key temporal dimension of household responses to climatic and socioeconomic drivers of change. Conducting these after the household surveys permitted the research team to further probe any discrepancies in household responses arising from the household survey. The key informant interviews were also used to triangulate information obtained from the FGDs.

To assess the long-term effects of coping and adaptation responses on development, focus group participants assessed the benefits and risks of each of the adaptation options identified in the study communities. In analysing the data, adaptation outcomes were classified as either: (i) rebounding vulnerability, (ii) shifting vulnerability and (iii) eroding sustainable development. Rebounding vulnerability is a "simple connection implying an adaptation action that increases current or future climate change vulnerability of the implementing actor" (Juhola et al., 2016; p. 136). Shifting vulnerability increases current or future vulnerability for one or several external actors. Eroding sustainable development occurs when adaptation action "increases greenhouse gases (GHG) emissions and negatively impacts environmental conditions and/or social and economic values" (Juhola et al., 2016, p. 136).

Quantitative data from the household questionnaire were analysed with SPSS using basic descriptive statistics. Qualitative data from key informant interviews and FGDs were analysed using an inductive coding method, which allowed patterns and themes in interview responses to be derived.

3. Results

3.1. Key stressors of changing agricultural practices and their impacts on livelihoods

Both household surveys and FGDs show that agriculture-dependent households in the study communities identified both socio-economic and climatic factors as stressors influencing change in agricultural systems (Table 1). In terms of socioeconomic stressors, high cost and poor access to farm inputs, labour shortages and population growth were reported. About 68% of respondents in the household survey cited high cost and poor access to farm inputs as drivers of changing agricultural practices in the study communities. High cost and poor access to farm inputs was linked to economic decision making by focus group participants. They argued that high costs made it difficult for small-holders farmers to purchase farm inputs and that leads to declining soil fertility. About 30% of the household survey participants reported a lack of labour especially during the peak farming season in June/July. Labour shortages were attributed mainly to migration of able-bodied men, especially the youth, to southern Ghana. "*Most of our youth and able-bodied men migrate to the south to look for employment opportunities. Many of them do not return at the start of the farming season and this affects availability of farm labour. This affects farm operations and crop yield, which has implications for food security in this community* [Male farmer, focus group participant, Lito, April 2015]. Population growth, according to focus group participants, has also resulted in less farmland available to farming households. One respondent noted: "*when I started farming in this village, farmland was never an issue. However, in recent years increased population pressure means that we have limited farmlands and do not have the luxury of allowing farmlands to fallow*" [Male farmer, focus group participant, Yapei-Yipala, April 2015].

Drought, high temperature, floods and erratic rainfall were the key climatic stressors identified by focus group participants. Most (64%) of the respondents in the household survey reported erratic rainfall patterns as one of the key drivers of changing agricultural practices in the study communities. There was consensus that it is now difficult to predict the onset of the rains using indigenous agro-ecological knowledge. They reported that erratic rainfall makes it difficult to plan farm operations. Focus group participants attributed the increasingly erratic pattern of the rainfall to farm practices and livelihood strategies pursued locally. Felling of trees for charcoal production and farming around water bodies were considered to play an important role. As one farmer noted: "*we are cutting all the trees around our river bodies and this is causing the rivers to dry up and we bear the consequences of such actions*" [Male farmer,

Table 1
Socioeconomic and climatic stressors of changing agricultural practices based on focus group participants and household surveys.

