Heterogeneous farm household perception about climate change: a case study of semi-arid region of Ghana
Heterogeneous Farm Household Perceptions about Climate Change
A Case Study of a Semi-arid Region of Ghana

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Abstract: Climate change is a serious challenge for the future development of Africa, particularly the drier regions. Knowledge and awareness about climatic patterns are important for adaptation planning. Although there are many studies on farmers’ perceptions about climate change, the views of heterogeneous farm households also need to be addressed. This paper investigates the variations and similarities in the views of heterogeneous farm households about climate change. We employed a household survey (186) and interviews for data collection. Using principal component analysis and K-mean cluster analysis, we identified two household types that differ in terms of assets (human, natural and financial) and we compared their perceptions about climate change. Household-1 farmers are better off than household-2 in terms of land area cultivated and income generated from rain fed rice. On the other hand, household-2 farmers are better off than household-1 in terms of area cultivated for maize and income generated from maize. In addition, household-2 farmers are better off than household-1 in terms of land area cultivated and income generated from irrigated rice. The findings from this study show that the two household types shared similar views with respect to rainfall and temperature patterns, as well as in the ranking of climate change drivers. However, variation was observed in the perceptions of the household types of adaptation constraints. More household-1 farmers (60%) compared to household-2 (43%) saw access to dry season farmland as a barrier for adaptation. This may be due to the fact that household-2 farmers are better off with respect to irrigated farming. Heterogeneous household perceptions about climate change reveal similarities, but differences still exist in some aspects. From a similar environment, we can see that farm household heterogeneity shows a relationship with climate change perception. Therefore, it will be important to account for diversities within our local environments when planning for climate change adaptation.

Keywords: Farm Household Heterogeneity, Climatic Change, Adaptation, Northern Ghana

Introduction

Africa has been described as a continent that will be seriously affected by the impacts of climate change. The sustainable development of developing countries and the ability to attain United Nations Millennium Development Goals (MDGs) has been questioned due to the far-reaching effects of climate change (UN 2007). Changing climate has always been a normal phenomenon and this is associated with natural causes. Recently, however, the alarming rate of the changing climate has been associated with various human activities, especially fossil fuel burning and land use/cover change. Climate change is adding more stress to already threatened habitats, ecosystems, and species in Africa (UNDP 2004). It has affected the quality and amount of land and water resources accessible for agriculture production and other climate-dependent sectors such as forestry and fisheries (Darwin 1999; Fischer et al. 2002). It is also responsible for changes in the spatial distribution of agroecological zones, habitats, and patterns of plant diseases and pests, which can have notable impacts on agriculture and food production (FAO 2007).

In Ghana, the widest temperature variability range is reported for the northern savannah section (World Bank 2009), and rainfall is unpredictable (McSweeney et al. 2010). The variability in rainfall has threatened the livelihood of smallholder farmers (Amikuzuno and Donkoh 2012). The three northern regions of Ghana (Northern, Upper East and Upper West) have a much higher incidence of poverty than most other regions of Ghana (GSS 2007). About...
30 to 40% of the total land area of Ghana, concentrated in the northern drier part of the country, experience land degradation of different forms (EPA 2003).

The real problem of farmers is the lack of reliability of rainfall associated to inter-annual variability of both the distribution and total amounts of rainfall (Van de Geest and Dietz 2004). The farmers in the study area are very sensitive to rainfall with respect to their agricultural land-use decisions (Badmos et al. 2014). Residents of some communities in the Upper East Region (UER) of Ghana have reported a shorter and more unpredictable rainy season from the standpoint of both amount and timing (Dietz et al. 2004). Braimoh (2004) reported that rainfall onset is always unpredictable, with the first rains, which are usually torrential with only a small quantity percolating into the soils. In a study conducted by Laube et al. (2008) in the UER, traditional land preparation, which usually starts around January, has shifted to April, as a result of unreliable and erratic climatic condition. In a study conducted by Dietz et al. (2004), the changes in the natural resources due to the changing climate has resulted to shift in natural vegetation from trees to grasses, gradual disappearance of economically-important trees, early drying of flowing streams in the dry season, leaving stagnant pool of mosquito-infested water of low quality, salinisation of water resources, fewer swimming holes along rivers, and unreliability of traditional signs that signals the start rainy season (e.g. birds and insects behavior, wind change, onsets of new leaves, water table levels in the wells).

