Better Safe than Sorry: Local Impacts of Climate Change on Agricultural Activities in North-East Ghana

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Abstract

Water is precious and vulnerable simultaneously in the face of climate change impacts. Farmers respond differently to climate change impacts depending on available resources. The aim of this study is to investigate the influence of access to water on smallholder farmers' coping strategies to climate change impacts in the semi-arid zone (Aw climate). Using a mixed method approach, 6 focus group discussions, 10 key informant interviews and 148 questionnaires were administered to farmers. Quantitative data were analysed and presented using descriptive statistics whilst qualitative data were transcribed and discussed alongside. The study found that in coping with local climate change, farmers' incomes are dependent on availability of water to supplement rainfall. Therefore, communities closer to the waters of the Tono irrigation dam have greater advantage over other communities that rely on waters from dugouts and wells. Also, income gained from farming is complemented with supplementary incomes from activities such as petty trading, carpentry and sale of farmers' labour on others farms. Availability of water, particularly, during the dry season is a determinant factor of success in terms of good farm produce, income and better coping with local climate change impacts. To help these water-stressed farmers, the provision of sustainable sources of water is inevitable. The government and smallholders need to work together to solve the problem.

Keywords: climate change impacts, water, Tono irrigation dam, dugouts, wells, income

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Introduction

Globally, smallholder farmers are prone to environmental, weather and climate extreme events, including climate change (Lasco, Delfino, Catacutan, Simelton & Wilson, 2014). Smallholder farmers in developing countries and in sub-Saharan Africa, particularly in Ghana, practice rain-fed agriculture. Global climate change is likely going to have significant impacts on rain-fed farming, impacts that will affect mostly smallholder farmers. The predictable impacts of global climate change such as increasing temperatures, rainfall variability, frequency and severity of extreme events, and increasing incidence of pests and diseases will likely expose smallholder farmers and their production systems to climate risks (Hansen, 2002; Meinke & Stone, 2005; Howden, 2007; IPCC, 2012; Lasco et al., 2014).

Ghana is considered as one of the most vulnerable countries to global climate change in sub-Saharan Africa (Asante & Amuakwa-Mensah, 2015). It is one of the countries that heavily relies on the complex interactions of the monsoon system, local heat and hydrological feedbacks (Lasco et al., 2014). Therefore, the country is highly prone to weather related hazards, including floods and droughts; the effects are likely to be suffered by the vulnerable population engaged in small-scale farming. Presently, Ghana's agriculture is declining in its contribution to national development. In 2016, the percentage contributions were 46.7%, 30.6%, and 22.7% from service, industry and agriculture sectors respectively. In 2017, the percentage contributions were 46.0%, 32.7%, 21.2% from service, industry and agriculture sectors respectively. And, in 2018, the percentage contributions were 46.3%, 34.0%, and 19.7% from service, industry and agriculture sectors respectively. The agricultural sector's performance was hampered by the Fall Army Worm pest and disease from 2017 to 2019, although, this is not readily attributed to climate change (Government of Ghana, 2019).

With the insufficiency of rainfall for rain-fed agriculture, irrigation offers opportunity for crop and livestock farming. The significance of water in the irrigation process is catalogued as photosynthesis, respiration, absorption, translocation, utilization of mineral nutrients, plant turgor among others (Thakur, 2018). In Ghana, farm water management is different from conventional irrigation management elsewhere. In the latter, reservoir, aqueducts, canals, conveyers, sprinklers and drippers are used to irrigate agricultural lands (Peprah, Amoah & Achana, 2015). And, there is keen competition between irrigation, industry and domestic water users (Mengu, Akkuzu, Anac & Sensoy, 2011). In Ghana, data on irrigation water user percentage to that of industry and domestic water users are difficult to come by. This is so, as crops and livestock are irrigated from many unconventional water storages such as wells, dugouts, dams, rivers and springs. In northern Ghana, creation of rainwater harvesting receptacles has been incorporated into road construction. In doing so, reservoirs are created by the roadside to harvest run-off water. Sometimes, cement concrete is used as embankments to reinforce the dam. Elsewhere, these reservoirs are created near human settlements to harvest water from ephemeral streams as village dams (Peprah et al., 2015). Due to the high cost of construction, the distribution is often skewed. The political ecology of irrigation water in sub-Saharan Africa, mainly, the discursive struggles of the natural environmental aspect, politics and economics and their interplay with local climate change impacts warrants an investigation.