Socioeconomic stressors	Respondents citing this stressor (n = 219)	Illustrative quote
a. Lack of access/high cost of farm inputs	150 (68%)	*We do not have appropriate soil amendments to improve yields. Even when these farm inputs including fertilizers and drought resistant varieties of crops are there we do not have money to purchase them. As a result, our soils are no longer as productive as they used to be.*" [Key informant interview, Lito, April 2015]
Labour shortages	66 (30%)	"*…gradually, farm labour is becoming a major problem for most farmers in this community. Sometimes, you may have the rains and money but you cannot get the farm labour to work on the farm. This affects various farm operations and eventually crop yield. This has become more critical in recent times when certain farming practices such as planting should be done at the appropriate time in order to avoid the dry spells that characterise most of the season*" [Female farmer, Focus group discussion, Lito, April 2015]
Population growth	26 (12%)	*"…increasing population growth is a major driver of changing agricultural practice in this village. Having large population means that you cannot practice some of the agricultural systems that you once practiced that allowed the soil to regain its lost fertility"* [Male farmer, focus group participants, Lito, April 2015]
Climatic stressors		
Erratic rainfall	140 (64%)	*"You can no longer predict when the rains will come in this village. The start to the farming season has become so unpredictable. You just have to prepare your lands and hope that the rains will come for you to start the sowing process. What is more worrying is the erratic distribution of the rains during the farming season. It rains today and then the rains stop for a few weeks and this negatively affects crop growth"* [Female farmer, Yapei-Yipala, May 2015]
Drought	36 (16%)	*"…prolonged periods without rains have become a common occurrence in this community and surrounding villages. The farming season is shortening due to drought. When I started farming in this village over 25 years ago, farmers could start the sowing process by late March or early April. In recent times, we now start planting in mid-May because of drought"* [Male farmer, Kusawgu, May 2015]
High temperatures	105 (48%)	*The weather has become hotter and this affects our crops. When crops begin to grow and the temperature is high, they wither, and this adversely affects yield. This affects food security for my family* [Female farmer, Kusawgu, May 2015]
Flood	13 (6%)	*"…it is becoming too depressing that sometimes, you wait too long for the rains to come and after the planting process and the crops begin to bear fruits, suddenly you have excessive rains and this destroys field crops. The last time it happened all our crops were flooded and this seriously affected food for households in this community. When there are no rains, there is trouble and when there are rains, too, you have it in excess and this creates problem for crops"* [Female farmer, focus group participant, Yapei-Yipala, May 2015]

Kusawgu, May 2015). Trees and forests play important role in regulating temperatures as well as the flow of fresh water resources. Hence, indiscriminate cutting of trees can have a devastating effect on water resources, adversely affecting crop productivity and related livelihoods in the study communities (Ellison et al., 2017). Such quotes show that farmers are aware of the key climatic and non-climatic stressors underpinning changes in livelihood and agricultural practices in the study communities.

There was strong agreement amongst respondents in the household survey that the stressors identified were negatively influencing their livelihoods and food security. Almost all the respondents who cited erratic rainfall as a climatic stressor indicated that it was affecting their farm operations and leading to lower yields. This was affirmed by participants in the FGDs who indicated that stressors, especially erratic rainfall, adversely affected their livelihoods. One focus group participant stated: *"Our livelihoods are predominantly dependent on the extent and distribution of the rains during the farming season. Any shift or variation in the rainfall during the farming season causes lots of distress to families in this community*" [Focus group participant, Lito, April 2015]. The high cost of farm inputs leading to the declining soil fertility was seen as responsible for low yield. A farmer reported: "*Our soils are no longer as productive as they used to be. When I started farming in this village 25 years ago, I could harvest almost thrice in terms of maize compared to what I get in recent years*" [Male farmer, focus group participant, Lito, April 2015]. Excessive heat linked to increasing temperature and dry spells during the farming season were also reported to adversely affect households' livelihoods. A farmer remarked: "*excessive heat makes farm crops wither, which eventually affects crop yield. Lower yields from our farms have devastating consequences for our families"* [Male farmer, focus group participant, Kusawgu, April 2015].

One key impact of climate variability on farming households was the inability of farmers to use their indigenous agro-ecological knowledge to forecast rainfall patterns. One farmer noted: "*when I started farming in this village about 40 years ago, one could tell when the rains would come and therefore be able to plan their planting appropriately. In recent years, we have to prepare the lands and wait in anticipation of the rains. The start of the farming season is also not constant and this affects farming operations which leads to lower crop yields"* [Female farmer, focus group participant, Yapei-Yipala, May 2015]. There was also a consensus among focus group participants and key informants that rainfall variability during the farming season in recent years has become more pronounced. This demonstrates that farming households are adversely affected by both socioeconomic and climatic-related stressors.

Table 2
Climate change coping and livelihood diversification activities according to gender.

