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How do land tenure arrangements influence adaptive responses of farmers? A study of crop farmers from semi-arid Ghana

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Abstract This study investigated land tenure potential to influence farmers' adaptive responses to climate change. A quantitative approach was employed to determine how crop farmers' farmland tenure arrangements influence their adaptive responses to climate change impacts in the Lawra District of semi-arid north western Ghana. Field data were gathered from 248 farming households between January and May, 2017 through a multi-stage sampling procedure. About 55.2%, 45.6%, 44.4%, 80.6% and 64.5% of the farmers adopted early maturing crop varieties, zai farming techniques, agroforestry, crop rotation and adjustment in planting dates respectively as adaptive choices to the impacts of climate change. Binary logistic regression models showed that farmland size, years of land occupancy or usage, method of land acquisition and perceived level of farmland tenure security significantly ($p \leq 0.05$) influenced farmers adaptive responses. We recommend that, government and non-governmental organizations should always consider farmers land tenure arrangements particularly regarding how they access or acquire their farmlands, the size of their farmlands and how they perceive the tenure security of those lands in the design and implementation of adaptation policies and programmes targeted at farmers so as to enhance sustainable adaptation.

Keywords Land tenure arrangements · Land tenure rights · Adaptive responses · Semi-arid Ghana · Climate variability and change

Introduction

Climate change remains a serious threat to many crop farmers, particularly in Africa (Karimi et al. 2018; Schlenker and Lobell 2010). In Ghana this threat is heightened in areas noted to be semi-arid especially northern Ghana where the rainfall regime is uni-modal (Ahmed et al. 2016; Badmos et al. 2018). Nevertheless, adapting effectively to climate change largely rests on the capacity of the farmers (Stanturf et al. 2011).

Farmers ability to effectively and efficiently adapt to climate change impacts is largely influenced by access to resources including land and water among

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others (Trinh et al. 2018). Pelling et al. (2015) posited that farmers' adaptation decisions are largely based on access to productive resources, with land forming a critical component. Similarly, Maru et al. (2014) opined that land forms a critical component of farmers' adaptation decision making. However, access and equity in tenure arrangements still remain problematic especially in semi-arid northern Ghana (Lestrelin et al. 2011; Subedi 2016). Farmers' access to and security over land are determined by land tenure rights, which are largely influenced by economic, political and institutional policies as well as local traditional norms (Doss et al. 2014). This has at times culminated in conflicts among interest groups especially in areas where land is noted to be scarce, thereby hindering farmers' ability to increase productivity through effective adaptation practices (Peters 2013). In semi-arid northern Ghana for instance, customary land tenure remains the major means of land ownership consisting of skin, clan, family and individual lands with largely patrilineal land rights (Amanor and Ubink 2016).

Though numerous efforts have been made towards improving farmers access to resources and modern agricultural technological practices as part of enhancing adaptive capacity, most farmers are still reported to be limited in their ability to effectively adapt to the impacts of climate change (Owusu et al. 2015). Some school of thought such as Abebe (2014) and Yaro et al. (2015) seem to largely attribute this to property rights (that is land tenure rights), which have hindered access and control over basic resources particularly land. Increased incidence of land conflicts and the fight over land resources such as pasture, water, and low lands have been on the increase due to rights over access created by customary land tenure regimes (Obeng-Odoom 2012). As social differentiation and inequalities in relation to land tenure can undermine farmers' efforts towards effective and sustainable adaptation, understanding how land tenure arrangements influence farmers' adaptive responses is vital for policies and programmes on adaptation. Yet, the nexus between land tenure arrangements and farmers responses to the impacts of climate change have not been largely explored by many researchers. Only a few existing studies have sought to draw a link between land tenure rights and farmers adaptive responses, see (Antwi-Agyei et al. 2015). Therefore, this study adopted a quantitative approach to determine how crop farmers' farmland tenure arrangements influence their adaptive responses to climate change impacts in the Lawra District of semi-arid north western Ghana.

Land tenure arrangements in Ghana

Bruce (2012) defined land tenure as a "social structure that encompasses complex rules governing land ownership and use". These rules vary largely across societies and communities. German et al. (2013) opined that, land tenure outlines how land ownership is acquired. It is a framework of procedures through which access to land, its management and control fit within a broader set of social, political and economic principles which are subject to societal change and reconstruction. Daley and Pallas (2014) assert that land tenure denotes how land as a resource is controlled. Land rights are claims that are legally or socially recognized and enforceable by an external legitimate authority which could be a village level institution or an institution at a higher state level (Agarwal and Bina 1994). Land ownership is synonymous with land rights and is defined generally by the land tenure system that basically determines land accessibility among individuals as well as security over such land (Kapitingana 2014). Access and use of a land in any setting is enshrined in an institutional framework that dictates who gets that land, when and how. Land tenure is also described as relationships that exist among individuals in a community regarding their rights to land (Mooya and Cloete 2008).