The significance of this paper, therefore, is to contribute to knowledge and strategies that will help reduce the negative impacts of climate change on people across the globe. Globally, hunger tends to be the greatest threat to livelihood. This is evident since there has been increases in the total number of undernourished people from 777 million in the year 2015 to 815 million in 2016 (United Nations Development Programme, 2018). It is, therefore, important to empower people to improve upon their livelihood most especially under the influence of climate change impacts. In addition, the enhanced farm income will reduce poverty. Furthermore, this study verges on contributions to Sustainable Development Goal 15 (life on land) target 15.1 (freshwater conservation) and 15.3 (desertification). In Africa, due to the vulnerable nature of the continent to climate change impacts, especially on water (Ngoran, Dogah & Xue, 2015; Awojobi & Tetteh, 2017), contribution to knowledge on strategies which will help people cope better is much appreciated. It is therefore, important that human development centres on initiatives aimed at helping people to cope better with the negative impacts of climate change. This includes providing resources such as water which will help people in their domestic, industrial and agricultural activities (United Nations Development Programme, 2018). Hence, there is the need for strategies that will help farmers in the northern parts of Ghana cope with limited access to water for income generation (Yaro, 2010; Ministry of Foreign Affairs, 2018). Thus, we argue that under the Aw climate, income and family food of majority of semi-arid land dwellers depend on water availability for farming. Thus, we aim at assessing the influence of access to water on farmer coping strategies to climate change impacts in the Kassena-Nankan East Municipality. To achieve this aim, we address the following specific objectives: to examine water crises as a local impact of climate change and its implications on agricultural activities; to identify the impacts of climate change on farmer's income; and, to examine farmer coping strategies to climate change impacts.

Political ecology has been used to analyse social justice and climate change (Forsyth, 2008; Forsyth, 2013). By political ecology, we mean ecology together with political economy, in which, political economy comprises of politics plus economics. "Together, this encompasses the constantly shifting dialect between society and land-based resources, and also within classes and groups within society itself" (Blaikie & Brookfield 1987:17). The political ecology of local climate change impacts in farming entails biological, chemical, physical, political, economic, cultural and religious issues on water stress. A number of stakeholders, that is, different actors with unequal power relationships are involved in the discursive struggles over the use of available water for farming. Solution to the environmental problem by addressing the water stress requires the interplay of both sciences (natural and social) with the principles of 'better safe than sorry'. By the axiom "better safe than sorry", we indicate that water in semi-arid lands is both precious and vulnerable. Hence, a precautionary principle needs to be applied in which safety is preferred to risk. And, it is in support of the precautionary principle of "he who hesitates is lost" (Bradatan, 2013).

This paper is divided into five sections. It begins with an introduction which discusses the dwindling contribution of agriculture to national development due to insufficient rainfall resulting from climate change among other factors. Other issues discussed under the introduction include insufficiency of irrigation to remedy agricultural water stress; aim, specific objectives and the theoretical underpinnings using political ecology. The second section outlines the study methodology. The third section presents the results and discussions whiles the fourth draws conclusions and the fifth, makes recommendations.

Study Area and Methodology

Our spatial focus is the semi-arid savannah of north-east Ghana, specifically, the Kassena-Nankana East Municipality in the Upper East Region. The geographic coordinates include latitude 11°10’ and 10°3’ North and longitude 10°1’ West. Its relative location is shown by the districts that surround it; Bongo and Bolgatanga Municipal to the east, Builsa South District, Builsa North District and Kassena- Nankana West District to the west, Burkina Faso to the north and the West Mamprusi Municipal to the south (Government of Ghana, 2020). The vegetation is the Guinea Savannah type; the ground is covered with tussock grass interspersed with short trees. Annual average rainfall is 950mm. Common trees which have economic value include Dawadawa (*Pakia biglobosa*), Sheanut (*Vitellaria paradoxa),* Baobab (*Adansonia digitata*) and Mango (*Mangifera indica*) (Ghana Statistical Service, 2014). Agricultural activities primarily crop farming is supported by Savannah Ochrosol soil which covers large portions of the Municipality. The rest of the Municipality is made up of groundwater lateritic soil which gets waterlog in the raining season and cramp in the dry season (Ministry of Food & Agriculture, 2018). The local climate is the interior savannah climate or tropical continental climate (Aw climate of Koppen classification) of tropical savannah with winter dry season. Monthly temperature ranges between 27.9ºC to 32.6ºC (Stanturf et al., 2011). The research design was cross-sectional with quantitative and qualitative mixed methods approach. Six communities extensively engaged in both rain-fed and dry season irrigation farming in which farmers were organised into farmer associations were purposively selected. The six communities include Saboro, Bui, Korania, Doba, Bonia and Mayoro. From a total of 235 farmers a sample size of 148 was determined for questionnaire administration by the use of $n = \frac{N}{1+N*(e)^2}$ = 235/1+235∗ $(0.05)^2$ = 235/ 1+235∗ (0.0025) = 235/ 1+0.5875 = 235/1.5875 =148.0 (Yamane, 1967) where $e = 0.05$. Analysed data from the questionnaire were triangulated with data from six focus group discussions. Additional qualitative data were generated from key informants from the Ministry of Food and Agriculture, Irrigation Company of the Upper Regions (ICOUR) and the General Agricultural Workers Union. Quantitative data were analysed and presented using descriptive statistics whilst qualitative data were transcribed and discussed alongside. The questionnaire data were entered into Statistical Package for Social Sciences (SPSS) version 20 and analysis proceeded using descriptive statistics tool, specifically, the use of central tendencies, cross tabulations and chi square test.

Results and Discussion

We proceed with the results presentation and discussion under the three specific objectives of the study.

