Journal of Emerging Trends in Economics and Management Sciences (JETEMS) 7(5): 307-321
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jetems.scholarlinkresearch.com

Protected Cultivation as Adaptive Response in Climate Change Policy: The Case of Smallholders in Northern Ghana

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Abstract
The Government of Ghana has launched the National Climate Change Policy (NCCP) which, inter alia, seeks to increase agricultural productivity through cutting-edge technologies. By focusing on Northern Ghana (most agricultural region of Ghana), this paper has found, among other things, that the provision of fertilizer subsidies is the major adaptive response provided by the government to smallholders. Notwithstanding the increase in fertilizer usage, crop yields and incomes for that matter continue to decrease. This paper problematizes a general tendency in the literature which promotes the use of fertilizer in affecting crop yields influenced by climate change. With the projection of the CSM coupled with the current plight of farmers in Northern Ghana, the provision of fertilizer subsidies does not appear to be an efficient adaptation mechanism to help farmers cope with climate change impacts. Through a survey, the paper has found that climate change has started to manifest in Northern Ghana in the form of erratic weather conditions resulting in reduced yields and incomes among smallholders.

Keywords: protected agriculture; global warming; Ghana; public policy; local development

INTRODUCTION

Given the fact that agriculture cannot be divorced from nature, especially in developing countries, climate change is projected to affect food security and production systems. All areas of food security including access to food, consumption, and price stability are expected to be affected (IPCC, 2014). Yields in major food crops such as maize, rice, and wheat will decline if frantic adaption strategies are not put in place (IPCC, 2014). Rural livelihood across the world is also expected to be negatively impacted by climate change through impacts on food security, agricultural yields, and incomes, as well as water availability and supply. Moreover, the welfare of the rural poor and smallholders will be negatively affected as they often lack access to sufficient farmlands, modern agricultural inputs, infrastructure, and education (IPCC, 2014). Developing countries, particularly in Africa, are especially vulnerable to climate change impacts as they already have high food insecurity and high inequality.

This study focuses on the West African nation of Ghana, particularly its northern region. Northern Ghana is the driest region in the country and is therefore projected to be the worst affected region by climate change. In the economy of Northern Ghana, agriculture plays a pivotal role and serves as a major source of livelihood and income for the majority of the population. The region also has the highest number of rural poor in Ghana. Under various governments, and through various policies, the country has tried to reduce poverty in the region. However, a World Development Report(WRD, 2008) pointed out that developing countries would never be successful in combating extreme poverty until they invest more in agriculture and give it more prominence across the board.

Existing research has focused on coping strategies, including the provision of drought resistant seeds, early farming, and food storage facilities. However, we consider these coping strategies to be only partial and short-term solutions, which will cease to be of any use in the long-run. If we consider a coping strategy like early farming, whereby farmers farm early enough but in the end there are scanty rains, they are still going to suffer from reduced yields. Therefore, there is a need for robust coping strategies that can solve the problem fully and serve as a long-term solution.

This study considers Protected Agriculture (PA)to be such a solution. PA generally refers to a system of farming which involves providing friendly surrounding conditions for a better plant growth and enhancing the production level through artificial means (Bhatnagar, 2014). This is achieved by controlling the climatic conditions through the provision of full or partial covering surrounding plants in order that they are not

exposed to higher or lower temperatures or humidity and at the same time getting enough light for photosynthesis as well as water and optimum fertilizer and other needs in order to achieve a better plant production (Bhatnagar, 2014). Protected Agriculture can not only enable smallholders to harvest enough yields to feed their families but also to generate a surplus, which they can sell to the market. The potential of Protected Agriculture has been shown to increase smallholders' incomes in arid areas such as Afghanistan, Yemen and Pakistan. In Afghanistan, pilot growers who adopted Protected Agriculture techniques increased their annual income by up to138% (Ahmed T. Moustafa et al, 2009). Similarly, in Yemen, cucumber producers using Protected Agriculture produced 2-3 crops per year instead of one crop and, as a result, growers' income increased up to four-fold (Ahmed T. Moustafa et al, 2009). In Pakistan, adoption of Protected Agriculture substantially increased the income earned per cubic meter of water (Ahmed T. Moustafa et al, 2009).

With the above-mentioned proven success of PA in resource-poor countries, knowledge and studies of Protected Agriculture need to be taken seriously in Ghana. Thus, research in this area—particularly research addressed topolicy makers in a position to help smallholders—is important for the improvement of rural livelihoods in Northern Ghana. Drawing on primary and secondary sources, including statistical data and a survey conducted with smallholders, this study argues that implementing and integrating Protected Agriculture within the National Climate Change Policy can help achieve risk-reduction on climate change impacts among rural farmers in Northern Ghana. The concluding section of the study includes several policy recommendations.

LITERATURE REVIEW

The United Nations Framework Convention on Climate Change (UNFCCC) defines climate change in Article 1 as "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods." The UNFCCC thus makes a distinction between climate change attributable to human activity altering the atmospheric composition and climate variability attributable to natural causes (Cited in IPCC, 2014). A simplified definition of climate change is given by Canada's Action on Climate Change (CACC, 2016): "Climate Change is a long-term shift in weather conditions measured by changes in temperature, precipitation, wind, snow cover, and other indicators. It can involve both changes in average conditions and changes in variability, including, for example, changes in extreme conditions."

Climate change is said to be attributable to both natural and human factors (IPCC, 2014; CACC, 2016; UNFCC, 2016; NASA, 2011; and America's Climate Choice, 2010) such as variability of solar radiation, volcanic eruptions, biotic processes, plate tectonics, changes in earth's orbit, and the burning of fossil fuels, anthropogenic changes and land use respectively leading to changes in the earth's ecosystem. Some of the expected outcomes of climate change include arise in sea levels, water shortages, soil degradation, an increase in the intensity and frequency of droughts, floods and storms, and disease outbreaks (IPCC, 2014 and NASA, 2011).