In Ghana, land ownership is categorized into two; state or public and private land ownerships (Asabere 1994). State lands are compulsorily possessed by the government (Larbi et al. 2004). On the other hand, private lands are mostly under communal ownership and under the care of chiefs and family heads on behalf of the community, groups or individuals (Asabere 1994; Attua and Fisher 2011). Apart from state and private lands, lands could be vested and thus owned partly by the state and individuals or traditional authorities (Berry 2009). In Ghana Tsikata and Yaro (2014), opined that land is dominantly owned based on customary norms. Kombe and Kreibich (2000) posited that under customary land tenure, land ownership is attained at clan, family or lineage levels whilst individuals only enjoy unrestricted rights of usage. More so, Gough and Yankson (2000) assert that

customary land tenure is like an institution and forms a basic component of every traditional society. In most parts of Northern Ghana, customary land rights are vested in skins and "*tendanas*" (land priests) (Yaro 2010). Among the Akan ethnic group in southern parts of Ghana, customary land rights are vested in the stools represented by the chief (Abdulai and Ndekugri 2007). This applies mostly to vacant lands but in many instances, land rights remain under the control of matrilineal lineages (Arko-Adjei 2011).

After colonialism, administration of customary and statutory land has gone through several reforms (Yaro 2010). In the early post-independence regime, the state land administration witnessed the evolution of state institutions notably the lands commission department (Kasanga and Kotey 2001). This was to satisfy a national interest in land deals, correct anomalies and problems that were common in the customary land sector, introduce written records through land deeds and titles registration, promote land tenure security and easier acquisition (Obeng-Odoom 2016). However, the focus of the reforms in the land sector was not necessarily to protect indigenous poor farmers but to guarantee tenure security for the state. In this regard, many land laws were enacted including state institutions like the Land Commission Department through Act 362 following the 1969 constitution (Schoneveld and German 2014).

Subsequently in 1999, a national policy on land was formulated but later amended in 2002 (Kasanga and Kotey 2001). The policy was aimed at facilitating the growth of the economy (Anaafo 2015). Its focus was also to bring poverty to a minimal level and ensure that there was social stability by improving the secure access to land, simplify the process for land acquisition and promote fairness, transparency and efficiency in land deals (Whitehead and Tsikata 2003). However, land remains a contested resource among many user groups (Quansah 2012). Having right to any land may connote access, ownership, use, control, transfer, inheritance and taking decision reagrding its related resources (Borras Jr et al. 2011).

Land tenure rights

The right to land includes the right to access, own, use, control, transfer, exclude, inherit and otherwise make a decision about land and its related resources (Toulmin et al. 2011). Land rights crucially influence land use planning and represent a complex set of socially and legally recognized claims enforceable by a legitimized authority either at a community level or a national level state institution (German et al. 2013). It is further admonished that land rights are dependent on the mode of land acquisition; inheritance, state transfer, tenancy arrangements or outright purchase characterized by various levels of authority on its use and management.

Whereas land may be acquired in numerous ways, rights to land are basically in three forms; user rights, control rights and transfer rights (Galiani and Schargrodsky 2010). User rights to a land exist when a holder of that land is given limitations regarding its usage. Individuals are instructed to use the land for specific activities like crop production or grazing and even the types of crops may be dictated in the agreement (Markussen et al. 2011). Under control rights, land holders have the authority to take decisions regarding how and what to use the land for and to benefit fully from the use of the land but cannot transfer the land to their heirs or sell it (Peluso and Lund 2011). With transfer rights, there is more authority by the user as he or she can transfer the land to heirs, sell or reallocate user and control rights associated with the land (Zevenbergen et al. 2013).

Kapitingana (2014) identified similar forms of land rights; user, control and transfer rights and opined that rights to land are allocated and validated by title issuance or other forms of ownership registration. Also, Knight (2010) identified other forms of land rights namely; communal land rights, open access, private and state rights. Communal rights to land are rights that are common in the rural setting (Baird 2013). There exists a common right in a given community where each member may have the right to use the holdings of the community (Feder and Feeny 1991). Members of the community may have the right to graze cattle on a pastureland or water body without denial. Private land rights connote the assignment of land rights to a private party be it an individual, a group of people, married couple or a corporate body like a commercial entity (Chimhowu and Woodhouse 2006). On the other hand, Seufert (2013), asserts that open access to land do not have specific rights assigned to individuals and as such, there is no one who can be excluded in the use of such lands. This may include rangelands and forests. For state lands, rights are assigned to an authority in the public sector. For

instance, forest lands may fall under the mandate of the state whether at the central or decentralized level of government.

Land acquisition and tenure security

In the opinion of Kuusaana and Eledi (2015) land acquisition by rural farmers is mostly influenced by traditional or customary norms. Land can be acquired through purchase, lease, sharecropping and inheritance. In Ghana, Abdulai et al. (2011) identified four main tenure arrangements among crop farmers. They included; owner operated with full property rights, owner operated with restricted property right, fixed rent and shared cropping contracts. Similarly, owner operated with full property rights and shared cropping tenure arrangements have been reported by Antwi-Agyei et al. (2015). Also, Adamu (2014) reported purchasing arrangements, inheritance, rent and gift as mode of land tenure arrangements among farmers. Moreover, Asaaga and Hirons (2019) reported inheritance, purchasing, renting, sharecropping and gift as means of land acquisition among farmers in south west and central Ghana. Lambrecht and Asare (2016) also reported farmers' means of land acquisition which included; shared cropping, inheritance, outright purchasing, gifted lands and those rented.