The impacts of climate change are inevitable, knowing the pattern and extent of climate change impacts on our livelihood will be useful in proffering effective adaptation strategies, particularly at the local level. Human is a dynamic and heterogeneous entity. Because of wealth, experience, cultural background as examples, human’s perception about climate change and other environmental change may differ with each other. According to Kuyvenhoven et al. (2004), the failure of some Integrated Rural Development Programmes is associated with limited recognition of the wide diversity and heterogeneity of farmers and fields as a principal characteristic of livelihoods and farming systems in less-favoured areas. Thus, incorporating farm household (household)’s heterogeneity could improve knowledge in climate change adaptation science.

In this study, we explored the heterogeneity of the farm household and determined their perceptions of climate change. Further, we analysed the similarities and variations in the perception of the heterogeneous farm household.

**Methodology**

**Study Area**

The Upper East Region (UER) of Ghana is located on the northeast corner of Ghana. The region is bordered by Burkina Faso in the North and Togo to the East. The region belongs to the West-African semi-arid Guinea Savannah belt with the exception of a small section in the very northeast part of the region that belongs to the Sudan Savannah (Adu 1972). UER covers a total land area of 8,842 km², which represents 3.7% of the total area of Ghana (GSS 2000). UER has a population of 1,046,545 (Male - 48.4%; Female - 51.6%), which represents 4.2% of the total population of Ghana, and a growth rate of 1.2% between 2000 and 2010. The region has an average household size of 5.8 and a 79% rural locality (GSS 2012). The population density of UER is between 118 persons km⁻² and exceeds the country’s average population density of 103.4 persons km⁻² (GSS 2012).

Rainfall in UER is mono-modal and the peak of the rainy season is around July - September. Rainfall over the past 40 years has averaged 1044 mm/annum, which is suitable for a single wet season crop (IFAD 2007). Over the past three decades, about 60% of the annual rainfalls between July and September. The wet time in UER is relatively short and is further marked by variations in arrival time, duration and intensity of rainfall. This creates inter-annual variations in
agricultural production potential (IFAD 2007). The annual temperature is around 28-29°C while the absolute minimum temperature is around 15-18°C (Mdemi 2008). The hottest time in the region is around March-April and coolest around August.

Agricultural activities are the main source of income for most of the people in UER (Liebe 2002). About 70% of the economically active population (ages 15 years and above) is involved in agricultural activities, followed by service and sales workers, craft and related trades workers which constitute of 10% each (GSS 2012). Production of crop is carried out both in the rainy season (rain-fed) and dry season (irrigated), but a larger part is concentrated in the rainy season. Millet (*Pennisetum spp.*) and guinea corn (*Sorghum spp.*) are the most important grain staples grown in the UER and Upper West Region, while maize (*Zea mays*), millet and sorghum are important staples in the Northern Region (Dietz et al. 2004; Gyasi et al. 2008).

Millet is the basis of the cropping system throughout UER. There are two groups of millet cultivars, a short-season millet (*naara*) harvested in July and a long-season millet (*zia*) harvested in November/ December. Early millet is inter-planted either with late millet or guinea corn (*kimulga*) in fields close to the compound where fertility is highest (Blench 2006). Stanton et al. (2011) described millet as the least risky with regard to climate-induced fluctuations in yield, followed closely by sorghum, making them important for food security. Other crops grown include groundnut (*suka*), cowpea (*tier*), maize (*kayene*) etc.

Manure application is the major source of nutrient for the rain-fed crop production, while fertiliser may be applied to rice (*Oryza sp.*) and maize. Dry season farming activity is possible in the region due to the availability of two major irrigation projects (Vea and Tono irrigation). Rice (*mui*) and vegetables (fruit and leafy) production are mostly carried out during the dry season. Common types of livestock reared in this part of the country include cattle, sheep, goat, fowls, guinea fowls, duck, pig, donkey, etc. Farmers in UER considered the rearing and keeping of cattle as a measure of wealth and social status (Dessalegn 2005). Together with smaller livestock, cattles are used to pay bride price. In the periods of immediate needs, the smaller livestock are easily converted to money to either take care of health needs or to pay children’s school fees.

Vea catchment is the selected catchment for this study (Figure 1). It is a sub-catchment of the White Volta. The catchment is between latitudes 10° 43’ 44” and 11° 0’ 49” north and longitudes 10° 0’ 3” and 00° 45’ 17” west. The catchment (301 km²) lies within Burkina Faso (8 km²) and Ghana (293 km²). This study was conducted within the Ghanaian section of the catchment, which lies in Bongo and Bolgatanga district in the UER of Ghana.