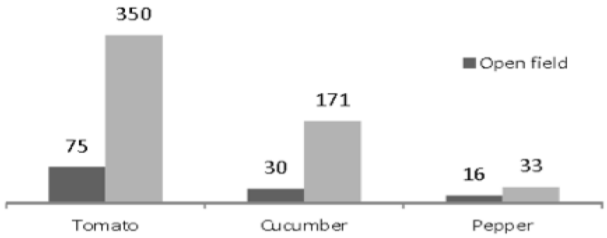
In dealing with climate change, adaptation has now become a watchword as opposed to mitigation. Adaptation here refers to the process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate and its effects (IPCC, 2014). The IPCC, 2014 has emphasized the importance and role of adaptation to Climate Change; people and societies throughout history have always adapted to and coped with climate and its variability and extremes with different levels of success. Sensitivity to the issue of adaptation has gained a momentum over the last couple of years, especially after the IPCC Third Assessment Report (TAR). Adaptation has now assumed the status of an urgent policy priority, prompting action both within and outside the climate change negotiations (Parry et al. 2005). One of the plausible reasons for the emphasis on adaptation now is perhaps climate change emerged as a problem related to the long term disturbance of the global geo-biochemical cycles and associated effects on the climate system (Cohen et. al. 1998).

The IPCC is of the view that with adaptation strategies, governments can attain risk reduction as far as the impacts of Climate Change are concerned (IPCC, 2014). Engineered and technological options are the commonly implemented adaptive responses often integrated within existing programs such as disaster risk management and water management. There is a growing recognition of the value of social, institutional, and ecosystem-based measures and the extent of constraints to adaptation. Adaptation options that are so far adopted continue to emphasize incremental adjustments and co-benefits and are starting to lay emphasis on flexibility and learning. Most assessments of adaptation have been restricted to

impacts, vulnerability, and adaptation planning, with very few assessing the processes of implementation or the effects of adaptation actions (IPCC, 2014).
Owing to the importance of adaptation, it is now increasingly resorted to across regions in both the public and private sector and within communities. Governments at various levels are starting to develop adaptation plans and policies and to integrate Climate Change considerations into broader development plans and spectra (IPCC, 2014).

Owing to the importance of adaptation to the agricultural sector, countries are increasingly resorting to various adaptation strategies as part of their frantic efforts to protecting crop production amidst climate change. For instance, in central and south America, resilient crop varieties, climate forecasts, and integrated water resources management are being adopted within the agricultural sector in some areas (IPCC, 2014).

PA generally refers to a system of farming which involves providing friendly surrounding conditions for a better plant growth and enhancing the production level through artificial means (Bhatnagar, 2014). What is known today as Protected Agriculture is an advanced form of what has been practiced by man throughout history. As early as Roman times, there were movable crop beds, which could be brought out on days with favorable weather conditions and put inside on days with bad weather conditions. Materials used in PA have included transparent slates, like plates or sheets of mica or alabaster, commonly used as covers (Wittwer and Castilla, 1995). Oiled translucent paper and glass were later used to grow and warm plants against severe cold; glass eventually became the major covering material (Jensen & Malter, 1994). In the late 1930s, polythene film was developed to replace glass panels, which were very expensive, and this practice was subsequently adopted all over the world (Espi et al. 2006). For the structure of greenhouses, bamboo was used early on but was later replaced by metallic channels or pipes. Presently, GI (Galvanized Iron) pipes or channels are the preferred material with different specifications, but MS (Mild Steel) pipes angles are also used in some places with some specific coatings. GI and MS pipes are metal pipes made from iron and steel respectively. GI and MS pipes are protected (or coated) with zinc and carbon respectively and are used in a variety of industries. Unlike MS pipes, GI pipes are made of pure iron coated with a layer of zinc which protects them from corrosion. Because pure iron is very ductile and free from carbon, GI pipes have a longer life span as opposed to MS pipes (Dugar, 2015).

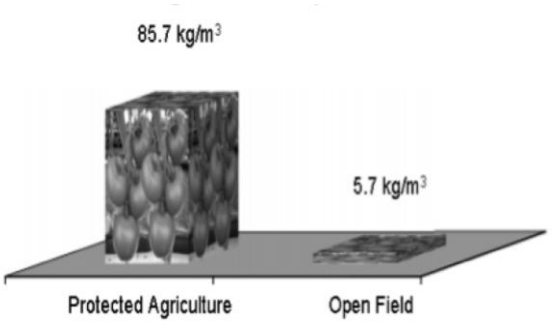


Source: Adapted from Moustafa, ICH-2009

Figure 1: Production Levels of Open Field and Protected Agriculture

Protected Agriculture is one possible solution to crop production in places where there are adversities due to erratic weather conditions, climate change, scarcity of natural resources like water and land, excessive heat or cold, food insecurity etc. PA supports the production of all crop types albeit cash crops are often the priority since the smallholder can earn income from selling them. The concept of PA generally involves providing friendly surrounding conditions for better plant growth and enhancing the production level through artificial means. This is achieved by controlling the climatic conditions through the provision of full or partial covering surrounding plants. This ensures that they are not exposed to excessively high or low temperatures or humidity, and, at the same time, so that they get enough light for photosynthesis as well as water and optimum fertilizer and other needs in order to achieve a better plant production. Examples of techniques used today include polythene covered greenhouses, net houses, low plastic tunnels, row covers, plastic film mulching and among others.