Strategy	Male-headed households (n = 132)	Female-headed households (n = 87)	Total (n = 219)
a. Selling livestock	63 (47.7)	16 (18.4)	79 (36.1)
b. Firewood harvesting	44 (33.3)	35 (40.2)	79 (36.1)
c. Basket weaving	7 (5.3)	2 (2.3)	9 (4.1)
d. Wage labour	32 (24.2)	13 (14.9)	45 (20.5)
e. Fishing	24 (18.2)	0 (0.0)	24 (11.0)
f. Shea nut picking	35 (26.5)	45 (51.7)	80 (36.5)
g. Petty trading	48 (36.4)	35 (40.2)	83 (37.9)
h. Gari processing	11 (8.3)	26 (29.9)	37 (16.9)
i. Charcoal burning	26 (19.7)	26 (29.9)	52 (23.7)
j. Changing diet	70 (53.0)	43 (49.4)	113 (51.6)
k. Reduce consumption	68 (51.5)	52 (59.8)	120 (54.8)
l. Rely on remittances	41 (31.1)	36 (41.4)	77 (35.2)
m. Rely on social networks	33 (25.0)	33 (37.9)	66 (30.1)

Numbers in parentheses indicate percentages and those not in parentheses are counts of households.

3.2. Household coping and adaptation strategies to socioeconomic and climatic drivers

Table 2 shows the key measures for coping with climate change and socioeconomic stressors including selling firewood, livestock, petty trading and wage labour. It needs to be stressed that some of these coping measures including selling firewood involve indiscriminate cutting of trees that can lead to destruction of important fauna and flora and erosion of other adaptation options. Additional coping measures included changing diet and reducing the number of meals and amount of food consumed by the household. The presence of the Black and White Volta and its tributaries in the Central Gonja district provides fishing opportunities, with 11% of households reporting using fishing as a coping strategy. Reliance on remittances by 35% of households was also noted to play a crucial role. Such remittances are linked to family members who migrate to the south during the lean season (December–April/May) to look for better job opportunities. Further, 30% of the households relied on their social networks including family and friends to cope with drought and other stressors. There were clear differences between the livelihood diversification strategies preferred by male and female farmers. Selling livestock was a predominantly male preferred strategy whilst shea nut picking was mostly reported by female farmers.

Table 3 presents results on the key adaptation strategies identified. Both male and female farmers reported using different farm management practices, notably, planting early to avoid dry spells and planting early maturing varieties of crops. Intercropping and the planting of drought tolerant varieties were also frequently reported. Focus group participants noted additional adaptation practices including increased use of fertilizers and changing tillage practices. Households reported that mulching was used to moderate high temperatures that increase evaporation. Households also reported temporary migration to southern Ghana to sell labour as an adaptation. Tables 2 and 3 show that gender influences the choice of different responses to socioeconomic and climate stressors. For instance, whilst the majority of male farmers (65%) reported using extensification of agriculture as a strategy, only 21% of the sampled female farmers indicated using extensification.

3.3. Outcomes of households' responses to climatic and socioeconomic stressors

Table 4 shows the various benefits and risks associated with the responses. With regard to agricultural intensification and extensification, benefits include enhanced availability of food for households and the opportunity to improve livelihoods. In terms of risks, results showed that agricultural intensification results in a less diverse agro-ecosystem. Agricultural intensification, through

Table 3
Climate change adaptation activities according to gender.

Strategy	Male-headed households (n = 132)	Female-headed households (n = 87)	Total (n = 219)
a. Intensification of agriculture	49 (37.1)	66 (75.9)	115 (52.5)
b. Extensification of agriculture	86 (65.2)	18 (20.7)	104 (47.5)
c. Temporary migration	41 (31.1)	16 (18.4)	57 (26.0)
d. Changing land management practices			
i. Planting early maturing crops	85 (64.4)	59 (67.8)	144 (65.8)
ii. Planting drought tolerant crops	56 (42.4)	42 (48.3)	98 (44.7)
iii. Mixed cropping	71 (53.8)	47 (54.0)	118 (53.9)
iv. Mixed farming	35 (26.5)	0 (0.0)	35 (15.9)
v. Irrigation	7 (5.3)	28 (32.1)	35 (16.0)
vi. Mulching	25 (18.9)	17 (19.5)	42 (19.2)
vii. Indigenous agro-ecological knowledge	28 (21.2)	37 (42.5)	65 (29.7)

Numbers in parentheses indicate percentages and those not in parentheses are counts of households.

Table 4
Evaluation of benefits and risks associated with households' coping and adaptations strategies to climatic and socioeconomic stressors in study communities.