To Assess Water Crises as a Local Impact of Climate Change and its Implications on Agricultural Activities

Environmental problem is made up of biological, chemical, physical, social, political, economic, cultural and religious issues put together. Water scarcity in semi-arid regions anywhere is an environmental problem which affects growth and production of cereals and fodder and Ghana's case is not an exception (Benniou & Bahlouli, 2015). With this problem, biology of plant life is the main cause for concern, particularly, crop water requirements for food production. Similar attention is required by livestock due to their use for food, labour and agricultural raw materials. Smallholder farmers in this study depend on cereals and tubers such as yam, cassava and to some extent potato in addition to livestock raising including local breeds of ruminants and poultry. Through some limited hunting, wildlife are of importance to farmer livelihood. Rainfall received from May to October should also sustain all biological activities in November to April during the dry season. Meanwhile, long term rainfall trend is reducing at $y = -3.2232x + 968.61$, and exacerbated by local climate change. This assertion came out of a focus group discussion:

> *I have heard, seen and also experienced the presence of changes in the climate. The rain does not set in the time it is supposed to and when it does, it suddenly stops when crops are yielding leaving the crops to wither and others even drying up therefore destroying the crops rendering all our hard work and efforts useless* (FGD, Bonia).

This finding brings to bear, the importance of water for farming and how changes in climatic elements (rainfall, temperature) affects supply of water for agricultural activities since '*the most dominant climate drivers for water availability are precipitation, temperature and evaporative demand*' (Bates, Kundzewicz, Wu, & Palutikof, 2008:38).

During the dry season, humans, crops and livestock share the water collected in the dams, dugouts and ponds as well as underground water from wells and springs as happens in any ecosystem. In the physical sense, farmers fetch water from dams and wells for domestic activities and use same water to crop in the dry season in 'bucket and calabash' irrigation. This is similar to findings from a study conducted by Kwoyiga & Stefan (2018) which revealed that locals rely on insufficient water supply for irrigation. Later, herders move in with their livestock, particularly, cattle to drink from the same source of water. Livestock drinking, tramping of feet, urination and defecation go on at the same time in these dugouts or dams. Steinfeld et al. (2006) noted that this affects chemical water content together with pathogenic bacteria and toxic agrochemicals. Contamination of water sources makes water harmful for domestic use even though communities rely on these water sources. The social setting worsens the water crisis with open defecation, communal ownership of water sources, land tenure system that makes land ownership closer to the dugouts and dam advantageous. Hence, proximity to water source due to land ownership helps farmers closer to the Vea and Tono state provided irrigation dams to the disadvantage of communities far away from the dam. Social networks such as marriage, ethnic playmates and cash arrangements are used to make access to such land possible. This is done by apportioning lands to in-laws, friends or playmates for a period of time. The mode of payment can either be cash or sharing farm produce after harvesting. In certain cases, land is allocated for free provided no permanent structure will be erected on it. Often, a distinction is made between land owning communities and settlers. Tenants such as settlers use land based on social networks established by customs and tradition. With the advent of multi-party democracy, national and local politics affect the water scarcity variously. The control of the two state dams depends on the political party in power. Often, party members and sympathizers have upper hand over the available water and other government provided agricultural resources. Smallholder farmers negotiate for their fair share based on their collective votes. Hence, communities that voted massively for the ruling party tends to have their water sources (dugouts) often repaired or improved. Presently, implementation is underway for one dam per community a Government of Ghana's attempt at solving the water scarcity. Smallholder farmers have aligned themselves to either the current political party in power or the main opposition political party that lost political power in 2016. Elections are conducted every four years. The economics depend on crop production released for sale to generate income. Prices of foodstuffs and other agricultural products depend on demand and supply (Lem, Bjorndal, & Lappo, 2014). No crop enjoys guaranteed government pricing apart from cocoa in southern Ghana. Hence, the volume of production determines the income levels of farmers. Often, at the glut, prices fall due to lack of storage facilities and perishability of the crops (vegetables e.g. tomato and fruits e.g. watermelon). Under such conditions, farmers have to dispose-off their products at the prevailing price whether favourable or not. This result agrees with findings (Adom, 2018) which revealed that post-harvest losses is a plight of farmers in Ghana. Culturally, women do not own land, hence, access is through family ownership or marriage. Labour on the farm is culturally defined as hard labour for males (e.g. land preparation) and, soft labour for females (e.g. planting/sowing and harvesting) (Dery, 2016). More women are needed even by commercial farmers to carry out these activities. Of late, tractors for ploughing and the use of combine harvesters are reducing the requirement of female labour, particularly, for commercial rice farmers (Amanor, 2019). Male labour has become very crucial in commercial rice farming. In religious term, the Earth Priest, "tendana", has to call on the gods to provide rainfall when there is delay in rainfall. They are to perform sacrifices before land preparation commences and organize new crop festivals to give first fruits/produce to the gods. The elders claim the lack of success in this endeavour is due to the youth's wilful disregard for tradition. Women are not allowed to pick shea nuts with aluminium pans but rather, with basket made from straw but the women refuse to obey. So, water scarcity is often looked at as punishment from the gods. For instance, 51.4% (76 respondents) perceived climate change as reduction in rainfall, 17.6% (26 respondents) as changes in other weather elements e.g. temperature, 6.8% (10 respondents) as shift in planting season and 24.3% (36 respondents) as punishment from God. Table 1 shows the cross tabulation between ages of respondents and their understanding of climate change impacts on water. According to an elder:

> *In the days of my father, children respected their parents and there was a form of discipline in society and the way things were done. Look at me for instance, growing up, I respected my elders and in the days of my youth, society had its dos and don't's that made living easy. Children of today do the opposite. They take alcohol and insult us as well as slap their elders ignoring the words of wisdom passed down onto them. Children, therefore, go about defying all the rules of the land and the resultant is the changes and the negative effects that are associated with change come that befall us* (FGD, Doba).

Table 1: Cross tabulation of farmer understanding of climate change and age of farmer

Understanding	**Age**			**Total**
	30-50	**51-70**	**Above 70**	
Change in rainfall	31(20.9%)	40(27%)	5(3.4%)	76(51.3%)
Change in the elements of the weather	8(5.4%)	14(9.5%)	4(2.7%)	26(17.6%)
Punishment from God	13(8.8%)	20(13.5%)	3(2.0%)	36(24.3%)
Shift in planting season	3(2.0%)	6(4.1%)	1(0.7%)	10(6.8%)
Total	55	80	13	148

Pearson chi-square test = 0.863

With a critical value of 0.05, the Pearson chi-square indicates that age and understanding of climate change are independent. There is not enough evidence to reject the null hypothesis of “no relationship”. Table 2 shows a cross tabulation of gender of respondents and their understanding of climate change impacts. Also, gender and farmer understanding of climate change are independent (0.05 < 0.200).

Table 2: Cross tabulation of farmer understanding of climate change and gender of farmer

Understanding	**Gender**		**Total**
	Male	**Female**	
Change in rainfall	28(18.9%)	48(32.4%)	76(51.3%)
Change in the elements of the weather	8(6.1%)	17(11.5%)	26(17.6%)
Punishment from God	16(10.8%)	20(13.5%)	36(24.3%)
Shift in planting season	7(4.7%)	3(2.0%)	10(6.8%)
Total	60(40.5%)	88(59.5%)	148(100)

Pearson chi-square test = 0.200

From the discussions when asked about signs associated with climate change a farmer had to say:

> *I have noticed signs of changes over the past 30 years and beyond to include severe dryness especially during the dry season, low rains and severe harmattan that set in earlier than they used to. As you can see and feel the winds aren't they strong, cold and dry? This wasn't the case when I was young during those days the winds were severe in January and February however, this has changed growing up. Imagine, we are in November and the winds are stronger than I can ever imagine experiencing. I am even cold as I speak* (FGD, Bui).

Elsewhere in Benin, findings reveal that rural water supply is affected by extended dry season, an indicator of local climate change (Bates et al., 2008).

The response identified rainfall accompanied with strong winds as a sign associated with climate change as it was clearly explained in their views that:

> *The rainfall has its own way of disturbing farming in our community. The time that we need the rains for crops to grow; all we get are showers that do not have significant influence on plant growth. Then when the crops do their best with the little water and do not need water in large quantity, it pours beyond the quantity the plants need* (FG D, Bonia).

This is similar to the findings of a study which revealed that 'there is a strong scientific consensus that the soil moisture content is being affected by rising temperatures and changes in precipitation patterns' (Daba, Bazi, & Belay, 2018:75).

Table 3 shows indicators of climate change by gender. The Pearson chi-square of 0.169 (16.9%) is higher than the alpha value of 0.05 (5%), hence, farmer indicators of climate change and gender of farmers are independent.

Table 3. Cross tabulation of farmer indicators of climate change and gender of farmer

Farmer Indicators of climate change	Gender		Total
	Male	Female	
Low rainfall	26 (17.6%)	22 (14.9%)	48 (32.5%)
Prolonged dry season	3 (2.0%)	12 (8.1%)	15 (10.1%)
High temperature	4 (2.7%)	5 (3.4%)	9 (6.1%)
Low rainfall with strong winds	4(2.7%)	11(7.4%)	15(10.1%)
Severe harmattan	12(8.1%)	20 (13.5%)	32(21.6%)
Low rainfall and high temperature	11(7.4%)	18 (12.2%)	29 (19.6%)
Total	60 (40.5%)	88 (59.5%)	148 (100)

Pearson chi-square = 0.169

In Table 4, farmer indicators of climate change and the extent of the impact of climate change on crops are independent as Pearson chi-square of 0.579 (5 7.9%) is higher than the alpha value of 0.05 (5%).