In PA, the environment and timing of the production are controlled, which leads to a substantial improvement in crop yield. PA and its associated production techniques can significantly improve productivity per unit of area and land for the production of high value cash crops (Moustafa, 2009). Figure 1 illustrates and compares the yield of tomato, cucumber, and pepper crops under Open Field and Protected Agriculture, and shows that yields in greenhouses are significantly higher for all three crops.



Source: Adapted from Moustafa, ICH-2009

Figure 2: Productivity of 1m3 of water Protected Agriculture vs. Open Field

Again, PA significantly reduces the amount of water and chemicals used in producing high value fresh produce compared with Open Field production (A. Moustafa 2006). Figure 2 compares the productivity per unit of water for tomato in Open Field and Protected Agriculture. Water productivity would be even higher if hydroponics (Soilless) production techniques were implemented with Protected Agriculture.

In general, Protected Agriculture and its associated techniques can help smallholders in rural and pre-urban areas to enhance their livelihoods and increase their incomes through the following means (Moustafa, 2009):

1. Significantly increases the yield and quality of products which can generate better revenue.
2. Utilizes marginal and non-productive lands in relatively small areas where other crops cannot be cultivated.
3. High water productivity compared to Open Field, which can save significant amounts of water that can in turn be used for expansion of farming systems to generate more income.
4. With good management, PA significantly reduces the amount of agrochemical products used, which makes produce safer and reduces production costs.
5. Offers all year-round production regardless of season, so multiple cropping on the same unit of land is possible. The flexibility of the system means that farmers can take advantage of market seasonality and higher prices.
6. Protected Agriculture can increase the level of diversification by producing high quality vegetable crops, which cannot be produced in rural areas otherwise.
7. Production of high value crops with greenhouses can be easily managed and handled by rural women with limited land and resources; therefore, Protected Agriculture has a good potential for supporting rural families headed by women.
8. On a small scale, the system can be managed by household labor alone, or on a larger scale, it can generate additional employment opportunities in the intensive management and care of crops. In particular, it favors the involvement of women, as it does not require heavy labor, and it provides an enclosed environment where women can work more satisfactorily.
9. Offers opportunities for the development of peri-urban agricultural production close to major markets, reducing transport and packaging costs.

Unlike other adaptive responses to climate change such as early farming, applying fertilizers, building storage facilities etc., PA allows for farming even in the dry season when there are hash climatic conditions. And because climate change is characterized by hash climatic conditions, this among the many benefits that PA provides as discussed above makes PA a more suitable and efficient adaptive response in the agricultural sector.

There are a number of stories of small-holder adoption of PA that illustrate the variety of benefits that PA provides. In Yemen for instance, the rain-fed terraces are major producers of food crops,but the money they earn is low. The terraces suffer from neglect because of lack of investment and a scarcity of labor due to migration of young men to the cities. An intensive network of water diversion, which collects the water harvested in upstream and delivers the surplus water to downstream terraces and the valleys, supports terraces. Neglect in proper maintenance of the upstream terraces could destructively affect the farms on downstream and valleys especially during the rainy seasons and floods.

To save the terraces and to provide smallholders with suitable livelihood alternative as a means to boost their incomes, ICARDA in collaboration with NARES introduced Protected Agriculture into mountain terraces. In 2000, three pilot smallholders in mountain terraces of Al Mahweet, Yareem and Taez were selected and greenhouses were constructed at their sites. Greenhouses were made from locally available materials. Harvested rain was the main source of water used in the three locations through drip irrigation system. ICARDA scientists, NARES researchers, and extension agents to provide technical backstopping visited pilot growers regularly. The overall yield of greenhouses for the first season was quite encouraging where they produced about the same yield as green

houses in NARES research station (12.5 kg/m2) (Mukred, Moustafa, Kirshi and Al Dhbhani.2003). Also, the plants were strong and healthy, and had low incidences of pests and diseases. The cost benefit analysis also showed that the cost of materials and construction could be covered within 3 growing seasons.

The success story of Protected Agriculture in Yemen terraces encouraged ICARDA and NARES to reach out to other donors for expansion of the activities. In 2005, the French-Yemen Food Aid Program funded new a project for ICARDA to introduce Protected Agriculture to 35 smallholders in Taiz (ICARDA, 2005. Supporting rural development and food security in Terraces of Yemen). The project provided the smallholders with greenhouse structures and production facilities while smallholders provided the water resources and laborforce. Each pilot smallholders received on the job training and technical backstopping on greenhouse production and management by ICARDA scientists and local project implementation team for about3-4 seasons. Cucumbers produced from the greenhouses generated higher revenue for the smallholders. (ICARDA, 2005. Supporting rural development and food security in Terraces of Yemen).Cucumber productions from the greenhouses were increased by420% comparing to that of the open field (ICARDA 2006).

Again, in Afghanistan, ICARDA in collaboration with local NARES and financial support of USAID introduced and transferred protected agriculture techniques to 65 smallholders. A Protected Agriculture Center(PAC) was established by the project in Kabul to support the research and training activities. During the implementation phase of the project that started in 2004 and lasted for 2 years, ICARDA organized 18 training courses for local smallholders and NARES in addition to a number of workshops and Farmers Field Schools.

The impact of the greenhouse technology on Afghan smallholder's income was assessed. Not all smallholders changed their cropping patterns, the number of crops or the size of land they use to cultivate prior to their introduction to Protected Agriculture. Therefore, for these farmers, greenhouses were "add-ons" to the portfolio of crops they use to grow as well as their incomes. Results showed that Protected Agriculture contributed upto 138% increase in income generated from crop production in 2005 (Moustafa, 2007). This economic success has somehow catalyzed the interest of new farmers to install greenhouses in their farms.