Tenure security remains critical in spurring agricultural investment and productivity (Ghebru and Lambrecht 2017). According to Deininger et al. (2011), tenure security is "the degree of confidence that land users will not be arbitrarily deprived of the rights they enjoy over land and the economic benefits that flow from it; the certainty that individuals rights to land will be recognized by others and protected in all cases of specific challenges; more specifically, the right of all individuals and groups to effective government protection against forced evictions". The perception of farmers regarding the tenure security of their farmlands can influence their on-farm investment decisions for adaptation (Ayamga et al. 2015). Farmers' perception of their farmland tenure security is based largely on the method of land acquisition. For instance, Ghebru and Lambrecht (2017) asserts that farmlands acquired through inheritance were perceived to be highly tenure secure compared those acquired based on grants or gifts by family or community members.

Hollingsworth (2014) identified; perception of future loss of farmland, the experience of previous loss of farmland, mode of land acquisition, duration of rights to land and conflicts over the land as proxy indicators of perceived land tenure security. Ayamga et al. (2015) argued that farmers who continue to cultivate on their farmlands are less likely to lose their farmland under customary land tenure and may feel tenure secure.

Adaptive responses to climate change

As Climate change continuous to disrupt agricultural activities in most parts of the world, farmers continue to employ various strategies in order to minimize the climatic related risks on their farming activities (Ali and Erenstein 2017; Antwi-Agyei et al. 2018). One effective strategy that is largely adopted by farmers is crop diversification (Lin 2011). It involves cultivating more than one variety of crops belonging to the same or different species in a given area or plot of farmland (Makate et al. 2016). Crop diversification can help reduce pest outbreak and pathogen transmission which may likely be exacerbated by climate change (Lin 2011). Crop diversification can help farmers to minimize climatic threats on yields (Makate et al. 2016).

Agroforestry practices have been reported as sustainable practices for climate change adaptation especially in sub-Saharan African (Tully et al. 2015). In examining the impact of agroforestry adoption on household food security in Malawi, Coulibaly et al. (2017) ascertained that, adoption of agroforestry practices coupled with the use of cultivation of improved crop varieties resulted in a significant increase in yield among farmers. According to Leakey (1996) agroforestry is a "dynamic ecologically based natural resource management system that, through the integration of trees in farm and rangelands diversifies and sustains smallholder production for increased social, economic and environmental benefits". With the increasing risks of climate change on food security, farmers continue adopt agroforestry practices in order to help boost productivity (Mbow et al. 2014).

Similarly, in most parts of Africa, adoption of improved crop varieties have been reported among many farmers (Makate et al. 2016; Onyeneke et al. 2017). For instance, in the Borno State of Nigeria, Bamire et al. (2010) discovered the use of improved

crop varieties as adaptive responses to the impacts of climate change. Improved crop varieties involve the use of disease and pest tolerant varieties, planting of certified seeds, planting of short term crop varieties as well as different maturity varieties and drought tolerant varieties (Delgado et al. 2011). In the eastern parts of Zambia, Khonje et al. (2015) reported the use of improved maize varieties among crop farmers resulting into increase in household food security. Moreover, in northern Ghana, Danso-Abbeam et al. (2017) reported the cultivation of improved crop varieties among farmers in order to effectively adapt to climate change.

In the drier upper eastern Kenya, Kimaru-Muchai et al. (2020) reported the use of zai pit technique as a strategy for climate change adaptation. Lahmar et al. (2012), described zai pit technique as a traditional soil nutrient and water conservation strategy usually made up of small pits measured 20–30 cm in width and 10–20 cm deep and spaced 60–80 cm. Seeds are sown into the pits after filling them with one to three handful of organic manure (Fatondji et al. 2011). The pits serve to collect and concentrate both nutrients and water at the plant and therefore reduce water stress especially in areas of low and erratic rainfall (Danjuma and Mohammed 2015). It takes about 450 h to dig 20,000–25,000 pits per hectare which discourages most farmers from adopting the practice despite its effectiveness in increasing yields (Kaboré and Reij 2004). In Nile Basin, Nigussie et al. (2018) found that crop rotation was practiced as soil and land management practice for climate change adaptation. Crop rotation implies growing different types of crop on the same piece of land in every cropping season (Arriaga et al. 2017). In Ghana, Ndamani and Watanabe (2015) reported the adoption of crop rotation practices by farmers as means of adapting to climate change. Farmers were found to be rotating cereals with legumes in order to reduce disease and pests attack and to improve soil fertility.