Table 4. Cross tabulation of farmer indicators of climate change and extent of climate change impacts on crops

Farmer Indicators of climate change	Degree of local climate change impacts on crops			Total
	Extremely severe	Severe	Moderately severe	
Low rainfall	25(16.9%)	19(12.8%)	4(2.7%)	48(32.4%)
Prolonged dry season	9(6.1%)	4(2.7%)	2(1.4%)	15(10.1%)
High temperature	5(3.4%)	3(2.0%)	1(0.7%)	9(6.1%)
Low rainfall with strong winds	11(7.4%)	3(2.0%)	1(0.7%)	15(10.1%)
Severe harmattan	20(13.5%)	7(4.7%)	5(3.4%)	32(21.6%)
Low rainfall and high temperature	12(8.1%)	14(9.5%)	3(2.0%)	29(19.6%)
Total	82(55.4%)	50(33.8%)	16(10.8%)	148(100)

Pearson chi-square = 0.579

The study shows that farmers' perception on climate change is influenced by many years of trial and error of personal experience, contact with Ministry of Food and Agriculture and working with NGOs in agriculture. One of the farmers remarked:

> *This knowledge of change has been influenced by my experience as a child when rains used to set in early and my father sowed on time giving us a good harvest. However, growing up, I have noticed changes with records of delay and low rainfall* (FGD, Bui).

In Table 5, cross tabulation of influences on farmers' perception on climate change impacts and age of farmers are not independent. The Pearson chi-square of 0.008 is less than the alpha value of 0.05, hence, the null hypothesis of "no relationship" is rejected. This implies that older farmers are the more experienced than younger farmers. Also, experience influences farmers' perception on climate change impacts (46%). Besides local farmers, other stakeholders with different power relations have roles to play in the water crisis. The traditional rulers (chief, tendana and elders), Ministry of Food and Agriculture (MoFA) with local offices and staff at the Municipal level, NGOs both local and international, international development partners (UNDP, USAID, JICA, etc). These stakeholders influence both the local farmers and the environmental problem in diverse ways depending on their development resource control which is equivalent to their power.

Table 5: Cross tabulation of influences on farmers' perception of climate change impacts and age of farmers

Influences on farmers' perception on climate change impacts	Age of farmers			Total
	30-50	51-70	Above 70	
Experience	15(10.1%)	48(32.4%)	5(3.4%)	68(45.9%)
Sensitization from MoFA	24(16.2%)	19(12.8%)	1(0.7%)	44(29.7%)
Sensitization from NGO	1(0.7%)	1(0.7%)	1(0.7%)	3(2.0%)
Experience and Sensitization from MoFA	12(8.1%)	10(6.8%)	5(3.4%)	27(18.2%)
Sensitization from MoFA and NGO	2(1.4%)	1(0.7%)	1(0.7%)	4(2.7%)
Experience and Sensitization from NGO	1(0.7%)	1(0.7%)	0(0.0%)	2(1.4%)
Total	55(37.2%)	80(54.1%)	13(8.8%)	148(100)

Pearson chi-square of 0.008

This state of water scarcity has also been observed by organizations such as the Irrigation Company of the Upper Regions as an official had this to say:

> *Excessive heat has led to evaporation which makes less water to be retained in the soil, affecting our river courses. Siltation of water bodies also, results in less water for farming activities* (KII, ICOUR).

This finding indicates that excessive heat affects water availability since 'soil moisture is a source of thermal inertia due to its heat capacity and the latent heat required for evaporation' (Bates et al., 2008:23).

This scarcity of water limits farmer's ability to cope with climate change impacts because it affects their access to water for farming and output (Serdeczny et al., 2015). In the views of a key informant:

> *Water scarcity turns to be the greatest challenge which affects farmer's ability to cope with climate change impacts. Water is a vital resource for both domestic and agricultural use. Access to it by farmers, therefore, increases farmer ability to expand agricultural activities* (KII, GAWU).

A challenge which needs to be addressed to reduce the impact of water scarcity on agricultural activities because 'Under such conditions the risk reduction of climate change-induced extreme hydrological events and soil moisture stresses consists of the following three soil moisture management elements: reduction of evaporation, surface runoff and filtration losses; increase of the available moisture content of the soil: to help infiltration into the soil, increase the water storage capacity; reduce the immobile moisture content; and, improving of the vertical and horizontal drainage conditions of the soil profile or the given area (prevention of over-saturation and waterlogging)' (Varallyay, 2010:391). Also, 'twelve countries would be limited to 1,000–1,700 m3/person/yr, and the population at risk of water stress could be up to 460 million people, mainly in western Africa' (Bates et al., 2008:79). The more reason why measures needed to improve access to water is crucial since projections indicate that countries in western Africa including Ghana, where the study communities are located, are vulnerable to water stress.

The ecological function of provisioning of water is exacerbated by local climate change impacts, hence, the inability of the natural ecology to retain water in the dams and dugouts. Rather, water is either transferred to the atmospheric reservoir (evaporation) or underground water reservoir (seepage). Political fixes are required to address the water crisis and to draw water from underground (drill bole hole) or re-engineer the dams and dugouts to retain water better during the dry season. The economics of it deals with implementation cost and generation of funds required. On the social context, often, the needs of communities that voted massively for the ruling political party are addressed first. Within the favourite communities, farmers who are members or sympathizers take control in the context of community ownership and management of the water sources. Floating or non-aligned farmers are courted with access to the water facility. Clerical jobs associated with the facility are given to wards of farmers with affiliation to the ruling political party who are often the members of the youth wing of the party.