Productivity of cucumber per unit of area under greenhouses was five times more than that from open field. Similarly, water productivity also shows significant increase of 9 folds. Pilot growers managed to get the higher market prices for greenhouse cucumber compare to the local varieties that produced in open field (Moustafa, 2007).Overall, the net income from one jerib of cucumber undergreen house was about five times more than the same in open field.

Moreover, stories of small-holder adoption of PA illustrate the variety of benefits that it provides.. For example, Mr. Mula Dad, a 28 years old grower from Parwan province in Afghanistan who inherited one jerib of land and cultivated wheat and turnip in rotation before his exposure to the greenhouse technology. Married with 2 children, Mr. Mula Dadhad been working as a laborer in the construction sector; his income was not only volatile but also very low (about US$40 per month). During his first season on 2005, he produced about 26,000cucumbers from his 270 m2 greenhouse and sold them at Afs 3 per cucumber on average. He remembered that he earned at least Afs60,000 (US$1200) cash from this activity (some cucumbers were given to friends and visitors) which he spent on his family and had a small saving (Moustafa, 2007).

Moreover, protected agriculture provides good livelihood alternative for poppy growers. While the ban on poppy cultivation is a positive development, there are serious implications for the rural economy. Poppy farmers and workers engaged in harvesting poppy, a highly labor intensive process; have lost a major source of income. If the ban on poppy cultivation is to be maintained, assistance is urgently needed in the creation of alternative income earning activities.

Interviews with growers shows that the net benefit of each Jerib (2000 m2) of poppy for growers is about US$ 500-600. Poppy cultivation is very difficult and has only one crop per year. The experience of ICARDA in Afghanistan shows that a smallholder with good management and by technical support could get a benefit of 700-1200 US$ per year (two season) from a 270 m2 under the Green House (Moustafa, Amegbeto, Wadid. El-Abd and Nejatian, 2006).

Moreover, in Baluchistan, ICARDA and its local partners promoted production diversification through Protected Agriculture. Three pilot smallholders were selected for the adoption of Protected Agriculture to produce high value vegetable crops beside their traditional crop, which is wheat. The production of cucumber from the greenhouses helped smallholders to

generate better income per m3of their valuable water by10 fold compared to the wheat production (Shomo 2008).

The feasibility study, which was conducted by ICARDA, revealed that the cucumber produced in greenhouses was clearly distinguished by the buyers and sold at premium prices during the whole production cycle compared to those produced in the open field. The average premium price received per crate (18kg) was around $2 dollars, which is 30-40% higher prices (Shomo, 2008).

The success stories above are relevant to northern Ghana due to the fact that, the farmers in these places are poor smallholders bedeviled with unfavorable weather conditions such as high temperatures, scanty rains, droughts and among others. Owing to this, this study holds the view that smallholders in northern Ghana can also stand the chance of reaping the benefits of PA.

METHODOLOGY AND STUDY DESIGN

Northern Ghana was chosen as the study area due to its sensitivity to climate change, especially precipitation. The region is also the most agriculturally dense part of Ghana with a very high percentage of its populace (80%) depending on agriculture as their main source of livelihood. Northern Ghana falls within the Northern Savanna agro-ecological zone. The highest temperatures are recorded in this zone with low rainfall. Rainfall here is uni-modal, which means there is only one rainy season in a year as opposed to Southern Ghana where there are two or more rainy seasons in a year. The major crops cultivated in this region are grains and cereals such as maize, rice, millet, sorghum, beans, and soya beans. Tuber crops such as yam and cassava are also cultivated. Some few vegetables such as tomatoes, pepper, okra etc. are also cultivated by some few farmers. The region has a total of 97,702 km^2 land size representing 40.9% of the total land area of Ghana. It has a population of 4,228,116 representing 17.1% of the total population of Ghana. According to Action Aid Ghana's Country Strategy Paper (CSP) V, the region has 70% of its populace living below the poverty line and some 43% children are malnourished. Up to 50% of the children in Northern Ghana (mostly females) either have little or no schooling. The region also has the highest incidence of poverty in the country and is projected to be the worst affected by climate change, which means food insecurity and poverty will be further exacerbated. For the past two decades, climate change has manifested in the region in the form of incessant floods and droughts, which have put the lives of people at jeopardy. Finding a working and efficient adaptive response to cope with climate change is thus crucial.

Population and Sampling

Northern Ghana comprises of three (3) administrative regions namely Upper East, Upper West and Northern Regions. The target population was all smallholders in these three (3) regions. These regions are divided into districts represented the sampling frame. From this sampling frame, a probability sampling technique was used to draw a representative sample size of 100 smallholders for the study. To arrive at the 100 farmers for the survey, the following formula by Taro (1967) was used:

$$n = \frac{N}{1 + N[e]^2}$$

Where; n= sample size, N= population frame, e= margin of error.

At ninety percent (90%) confidence level; margin of error (e) = 0.1 and N=2.5 million (estimated number of smallholders in Northern Ghana, GPHC, 2010).
Hence, n= 2.5 million/1+2.5 million $(0.1)^2$ = 99.996 ≈ 100

The regions were given a quota based on their population. Northern Region has the highest population and was given a quota of 60, followed by Upper East Region with a quota of 30 and then Upper West Region with a quota of 20.