Influence of land tenure arrangements on adaptive responses

In most parts of West Africa, particularly semi-arid Ghana, Sarr (2012) found that the choice of adaptation practices was largely influenced by land tenure arrangements. In most parts of West Africa, decisions regarding the selection of various adaptation practices are significantly based on size of farmland and lack of secure land rights (Sietz and Van Dijk 2015). Antwi-Agyei et al. (2015) revealed in the northern savanna and forest belt of Ghana that, adaptation strategies commonly used by farmers cultivating on rented lands were inefficient and unsustainable as they perceived their farmlands were tenure insecure. Farmers who were cultivating on rented and shared cropped lands were less likely to employ strategies such as agroforestry, zai pit techniques, crop rotation and land fallowing for adaptive purposes. In addition, farmers' perceived level of their farmland tenure security influences their ability to accurately anticipate, incorporate and respond to climatic changes (Elum et al. 2017). Ayamga et al. (2016) reported, tenure security had a positive relationship with farmers' adoption of long-term farm investment strategies. Farmers who were cultivating on their household lands and lands acquired through inheritance were more likely to employ long term effective and efficient strategies in the improvement of productivity of their farmland. Ma et al. (2013) ascertained that, farmers who perceived their tenure rights as secure invested in the creation of irrigation canals on their farmland in order to improve water supply to their crops during droughts. Akram et al. (2019) reported the use of soil fertility management options among individuals who held transfer rights to their farmlands leading to improved productivity than shared cropped farmers. Similarly, Gao et al. (2017) posited that farmers who acquired their farmlands based on inheritance or purchase have more secure tenure rights and mostly invest in the improvement of the fertility of their farmland. Bambio and Agha (2018) revealed, farmers who had secure land rights such as transfer rights and control rights were more likely to invest in the adoption of adaptive responses including; agroforestry, zai pit technique, fertilizer application, crop rotation and land fallowing. In contrast, Kahsay (2011) reported land tenure rights did not have any influence on farmers adaptive decisions. In Ghana's forest region, Fosu-Mensah et al. (2012) reported land tenure rights significantly influenced farmers adaptive response to climate change. Roco et al. (2014), ascertained that farmers who cultivated on household lands or own their farmlands adopted strategies including crop rotation, land fallowing and irrigation canals among other strategies for adaptation. In northeast Nigeria, Yila and Resurreccion (2013) reported, farmers adaptive

options to climate change were influenced by land tenure arrangements especially on the basis upon which their farmlands were acquired. It was observed that farmers who acquired their farmlands through inheritance adopted strategies like land fallowing and crop rotation for adaptation. In Kenya Mugure et al. (2013) found that, adoption of agroforestry practices for climate change adaptation were low among farmers due to land ownership challenges.

In Uganda, Hisali et al. (2011) found that farmers adaptation decisions were influenced by land tenure security. Tenure security increases the probability of investing in sustainable and effective adaptive strategies. Similarly, Gbetibouo et al. (2010) in "modeling farmers adaptation strategies for climate change and variability", reported farmers adaptation strategies were positively influenced by tenure security as farmers whose land tenure arrangements were secure were more likely to invest in innovative adaptation strategies. In sub-Saharan Africa, Descheemaeker et al. (2016), found that tenure insecurity was a disincentive to farmers adaptation decisions. In the rural uplands of Lao, Keovilignavong and Suhardiman (2020) discovered a positive relationship between farmland tenure security and food security. Tenure security serves as an incentive for farm investment in that as farmers feel secure of not losing their farmlands in the future, they become motivated to adopt effective and efficient strategies that increase farm productivity. Khanal and Wilson (2019) found in Nepal that the probability of farming households with large land size investing in adaptive strategies such as adoption of improved crop varieties was high.

Study area and research methodology

The study was conducted in the Lawra District of Upper West Region, north-western Ghana (Fig. 1). The district shares boundaries with Nandom and Lambussie/Kani Districts to its northern and eastern parts respectively and with La Cote d'Ivoire at the south-west and western parts (GSS 2014). It has about 527.37 square kilometers of land area (GSS 2014). Based on the 2010 population census, the Lawra District has a total population 54,889 which constitute about 7.8% of the total population of the Upper West Region (GSS 2014). Female constitute 52% of the population and males 48%. Out of the district's total population of 54,889, 88.2% are living in rural localities whilst only 11.8% constitute an urban population thereby making the district more agrarian.

Field data were gathered between January and May, 2017 and subsequently updated between May and August, 2020. A quantitative research approach was adopted for the study. A multi-stage sampling procedure was used to select 248 crop farming households from four communities within four zones of the district- Babile, Nayiri (Eremon), Tabie and Tolibri (Fig. 1). The first stage was a homogeneous purposive selection of crop farming households in the Lawra District classified within the semi-arid zone of Ghana. Homogeneous purposive sampling is applicable when a researcher wants to study a phenomenon in relation to a population that has similar characteristics like occupation, culture or experiences among others (Etikan et al. 2016). Crop farmers remain largely affected by climatic stress since their farming activities are climate dependent (Blanc 2011). Hence it was important to purposively sample them for the study. Moreover, the Lawra District was selected because it is largely agrarian and climate dependent (Ndamani and Watanabe 2015). Apart from that, high incidence of vulnerability has been reported among farmers in the district (Naab and Koranteng 2012). Secondly, the district was grouped into four zones; north, south, east and west and one community was simple randomly selected from each zone making a total of four communities. A total of 248 crop farming households made up of 69 female headed households and 179 male headed households were selected through stratified random sampling. Thus, the farming households were grouped into male headed households and female headed households. The respondents were then simple randomly selected from the two subgroups. Stratified random sampling explains a sampling process where a study population is subdivided into groups such as males or females after which a sample is randomly selected from each subgroup to obtain the calculated sample size (Teddlie and Yu 2007). The choice of this sampling procedure was to ensure that the various social groups of farmers particularly on the basis of gender were represented in the study since men and women may have had different issues with regards to land tenure arrangements and how it influences their adaptive responses. This assertion is corroborated by Antwi-Agyei et al. (2015) who reported that different social groups are differently affected by land tenure