Adaptation strategy	Benefits	Risks	Overall outcomes
a. Agricultural intensification	• Intensification includes the use of improved varieties and breeds, more efficient use of labour, and better farm management that leads to increased productivity (Dixon et al. 2001) • Improves household food security (Godfray and Garnett, 2014)	• The intensive use of agro-chemicals especially nitrogen based fertilizers releases greenhouse gases (Stehfest et al., 2010) • The move toward agricultural intensification has resulted in less diverse, less physiologically efficient (because of the need for external inputs), and less adaptable systems (Lin et al., 2008)	Eroding sustainable development
Agricultural extensification	• Contributes to preservation of the environment by reducing the inputs of chemical fertilizers and pesticides • Improves soil and water conservation, promote better stewardship of the land itself, and enhance the appreciation of land values	• Extensification is a significant contributor to deforestation in many dryland farming systems (Hosonuma et al., 2012) • Slash and burn practices result in reduced biodiversity. • Using natural biological processes and cycles in controlling pest (in lieu of pesticides), and fewer external inputs such as chemical fertilizers may result in lower crop production	Eroding sustainable development
Temporary Migration	• Reduces pressure on household food reserves (McLeman and Hunter, 2010) • Improves livelihoods and minimizes harm to individuals (Ionesco and Chazalnoel, 2015). • Helps to diversify incomes and enhances capacities to deal with environmental and climatic changes (Kelpsaite and Mach, 2015)	• Increases pressure on inadequate social services provision (Ionesco and Chazalnoel, 2015) • Leads to reduced farm labour which affects farm operations • Farmers can miss critical periods including sowing if they do not return on time • Migration every season reduces ability to plan household farm operations	Rebounding vulnerability; Shifting vulnerability
b. Changing land management practices (strategy)			Overall: Shifting vulnerability; rebounding vulnerability
i. Irrigation (activity)	• Contributes to the reduction of poverty since it can facilitate many farmers to cultivate high value crops such as paddy, fruits and vegetables (Shongwe, 2013)	• Irrigation could potentially result in conflict because of competing demands for water in these villages • Requires a good and reliable water source	Eroding sustainable development; Shifting vulnerability
ii. Planting drought tolerant plants (activity)	• It increases the water-use efficiency of not only the plants but the whole farm	N/A	N/A
iii. Planting of early maturing crops (activity)	• Early maturing seeds enable crops to escape long dry spells towards the end of the growing season (Shongwe, 2013)	• Early maturing crops can be affected by the long drought spell and lead to crop failure (Kihupi et al., 2015) • Early maturing crops (for instance hybrid maize) is capital intensive in terms of seeds and fertilizer (Shongwe, 2013)	N/A
iv. Mulching (activity)	• Prevents erosion and increases soil fertility thereby improving crop yield • Protects the soil from excessive heat, exposure to wind, and moisture loss (Recha et al., 2014)	N/A	N/A
Livelihood diversification (strategy)			Overall: rebounding vulnerability; Shifting vulnerability
i. Selling livestock (activity)	• Selling livestock provides increased stability in income for the family without disrupting other food producing activities (FAO, 1999)	• Selling of livestock depletes the livestock stock and perpetuates poverty (Haggblade et al., 2010)	Rebounding vulnerability
ii. Selling wage labour (activity)	• Provides opportunity for farmers to earn income for food and other households' needs (Laube et al., 2012; Bawakyillenuo et al., 2016)	• Selling farm labour leaves farmers with limited time to work on their own farms, which affect farm operations and crop yield	Shifting vulnerability
c. Dietary management (strategy)			Overall: rebounding vulnerability

(*continued on next page*)

Table 4 (*continued*)

Adaptation strategy	Benefits	Risks	Overall outcomes
i. Reducing food consumption (activity)	• This ensures regular availability of food	• Reducing food consumption will imply that people will be fed less or endure some form of hunger • Reducing food consumption can have devastating consequences for health especially for children and the elderly	Rebounding vulnerability
ii. Changing diet (activity)	N/A	• Changing diets also erodes cultural identity of the households	Rebounding vulnerability

increased fertilizer input can result in biodiversity loss, pesticide poisoning, and decline of ecosystem services (Zhao et al., 2013, Tilman et al. 2002). Similarly, the conversion of natural habitats for food production via agricultural extensification and intensive agriculture reduces biodiversity which can affect capacity of the ecosystem to provide services such as flood prevention and water purification (Frison et al., 2011). Results showed that diversification into non-farm livelihood activities provide opportunities for employment that bring extra financial resources to support farm income (Table 4). The availability of abundant water resources including the White and Black Volta provides another opportunity that farming households could exploit. Again, planting early maturing varieties of crops allowed farmers to harvest crops early in the season to prevent starvation.