Majority of the respondents representing 97% were males as opposed to females who represented only 3%. It is also strikingly noticeable that majority of the respondents representing 48% were between the ages of thirty-five and forty-nine. The only females that took part in the survey representing 3% were between the ages of fifty and fifty-nine. Also, majority of the respondents representing 63% are engaged in only farming as their source of livelihood. This means that, they are employed only during the rainy season and remain idle during the dry season when there are no rains. There is also 34% who aside farming is engaged in livestock rearing. The livestock is used as a buffer during the dry season. The females representing 3% who participated in the survey are also engaged in weaving and shea butter processing aside farming. Weaving and shea butter processing are considered secondary occupation after farming which are usually resorted to by women during the dry season when farming is not done because there are no rains. Again, majority of the respondents (93 out of 100) had no formal education. Only 7 respondents had formal education up to Junior High School. The 3 women who

participated in the survey never had any formal education but they did learn weaving and shea butter processing to supplement their farming. The majority of respondents (83) have a family size of seven children or more. However, the questionnaire did not specify if children were biological, adopted, or brought by other family relatives to be taken care of. Notwithstanding, the respondents have commitments to cater for the basic needs of the children including food, clothing, shelter, and health care.

Questionnaire Design

The survey of smallholders was exploratory in nature aimed at investigating the views (opinions) of smallholders on climate change and its impact on their livelihood. It was intended to get an understanding and an insight on what they know about climate change and how it affects their livelihood. The questionnaire was divided into 8 sections. Section 1 dealt with the bio-data of the respondents. Section 2 focused on smallholders' knowledge of climate change while section 3 sought the views of respondents on how they understand and explain climate change. Section 4 dealt with the changes they have witnessed in their yields and food insecurity while section 5 looked at changes in their income. Further, section 6 dealt with the government support to smallholders, section 7 looked at social security and protection and finally section 8 dealt with expectations of farmers on mitigation and adaptation measures to climate change. Close-ended questions were used to allow for easier data analyses and to save time. With these, answers given by respondents were easily ticked in their corresponding boxes. Respondents' anonymity was highly maintained and bio data only focused on age, sex, level of education, nationality, family size/marital status and occupation. Majority of the respondents were illiterates, so field assistants had to translate the questions to the respondents in their various local languages and then tick answers given by respondents.

Field Assistants were engaged to conduct the data collection from field for the survey under the close supervision of an extension officer. These field assistants were given monetary compensation for each completed questionnaire as well as the cost of travel to the regions to administer the questionnaires. In order to maintain standards, briefing papers were prepared for each field assistant that detailed how to administer the questionnaires. In addition to this, the field assistants were briefed collectively prior to the commencement of the survey. For the purposes of easy identification and verification, questionnaires were given codes. The survey was successful in the end as the field assistants were able to cover all the 100 respondents. All the questionnaires were collated by the supervisor of the project and were made ready for analysis with the help of SPSS (data analysis software).

FINDINGS AND ANALYSIS

This section presents the findings from the 100 farmers who participated in the survey. The section also discusses the National Climate Change Policy, which is currently underway and suggests that Protected Agriculture be implemented and incorporated as an adaptive program to help farmers cope with climate change.

Knowledge of Climate Change and Description of Weather Conditions

This section presents the responses given by the respondents on their knowledge of climate change and how they described weather conditions.

Table 1: Knowledge of Climate Change and Description of Weather Conditions

Have you heard about climate change?	**Yes**	**No**	**Total**
Male respondents	97	0	97
Female respondents	3	0	3
Total	100	0	100
Where have heard you about climate change?	**No.**		
Extension Officer	32		
On Radio	68		
TV	0		
Total	100		

As Table 1 shows, all respondents, both male and female, have heard about climate change. The fact that they are aware of climate change is perhaps an indicator that the phenomenon is living with them and affecting their lives. Also, the radio is the respondents' most relied upon source of information. This is partly explained by the fact that many people in rural areas possess radios and not TVs. There are also extension officers who reach out to farmers in the hinterlands to educate them on best farming practices. This is significant, as 32 of the respondents rely on these extension officers for information regarding farming.

Table 2: Experience of Weather Conditions

According to my experience, the weather has been steady for the past 5 years					
		Agree	Not Sure	Disagree	Total
Region	Northern	0	3	47	50
	Upper East	0	1	29	30
	Upper West	0	2	18	20
Total		0	6	94	100

As Table 2 shows, 94 respondents in all regions categorically disagreed that the weather has been steady over the past five years. Only six respondents were not sure. This was probably due to their inability to clearly remember the situation of the weather for the past five years.

Table 3: Change of Weather Conditions

The weather has become hotter and rains have reduced over the past years					
		Agree	Not Sure	Disagree	Total
Region	Northern	50	0	0	50
	Upper East	30	0	0	30
	Upper West	20	0	0	20
Total		100	0	0	100

All 100 respondents agreed that temperatures have increased and rains have decreased all over Northern Ghana over the past years. It can also be observed that the six respondents who were not sure in Table 2 did agree with this statement. One possible reason for this could be that the effects of increases in temperature and decreases in rainfall have started to manifest in the lives of the people.

Table 4: Assessment of Weather Conditions

The weather is increasingly becoming unpredictable every year					
		Agree	Not Sure	Disagree	Total
Region	Northern	48	1	1	50
	Upper East	27	0	3	30
	Upper West	18	0	2	20
Total		93	1	6	100

The majority of respondents (93) held the view that the weather is becoming increasingly unpredictable. Only a handful of the respondents disagreed with the statement, and only one respondent said he was not sure.

Table 5: Weather conditions and climate change

Perceived changes in the weather conditions are caused by Climate Change					
		Agree	Not Sure	Disagree	Total
Region	Northern	45	3	2	50
	Upper East	26	1	3	30
	Upper West	19	0	1	20
Total		90	4	6	100

The majority of respondents (90) were of the view that the changes in weather conditions they are experiencing are due to ongoing climate change. Notwithstanding, six respondents did not agree that climate change was responsible for the erratic weather conditions, and four respondents were not sure of the cause of the current erratic weather conditions.