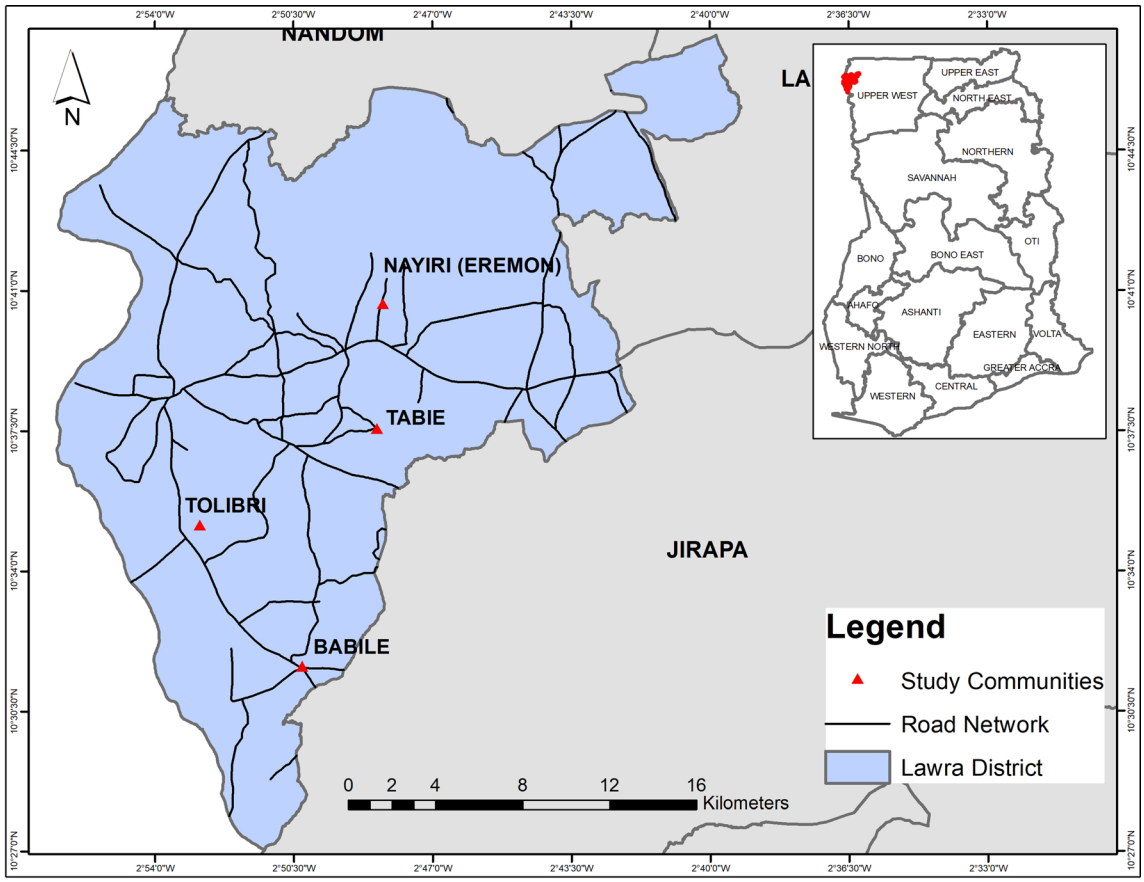

Fig. 1 Map of study area showing interviewed communities

arrangements. The sample size was calculated through the adoption of Yamane (1967) sample size determination formula (Eq. 1).

$$n = \frac{N}{1 + N(e)^2} \tag{1}$$

where n = sample size, N_1 = total number of female headed households (83), N_2 = total number of male headed households (324), e = margin of error at 5%.

Total sample size (n) = sample size for female headed households (n_f) + sample size for male headed households (n_m)

$$n_f = \frac{83}{1 + 83(0.05)^2} = \frac{83}{1 + 0.208} = \frac{83}{1.208} = 68.709 = 69$$

$$n_m = \frac{324}{1 + 324(0.05)^2} = \frac{324}{1 + 0.81} = \frac{324}{1.81} = 179.006 = 179$$

$$n = n_f + n_m$$

$$n = 69 + 179 = 248$$

Data on the demographic and farm level characteristics including adaptive responses were obtained at the household level using a survey questionnaire which was structured with closed ended questions. The questionnaire was pretested based on the study objective in the study communities to ensure that it was clear and within the framework of the study.

The field data was processed and analyzed using SPSS version 21. A binary logistic regression model was used to examine the influence of land tenure arrangements on crop farmers' adaptive responses. Binary logistic regression was chosen because the adaptive strategies were simultaneously adopted by the farmers hence there were separate models for the adaptive strategies adopted by the farmers. Moreover, each of the dependent variables had two response categories and therefore it was more appropriate to use binary logistic regression technique, see (Harrell 2015; Maharjan and Joshi 2011). That aside, binary

logistic regression has been used in similar studies and has proven to be consistent and robust in enhancing the validity and reliability of the study results for informed policy decision making see (Abid et al. 2015; Maharjan and Joshi 2011).