Selling labour could provide immediate relief to the households, nevertheless, there are risks associated with this coping mechanism. For instance, wage labour elsewhere through seasonal migration means less labour in these communities for farming activities, and this can result in key deadlines for critical farming operations being missed, affecting crop yield and the ability of subsistence farmers to feed their families. Focus group participants and key informants noted that selling farm labour could potentially lead to less time on one's own farm. A farmer provided a typical response during a FGD: "*Selling farm labour as a coping strategy could be counter-productive because it leaves one with less time to work on their own farm on time.*" [Male farmer, focus group participant, Lito, April 2015]. Selling livestock to cope with climate change induced food insecurity may be a good strategy in the short term but in the long term may not contribute positively to development. This is reflected in the following remark: "*I always restock my livestock in the beginning of the season. This is because I sell most of my livestock to cope with* [drought-induced] *food shortages*" [Male farmer, key informant interview, Yapei-Yipala, May 2015]. Irrigation provides protection against drought and ensures availability of food reserve but may also result in less water becoming available for domestic uses. Yet, irrigation involves high capital investment, which can be a challenge to many rural households because of their poor financial backgrounds (Shongwe, 2013), and erosion of the financial capital of poor households could limit their capacity to respond to future threats posed by climate change and variability.

4. Discussion

Results in this study reveal that households employ a host of coping and adaptation strategies in responding to the threats of climate change and variability. These strategies can be categorised into intensification of agriculture, extensification of agriculture, migration, changing land management practices and livelihood diversification. The use of irrigation has been reported as one of the key climate change adaptation strategies by households across northern Ghana (see Laube et al., 2012; Dovie, 2011). Irrigation has been identified by development partners and the Government of Ghana as one of the key strategies for tackling the adverse impacts of climate change on rural resource-poor marginalised farmers (GoG, 2011). Coping measures broadly related to livelihood diversification activities including, selling of firewood, wage labour, shea nut picking and selling livestock to cushion marginalised households against climatic and non-climatic shocks. For instance, livestock represent a key asset and insurance mechanism for the farmers as they can easily be sold to raise financial capital to purchase food (Hesselberg and Yaro, 2006). The use of drought resistant varieties of crops and mixed farming practices are age-old agricultural practices, but which are assuming greater prominence in households' quest to find solutions to climate change (Yaro, 2013). Households reported using their indigenous agro-ecological knowledge (including the flowering and fruiting of certain trees etc.) to indicate the onset of the rains. This helps households in preparing their farms in anticipation of the rains. Such findings match other studies suggesting that farmers across sub-Saharan Africa rely on their indigenous agro-ecological practices and knowledge to cope with climate change and variability (see Antwi-Agyei, 2012; Nyong et al., 2007; Speranza et al., 2010). Yet, with temperatures projected to increase between roughly + 2.0 °C and + 4.5 °C by 2100 across sub-Saharan Africa (Muller, 2009), the reliability and sustainability of indigenous agro-ecological knowledge has been questioned (Naess, 2013). This raises serious concerns with grave implications for climate change adaptation because these farmers have limited capacity to employ other adaptation measures that may require high financial capital outlay such as the use of drought resistant varieties of crops.

Results also highlight cases where negative outcomes are leading to maladaptation. Following Juhola et al. (2016), we highlight three specific ways in which coping and adaptation actions can deliver maladaptive outcomes: *rebounding vulnerability, shifting vulnerability and eroding sustainable development*. The first type of maladaptive outcome is related to *rebounding vulnerability*. Despite the potential of livelihood diversification to provide a pathway for adaptation to climatic change, Haggblade et al. (2010) have highlighted the complexity of disentangling the links between non-farm livelihood activities and poverty reduction. Some of the

livelihood diversification activities deliver maladaptive outcomes which have the potential to either reduce the adaptive capacity of the household or increase its sensitivity and exposure. For instance, selling livestock has been reported to offer opportunities for households to cope with droughts in northern Ghana (see Laube et al., 2012; Bawakyillenuo et al., 2016). Yet, this reduces the farmers' stock and the capacity to use such assets to manage future climate vulnerabilities. Such measures potentially result in lock-in effects (Wilson, 2014), and these may be detrimental to the capacity of households to respond to existing and future climate change. Lock-ins lead to vicious cycles in which households resort to short-term *ad-hoc* measures in coping with climate change vulnerability year after year. Adopting such an approach in managing the adverse impacts of climate change perpetuates vulnerability and pushes households further into the poverty trap, making it difficult for households to get out of such lock-ins.