Table 6: Main Source of Water

Main source of water for farming activities						
		Rain	Dam	Well/Borehole	Tap	Total
Region	Northern	50	0	0	0	50
	Upper East	30	0	0	0	30
	Upper West	20	0	0	0	20
Total		100	0	0	0	100

All respondents depend on rain water for farming, as Table 6 shows. Water from wells/boreholes and taps is normally used for drinking and cooking, while dam water is used for washing, bathing, and other household chores. Farming activities in Northern Ghana depend on rain water.

The majority of respondents (98) held the view that water availability is decreasing. The respondents already agreed that rains are decreasing. Water bodies, like dams, use rain as their source, and when rains decrease less water is collected in dams, which leads to water scarcity. All respondents also agreed that soil moisture has decreased. In other words, the land used for farming is increasingly becoming drier

Table 7: Changes in Water Sources

Increase or Decrease							
		Water Availability		Soil Moisture		Soil Fertility	
		Increase	Decrease	Increase	Decrease	Increase	Decrease
Region	Northern	2	48	0	50	3	47
	Upper East	0	30	0	30	1	29
	Upper West	0	20	0	20	0	20
Total		2	98	0	100	4	96

This phenomenon can be traced to the increase in temperatures and decrease in rains. It is important to point out that drier land makes for more difficult tilling. In addition to the decrease in soil moisture, the majority of respondents (96) also noted a decrease in soil fertility. This can be explained by the common farming practice in Northern Ghana known as 'continuous cropping'. This is a practice whereby a farmer continuously farms on a particular land for a very long period. When this happens, the land eventually loses its fertility. There are many virgin lands in Northern Ghana. However, farmers lack the resources to develop them for farming purposes, which is why they continue to farm only on small lands (less than 2ha) without changing to different lands. A land that loses its fertility yields fewer products of lower quality.

Changes in Production, Productivity, Sales, and Income

This section looked at issues pertaining to production, productivity, market, and sales as reflected in changes in weather conditions. As the previous tables have shown, respondents hold the view that changes in weather manifest in increases in temperatures, decreases in rainfall, drier lands, and other consequences. It is therefore imperative to find out how the respondents' farming activities are affected by the changing weather conditions. In order to understand the challenges respondents have faced in agricultural production, the survey asked them about the losses they have encountered over the past years in terms of quantity and quality and their impact on sales.

Table 8: Weather Conditions and Crops

Have you lost more of your crops over the past years due to bad weather conditions?					
		Yes	Not Sure	No	Total
Region	Northern	48	0	2	50
	Upper East	29	1	0	30
	Upper West	19	0	1	20
Total		96	1	3	100

The majority of respondents (96) said they lose crops every year due to bad weather conditions. This cuts across all regions. Thus, due to increased temperatures, reduced rainfall and soil fertility, crops are beginning to be affected adversely in Northern Ghana. One of the respondents was not sure of any loss in crops. Another three respondents had not experienced any loss in their crops. To understand the scope of the lost crops, the survey asked respondents to give an estimate of the percentage of their crops that were lost.

Table 9: Crop Loss

What is the estimate percentage of your crop loss?						
		Under 10%	10% - 30%	31%-50%	Above50%	Total
Region	Northern	2	38	3	7	50
	Upper East	1	23	2	4	30
	Upper West	2	16	0	2	20
Total		5	77	5	13	100

Table 9 shows that the majority of respondents have experienced crop losses of up to a 30%. It is important to note that, since this reflects the perception of the farmers, it might not be necessarily an accurate percentage. Nonetheless, it gives an overall picture of the current production outcome of the farmers in Northern Ghana. It is imperative to point out that crop losses also reflect reductions in the income of farmers.

Another factor that can reduce the income of farmers is the quality of the yield. Quality affects the prices of commodities and even the opportunity to sell them in the market.

Table 10: Quality of Yield

The quality of yield has reduced over the past years					
		Agree	Not Sure	Disagree	Total
Region	Northern	42	2	6	50
	Upper East	26	1	3	30
	Upper West	17	2	1	20
Total		85	5	10	100

As Table 10 shows, the majority of respondents agreed that the quality of their yields has reduced over the past years. The respondents in all regions (85) complained bitterly about the poor quality of their products after harvest. They added that the poor quality was due to the bad weather conditions. In addition to crop losses, this further aggravates the plight of farmers in Northern Ghana. It makes it particularly difficult for those with large families, who may not have enough food due to a poor harvest. Northern Ghana is already notorious for extreme poverty and food insecurity. Any further decline in quantity and quality of yields will jeopardize the lives of the people.

Given the fact that the quality of the harvest affects sales, the survey also tried to find out from the farmers how their sales have been over the past years.

Table 11: Quality of Harvest

The quality of harvest affected the sales of products					
		Agree	**Not Sure**	**Disagree**	**Total**
Region	Northern	46	3	1	50
	Upper East	29	1	0	30
	Upper West	17	0	3	20
Total		92	4	4	100

The majority of respondents held the conviction that sales are hampered due to the poor quality of harvests. Due to existing competition at local, regional, and even international markets, consumers are less likely to purchase poor quality products. This issue has manifested in the case of farmers in Northern Ghana.
The survey also asked farmers whether reductions in sales had something to do with the ongoing climate change.