**Data Collection**

This study commenced in 2013, and at that time, the 2010 census of Ghana, which is the most recent, was yet to provide community level household information. However, district level data of the 2010 census was available (GSS 2012). Using geographic information system (GIS), the area occupied by the districts and the Vea catchment were determined. These were combined with the district household data to extrapolate the total household for the catchment (eq. 1). The extrapolated number of household within the catchment was used to estimate the sample size. Surveyed communities within the study were identified by georeferencing Optimum accessibility map of Bongo and Bolgatanga districts produced by Centre for Remote Sensing and Geographic Information Systems (CERSGIS), University of Ghana. Shapefile of the study area was then overlaid on the georeferenced map. The sample was distributed randomly across the catchment.
Data used in this study were collected from farmers by means of household survey questionnaire (186) and interview. A household consists of people who feed on the same pocket. People who stayed temporarily with another household probably because of absent parents/guardian or for other reasons were not considered as part of the household. Household members who are on seasonal migration were considered as a member. In situations where compound house exists (i.e. more than one household), data were collected from the head of the compound about his household. However, when the compound head is absent, data were collected from the household of the first person of contact. Data collected includes household characteristics and possessions, land-use data and perception about climate change.

\[ hh = \frac{(HH \times a)}{A} \]  \hspace{1cm} (eq. 1)

where \( hh \) = Number of households within the catchment, \( HH \) = Total number of households in the districts, \( a \) = area occupied by the catchment \( (km^2) \), and \( A \) = Total area occupied by the districts \( (km^2) \).
Data Analysis

Principal component analysis (PCA) and K-mean cluster analysis (KCA) were the procedures used in generating the household types. PCA is used to identify patterns in data and expressing the data in such a way as to highlight their similarities and differences (Smith 2002). In using PCA, the reduction should ensure minimal loss of information. The component scores produced in PCA were saved, standardised and used in running KCA. The process of PCA and KCA went iteratively because it is important to have principal components that will have realistic categories. Also, it is important to ensure a high value for Kaiser-Meyer-Olkin (KMO), which is a measure of sampling adequacy, and it checks how appropriate the factor analysis is. As we analyse for PCA, the KMO was checked concurrently and the KCA was run to check for the representativeness of each cluster.

The most meaningfully original variables corresponding to each principal component were used as key categorising variables for the identified household. Using descriptive statistics, we compared the similarities and variations in the perception of the identified household types. In addition, association between the household types and their perception about climate change was also tested. The perception scale used in this study is limited to 3 and 4 because during the pretest of the questionnaire, the local farmers demonstrate uncertain response when the perception scale is wider.

Results

Household Description and Categorisation

The descriptive statistics of key categorising variables used for the surveyed household is presented in table 1. Two types of household were identified. The first household type (household-1) consists of 111-farm households, while the second household type (household-2) consists of 75-farm households. Traditional cereals and groundnut cultivation cut across almost all the surveyed household. However, rice and maize farming by the two identified household shows a different pattern. Household-1 is better off than household-2 in terms of land area cultivated and income generated from rain-fed rice. Consequently, this household type was described as traditional-rice farmers. On the other hand, household-2 is better off than household-1 in terms of area cultivated for maize and income generated from maize. As a result, household-2 was described as traditional-maize farmers (Figure 2). In addition, household-2 is better off than household-1 with respect to land area cultivated and income generated from irrigated rice. Overall, household-2 is better-off than household-1 in terms labour potential, total land area cultivated per capita and total income generated per capita. Hence, household-2 was further described as the endowed household and household-1 as the less endowed household.
### Table 1: Descriptive Statistics of Key Categorising Variables for Each Household Type