Identify Climate Change Impact on Farmers Income

Political ecology of climate change impacts on farmers' income is a function of discursive struggles over ecology plus politics plus economics. The discourse proceeds on the basis of direct and indirect impacts. On the side of indirect impacts, farmers complained about the effect of changes in climate on water. Both local climate change and the water crisis is worsening the ecological provisioning service of the ecosystem (Sintayehu, 2018). The related political and economic aspects have been explained earlier. In the words of a farmer:

> *Growing up, signs of changes in the climate have been noticed for the past 30 years and beyond to include severe dryness especially during the dry season, which results in crops drying up leading to the reduction in crop yield. As of March, due to low rains and high sunshine, our dugout dried up and our animals suffered the most because that is their source of drinking water during the dry season* (FGD, Doba).

Farmers lamented about the impact of low output on their income. In the words of a farmer:

> *These changes have brought a lot of hardship upon our lives. Our parents used to cultivate on smaller parcels of land as compared to the acres and hectares of land we farm on yet upon all this, their harvest was far greater than ours. Upon all this, we are burdened with responsibilities such as paying school fees, feeding children and buying other necessities to make living easy. So, you can imagine the struggles we are going through and wonder what your generation will go through.* (FGD, Bonia).

The quantum of farm produce determines the level of farm income (Parvin & Akteruzzaman, 2012). With local climate change impacts, crop production is declining, hence, expected farm incomes are not realized. In Table 6, farmers perceived water unavailability to account for 50% of local climate change impacts on crops. A cross tabulation of local climate change impacts on crops and gender of farmers show that the two indicators are independent (0.357 > 0.05).

A key informant intimated:

> *Farmers' incomes and livelihoods are greatly affected by access to water. As a result of these factors, yields from our farming activities are poor and continue to decline. This is making us food insecure as well as reducing our household income thereby impoverishing us and reducing our standards of living (KII, Saboro).*

Table 6. Cross tabulation of local climate change impacts on crops and gender of farmers

Local climate change impacts on crops	Gender		Total
	Male	Female	
Water unavailability	34(23.0%)	40(27.0%)	74(50.0%)
Pest and disease	14(9.5%)	24(16.2%)	38(25.7%)
Post-harvest losses	3(2.0%)	11(7.4%)	14(9.4)
Water unavailability plus pest and disease	9(6.1%)	13(8.8%)	22(14.9%)
Total	60(40.5%)	88(59.5%)	148(100)

Pearson chi-square = 0.357

Findings from key informant interviews further revealed that changes in climate affects water availability negatively. This is similar to a finding from a study which revealed that water determines the harvest for the season which happens at the end of the raining season (De Pinto, Demirag, Haruna, Koo, & Asamoah, 2012). Dry season vegetables are mainly farmed to generate income. If the main season harvest is good, additional income from dry season vegetable farming is used on other family needs rather than food. In the words of a key informant interviewee:

> *As a result of climate change, most of the time there isn't enough rainwater for raining season farming activities, and the dams, wells and dugouts used for irrigation dry up making it difficult or impossible to do dry season irrigation farming* (KII, Saboro).

Akinnagbe & Irohibe (2014), noted that, crop farming success begins with proper implementation of the cropping calendar. However, due to local climate change impacts, traditional cropping calendar cannot be followed.

Farmers do trial and error with timing for planting/sowing of seeds. Another interviewee had this to add:

> *The heat also lasts longer that is, from March to June and the rains come late and at the wrong time. At times too much rain, at times too little. So, it makes cropping unpredictable; sometimes we crop in May, sometimes in June and July as a result of inadequate or no rainwater at all* (KII, Korania).

A key informant intimated that:

> *Access to water especially for farming communities is very significant for income generation. Most farmers cultivate vegetables such as carrot, green paper and okro which is sold on the market for income. Currently, most farmers with access to water, have diverted from cultivating varieties of vegetables to cultivating pepper because the price for a bag of pepper is good. As of November, this year, a bag of pepper on the market cost 750 Ghana cedis. This has been beneficial to people closer to the irrigation dam who have access to water to cultivate pepper on large scale* (KII, Bui).

Findings indicate that continuous reliance on the Vea Irrigation dam is challenged by the impacts of local climate change. This is because 'Water managers have long dealt with changing demands for water resources. To date, water managers have typically assumed that the natural resource base is reasonably constant over the medium term and, therefore, that past hydrological experience provides a good guide to future conditions. Climate change challenges these conventional assumptions and may alter the reliability of water management systems. [WGII 3.6.1]' (Bates et al., 2008:48).

In the absence of political provision of water sources, farmers bear the cost of constructing improvised wells and dugouts. Hence, crop production cost increases to the detriment of farm income. A key informant said:

> *Digging of wells or dugouts for irrigation has become expensive to the farmer because we now have to dig deep to reach and retain water for irrigation (KII. Doba).*

This can be related to projections which indicate that 'climate change poses a conceptual challenge to water managers by introducing uncertainty in future hydrological conditions. It may also be very difficult to detect an underlying trend …, meaning that adaptation decisions may have to be made before it is clear how hydrological regimes may actually be changing'(Bates et al., 2008:49).