Table 12: Decrease in Sales and Climate Change

The decrease in sales has something to do with Climate Change				
		Yes	**No**	**Total**
Region	Northern	48	2	50
	Upper East	27	3	30
	Upper West	16	4	20
Total		91	9	100

According to the majority of respondents (91), ongoing climate change has hampered sales. They also expressed that it is time that something was done to help farmers to overcome this predicament.

As pointed out above, farmers in Northern Ghana get their income through the sales of their harvest. If sales are negatively affected due to crop loss or other factors, farmers' incomes will also be reduced. Income also serves as source of food security in Northern Ghana during the dry season when there is no farming. In an attempt to understand the impact of crop loss on the incomes of farmers, the survey asked whether or not decreases in income were due to crop loss that resulted from bad weather conditions.

Table 13: Crop Loss and Weather Conditions

My income decreased due to the loss of crops resulting from bad weather conditions					
		Agree	**Not Sure**	**Disagree**	**Total**
Region	Northern	47	3	0	50
	Upper East	25	1	4	30
	Upper West	19	1	0	20
Total		91	5	4	100

The majority of respondents (91) were of the view that their incomes have decreased due to crop loss associated with bad weather conditions. Decreases in income are a threat to farmers' standard of living as they may not be able to cover expenses such as education, health, shelter, etc.

Government Support

Support from the government is crucial to farmers in Northern Ghana, since they are so vulnerable to the impacts of climate change. Under various governments, Ghana has initiated a number of programs to combat poverty in Northern Ghana. The World Development Report advised that, if governments want to end poverty in developing countries, they should invest more into agriculture, given that so many depend on this sector (WDR, 2008). The survey tried to find out what farmers in Northern Ghana think about government support for their plight in the context of climate change.

Table 14: Role of Government Support

What kind of support did/do you get from the government in the past/now?		
	Past	**Present**
Fertilizer subsidies	79	87
Micro finance/Investment support	9	8
Mechanized subsidies	6	3
Support to rural communities	2	1
Procurement of agricultural products	4	1
Total	100	100

As Table 14 shows, the majority of farmers receive fertilizer subsidies from the government. It can also be noted that, since the number of respondents increased from 79 to 87, there has been an increase in fertilizer subsidies to farmers. Despite these fertilizer subsidies, however, yields of farmers are still declining and incomes are still being reduced. According to the Crop Simulation Model (CSM) used by MacCarthy et al. (2012), the use of fertilizer will have no impact on crop yields affected by climate change. With the projection of the CSM coupled with the current plight of farmers in Northern Ghana, the provision of fertilizer subsidies does not appear to be an efficient adaptation mechanism to help farmers cope with climate change impacts. The government needs to implement a robust adaptation mechanism that is capable of combating climate change impacts especially in the long-run. This is why this study suggests Protected Agriculture as a solution for climate change impacts. There are other instruments used by the government to help farmers, but they are given lesser priority as can be seen from the responses of the farmers.

The time has come, therefore, for the current programs in place to cope with climate change to be reviewed and updated to meet the current conditions of farmers—even if that means allocating a higher budget to programs that had hitherto been given a lesser priority. According to the respondents, government procurement of agricultural products in Northern Ghana is also very low, which is alarming. This study is of the view that the government should buy more agricultural products locally from small-scale farmers in order to help them and their families, especially since incomes are now increasingly reduced due to bad weather conditions. There are such programs as the School Feeding Program, which has been implemented to provide food to students in all public schools. Instead of importing food from outside to support this program, the government can implement a system of buying food from the peasant farmers in Northern Ghana and, in so doing, reduce their plight.

Expectations of the Farmers from the Government

The farmers had a number of expectations from the government concerning their situation. Farmers not only form the majority of the workforce in the county, but also agriculture remains the mainstay of the country's economy. As a result, the government cannot afford to neglect this vital workforce and sector, and they must implement certain adaptive mechanisms. With regards to floods, droughts, and other natural disasters, the farmers expect that the government should help in the event that they occur.

Table 15: Role of Government in Policy Making

The government must cater for floods, droughts, and other natural disasters.					
		Agree	**Not Sure**	**Disagree**	**Total**
Region	Northern	49	0	1	50
	Upper East	27	1	2	30
	Upper West	20	0	0	20
Total		96	1	3	100

As Table 15 shows, the majority of farmers (96) hold the view that the government should intervene when natural disasters occur. There are certain areas in the county that have been described as flood prone zones, and people have been warned not to build or settle in those areas. In cases where people have ignored the warnings and builtor settled in those zones, it can be argued that it is not binding on the government to help such victims. However, for droughts and heavy downpours, which occur because of changes in climatic conditions, the government should come out with programs that can mitigate impacts such as crop loss. Such interventions are highly needed for the sake of the poor in the country who are often the most vulnerable. In such cases, interventions should be discussed by policy makers and planned wisely.

The farmers also emphasized that the government should help them to implement adaptive programs.

Table 16: The Role and Capacity of Government

The government should implement adaptive programs to help mitigate climate change impacts					
		Agree	**Not Sure**	**Disagree**	**Total**
Region	Northern	50	0	0	50
	Upper East	28	2	0	30
	Upper West	20	0	0	20
Total		98	2	0	100

The vast majority of farmers (98) said the government should implement projects to minimize the effects of climate change. Adaptive responses, therefore, are highly needed.

ANALYSIS FROM THE FINDINGS

In taking action against climate change, Ghana has come out with the National Climate Change Policy and an accompanying strategic document. This is a step in the right direction as far as handling climate change is concerned. The first strategy in the National Climate Change Adaptation Strategy (NCCAS) is to build and strengthen the capacity of local farmers to increase agricultural productivity and awareness of climate

issues. The second strategy is to build and strengthen the capacity of extension officers in new farming technologies in order to enhance their support for farmers. These two strategies are important adaptive responses, which, when implemented, can go a long way to help farmers adapt to ongoing climate change.