Farmers' choice of an adaptive response (strategy) was treated as the dependent variable whilst tenure arrangements represented the independent (explanatory) variables. See model in Eq. 2. Goodness of fit test was conducted to ascertain the strength or robustness of the models. We calculated Pseudo-R^2 values for all the models using SPSS version 21. The values obtained were within the ranges of 0.051–0.839 indicating the robustness of the models. Additionally, Variance Inflation Factor analysis was conducted to determine if there were cases of multicollinearity. The Variance Inflation Factor values for the five models was within 1.019–4.076 indicating there were no cases of collinearity among the explanatory variables in the models.

$$\gamma_i = \mu + \mu_1 x_1 + \mu_2 x_2 + \mu_3 x_3 + \mu_4 x_4 + \mu_5 x_5 + \lambda_i \quad (2)$$

where $\mu x_1 \ldots \mu x_n$ represents independent variables explaining the selection of a particular adaptation strategy (γ_i) and λ_i be the error term of the estimated regression model. A farmer's decision was $\gamma_i = 1$ if he/she adopted a strategy and 0 if he/she did not adopt a strategy. See Table 1 for independent variables.

Results

Demographic and farm level characteristics

About 72.2% and 27.8% of the respondents were males and females respectively. With regards to age, 8.9% of the respondents were about 25 years and below but majority (27.8%) were aged from 46 to 55 years. Those whose age ranged from 36 to 45 years were 15.7% whereas those who were above 66 years were 15.3%. The least (11.17%) were those from 26 to 35 years. With regards to formal education, about 51.6% of the respondents never had formal education but 11.7% were educated up to the tertiary level. The rest of them, representing 30.6% and 6% had formal education up to basic and secondary/technical levels respectively. Moreover, majority (63.3%) of the respondents were heads of their various households whereas 36.7% reported of not being the heads of their households. About 45.6% and 33.1% of the respondents had household sizes of one to five members and six to ten members respectively. Those whose household sizes were more than ten members, represents about 21.4% of the respondents. Pertaining to the common types of crops cultivated by the respondents, about 69.4% were engaged in the cultivation of vegetables, cereals and legumes whilst exactly 2% were cultivating only cereals. Similarly, about 0.4% of the farmers were cultivating only vegetables whilst 28.2% were cultivating vegetables, cereals, legumes and tuber crops. Majority (60.5%) of the respondents had climate change education but about 39.5% of them never got education on climate change and possibly on how to adapt.

Table 1 Independent variables used in the binary logistic regression models

Independent variable	Description	Expected sign
Method of land acquisition (x_1)	Continuous	±
Size of farmland (x_2)	Continuous	±
Types of tenure rights (x_3)	Continuous	±
Years of land usage (x_4)	Continuous	±
Perceived tenure security (x_5)	Continuous	+

Land tenure arrangements

With regards to the methods through which the farmers acquired their farmlands, about 43.5% of them acquired their farmlands through inheritance from their parents and other family members whilst 42.7% reported their farmlands were granted to them by their family members. On the other hand, 3.2% and 10.5% of them acquired their farmlands through gifts and leasehold arrangements respectively. Whereas about 5.6% of the respondents had farmland size of more than ten acres, majority (61.3%) of them had below six acres. About 33.1% had farmland size of about 6–10 acres. Those who had user rights to their farmlands were 32.7% whilst about 26.2% and 41.1% had control and transfer rights respectively to their farmlands. Based on the years of land occupancy, about 5.6% of the respondents have been cultivating on their farmlands up to 10 years whereas about 28.2% have been cultivating on their farmlands for

11–20 years. Majority of the respondents (38.7%) have been cultivating on their farmlands for about 21–30 years whilst about 5.6% have been cultivating theirs for over 30 years. With respect to tenure security, about 38.7% of the respondents were tenure secure to the maximum whilst 33.1% were perceived to be secure to the minimum. On the other hand, about 7.3% of the respondents perceived they had moderate tenure security whilst 21% were perceived to have no security at all over their farmlands.

Adaptive responses among crop farmers

From the results, five common adaptive practices were simultaneously employed by crop farmers in the Lawra District. These included; the cultivation of early maturing crop varieties, practice of zai farming techniques, agroforestry practices, crop rotation and adjustment in planting dates. About 55.2% of them cultivated early maturing crop varieties. With regards to the adoption of zai farming techniques, about 45.6% of the respondents reported of employing zai pit techniques in order to contain water and soil nutrients within their farmlands. Moreover, about 44.4% of the respondents also adopted agroforestry practices. Crop rotation practices were largely adopted by the respondents. For instance, about 80.6% of them were practicing crop rotation whereas those who adjusted their planting dates were about 64.5%.

Influence of land tenure arrangements on adaptive responses

This section presents results on a binary logistic regression aimed at determining the influence of land tenure arrangements on farmers' adaptive responses in the surveyed communities. In ascertaining how tenure arrangements influence farmers decision to cultivate early maturing crop varieties for climate change adaptation, results from the binary logistic regression model showed tenure arrangements influenced farmers adaptive responses basically in one way; size of farmland. Crop farmers who were cultivating on more than ten acres of farmland were about three times less likely to cultivate early maturing crop varieties as an adaptive response (Table 2).