In this context, autonomous adaptation strategies which are basically unplanned and are based on farmer's experience and perceptions are advocated for.

Examine farmer adaptation strategies to climate change impacts

Solution to environmental problem such as the one in this study (water crisis in semi-arid zone) requires both natural and social sciences collaborative work. Farmer coping strategies are highly influenced by access to resources (Komba & Muchapondwa, 2015). Farmers engage in other livelihood activities such as carpentry, 'pito' brewing, labour for hire and petty trading which helps them to generate income to augment output even though these supplementary activities are unsustainable. Most of these livelihood activities require capital to start. A farmer had this to say with respect to the source of funds for petty trading:

> *After I harvest, I keep some of the produce for consumption. The surplus is sold on the market and the income from the sale is used to buy manufactured goods for further retail in the community. The money earned [profit] is used to provide other needs which my farm income cannot provide* (FGD, Bui).

Also, most farmers revealed that they travel to neighbouring towns such as Tumu (distance between Tumu and Navrongo is 109km) to offer their labour for hire. Farmers are paid in cash (money) or in kind (food stuff) after harvesting and bagging farm produce. A farmer had this to say:

> *Others also travel as far as Tumu to offer their services in picking cotton as well as harvesting maize. The trucks just arriving with the women getting off it are from Tumu after a week's stay. These are some of the things we do to help survive with these changes* (FGD, Manyoro).

Aside individual coping strategies, collectively, farmers indicated that, joining farmer groups also helps them cope with the negative impacts caused by local climate change.

This is because of the support they provide to each other usually in forms of cash and kind. In the words of a farmer:

> *Joining this farmer group has helped a lot most especially for members that are old and not strong enough to travel to the irrigation site to offer services for a fee. This is because collectively, working with others on our group gardens helps us earn money from the sale of vegetables* (FGD, Manyoro).

Farmers who have access to water, especially farmers located in the western and southern parts of the Municipality due to their nearness to the Tono irrigation dam, use water from the dam for gardening. Produce from these gardens are sold for income. Also, women were praised for their ability to manage with proceeds available. Women were further acknowledged for their ability to find food and other necessities for their families in times of shortage.

Farmers have also put in place measures to help them trap water for farming. In the words of an interviewee*:*

> *Luckily, our farms are near a big stream, so we use sand bags to divert water into our fields and wells and dugouts and then use pumping machines to draw the water into our fields (*KII, Doba).

In Table 7, all the farmers perceived that farmer adaptation to local climate change impacts are effective. Some 41.2% (61 farmers) see changing planting/sowing date as the most preferred by farmers.

Table 7. Effectiveness of farmers' adaptation strategies to climate change impacts

Farmers' adaptation strategies to climate change impacts	Are these strategies reducing climate change impacts? YES Frequency	Percentage
Crop diversification	34	23
Changing planting/sowing date	61	41.2
Soil fertility conservation measures	37	25
Crop diversification and changing planting date	6	4.1
Crop diversification and soil fertility conservation measures	6	4.1
Changing planting date and soil fertility conservation measures	4	2.6
Total	148	100

It came out of a focus group discussion that:

> *My father used to sow around March harvest early millet and sow late millet and groundnut before the rainy and planting season was over this, however, cannot be said to be the case in our day. In our day, we do not only sow late but also once and as to whether the crops we sow will do well is another problem that we pray to God not to fail us* (FGD, Manyoro).

Crop diversification requires the services of crop scientists (natural science). Changing planting/sowing date needs crop science, climatology, meteorology and pedology (natural science); and, agricultural economics, sociology, psychology and geography (social science). Soil fertility conservation demands the work of pedologist, crop scientists, botanist, zoologist, chemist and geographer among others. Above all, the local smallholder farmer needs to collaborate with these natural and social scientists to find amicable solution to climate change impacts on crops and on the natural ecosystem in general. From Table 8, lack of access to capital and knowledge gap impedes farmers' ability to make maximum benefits from farmer adaptation strategies.

Table 8. Limitation to farmer adaptation strategies

Farmers' adaptation strategies to climate change impacts	Measures that limit application of adaptation strategies		Total
	Access to capital	Knowledge gap	
Crop diversification	23(15.5%)	11(7.4%)	34(23.0%)
Changing planting/sowing date	44(29.7%)	17(11.5%)	61(41.2%)
Soil fertility conservation measures	21(14.5%)	16(10.8%)	37(25.0%)
Crop diversification and changing planting date	5(3.4%)	1(0.7%)	6(4.1%)
Crop diversification and soil fertility conservation measures	5(3.4%)	1(0.7%)	6(4.1%)
Changing planting date and soil fertility conservation measures	2(1.4%)	2(1.4%)	4(2.7%)
Total	100(67.6%)	48(3.4%)	148(100)