<table>
<thead>
<tr>
<th>Variable</th>
<th>Household Types</th>
<th>Mean</th>
<th>Std. Err. of Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Household labour potential</td>
<td>1</td>
<td>7</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>9</td>
<td>0</td>
</tr>
<tr>
<td>Land area cultivated for rain-fed rice (ha)</td>
<td>1</td>
<td>0.08</td>
<td>0.01</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>0.23</td>
<td>0.03</td>
</tr>
<tr>
<td>Income from rain-fed rice ($USD)</td>
<td>1</td>
<td>41.91</td>
<td>4.98</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>122.08</td>
<td>18.43</td>
</tr>
<tr>
<td>Land area cultivated for irrigated rice (ha)</td>
<td>1</td>
<td>0.01</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>0.04</td>
<td>0.01</td>
</tr>
<tr>
<td>Income from irrigated rice ($USD)</td>
<td>1</td>
<td>4.85</td>
<td>1.84</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>20.89</td>
<td>6.42</td>
</tr>
<tr>
<td>Per-capita income ($USD)</td>
<td>1</td>
<td>47.51</td>
<td>4.57</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>63.17</td>
<td>5.87</td>
</tr>
<tr>
<td>Land area cultivated per capita (ha)</td>
<td>1</td>
<td>0.19</td>
<td>0.02</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>0.19</td>
<td>0.01</td>
</tr>
<tr>
<td>Land area cultivated for maize (ha)</td>
<td>1</td>
<td>0.04</td>
<td>0.01</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>0.08</td>
<td>0.02</td>
</tr>
<tr>
<td>Income from maize production ($USD)</td>
<td>1</td>
<td>4.81</td>
<td>1.54</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>13.82</td>
<td>3.79</td>
</tr>
</tbody>
</table>

Figure 2: Variation between household (hh) 1 and 2

(N= natural capital; H= human capital; F = financial capital. All variables are normalised within the 0-1 range)

### Heterogeneous Farm Household Perception about Rainfall and Temperature

The two household types revealed similar perception about the rainfall and temperature (Figure 3). About 82% and 75% of household-1 and household-2 farmers respectively perceived that the temperature has increased. About rainfall pattern, the two household groups did not show a clear pattern as observed for temperature. Observation was a mix of increasing, decreasing and fluctuating. About 58% of household-1 members perceived rainfall to have reduced while 24% and 18% perceived rainfall to have increased and fluctuating respectively. Similarly, for household-2, about 47% perceived rainfall to have declined, while 29% and 23% perceived rainfall to have increased and fluctuating respectively.
Heterogeneous Farm Household Perception about Drivers of Climate Change

Household’s view on the drivers of climate change is presented in Figure 4. Amongst the drivers of climate change, more respondents from household-1 perceived tree cutting (93%) and bush burning (90%) as a driver of climate change, while increasing population was perceived (43%) as the least of the drivers of climate change. Similarly, respondents from household-2 also perceived tree cutting (87%) and bush burning (87%) as the main drivers, while increasing population was also perceived (48%) as the least of the drivers of climate change. Variation was observed in the view of the household as to whether increasing population is a driver of climate change. About 43% and 53% of household-1 members perceived growing population as a driver and non-driver of climate change respectively. The reverse is the case for household-2 where 48% and 43% saw growing population as a driver and non-driver of climate change respectively (Figure 4).

Heterogeneous Farm Household Perception about Adaptation Barriers

Barriers to adaptation were classified into capital (i.e. land and finance), inputs, household status and climate information. These constraints (finance availability, land availability, labour availability, fertiliser availability, dry season farmland access, household size increment, quality seed accessibility and weather information access) were tested on the farmers and their responses are presented in Figure 5. In the case of household-1, finance availability (98%), quality seed accessibility (87%) and weather information accessibility (87%) were most perceived as a barrier to adaptation, while dry season farmland access was perceived as the least (60%) barrier to adaptation. Similarly for household-2, finance availability (97%), quality seed accessibility (93%) and weather information accessibility (88%) were most perceived as a barrier to adaptation, while dry season farmland access was also perceived (43%) as the least.

Association between Heterogeneous Farm Household and Climate Change Perception

The association (likelihood ratio test) between heterogeneous farm household and their perception about climate change is presented in table 2. There was no significant association (p < 0.1) between the household types and their perception on rainfall and temperature pattern, likewise their perception on the drivers of the changing climate. However, their perception on...
adaptation constraints showed association (p < 0.1) with respect to dry season farmland access and labour availability. This indicates that household-1 farmers have greater likelihood to see access to dry season farming as a barrier to adaptation compared to household-2 farmers.

Figure 4: Heterogeneous farm household perception about drivers of climate change, (a) household-1; (b) household-2

Figure 5: Heterogeneous farm household perception about adaptation constraints, (a) household-1; (b) household-2
Table 2: Association Between Heterogeneous Farm Household and Climate Change Perception