As shown (Table 2), farmers' decision to employ zai farming techniques for adaptation was influenced by the procedure through which they acquired their farmlands. The regression models showed that farmers who were cultivating on lands granted to them by their family members or relatives were about eight times more likely to practice zai farming techniques compared to those who acquired their farmlands through inheritance. Moreover, if other factors were controlled, farmers who perceived the tenure security of their farmlands as maximum were about three hundred and thirty-three times less likely to practice zai farming techniques compared to those who did not have tenure security over their lands. Based on the binary logistic regression model, about 83.9% of variations in the probability of the farmers adopting zai farming techniques was explained by all the explanatory variables included in the model.

Tenure arrangements influenced farmers' decisions to adopt agroforestry practices for adaptation through size of farmland and years of land usage or occupancy. If other factors were controlled, farmers whose farmland size was more than ten acres were about twenty-three times less likely to opt for agroforestry practices compared to those whose farmland size was less than six acres. Moreover, if other factors were controlled, farmers who had been cultivating on their farmlands for more than 30 years were about eleven times more likely to practice agroforestry compared to those who have been cultivating on their farmlands for about 10 years and below. The differences in the probability of the farmers adopting agroforestry practices for adaptation is explained by all the explanatory variables included in the model. With reference to the binary logistic regression model, land tenure arrangements had no any significant influence on farmers' decision to adopt crop rotation practices for adaptation (Table 2).

Based on the regression model, about 15.2% of the variations in the probability of the farmers adjusting their planting dates as a way of adapting to climate change are explained by all the explanatory variables included in the model. The decision of farmers regarding whether to adjust their planting dates as strategy for adapting to climate change was influenced by the size of farmland cultivated by a farmer and their perceived tenure security associated with that farmland. If all other factors are controlled, farmers whose farmland size was more than ten acres were about eight times less likely to adjust their planting dates compared to those whose farm size was less than six acres. On the other hand, if all other factors are

Table 2 Influence of land tenure arrangements on adaptive responses

Explanatory variables	Early maturing crop varieties		Zai farming technique		Agroforestry		Crop rotation		Adjustment in planting date	
	Odd ratio	P.value	Odd ratio	P.value	Odd ratio	P.value	Odd ratio	P.value	Odd ratio	P.value
Land acquisition										
Inheritance (reference)	1.000		1.000		1.000		1.000			
Gifted	1.715	0.584	9.223	0.999	0.000	0.999	0.936	0.963	0.342	0.329
Leasehold	1.780	0.460	2.968	0.327	0.000	0.999	0.881	0.907	0.418	0.298
Family grant	0.833	0.784	8.158	0.030**	0.000	0.999	2.489	0.324	0.381	0.168
Land size										
Below 6 acres (reference)	1.000		1.000		1.000		1.000			
6–10 acres	0.645	0.161	0.365	0.122	0.534	0.310	1.238	0.614	0.662	0.214
Over 10 acres	0.263	0.058**	0.298	0.260	0.043	0.008*	2.186	0.312	0.129	0.016**
Land rights										
User rights (reference)	1.000		1.000		1.000		1.000			
Control rights	0.786	0.512	0.417	0.205	0.644	0.504	0.746	0.741	1.206	0.653
Transfer rights	0.725	0.754	0.785	0.861	0.000	0.998	0.563	0.492	0.893	0.917
Years of land usage										
Up to 10 years(reference)	1.000		1.000		1.000		1.000			
11–20 years	1.429	0.571	0.645	0.721	1.752	0.603	1.861	0.583	0.871	0.840
21–30 years	1.180	0.787	1.255	0.847	5.081	0.135	2.886	0.341	1.420	0.595
Over 30 years	1.333	0.649	0.849	0.892	11.863	0.031**	3.110	0.316	1.119	0.868
Tenure security										
No security (reference)	1.000		1.000		1.000		1.000			
Minimum security	1.221	0.592	1.185	0.801	1.726	0.409	1.300	0.539	1.548	0.322
Moderate security	1.019	0.977	0.377	0.334	0.950	0.958	0.613	0.596	6.867	0.008*
Maximum security	1.310	0.748	0.003	0.000*	0.238	0.210	0.775	0.825	1.821	0.514

* and ** indicate significant values at 1% and 5% respectively

controlled, farmers who perceived the tenure security of their farmlands as moderately secure were about six times more likely to adjust their planting dates as an adaptive strategy to climate change (Table 2).

Discussion

As climate change continuous to adversely impact agricultural production, it is imperative for farmers to identify effective and efficient strategies in order to optimize productivity Serdeczny et al. 2017). Based on results of the logistic regression model, crop farmers who were cultivating on more than ten acres of farmland were three times less likely to cultivate early maturing crop varieties as an adaptive strategy (Table 2). This contradicts Khanal and Wilson (2019) who found that in Nepal farming households with large land size were more likely to invest in adaptive strategies such as the adoption of improved crop varieties. However, it is corroborated by Oyekale and Oladele (2012) who found in south west Nigeria that farmers who owned more farmlands reduced their probability of investing in the adoption of crop diversification strategies including improved crop varieties. Farmers who own more land are more likely to expand the scale of their production which may

guarantee them more output compared to those with smaller land size.