Pearson chi-square of 0.483

The positive influences of farmer adaptation strategies on farm produce and livelihood contributions are enlisted in Table 9. According to Bates et al. (2008), 'enhancing resilience to future periods of drought stress by improvements in present rainfed farming systems through improvements in the physical infrastructure including: water harvesting systems; dam building; water conservation and agricultural practices; drip irrigation; development of drought-resistant and early-maturing crop varieties and alternative crop and hybrid varieties, WGII 9.5' (p.50) are beneficial in addressing stress caused by limited access to water. Again, tree planting and provision of vegetation cover has double benefits of ensuring rainfall and soil water circulation in the water cycle system since '... in semi-arid regions such as the Sahel, the presence of vegetation can enhance conditions for its own growth by recycling soil water into the atmosphere, from where it can be precipitated again'(Bates et al., 2008:23).

Table 9. Positive influences of farmer adaptation strategies against local climate change impacts

Other local climate change adaptation strategies	Positive influence on produce	Positive influence on farmer livelihood
Dry season farming	Availability of produce	Availability of food year round
Tree planting	Protects produce from strong winds and rains	Secured yield
Manure and chemical fertilizer application	Availability of nutrients for produce	Increase in yield
Multiple cropping	Produce benefit from each other	Increase in yield
Raising bunds on farmlands	Produce have access to water	Increase in yield
Change in planting date	Produce have access to water	Increase in yield
Soil conservation	Sufficient nutrients for produce	Increase in yield
Crop diversification	Good yield due to resistance	Increase in output

A key informant added that:

> *To an extent, the strategies farmers have adopted has reduced their vulnerability to climate change. This, however, is minimal as change is quite difficult for farmers to abandon the traditional ways of doing things* (USAID: ADVANCE).

Conclusions

From the specific objective one, it is clear that water crisis for agricultural activities is an environmental problem exacerbated by local climate change impacts. From political ecology point of view, the water crisis is a multifaceted environmental problem with biological, chemical, physical, social, political, economic, cultural and religious aspects. Farmers have witnessed decreases in the volume of rainwater received, unpredictability of commencement and end of the raining season, and the overall negative impacts on agricultural activities. To undo the potential impacts the water crisis has on agricultural output, both individual farmers and the government play different roles. The stakeholders are many with different levels of influences on the solution (provision of sustainable water sources). The government's provision of funds and other resources to solve the problem is done in anticipation of political votes during national presidential and parliamentary elections. Various social and political networks are relied on to access the water in the dams provided by the state.

The second specific objective relates the effect of the water crisis to income from agricultural activities. Political ecology's perspective is that the water crisis's linkages with farm income is a discursive struggle over ecology, politics and economics. The water scarcity is a normal dry season phenomenon. However, due to the impacts of local climate change affecting rainfall and temperature, the water problem has reached the crisis state with the present increases in human population that depends on water for their agricultural livelihood. The provisioning function of the ecological system is failing to retain water in the dams and dugouts. This is aggravated by local climate change impacts. Government intervention is essential which is tied to political votes in which provision of dams or rehabilitations are done to reward communities for voting the government into political power or to lure these farmers for votes in the next elections. This has been made possible because of the economics involved (provision of funds and other resource allocation). Farm income depends on quantum of farm produce offered for sale in the market. The farm produce depends on both rain-fed tuber and cereal crop farming and dry season irrigation dam supported vegetable farming. Farmers have described crop yield/production as declining, reducing, decreasing or poor. Water scarcity in the dry season equally affects livestock production. Both food and income of farmers are prone to local climate change impacts adversely.

The third specific objective shows the adaptation strategies farmers have adopted to deal with the water crisis. Farmers are cropping larger farm sizes as compared to the farms their parents once kept. Some farmers have added supplementary livelihood activities such as petty trading, and food vending as well as brewing of local drinks and processing of shea butter from shea nuts. Straw production like baskets and hats is another option. Other farmers sell their labour to medium and large-scale farmers outside the Municipality. Collective action is employed where farmers work in groups to operate farms and share the benefits. Innovative farmers have stepped up "calabash and bucket" irrigation by diverting streams to their farms to do flood irrigation or use water pumping machines and PVC pipes to send water to their farms. The religious farmers appeal to

God for grace and mercies to do well under the circumstances. Political ecology postulates that both natural science (crop science, climatology, meteorology and soil science) and social science (agricultural economics, sociology, psychology and geography) should be put together in interdisciplinary collaboration to solve the environmental problem of water crisis exacerbated by local climate change impacts.

Recommendations

The paper recommends that stakeholders have different powers and interest in solving the water crisis. Their interests are threatened by the water crisis. Hence, farmers, academia, traditional rulers, government (both local and central), sector ministries (particularly, MoFA and Ministry of Trade and Industry), middlemen and middle women, local traders of agricultural inputs and outputs, NGOs and international agricultural development partners should collaborate in a representative association or group to deal with the water crisis and other related environmental and agricultural problems. They should work together to play it safe than tarry and take the risk. He who hesitates to take the risk in this water crisis is definitely lost.

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