<table>
<thead>
<tr>
<th>Variables</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perception about Temperature and Rainfall</td>
<td></td>
</tr>
<tr>
<td>Rainfall</td>
<td>0.290</td>
</tr>
<tr>
<td>Temperature</td>
<td>0.438</td>
</tr>
<tr>
<td>Perception about drivers of climate change</td>
<td></td>
</tr>
<tr>
<td>Removal of trees</td>
<td>0.160</td>
</tr>
<tr>
<td>Bush burning</td>
<td>0.631</td>
</tr>
<tr>
<td>Use of fossil fuels</td>
<td>0.341</td>
</tr>
<tr>
<td>Agricultural expansion</td>
<td>0.327</td>
</tr>
<tr>
<td>Population increase</td>
<td>0.160</td>
</tr>
<tr>
<td>Perception about adaptation constraints</td>
<td></td>
</tr>
<tr>
<td>Finance</td>
<td>0.693</td>
</tr>
<tr>
<td>Land availability</td>
<td>0.934</td>
</tr>
<tr>
<td>Fertiliser availability</td>
<td>0.347</td>
</tr>
<tr>
<td>Dry season farming accessibility</td>
<td>0.059*</td>
</tr>
<tr>
<td>Labour availability</td>
<td>0.064*</td>
</tr>
<tr>
<td>Quality seed accessibility</td>
<td>0.178</td>
</tr>
<tr>
<td>Weather information accessibility</td>
<td>0.941</td>
</tr>
</tbody>
</table>

* indicate statistical significance at 0.1 level

Discussion

In agreement with previous studies (Fosu-Mensah et al. 2012; Enete and Onyekuru 2011; Acquah and Onumah 2011), we also observed in this study that a majority of the households i.e., household-1 (82%) and household-2 (75%) perceived temperature to be increasing. In contrast to findings of Tessema et al. (2013) and Fosu-Mensah et al. (2012), where a majority of farmers reported a decline in rainfall, a mixed observation with respect to rainfall pattern was observed in the responses of farmers in this study. However, it agrees with the finding of Acquah and Onumah (2011) in Shama (Western part of Ghana) where mixed view was reported for the rainfall pattern. Additionally, rainfall model simulation results for Ghana showed more uncertainty as compared to temperature model simulation (McSweeney et al. 2010). Hence, a new and localised climate forecasting approach would be useful in addressing the uncertainty in weather pattern.

In this study, finance availability, quality seed accessibility and weather information access were perceived highest of the barriers to climate change adaptation. In agreement with Tessema et al. (2013), lack of information about climate change, lack of seed and shortage of land were perceived highest amongst the barrier to adaptation. Enete and Onyekuru (2011) perceived the same adaptation barriers such as finance, land and information constraints. Thus, it may be worthwhile for government support, as well as international aides to consider these adaptation barriers.

Rain-fed agriculture is the main type of agriculture practiced in Ghana (Namara et al. 2011). Therefore, it is unsurprising to see dry season farmland access as the least perceived of the barrier to adaptation. In the study area, not all households have access to dry season farmland. Interestingly, the view of the two household types, with respect to access to dry season farming as an adaptation barrier showed a different pattern compared to other adaptation barriers. More household-1 farmers (60%) saw dry season farming accessibility as a barrier for adaptation compared to household-2 (43%). The initial household classification (Figure 2) showed that
household-2 are better off than household-1 in terms of access to dry season farming. Hence, this may be the reason why more farmers from household-1 perceived access to dry season farmlands as an adaptation constraint.

**Conclusion and Recommendation**

Adaptation is very crucial aspect in Northern Ghana. In planning effective adaptation programmes, reliance only on the results of computer simulations may not be enough. Incorporating the views of local households on climate change impact and factors associated with their view will improve adaptation planning. Due to the diversity and heterogeneous nature of these local people, their opinion varies. It is, therefore, necessary to capture the similarities and variation in their perceptions.

From this study, we can learn that similarities and differences in perception of climate change exist among farmers from the same communities. Farmers’ socio-economic traits play significant roles in the challenges farm households face when adapting to climate change. This study recommends the recognition of diversities and heterogeneity of stakeholders in adaptation policies, in order to make these policies effective and successful. A localised approach should be adopted in climate change adaptation science. Given the limited resources (particularly time to adapt), focus must be given to household types who are most vulnerable and least able to adapt to climate change impacts. Thus, incorporating many features in categorising target groups would help policy makers, international aids, and other donors to prioritise these groups. The role of government in ensuring an adaptable environment in relation to climate change impact cannot be over-emphasised. Finance is critical for adaptation, but the farming households are mostly subsistence. However, there are other ways to improve their adaptive capability. For example, the two household types considered access to weather information as an important barrier for adaptation in the study area. Thus, improving the accuracy and reliability of our weather forecasting system and timely availability of this information to farmers would go a long way to improve their adaptive strength.

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