Zai farming techniques help farmers to collect about 25% of run-off water from their farmlands as well as the retention of soil nutrients (Amede et al. 2014). As shown in Table 2, farmers' decision to employ zai farming techniques for adaptation was influenced by the procedure through which they acquired their farmlands. Farmers whose farmlands were granted to them by family members were about eight times more likely to practice zai farming techniques compared to those who acquired their farmlands through inheritance. It is most likely that granted lands were not fertile compared to the inherited ones hence farmers were more willing to adopt better soil nutrients and water management strategies like zai farming techniques in order to effectively adapt to climate change. This assertion is corroborated by Yila and Resurreccion (2013) who found in northeastern Nigeria that farmers adaptation options were influenced by the methods farmers went through to acquire their farmlands. Whereas farmers whose farmlands were acquired through inheritance are more likely to practice soil nutrient management strategies such as land fallowing, those whose lands were granted to them employed short term strategies including zai farming techniques to be able to maximize output in the short term. This concurs with Ayamga et al. (2016) who found in Ghana that farmers whose land tenure arrangements were not secure were more likely to invest in the adoption of short term adaptation strategies.

Moreover, if other factors were controlled, farmers who perceived the tenure security of their farmlands as maximum were about three hundred and thirty-three times less likely to practice zai farming techniques compared to those who did not have tenure security over their lands. Tenure security serves as an incentive for the adoption of long term strategies like creation of irrigation canals as means of ensuring continuous water supply in the farm instead of adopting strategies like zai farming techniques (Ayamga et al. 2016). In North-west China, Ma et al. (2013) ascertained that, farmers who perceived their tenure rights as secure invested in the creation of irrigation canals on their farmland in order to improve water supply to their crops during droughts. The low adoption of the zai technique among farmers with secure land tenure arrangements could also be attributed to high cost and difficulty of digging the zai pits as it takes about 450 h to dig 20,000–25,000 pits per hectare which discourages most farmers from adopting the practice despite its effectiveness in increasing yields (Kaboré and Reij 2004).

In semi-arid areas, agroforestry can be an effective option for adaptation (Mbow et al. 2014). If other factors were controlled, farmers who had been cultivating on their farmlands for more than 30 years were about eleven times more likely to opt for agroforestry practices (Table 2). Years of land occupancy gives farmers a certain level of satisfaction about the security of tenure regarding their lands (Ayamga et al. 2015). In Burkina Faso, Bambio and Agha (2018) revealed, farmers who had secure land rights were more likely to invest in the adoption of adaptive responses including; agroforestry and zai pit techniques. Moreover, if other factors were controlled, farmers whose farmland size was more than ten acres were about twenty-three times less likely to opt for agroforestry practices compared to those whose farmland size was less than six acres. This implies that, since they have access to larger plots of farmlands they would prefer to choose long term strategies such as land rotation or bush fallowing where they allow portion of their farm plots to lie idle for some years to regain fertility. This assertion resonates with Ayamga et al. (2016) who found that farmers who had more plots of farmlands and felt secure were more likely to fallow their farmlands.

In most parts of West Africa, decisions regarding the selection of various adaptation practices are significantly influenced by size of farmland and tenure security (Sietz and Van Dijk 2015). From the logistic regression, the decision of farmers regarding whether to adjust their planting dates was influenced by the size of their farmland and perceived land tenure security. Other studies have reported similar findings. For instance, Piya et al. (2013) discovered that in the Mid-Hills of Nepal, farmers adaptation decisions were significantly influenced by tenure arrangements including farmland size. From the regression analysis if all other factors are controlled, farmers whose farmland size was more than ten acres were about eight times less likely to adjust their planting dates compared to those whose farm size was less than six acres. However, Jones et al. (2010) posited that, improving farmers access to more productive resources like land increases the probability of farmers

adopting innovative strategies to effectively adapt to the impacts of climate change. Gao et al. (2017) opined tenure security encourages farmers in deciding on strategies that can help them optimize productivity. Farmers who perceived the tenure security of their farmlands as moderately secure were about six times more likely to adjust their planting dates as an adaptive strategy to climate change (Table 2). Adjusting planting dates may require some postponement of the planting time hence farmers whose farmlands are tenure insecure may have fears of losing their lands if they decide to postpone their planting dates as farmers' perceived level of their farmland tenure security influences their ability to accurately anticipate, incorporate and respond to climatic changes (Ayamga et al. 2015; Elum et al. 2017).

Conclusion

As climate change continuous to threaten agricultural production in semi-arid North West Ghana, a combination of on-farm adaptive strategies has been adopted by farmers to optimize productivity in order to meet their household food needs. On-farm adaptive strategies including cultivation of early maturing crop varieties, zai farming techniques, agroforestry practices, crop rotation and adjustment in planting dates were simultaneously practiced by majority of the crop farmers in the Lawra District. We conclude that land tenure arrangements influenced the farmers' decision to adopt the cultivation of early maturing crop varieties, zai farming techniques, agroforestry practices, crop rotation and adjustment in planting dates as adaptive strategies through; farmland size, years of land occupancy or usage, method of land acquisition and perceived level of farmland tenure security.

Based on our findings, we recommend that, government and non-governmental organizations should always consider farmers land tenure arrangements particularly regarding how they access or acquire their farmlands, the size of their farmlands and how they perceive the tenure security of those lands in the design and implementation of adaptation policies and programmes targeted at farmers so as to enhance sustainable adaptation.

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