The second type of maladaptive outcome is *shifting vulnerability*. For instance, excessive use of agro-chemicals and inputs by farmers through agricultural intensification, can then leach into nearby water bodies, compromising their use for human consumption. A lack of water predisposes such households and community members to diseases and reduces their adaptive capacity to climate change, thereby increasing their overall vulnerability. Such cases are in line with McEvoy and Wilder's (2012) argument that one group's adaptation may constitute environmental hazards for another group. This shows that successful climate change adaptation actions at the household level can result in climate vulnerability at the community scale. Shifting vulnerability emphasises the need to address spatial dimensions of climate change adaptations. Similarly, agricultural biodiversity is also critical for food and nutritional security as well as enhancing adaptation to climate change and this too is placed at risk from intensification (Frison et al., 2011). Using limited water resources for irrigation purposes in these dryland farming communities could potentially result in conflict because of competing demands for water for domestic and agricultural purposes. With an estimated 75–250 million people in Africa facing climate change related water scarcity by 2020s (Arnell, 2004), the long-term reliance on irrigation as an adaptation strategy could be in jeopardy.

Results also indicated that some of these adaptation responses including agricultural intensification, agricultural extensification and irrigation could *erode sustainable development*. For instance, expanding the amount of land used for agricultural production via agricultural extensification can have devastating consequence for development through increased land degradation and deforestation. Agriculture is a significant contributor to deforestation in many dryland farming systems (Hosonuma et al., 2012). Agricultural extensification involves the conversion of new land to agriculture which results in very significant releases of greenhouse gases into the atmosphere and is particularly devastating when forests are converted into agriculture to feed the increasing population (Godfray and Garnett, 2014). Cultivating more farmland in an attempt to adapt to climate change could also alter carbon fluxes and consequently increase emissions, depending on the land management practices adopted (Stringer et al., 2012). Cutting trees to sell as firewood could provide immediate relief to households but in the long-term could exacerbate their vulnerability to climate change by reducing carbon sinks. Such adaptation actions have the potential to affect the attainment of Sustainable Development Goal 13, which advocates for actions against climate change (UNDP, 2015). Adaptation outcomes resulting in maladaptation and lock-ins raise serious concerns about equity, efficiency and legitimacy of adaptation actions (Paavola and Adger, 2006). Adaptation actions that erode sustainable development also have the tendency to degrade the environment because they usually degrade common pool resources. Findings relating to adaptation options that result in increased GHG emissions and environmental degradation are consistent with reports in other studies (Beilin et al., 2011; Barnett and O'Neill, 2010; Andersson-Skold et al., 2015). This indicates the need to reflect on the long-term impacts and temporal dimensions of climate change adaptations on development. Adaptation actions should critically explore the relationship between adaptation and sustainable development and understand the context of vulnerability, including unravelling the feedbacks between multiple stressors (Eriksen et al., 2011), as well understanding the spatial and temporal interplay that can potentially adversely influence adaptation outcomes.

5. Conclusions

This paper has explored how climate change coping and adaptation responses can sometimes lead to maladaptive outcomes. Findings identified the key climatic and socioeconomic stressors that adversely influence agricultural systems in northern Ghana. Socioeconomic stressors included lack of access and high cost of farm inputs, labour shortages and population growth whilst the climatic stressors included erratic rainfall, high temperatures, droughts and floods. The paper demonstrated that climatic and non-climatic factors interact to affect agricultural practices. In terms of coping and adaptation measures, the study identified various options including extensification and intensification of agriculture, temporary migration, planting of drought resistant varieties, mulching etc. Advancing the work of Juhola et al. (2016), the paper has demonstrated with empirical evidence three types of maladaptive outcomes that are occurring in the study communities: *rebounding vulnerability, shifting vulnerability and eroding sustainable development.*

These findings suggest that climate change adaptation policy should be devised in a manner that enhances household adaptive capacity in the short term whilst promoting their development benefits in the long-term. It is vital that development partners and policy makers develop appropriate and robust indicators to assess the long-term effects of various climate change adaptation actions in order to reduce maladaptation. This paper contributes to the burgeoning literature on adaptation and climate risk management by providing empirical evidence to enhance understanding of how coping and adaptations measures are delivering maladaptive outcomes in vulnerable communities of northern Ghana.

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