This study has found that climate change has started to rear its ugly head among smallholders in Northern Ghana in the form of erratic weather conditions amounting to reduced crop yields and incomes.. There is therefore an urgent need for the government to come out with programs to help these smallholders increase crop yields. One way to do this efficiently is through the introduction of new farming technologies. This is what the second strategy of the National Climate Change Policy seeks to achieve.

As discussed, this study has found a number of success stories of small-holder adoption of PA that illustrate a wide variety of benefits that PA provides. The study therefore suggests PA as a potential solution to help smallholders cope with climate change. PA will not only enable smallholders to cope with climate change but also allow them to enjoy all the benefits that go with it. With the National Climate Change Policy currently in the second phase of implementation, which involves identifying initiatives and programs to help farmers adapt to climate change, PA ought to be included in the programs to help farmers cope with climate change impacts. The inclusion of PA in the National Climate Change Policy can help the government to ameliorate the conditions of smallholders in Northern Ghana.

CONCLUSIONS AND RECOMMENDATIONS

Climate change is much talked about today, nationally and internationally. Adaptation has become a crucial strategy for dealing with climate change impacts. Based on our survey of farmers in Northern Ghana, the study found that crop yields and incomes are decreasing. The government has tried to intervene by providing fertilizer subsidies to farmers, which has been shown to be less effective as yields are still decreasing. To this effect, the government has launched the National Climate Change Policy, which, inter alia, seeks to increase agricultural productivity through cutting-edge technologies. The strategic implementation document of the policy is now at the stage of identifying adaptive initiatives and programs that can be implemented and integrated within the National Climate Change Policy to help farmers cope with climate change.

This study suggests the potential of Protected Agriculture as one such technology to help farmers cope with climate change. The potential of Protected Agriculture derives from the fact that it has been successful in other developing and resource-poor countries such as Yemen, Afghanistan, and Baluchistan (Pakistan). In regions where Protected Agriculture has been implemented, farmers' yields and incomes have increased up to 138%, and they are able to farm all year-round and harvest top quality produce. This has helped increase food security and reduce poverty among farmers in these regions. Thus this study draws the attention of policy makers in Ghana to consider Protected Agriculture as an efficient adaptive tool to cope with climate change. And it suggests PA be implemented and integrated within the National Climate Change Policy.It is therefore the anticipation of the study that it finds itself in the hands of other researchers and more importantly policy makers in the country.

Policy Recommendations

The findings of this study warrant that certain actions be taken. Accordingly, the following recommendations are put forward with the hope that they be given consideration.

1. Implementing and integrating Protected Agriculture within the National Climate Change Policy (NCCP)

As discussed above, the NCCP is currently in its second phase, which involves identifying adaptive initiatives and programs to help farmers cope with climate change. Protected Agriculture is not a new technology; it has been in practice for many years,particularly in developed countries. It is now gaining momentum as a solution to climate change in developing countries. The time has come for Ghana to start looking at how Protected Agriculture can be adopted and adapted to suit the context of the country.

2. Launching R&D to look into Protected Agriculture

For Protected Agriculture to be successful in Ghana, it needs to be strongly backed by R&D. Protected Agriculture isa new technology in Ghana and its knowledge and practice can only gain momentum through R&D. One way to do this would be by training the educated youth in Protected Agriculture. Thus, courses on Protected Agriculture could be designed and taught to extension officers, farmers, and other agricultural workers. Practical demonstration units could also be set up to give practical training to people. This would require support and investment from the government and other stakeholders. The government could facilitate this by creating an enabling environment for other stakeholders to come in.

3. Stepping up Agricultural Extension Services

The survey revealed that extension work in Northern Ghana is low. Part of the work of extension officers is to disseminate information to farmers. However, farmers complained that they rarely find officers in their midst during farming season, when their services are highly

needed. To augment agricultural productivity and raise the incomes of farmers in Northern Ghana that the National Climate Change Policy envisions to achieve, agricultural extension must be intensified. With this, provision and public financing of extension services should be embarked upon. Again, extension officers should be given certain incentives in order to encourage them to reach out to farmers in especially the remote areas. When Protected Agriculture is finally adopted, the government will need the services of these extension officers. Extension officers, therefore, need to be properly trained in new farming technologies so as to enable them to extend their knowledge to the farmers.

4. Interventions to cushion farmers' current conditions

To address decreases in productivity due to bad weather conditions, intervention schemes should be established to assist farmers and cushion them against such plights. Climate change poses increasing production threats to farmers in Northern Ghana and marginalizes their abilities to manage risks on their own. Lest poverty and hunger are to rise in this part of the country, government interventions are needed. Intervention mechanisms can assume the form of provision of improved seed varieties, storage facilities, credit facilities, good markets, and others.

5. Providing Safety Nets

When everything else fails, farmers need safety nets to help them cope with sudden shocks. Safety nets can take the form of social transfers and emergency assistance, either in cash or in kind. Safety net initiatives and programs have to target the particular risks and vulnerabilities that farmers face. While the performance of the macro-economy may be outside the control of development practitioners, interventions can be designed to assist farmers to buffer or cushion them against the adverse effects of erratic weather conditions. For example, alternative livelihood opportunities need to be carved out for farmers in areas with very poor soils, which often lead to poor crop yields.

ACKNOWLEDGMENT

This research is partially supported by the Qatar National Research Priority Program project, entitled "Governance of Natural Resources in Sub-Saharan Africa: Advancing a Qatari Perspective" NPRP # 6-1272-5-160 funded by Qatar National Research Fund (QNRF).

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